**December 14, 2017**

# The following is a list of research publications (1990-2017) on the biological effects of radiofrequency and cell phone radiation. Use the 'Find' command to search for keywords, e.g., sleep, melatonin, micronucleus, etc.

### Aalto S, Haarala C, Bruck A, Sipila H, Hamalainen H, Rinne JO. Mobile phone affects cerebral blood flow in humans. J Cereb Blood Flow Metab. 26(7):885-890, 2006.

Mobile phones create a radio-frequency electromagnetic field (EMF) around them when in use, the effects of which on brain physiology in humans are not well known. We studied the effects of a commercial mobile phone on regional cerebral blood flow (rCBF) in healthy humans using positron emission tomography (PET) imaging. Positron emission tomography data was acquired using a double-blind, counterbalanced study design with 12 male subjects performing a computer-controlled verbal working memory task (letter 1-back). Explorative and objective voxel-based statistical analysis revealed that a mobile phone in operation induces a local decrease in rCBF beneath the antenna in the inferior temporal cortex and an increase more distantly in the prefrontal cortex. Our results provide the first evidence, suggesting that the EMF emitted by a commercial mobile phone affects rCBF in humans. These results are consistent with the postulation that EMF induces changes in neuronal activity.

### Abdel-Rassoul G, El-Fateh OA, Salem MA, Michael A, Farahat F, El-Batanouny M, Salem E. Neurobehavioral effects among inhabitants around mobile phone base stations. Neurotoxicology. 28(2):434-40, 2007.

BACKGROUND: There is a general concern on the possible hazardous health effects of exposure to radiofrequency electromagnetic radiations (RFR) emitted from mobile phone base station antennas on the human nervous system. AIM: To identify the possible neurobehavioral deficits among inhabitants living nearby mobile phone base stations. METHODS: A cross-sectional study was conducted on (85) inhabitants living nearby the first mobile phone station antenna in Menoufiya governorate, Egypt, 37 are living in a building under the station antenna while 48 opposite the station. A control group (80) participants were matched with the exposed for age, sex, occupation and educational level. All participants completed a structured questionnaire containing: personal, educational and medical histories; general and neurological examinations; neurobehavioral test battery (NBTB) [involving tests for visuomotor speed, problem solving, attention and memory]; in addition to Eysenck personality questionnaire (EPQ). RESULTS: The prevalence of neuropsychiatric complaints as headache (23.5%), memory changes (28.2%), dizziness (18.8%), tremors (9.4%), depressive symptoms (21.7%), and sleep disturbance (23.5%) were significantly higher among exposed inhabitants than controls: (10%), (5%), (5%), (0%), (8.8%) and (10%), respectively ($P<0.05$). The NBTB indicated that the exposed inhabitants exhibited a significantly lower performance than controls in one of the tests of attention and short-term auditory memory [Paced Auditory Serial Addition Test (PASAT)]. Also, the inhabitants opposite the station exhibited a lower performance in the problem solving test (block design) than those under

the station. All inhabitants exhibited a better performance in the two tests of visuomotor speed (Digit symbol and Trailmaking B) and one test of attention (Trailmaking A) than controls. The last available measures of RFR emitted from the first mobile phone base station antennas in Menoufiya governorate were less than the allowable standard level. CONCLUSIONS AND RECOMMENDATIONS: Inhabitants living nearby mobile phone base stations are at risk for developing neuropsychiatric problems and some changes in the performance of neurobehavioral functions either by facilitation or inhibition. So, revision of standard guidelines for public exposure to RER from mobile phone base station antennas and using of NBTB for regular assessment and early detection of biological effects among inhabitants around the stations are recommended.

**Aboul Ezz HS, Khadrawy YA, Ahmed NA, Radwan NM, El Bakry MM. The effect of pulsed electromagnetic radiation from mobile phone on the levels of monoamine neurotransmitters in four different areas of rat brain. Eur Rev Med Pharmacol Sci. 17(13):1782-1788, 2013.**

BACKGROUND: The use of mobile phones is rapidly increasing all over the world. Few studies deal with the effect of electromagnetic radiation (EMR) on monoamine neurotransmitters in the different brain areas of adult rat. AIM: The aim of the present study was to investigate the effect of EMR on the concentrations of dopamine (DA), norepinephrine (NE) and serotonin (5-HT) in the hippocampus, hypothalamus, midbrain and medulla oblongata of adult rats. MATERIALS AND METHODS: Adult rats were exposed daily to EMR (frequency 1800 MHz, specific absorption rate 0.843 W/kg, power density 0.02 mW/cm2, modulated at 217 Hz) and sacrificed after 1, 2 and 4 months of daily EMR exposure as well as after stopping EMR for 1 month (after 4 months of daily EMR exposure). Monoamines were determined by high performance liquid chromatography coupled with fluorescence detection (HPLC-FD) using their native properties. RESULTS: The exposure to EMR resulted in significant changes in DA, NE and 5-HT in the four selected areas of adult rat brain. CONCLUSIONS: The exposure of adult rats to EMR may cause disturbances in monoamine neurotransmitters and this may underlie many of the adverse effects reported after EMR including memory, learning, and stress.

**Abramson MJ, Benke GP, Dimitriadis C, Inyang IO, Sim MR, Wolfe RS, Croft RJ. Mobile telephone use is associated with changes in cognitive function in young adolescents. Bioelectromagnetics. 30(8):678-686, 2009.**

As part of the Mobile Radiofrequency Phone Exposed Users' Study (MoRPhEUS), a cross-sectional epidemiological study examined cognitive function in secondary school students. We recruited 317, 7th grade students (144 boys, 173 girls, median age 13 years) from 20 schools around Melbourne, Australia. Participants completed an exposure questionnaire based on the Interphone study, a computerised cognitive test battery, and the Stroop colour-word test. The principal exposure metric was the total number of reported mobile phone voice calls per week. Linear regression models were fitted to cognitive test response times and accuracies. Age, gender, ethnicity, socio-economic status and handedness were fitted as covariates and standard errors were adjusted for clustering by school. The accuracy of working

memory was poorer, reaction time for a simple learning task shorter, associative learning response time shorter and accuracy poorer in children reporting more mobile phone voice calls. There were no significant relationships between exposure and signal detection, movement monitoring or estimation. The completion time for Stroop word naming tasks was longer for those reporting more mobile phone voice calls. The findings were similar for total short message service (SMS, also known as text) messages per week, suggesting these cognitive changes were unlikely due to radiofrequency (RF) exposure. Overall, mobile phone use was associated with faster and less accurate responding to higher level cognitive tasks. These behaviours may have been learned through frequent use of a mobile phone.

**Abu Khadra KM, Khalil AM, Abu Samak M, Aljaberi A. Evaluation of selected biochemical parameters in the saliva of young males using mobile phones. Electromagn Biol Med. 2014 Feb 5. [Epub ahead of print]**

The biochemical status in the saliva of 12 males before/after using mobile phone has been evaluated. Radio frequency signals of 1800 MHz (continuous wave transmission, 217 Hz modulate and Global System for Mobile Communications [GSM - non-DTX]) with 1.09 w/kg specific absorption rate (SAR) value were used for 15 and 30 min. Cell phone radiation induced a significant increase of superoxide dismutase (SOD); there was a statistically significant effect of talking time on the levels of SOD, $F(2, 33) = 8.084$, $p < 0.05$, $\omega = 0.53$. The trend analysis suggests a significant quadratic trend, $F(1, 33) = 4.891$, $p < 0.05$; indicating that after 15 min of talking the levels of SOD increased, but as talking time increased the SOD activity started to drop. In contrast to this, there was no statistically significant effect of talking time on the level of salivary albumin, cytochrome c, catalase or uric acid. Results suggest that exposure to electromagnetic radiation may exert an oxidative stress on human cells as evidenced by the increase in the concentration of the superoxide radical anion released in the saliva of cell phone users.

**Acar GO, Yener HM, Savrun FK, Kalkan T, Bayrak I, Enver O. Thermal effects of mobile phones on facial nerves and surrounding soft tissue. Laryngoscope. 119(3):559-562, 2009.**

OBJECTIVE: To investigate the possible thermal effects of microwaves from mobile phones on facial nerves (FN) and surrounding soft tissue. STUDY DESIGN:: A prospective study. METHODS: We studied FN conduction rate and compound muscle action potentials (CMAP) on 12 rabbits before exposure to radiofrequency radiation (RFR) emitted from a mobile phone. Also, the temperature change in the soft tissues around the FN was investigated by a four channel Luxtron fiber optic system. A mobile phone with 1900 MHz frequency was placed over the ipsilateral ear of the rabbit for 25 minutes, and FN and surrounding tissues were exposed to a 1.5 watts pulse modulated (217 packets/s) electromagnetic field. During exposure to RFR, immediately after turning off the mobile phone, and 25 minutes after the exposure temperature change in the surrounding tissue of the FN was recorded and compared to preexposure values. Additionally, another recording regarding the FN functions was done and the data were compared to preexposure values. RESULTS: The average temperature of the

surrounding soft tissues was 0.39 K higher than the preexposure values during the exposure and immediately after turning off the mobile phone, and decreased to normal levels 25 minutes after the exposure, which was statistically significant. The amplitudes of FN CMAP after radiofrequency radiation exposure were significantly smaller than the preexposure amplitudes and the amplitudes were normal in the 25 minute measurement. CONCLUSION: The RFR emitted from a mobile phone can cause temporary FN dysfunction that can be due to temporary temperature increase in the soft tissue around the FN.

**Achudume A, Onibere B, Aina F, Tchokossa P. Induction of oxidative stress in male rats subchronically exposed to electromagnetic fields at non-thermal intensities. J Electromagnetic Analysis and Applications 2(8), 482-487, 2010.**

To investigate the oxidative stress-inducing potential of non-thermal electromagnetic fields in rats. Male Wister rats were exposed to electrical field intensity of 2.3 ± 0.82 µV/m . Exposure was in three forms: continuous waves, or modulated at 900 MHz or modulated GSM-nonDTX. The radio frequency radiation (RFR) was 1800 MHz, specific absorption radiation (SAR) (0.95-3.9 W/kg) for 40 and/or 60 days continuously. Control animals were located > 300 m from base station, while sham control animals were located in a similar environmental conditions, but in the vicinity of a non-functional base station. The rats were assessed for thiobarbituric and reactive species (TBARS), reduced glutathione (GSH) content, catalase activity, glutathione reductase (GR) and glucose residue after 40 and 60 days of exposure. At 40 days, electromagnetic radiation failed to induce any significant alterations. However, at 60 days of exposure various attributes evaluated decreased. The respective decreases in both nicotinamide adenine dinucleotide phosphate (NADPH) and Ascorbate- linked lipid peroxidation (LPO) with concomitant diminution in enzymatic antioxidative defense systems resulted in decreased glucose residue. The present studies showed some biochemical changes that may be associated with a prolong exposure to electromagnetic fields and its relationship to the activity of antioxidant system in rat. Regular assessment and early detection of antioxidative defense system among people working around the base stations are recommended.

**Adachi-Mejia AM, Edwards PM, Gilbert-Diamond D, Greenough GP, Olson AL.TXT Me I'm Only Sleeping: Adolescents With Mobile Phones in Their Bedroom. Fam Community Health. 37(4):252-257, 2014.**

The purpose of this study was to determine if mobile phones interfere with adolescent sleep. We conducted a pilot test in a pediatric primary care practice of 454 patients, half female (51.2%), 12 to 20 years old (mean = 15) attending a well-child visit. Adolescents completed paper-and-pencil surveys in the waiting room. More than half took their mobile phone to bed (62.9%) and kept it turned on while sleeping (56.8%). Almost half used their phone as their alarm (45.7%). More than one-third texted after going to bed (36.7%). Two or more times per week, 7.9% were awakened by a text after going to sleep.

**Adair ER, Adams BW, Hartman SK, Physiological interaction processes and radio-frequency energy absorption. Bioelectromagnetics 13(6):497-512, 1992.**

Because exposure to microwave fields at the resonant frequency may generate heat deep in the body, hyperthermia may result. This problem has been examined in an animal model to determine both the thresholds for response change and the steady-state thermoregulatory compensation for body heating during exposure at resonant (450 MHz) and supra-resonant (2,450 MHz) frequencies. Adult male squirrel monkeys, held in the far field of an antenna within an anechoic chamber, were exposed (10 min or 90 min) to either 450-MHz or 2,450-MHz CW fields (E polarization) in cool environments. Whole-body SARs ranged from 0-6 W/kg (450 MHz) and 0-9 W/kg (2,450 MHz). Colonic and several skin temperatures, metabolic heat production, and evaporative heat loss were monitored continuously. During brief RF exposures in the cold, the reduction of metabolic heat production was directly proportional to the SAR, but 2,450-MHz energy was a more efficient stimulus than was the resonant frequency. In the steady state, a regulated increase in deep body temperature accompanied exposure at resonance, not unlike that which occurs during exercise. Detailed analyses of the data indicate that temperature changes in the skin are the primary source of the neural signal for a change in physiological interaction processes during RF exposure in the cold.

**Adair ER, Kelleher SA, Mack GW, Morocco TS, Thermophysiological responses of human volunteers during controlled whole-body radio frequency exposure at 450 MHz. Bioelectromagnetics 19(4):232-245, 1998.**

Thermoregulatory responses of heat production and heat loss were measured in seven adult volunteers (four women and three men, aged 21-57 yr) during 45-min dorsal exposures of the whole body to 450 MHz continuous wave radio frequency (RF) fields. Two power densities (PD) (local peak PD = 18 and 24 mW/cm2; local peak specific absorption rate = 0.320 [W/kg]/[mW/cm2]) were tested in each of three ambient temperatures (Ta = 24, 28, and 31 degrees C) plus Ta controls (no RF). No changes in metabolic heat production occurred under any exposure conditions. Vigorous increases in sweating rate on back and chest, directly related to both Ta and PD, cooled the skin and ensured efficient regulation of the deep body (esophageal) temperature to within 0.1 degrees C of the normal level. Category judgments of thermal sensation, comfort, sweating, and thermal preference usually matched the measured changes in physiological responses. Some subtle effects related to gender were noted that confirm classic physiological data. Our results indicate that dorsal exposures of humans to a supraresonant frequency of 450 MHz at local peak specific absorption rates up to 7.68 W/kg are mildly thermogenic and are counteracted efficiently by normal thermophysiologic heat loss mechanisms, principally sweating.

**Adair ER, Cobb BL, Mylacraine KS, Kelleher SA, Human exposure at two radio frequencies (450 and 2450 MHz): similarities and differences in physiological response. Bioelectromagnetics Suppl 4:12-20, 1999.**

Thermoregulatory responses of heat production and heat loss were measured in two different groups of seven adult volunteers (males and females) during 45-min dorsal exposures of the whole body to 450 or 2450 MHz continuous-wave radio frequency (RF) fields. At each frequency, two power densities (PD) were tested at each of three

ambient temperatures (T(a) = 24, 28, and 31 degrees C) plus T(a) controls (no RF). The normalized peak surface specific absorption rate (SAR), measured at the location of the subject's center back, was the same for comparable PD at both frequencies, i.e., peak surface SAR = 6.0 and 7.7 W/kg. No change in metabolic heat production occurred under any exposure conditions at either frequency. The magnitude of increase in those skin temperatures under direct irradiation was directly related to frequency, but local sweating rates on back and chest were related more to T(a) and SAR. Both efficient sweating and increased local skin blood flow contributed to the regulation of the deep body (esophageal) temperature to within 0.1 degrees C of the baseline level. At both frequencies, normalized peak SARs in excess of ANSI/IEEE C95.1 guidelines were easily counteracted by normal thermophysiological mechanisms. The observed frequency-related response differences agree with classical data concerning the control of heat loss mechanisms in human beings. However, more practical dosimetry than is currently available will be necessary to evaluate realistic human exposures to RF energy in the natural environment.

**Adair ER, Blick DW, Allen SJ, Mylacraine KS, Ziriax JM, Scholl DM.Thermophysiological responses of human volunteers to whole body RF exposure at 220 MHz. Bioelectromagnetics. 26(6):448-461, 2005**

Since 1994, our research has demonstrated how thermophysiological responses are mobilized in human volunteers exposed to three radio frequencies, 100, 450, and 2450 MHz. A significant gap in this frequency range is now filled by the present study, conducted at 220 MHz. Thermoregulatory responses of heat loss and heat production were measured in six adult volunteers (five males, one female, aged 24-63 years) during 45 min whole body dorsal exposures to 220 MHz radio frequency (RF) energy. Three power densities (PD = 9, 12, and 15 mW/cm(2) [1 mW/cm(2) = 10 W/m(2)], whole body average normalized specific absorption rate [SAR] = 0.045 [W/kg]/[mW/cm(2)] = 0.0045 [W/kg]/[W/m(2)]) were tested at each of three ambient temperatures (T(a) = 24, 28, and 31 degrees C) plus T(a) controls (no RF). Measured responses included esophageal (T(esoph)) and seven skin temperatures (T(sk)), metabolic rate (M), local sweat rate, and local skin blood flow (SkBF). Derived measures included heart rate (HR), respiration rate, and total evaporative water loss (EWL). Finite difference-time domain (FDTD) modeling of a seated 70 kg human exposed to 220 MHz predicted six localized 'hot spots' at which local temperatures were also measured. No changes in M occurred under any test condition, while T(esoph) showed small changes (</=0.35 degrees C) but never exceeded 37.3 degrees C. As with similar exposures at 100 MHz, local T(sk) changed little and modest increases in SkBF were recorded. At 220 MHz, vigorous sweating occurred at PD = 12 and 15 mW/cm(2), with sweating levels higher than those observed for equivalent PD at 100 MHz. Predicted 'hot spots' were confirmed by local temperature measurements. The FDTD model showed the local SAR in deep neural tissues that harbor temperature-sensitive neurons (e.g., brainstem, spinal cord) to be greater at 220 than at 100 MHz. Human exposure at both 220 and 100 MHz results in far less skin heating than occurs during exposure at 450 MHz. However, the exposed subjects thermoregulate efficiently because of increased heat loss responses, particularly sweating. It is clear that these responses are controlled by neural signals from thermosensors deep in the brainstem and spinal cord, rather than those in the skin.

**Adang D, Remacle C, Vorst AV. Results of a long-term low-level microwave exposure of rats. IEEE Trans Microwave Theor Tech 57: 2488-2497, 2009.**

This paper summarizes the results of experimental research on biological effects induced by electromagnetic exposure to low-level microwaves. We exposed four-month-old Wistar albino rats during 21 months to two different microwave frequencies and exposure modes, 2 h a day, seven days a week. In order to assess possible biological effects of microwaves, we selected among others the following parameters: leucocytes, erythrocytes, monocytes, neutrophils, lymphocytes, hemoglobin, mean corpuscular hemoglobin concentration, and mortality rate. After three and eight months of exposure, we found a statistically significant difference of about 20% between the 970-MHz continuous wave group and sham-exposed group regarding the monocytes in both considered periods. After 14 and 18 months of exposure, we observed a significant increase in white blood cells and neutrophils of about 15% and 25%, respectively. Lymphocytes fell down after 18 months of exposure with about 15% compared to the sham-exposed group. No other statistically significant differences were found, except for minor changes with little biological significance. The most obvious effect we detected is the increase in mortality rate of the exposed groups with respect to the sham-exposed group after 21 months of exposure at the age of 25 months. This increase even increases when observing rats until the age of 28 months: mortality in exposed groups then reaches almost twice the value observed in the sham-exposed group.

**Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G, Phillips JL, Haggren W, Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. Radiat Res 152(3):293-302, 1999.**

We have tested an 836.55 MHz field with North American Digital Cellular (NADC) modulation in a 2-year animal bioassay that included fetal exposure. In offspring of pregnant Fischer 344 rats, we tested both spontaneous tumorigenicity and the incidence of induced central nervous system (CNS) tumors after a single dose of the carcinogen ethylnitrosourea (ENU) in utero, followed by intermittent digital-phone field exposure for 24 months. Far-field exposures began on gestational day 19 and continued until weaning at age 21 days. Near-field exposures began at 35 days and continued for the next 22 months, 4 consecutive days weekly, 2 h/day. SAR levels simulated localized peak brain exposures of a cell phone user. Of the 236 original rats, 182 (77%) survived to the termination of the whole experiment and were sacrificed at age 709-712 days. The 54 rats (23%) that died during the study ("preterm rats") formed a separate group for some statistical analyses. There was no evidence of tumorigenic effects in the CNS from exposure to the TDMA field. However, some evidence of tumor-inhibiting effects of TDMA exposure was apparent. Overall, the TDMA field-exposed animals exhibited trends toward a reduced incidence of spontaneous CNS tumors ($P < 0.16$, two-tailed) and ENU-induced CNS tumors ($P < 0.16$, two-tailed). In preterm rats, where primary neural tumors were determined to be the cause of death, fields decreased the incidence of ENU-induced tumors ($P < 0.03$, two-tailed). We discuss a possible approach to evaluating with greater certainty the possible inhibitory effects of TDMA-field exposure on tumorigenesis in the CNS.

**Adey WR, Byus CV, Cain CD, Higgins RJ, Jones RA, Kean CJ, Kuster N, MacMurray A, Stagg RB, Zimmerman G. Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats exposed to frequency-modulated microwave fields. Cancer Res 60(7):1857-1863, 2000.**

In a 2-year bioassay, we exposed Fischer 344 rats to a frequency-modulated (FM) signal (836.55 MHz +/- 12.5 KHz deviation) simulating radiofrequency exposures in the head of users of hand-held mobile phones. We tested for effects on spontaneous tumorigenicity of central nervous system (CNS) tumors in the offspring of pregnant rats and also for modified incidence of primary CNS tumors in rats treated with a single dose of the neurocarcinogen ethylnitrosourea (ENU) in utero. ENU dosage (4 mg/kg) was selected to give an expected brain tumor incidence of 10-15% over the mean life span of 26 months. Pregnant dams (n = 102) were randomly assigned to six groups. Their offspring were treated as cohorts in each of the six groups (n = 90 per group; total, n = 540): Sham ENU/Sham Field, Sham ENU/Field Exposed, ENU/Sham Field, ENU/Field Exposed, ENU/Cage Control, and Sham ENU/Cage Control. Intermittent field exposures began on gestation day 19 and continued until weaning at 21 days, resuming thereafter at 31 days and continuing until experiment termination at 731-734 days. Energy absorption rates (SARs) in the rats' brains were similar to localized peak brain exposures of a phone user (female, 236 g, 1.0 W/kg; male, 450 g, 1.2 W/kg). Of the original 540 rats, 168 died before the termination of the experiment. In these rats, ENU significantly reduced survival from a mean of 708 days in three groups without ENU treatment to 645 days in three groups treated with ENU ($P < 0.0005$). There were no effects on survival attributable to FM field exposure in either ENU-treated or in sham-treated groups. Spontaneous CNS tumor incidence in control groups was 1.1-4.4% but sharply higher in rats receiving ENU (14.4-22.2%; $P < 0.0001$). No FM field-mediated changes were observed in number, incidence, or histological type of either spontaneous or ENU-induced brain tumors, nor were gender differences detected in tumor numbers. These negative findings with FM fields contrast with our study using standard digital phone fields pulsed on and off at 50/se, where a trend was noted toward reduced incidence of both spontaneous and ENU-induced CNS tumors (W. R. Adey et al., Radiat. Res., 152: 293-302, 1999). Although consistent but not attaining significance in the experiment overall (spontaneous CNS tumors, $P < 0.08$ one-tailed; $P < 0.16$ two-tailed; ENU-induced CNS tumors, $P < 0.08$ one-tailed, $P < 0.16$ two-tailed), the trend was significant ($P < 0.015$ one-tailed, $P < 0.03$, two-tailed) in rats that received ENU and died prior to experiment termination, with a primary brain tumor as the cause of death. We discuss differences in the signaling structure of digital and FM fields. Certain bioeffects induced by either amplitude-modulated or pulsed radiofrequency fields at athermal levels have not been seen with fields of similar average power but unvarying in intensity (continuous wave or frequency-modulated fields).

**Adibzadeh F, Bakker JF, Paulides MM, Verhaart RF, van Rhoon GC. Impact of head morphology on local brain specific absorption rate from exposure to mobile phone radiation. Bioelectromagnetics. 2014 Nov 15. doi: 10.1002/bem.21885. [Epub ahead of print]**

Among various possible health effects of mobile phone radiation, the risk of inducing cancer has the strongest interest of laymen and health organizations. Recently, the

Interphone epidemiological study investigated the association between the estimated Radio Frequency (RF) dose from mobile phones and the risk of developing a brain tumor. Their dosimetric analysis included over 100 phone models but only two homogeneous head phantoms. So, the potential impact of individual morphological features on global and local RF absorption in the brain was not investigated. In this study, we performed detailed dosimetric simulations for 20 head models and quantified the variation of RF dose in different brain regions as a function of head morphology. Head models were exposed to RF fields from generic mobile phones at 835 and 1900 MHz in the "tilted" and "cheek" positions. To evaluate the local RF dose variation, we used and compared two different post-processing methods, that is, averaging specific absorption rate (SAR) over Talairach regions and over sixteen predefined 1 $cm^3$ cube-shaped field-sensors. The results show that the variation in the averaged SAR among the heads can reach up to 16.4 dB at a 1 $cm^3$ cube inside the brain (field-sensor method) and alternatively up to 15.8 dB in the medulla region (Talairach method). In conclusion, we show head morphology as an important uncertainty source for dosimetric studies of mobile phones. Therefore, any dosimetric analysis dealing with RF dose at a specific region in the brain (e.g., tumor risk analysis) should be based upon real morphology.

**Aerts S, Deschrijver D, Joseph W, Verloock L, Goeminne F, Martens L, Dhaene T. Exposure assessment of mobile phone base station radiation in an outdoor environment using sequential surrogate modeling. Bioelectromagnetics. 34(4):300-311, 2013.**

Human exposure to background radiofrequency electromagnetic fields (RF-EMF) has been increasing with the introduction of new technologies. There is a definite need for the quantification of RF-EMF exposure but a robust exposure assessment is not yet possible, mainly due to the lack of a fast and efficient measurement procedure. In this article, a new procedure is proposed for accurately mapping the exposure to base station radiation in an outdoor environment based on surrogate modeling and sequential design, an entirely new approach in the domain of dosimetry for human RF exposure. We tested our procedure in an urban area of about 0.04 km(2) for Global System for Mobile Communications (GSM) technology at 900 MHz (GSM900) using a personal exposimeter. Fifty measurement locations were sufficient to obtain a coarse street exposure map, locating regions of high and low exposure; 70 measurement locations were sufficient to characterize the electric field distribution in the area and build an accurate predictive interpolation model. Hence, accurate GSM900 downlink outdoor exposure maps (for use in, e.g., governmental risk communication and epidemiological studies) are developed by combining the proven efficiency of sequential design with the speed of exposimeter measurements and their ease of handling.

**Aerts S, Deschrijver D, Verloock L, Dhaene T, Martens L, Joseph W. Assessment of outdoor radiofrequency electromagnetic field exposure through hotspot localization using kriging-based sequential sampling. Environ Res. 126:184-191, 2013.**

In this study, a novel methodology is proposed to create heat maps that accurately pinpoint the outdoor locations with elevated exposure to radiofrequency electromagnetic fields (RF-EMF) in an extensive urban region (or, hotspots), and that would allow local authorities and epidemiologists to efficiently assess the locations and spectral composition of these hotspots, while at the same time developing a global picture of the exposure in the area. Moreover, no prior knowledge about the presence of radiofrequency radiation sources (e.g., base station parameters) is required. After building a surrogate model from the available data using kriging, the proposed method makes use of an iterative sampling strategy that selects new measurement locations at spots which are deemed to contain the most valuable information-inside hotspots or in search of them-based on the prediction uncertainty of the model. The method was tested and validated in an urban subarea of Ghent, Belgium with a size of approximately 1 km2. In total, 600 input and 50 validation measurements were performed using a broadband probe. Five hotspots were discovered and assessed, with maximum total electric-field strengths ranging from 1.3 to 3.1 V/m, satisfying the reference levels issued by the International Commission on Non-Ionizing Radiation Protection for exposure of the general public to RF-EMF. Spectrum analyzer measurements in these hotspots revealed five radiofrequency signals with a relevant contribution to the exposure. The radiofrequency radiation emitted by 900 MHz Global System for Mobile Communications (GSM) base stations was always dominant, with contributions ranging from 45% to 100%. Finally, validation of the subsequent surrogate models shows high prediction accuracy, with the final model featuring an average relative error of less than 2dB (factor 1.26 in electric-field strength), a correlation coefficient of 0.7, and a specificity of 0.96.

**Aerts S, Plets D, Thielens A, Martens L, Joseph W. Impact of a Small Cell on the RF-EMF Exposure in a Train. Int J Environ Res Public Health. 12(3):2639-2652, 2015.**

The deployment of a miniature mobile-phone base station or small cell in a train car significantly improves the coverage and the capacity of a mobile network service on the train. However, the impact of the small cell on the passengers' exposure to radio-frequency electromagnetic fields (RF-EMF) is unknown. In this study, we assessed experimentally the RF-EMF exposure of a mobile-phone user who is either connected to the outdoor macrocell network or to an in-train small cell, while traveling on the train, by means of the absorbed-dose concept, which combines the base station downlink exposure with the mobile-phone uplink exposure. For Global System for Mobile Communications (GSM) technology at 1800 MHz, we found that by connecting to a small cell, the brain exposure of the user could realistically be reduced by a factor 35 and the whole-body exposure by a factor 11.

**Aerts S, Wiart J, Martens L, Joseph W. Assessment of long-term spatio-temporal radiofrequency electromagnetic field exposure. Environ Res. 2017 Nov 13;161:136-143. doi: 10.1016/j.envres.2017.11.003.**

As both the environment and telecommunications networks are inherently dynamic, our exposure to environmental radiofrequency (RF) electromagnetic fields (EMF) at an

arbitrary location is not at all constant in time. In this study, more than a year's worth of measurement data collected in a fixed low-cost exposimeter network distributed over an urban environment was analysed and used to build, for the first time, a full spatio-temporal surrogate model of outdoor exposure to downlink Global System for Mobile Communications (GSM) and Universal Mobile Telecommunications System (UMTS) signals. Though no global trend was discovered over the measuring period, the difference in measured exposure between two instances could reach up to 42dB (a factor 12,000 in power density). Furthermore, it was found that, taking into account the hour and day of the measurement, the accuracy of the surrogate model in the area under study was improved by up to 50% compared to models that neglect the daily temporal variability of the RF signals. However, further study is required to assess the extent to which the results obtained in the considered environment can be extrapolated to other geographic locations.

**Afromeev VI, Tkachenko VN, [Change in the percent of lactate dehydrogenase isoenzyme level in testes of animals exposed to superhigh frequency radiation]. Biofizika 44(5):931-932, 1999.** [Article in Russian]

The content of six lactate dehydrogenase isoenzymes in testes of rats exposed to electromagnetic field of 3-cm wavelength range was studied. The changes in their percent contents were found to be inhomogeneous compared with control. It is assumed that electromagnetic radiation affects the organs of the human urinogenital system. The results can be used for estimating the safety of persons professionally exposed to electromagnetic radiation of the industrial frequency range and in the therapy of diseases of the urinogenital system.

**Agarwal A, Deepinder F, Sharma RK, Ranga G, Li J. Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. Fertil Steril. 89(1):124-128, 2008.**

OBJECTIVE: To investigate the effect of cell phone use on various markers of semen quality. DESIGN: Observational study. SETTING: Infertility clinic. PATIENT(S): Three hundred sixty-one men undergoing infertility evaluation were divided into four groups according to their active cell phone use: group A: no use; group B: <2 h/day; group C: 2-4 h/day; and group D: >4 h/day. INTERVENTION(S): None. MAIN OUTCOME MEASURE(S): Sperm parameters (volume, liquefaction time, pH, viscosity, sperm count, motility, viability, and morphology). RESULT(S): The comparisons of mean sperm count, motility, viability, and normal morphology among four different cell phone user groups were statistically significant. Mean sperm motility, viability, and normal morphology were significantly different in cell phone user groups within two sperm count groups. The laboratory values of the above four sperm parameters decreased in all four cell phone user groups as the duration of daily exposure to cell phones increased. CONCLUSION(S): Use of cell phones decrease the semen quality in men by decreasing the sperm count, motility, viability, and normal morphology. The decrease in sperm parameters was dependent on the duration of daily exposure to cell phones and independent of the initial semen quality.

**Agarwal A, Desai NR, Makker K, Varghese A, Mouradi R, Sabanegh E, Sharma R.**

**Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an in vitro pilot study. Fertil Steril. 92(4) 1318-1325, 2009.**

OBJECTIVE: To evaluate effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed (neat) ejaculated human semen. DESIGN: Prospective pilot study. SETTING: Center for reproductive medicine laboratory in tertiary hospital setting. SAMPLES: Neat semen samples from normal healthy donors (n = 23) and infertile patients (n = 9). INTERVENTION(S): After liquefaction, neat semen samples were divided into two aliquots. One aliquot (experimental) from each patient was exposed to cellular phone radiation (in talk mode) for 1 h, and the second aliquot (unexposed) served as the control sample under identical conditions. MAIN OUTCOME MEASURE(S): Evaluation of sperm parameters (motility, viability), reactive oxygen species (ROS), total antioxidant capacity (TAC) of semen, ROS-TAC score, and sperm DNA damage. RESULT(S): Samples exposed to RF-EMW showed a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage showed no significant differences from the unexposed group. CONCLUSION(S): Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress in human semen. We speculate that keeping the cell phone in a trouser pocket in talk mode may negatively affect spermatozoa and impair male fertility.

**Aguirre E, Iturri PL, Azpilicueta L, de Miguel-Bilbao S, Ramos V, Gárate U, Falcone F. Analysis of estimation of electromagnetic dosimetric values from non-ionizing radiofrequency fields in conventional road vehicle environments. Electromagn Biol Med. 2014 Jan 24. [Epub ahead of print]**

A high number of wireless technologies can be found operating in vehicular environments with the aim of offering different services. The dosimetric evaluation of this kind of scenarios must be performed in order to assess their compatibility with current exposure limits. In this work, a dosimetric evaluation inside a conventional car is performed, with the aid of an in-house 3D Ray Launching computational code, which has been compared with measurement results of wireless sensor networks located inside the vehicle. These results can aid in an adequate assessment of human exposure to non-ionizing radiofrequency fields, taking into account the impact of the morphology and the topology of the vehicle for current as well as for future exposure limits.

**Ahlbom A, Feychting M, Green A, Kheifets L, Savitz DA, Swerdlow AJ; ICNIRP (International Commission for Non-Ionizing Radiation Protection) Standing Committee on Epidemiology. Epidemiologic Evidence on mobile phones and tumor risk: a review. Epidemiology. 20(5):639-652, 2009.**

This review summarizes and interprets epidemiologic evidence bearing on a possible causal relation between radiofrequency field exposure from mobile phone use and tumor risk. In the last few years, epidemiologic evidence on mobile phone use and the risk of brain and other tumors of the head in adults has grown in volume, geographic diversity of study settings, and the amount of data on longer-term users. However, some key methodologic problems remain, particularly with regard to selective nonresponse and

inaccuracy and bias in recall of phone use. Most studies of glioma show small increased or decreased risks among users, although a subset of studies show appreciably elevated risks. We considered methodologic features that might explain the deviant results, but found no clear explanation. Overall the studies published to date do not demonstrate an increased risk within approximately 10 years of use for any tumor of the brain or any other head tumor. Despite the methodologic shortcomings and the limited data on long latency and long-term use, the available data do not suggest a causal association between mobile phone use and fast-growing tumors such as malignant glioma in adults (at least for tumors with short induction periods). For slow-growing tumors such as meningioma and acoustic neuroma, as well as for glioma among long-term users, the absence of association reported thus far is less conclusive because the observation period has been too short.

**Ahlers MT, Ammermüller J. No influence of acute RF exposure (GSM-900, GSM-1800, and UMTS) on mouse retinal ganglion cell responses under constant temperature conditions. Bioelectromagnetics. 2013 Sep 21. doi: 10.1002/bem.21811. [Epub ahead of print]**

Possible non-thermal effects of radio frequency electromagnetic fields (RF-EMF) on retinal ganglion cells were studied in vitro under conditions of constant temperature. Isolated mouse retinae were exposed to GSM-900, GSM-1800, and universal mobile telecommunication system (UMTS) RF-EMF applying specific absorption rates (SAR) of 0 (sham), 0.02, 0.2, 2, and 20 W/kg. Temperature was kept constant within ±0.5 to 1 °C for GSM-900 and ±0.5 °C for GSM-1800 and UMTS. Responses of retinal ganglion cells to light stimuli of three intensities (0.5, 16, and 445 lx) were recorded before, during, and up to 35 min after exposure. Experiments were performed under double-blind conditions. Changes in light responses during and after exposure were determined for each condition (RF-EMF; SAR value; light intensity) with respect to the responses before exposure, respectively. Changes were calculated using the Euclidian distance of the n-dimensional response vectors, respectively. Some changes already occurred during sham (0 W/kg) exposure, reflecting the intrinsic variability in retinal ganglion cell responses. Comparison of the distance values from sham exposure with those from actual exposure yielded no significant differences. In addition, linear regression analysis of the distance values versus SAR values yielded no consistent dependence of light response changes. From these results we conclude that RF-EMF exposure at three mobile phone frequencies (GSM-900, GSM-1800, UMTS) and SARs up to 20 W/kg has no acute effects on retinal ganglion cell responses under constant temperature conditions.

**Ahmed NA, Radwan NM, Aboul Ezz HS, Salama NA. The antioxidant effect of Green Tea Mega EGCG against electromagnetic radiation-induced oxidative stress in the hippocampus and striatum of rats. Electromagn Biol Med. 36(1):63-73, 2017.**

Electromagnetic radiation (EMR) of cellular phones may affect biological systems by increasing free radicals and changing the antioxidant defense systems of tissues, eventually leading to oxidative stress. Green tea has recently attracted significant attention due to its health benefits in a variety of disorders, ranging from cancer to weight

loss. Thus, the aim of the present study was to investigate the effect of EMR (frequency 900 MHz modulated at 217 Hz, power density 0.02 mW/cm$^2$, SAR 1.245 W/kg) on different oxidative stress parameters in the hippocampus and striatum of adult rats. This study also extends to evaluate the therapeutic effect of green tea mega EGCG on the previous parameters in animals exposed to EMR after and during EMR exposure. The experimental animals were divided into four groups: EMR-exposed animals, animals treated with green tea mega EGCG after 2 months of EMR exposure, animals treated with green tea mega EGCG during EMR exposure and control animals. EMR exposure resulted in oxidative stress in the hippocampus and striatum as evident from the disturbances in oxidant and antioxidant parameters. Co-administration of green tea mega EGCG at the beginning of EMR exposure for 2 and 3 months had more beneficial effect against EMR-induced oxidative stress than oral administration of green tea mega EGCG after 2 months of exposure. This recommends the use of green tea before any stressor to attenuate the state of oxidative stress and stimulate the antioxidant mechanism of the brain.

**Aït-Aïssa S, Billaudel B, Poulletier de Gannes F, Ruffié G, Duleu S, Hurtier A, Haro E, Taxile M, Athané A, Geffard M, Wu T, Wiart J, Bodet D, Veyret B, Lagroye I. In utero and early-life exposure of rats to a Wi-Fi signal: screening of immune markers in sera and gestational outcome. Bioelectromagnetics. 33(5):410-420, 2012.**

An experimental approach was used to assess immunological biomarkers in the sera of young rats exposed in utero and postnatal to non-ionizing radiofrequency fields. Pregnant rats were exposed free-running, 2 h/day and 5 days/week to a 2.45 GHz Wi-Fi signal in a reverberation chamber at whole-body specific absorption rates (SAR) of 0, 0.08, 0.4, and 4 W/kg (with 10, 10, 12, and 9 rats, respectively), while cage control rats were kept in the animal facility (11 rats). Dams were exposed from days 6 to 21 of gestation and then three newborns per litter were further exposed from birth to day 35 postnatal. On day 35 after birth, all pups were sacrificed and sera collected. The screening of sera for antibodies directed against 15 different antigens related to damage and/or pathological markers was conducted using enzyme-linked immunosorbent assay (ELISA). No change in humoral response of young pups was observed, regardless of the types of biomarker and SAR levels. This study also provided some data on gestational outcome following in utero exposure to Wi-Fi signals. Mass evaluation of dams and pups and the number of pups per litter was monitored, and the genital tracts of young rats were observed for abnormalities by measuring anogenital distance. Under these experimental conditions, our observations suggest a lack of adverse effects of Wi-Fi exposure on delivery and general condition of the animals.

**Aït-Aïssa S, de Gannes FP, Taxile M, Billaudel B, Hurtier A, Haro E, Ruffié G, Athané A, Veyret B, Lagroye I. In Situ Expression of Heat-Shock Proteins and 3-Nitrotyrosine in Brains of Young Rats Exposed to a WiFi Signal In Utero and In Early Life. Radiat Res. 179:707-716, 2013.**

The bioeffects of exposure to Wireless High-Fidelity (WiFi) signals on the developing nervous systems of young rodents was investigated by assessing the in vivo and in situ expression levels of three stress markers: 3-Nitrotyrosine (3-NT), an oxidative stress marker and two heat-shock proteins (Hsp25 and Hsp70). These biomarkers were measured in the brains of young rats exposed to a 2450 MHz WiFi signal by immunohistochemistry. Pregnant rats were first exposed or sham exposed to WiFi from day 6 to day 21 of gestation. In addition three newborns per litter were further exposed up to 5 weeks old. Daily 2-h exposures were performed blind in a reverberation chamber and whole-body specific absorption rate levels were 0, 0.08, 0.4 and 4 W/kg. 3-NT and stress protein expression was assayed in different areas of the hippocampus and cortex. No significant difference was observed among exposed and sham-exposed groups. These results suggest that repeated exposure to WiFi during gestation and early life has no deleterious effects on the brains of young rats.

**Aitken RJ, Bennetts LE, Sawyer D, Wiklendt AM, King BV. Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline**. **Inter J Androl 28:171-179, 2005.**

Concern has arisen over human exposures to radio frequency electromagnetic radiation (RFEMR), including a recent report indicating that regular mobile phone use can negatively impact upon human semen quality. These effects would be particularly serious if the biological effects of RFEMR included the induction of DNA damage in male germ cells. In this study, mice were exposed to 900 MHz RFEMR at a specific absorption rate of approximately 90 mW/kg inside a waveguide for 7 days at 12 h per day. Following exposure, DNA damage to caudal epididymal spermatozoa was assessed by quantitative PCR (QPCR) as well as alkaline and pulsed-field gel electrophoresis. The treated mice were overtly normal and all assessment criteria, including sperm number, morphology and vitality were not significantly affected. Gel electrophoresis revealed no gross evidence of increased single- or double-DNA strand breakage in spermatozoa taken from treated animals. However, a detailed analysis of DNA integrity using QPCR revealed statistically significant damage to both the mitochondrial genome ($p < 0.05$) and the nuclear $\beta$-globin locus ($p < 0.01$). This study suggests that while RFEMR does not have a dramatic impact on male germ cell development, a significant genotoxic effect on epididymal spermatozoa is evident and deserves further investigation.

**Akar A, Karayiğit MO, Bolat D, Gültiken ME, Yarım M, Castellani G. Effects of low level electromagnetic field exposure at 2.45 GHz on rat cornea. Int J Radiat Biol. 2012 Dec 3. [Epub ahead of print]**

Abstract Purpose: To investigate the effects of low level Electromagnetic Field (low level-EMF) exposure, as frequently encountered in daily life, on the yesmal rat cornea using histological and stereological method. Methods: Twenty-two adult male Wistar rats were randomly divided into two groups: study group (n=11) and control group (n=11). Rats in the study group were exposed to 2.45 GHz Microwave (MW) radiation (11.96±0.89V/m), 0.25 W/kg specific absorption rate (SAR) for 2 hours each day for 21 days. The corneal thickness and the anterior epithelium corneal thickness were

measured using two different methods. Results: Using the histological method, the mean corneal thicknesses in the control and study group were 278.9±54.5 µm, and 272.4±85.6 µm, respectively. There was no statistically significant difference between the groups ($p>0.05$). The anterior corneal epithelium thickness was 28.1±4.9 µm in the control group and 31.7±5.5 µm in the study group. There were statistically differences between the groups with regard to the thickness of anterior epithelium ($p<0.05$). In the measurement made by the stereological method, the percentage of the cornea occupied by anterior corneal epithelium was 15.94% in the control group and 17.9% in the study group. Despite the fact that there was a relation between increased anterior epithelial area (AEA) and radiation exposure, no statistically significant relationship in area fraction of each compartment was found between the control and study groups. Conclusions: Results of this preliminary study show that exposure to MW radiation might cause alterations in the rat cornea.

**Akbari A, Jelodar G, Nazifi S. Vitamin C protects rat cerebellum and encephalon from oxidative stress following exposure to radiofrequency wave generated by a BTS antenna model. Toxicol Mech Methods. 24(5):347-352, 2014.**

Radio frequency wave (RFW) generated by base transceiver station has been reported to produce deleterious effects on the central nervous system function, possibly through oxidative stress. This study was conducted to evaluate the effect of RFW-induced oxidative stress in the cerebellum and encephalon and the prophylactic effect of vitamin C on theses tissues by measuring the antioxidant enzymes activity, including: glutathione peroxidase, superoxide dismutase, catalase, and malondialdehyde (MDA). Thirty-two adult male Sprague-Dawley rats were randomly divided into four equal groups. The control group; the control-vitamin C group received L-ascorbic acid (200 mg/kg of body weight/day by gavage) for 45 days. The RFW group was exposed to RFW and the RFW+ vitamin C group was exposed to RFW and received vitamin C. At the end of the experiment, all groups were killed and encephalon and cerebellum of all rats were removed and stored at -70 °C for measurement of antioxidant enzymes activity and MDA. The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($p < 0.05$). The protective role of vitamin C in the treated group improved antioxidant enzymes activity and reduced MDA compared with the test group ($p < 0.05$). It can be concluded that RFW causes oxidative stress in the brain and vitamin C improves the antioxidant enzymes activity and decreases MDA.

**Akbarnejad Z, Esmaeilpour K, Shabani M, Asadi-Shekaari M, Saeedi-Goraghani M, Ahmadi M. Spatial memory recovery in Alzheimer's rat model by electromagnetic field exposure. Int J Neurosci. 2017 Nov 29:1-14. doi: 10.1080/00207454.2017.1411353.**

INTRODUCTION: Although studies have shown a potential association between extremely low frequency electromagnetic fields (ELF-EMFs) exposure and

Alzheimer's disease (AD), few studies have been conducted to investigate the effects of weak magnetic fields on brain functions such as cognitive functions in animal models. Therefore, this study aimed to investigate the effect of ELF-EMF exposure (50 Hz, 10 mT) on spatial learning and memory changes in AD rats. METHODS: Amyloid-β (Aβ) 1-42 (5 μl/ bilateral, single-dose) was injected into lateral ventricle to establish an AD rat model. The rats were divided into six groups: Group I (control); Group II (surgical sham); Group III (AD) Alzheimer's rat model; Group IV (MF) rats exposed to ELF-MF for 14 consecutive days; Group V (Aβ injection+M) rats exposed to magnetic field for 14 consecutive days from day 0-14 days after the Aβ peptide injection; Group VI (AD+M) rats exposed to magnetic field for 14 consecutive days after 2 weeks of Aβ peptide injection from 14th to 28th day. Morris water maze investigation were implemented and performed 24 h after termination of ELF-MF, respectively. RESULTS: AD rats showed a significant impairment in learning and memory compared to control rats. The results showed that ELF-MF improved the learning and memory impairments in Aβ injection+M and AD+M groups. CONCLUSION: Our results showed that application of ELF-MF not only has improving effect on different cognitive disorder signs of AD animals, but also disrupts the processes of AD rat model formation.

**Akdag MZ, Dasdag S, Canturk F, Karabulut D, Caner Y, Adalier N. Does prolonged radiofrequency radiation emitted from Wi-Fi devices induce DNA damage in various tissues of rats? J Chem Neuroanat. 2016 Jan 8. pii: S0891-0618(16)00005-3. doi: 10.1016/j.jchemneu.2016.01.003. [Epub ahead of print]**

Wireless Internet (Wi-Fi) providers have become essential in our daily lives, as wireless technology is evolving at a dizzying pace. Although there are different frequency generators, one of the most commonly used Wi-Fi devices are 2.4GHz frequency generators. These devices are heavily used in all areas of life but the effect of radiofrequency (RF) radiation emission on users is generally ignored. Yet, an increasing share of the public expresses concern on this issue. Therefore, this study intends to respond to the growing public concern. The purpose of this study is to reveal whether long term exposure of 2.4GHz frequency RF radiation will cause DNA damage of different tissues such as brain, kidney, liver, and skin tissue and testicular tissues of rats. The study was conducted on 16 adult male Wistar-Albino rats. The rats in the experimental group (n=8) were exposed to 2.4GHz frequency radiation for over a year. The rats in the sham control group (n=8) were subjected to the same experimental conditions except the Wi-Fi generator was turned off. After the exposure period was complete the possible DNA damage on the rat's brain, liver, kidney, skin, and testicular tissues was detected through the single cell gel electrophoresis assay (comet) method. The amount of DNA damage was measured as% tail DNA value. Based on the DNA damage results determined by the single cell gel electrophoresis (Comet) method, it was found that the% tail DNA values of the brain, kidney, liver, and skin tissues of the rats in the experimental group increased more than those in the control group. The increase of the DNA damage in all tissues was not significant ($p > 0.05$). However the increase of the DNA damage in rat testes tissue was significant ($p < 0.01$). In conclusion, long-term exposure to 2.4GHz RF radiation (Wi-

Fi) does not cause DNA damage of the organs investigated in this study except testes. The results of this study indicated that testes are more sensitive organ to RF radiation.

**Akhavan-Sigari R, Baf MM, Ariabod V, Rohde V, Rahighi S. Connection between Cell Phone use, p53 Gene Expression in Different Zones of Glioblastoma Multiforme and Survival Prognoses. Rare Tumors. 2014 Aug 8;6(3):5350. doi: 10.4081/rt.2014.5350.**

The aim of this paper is to investigate p53 gene expression in the central and peripheral zones of glioblastoma multiforme using a real-time reverse transcription polymerase chain reaction (RT-PCR) technique in patients who use cell phones ≥3 hours a day and determine its relationship to clinicopathological findings and overall survival. Sixty-three patients (38 males and 25 females), diagnosed with glioblastoma multiforme (GBM), underwent tumor resection between 2008 and 2011. Patient ages ranged from 25 to 88 years, with a mean age of 55. The levels of expression of p53 in the central and peripheral zone of the GBM were quantified by RT-PCR. Data on p53 gene expression from the central and peripheral zone, the related malignancy and the clinicopathalogical findings (age, gender, tumor location and size), as well as overall survival, were analyzed. Forty-one out of 63 patients (65%) with the highest level of cell phone use (≥3 hours/day) had higher mutant type p53 expression in the peripheral zone of the glioblastoma; the difference was statistically significant (P=0.034). Results from the present study on the use of mobile phones for ≥3 hours a day show a consistent pattern of increased risk for the mutant type of p53 gene expression in the peripheral zone of the glioblastoma, and that this increase was significantly correlated with shorter overall survival time. The risk was not higher for ipsilateral exposure. We found that the mutant type of p53 gene expression in the peripheral zone of the glioblastoma was increased in 65% of patients using cell phones ≥3 hours a day.

**Akimoto S, Nagaoka T, Saito K, Watanabe S, Takahashi M, Ito K. Comparison of SAR in realistic fetus models of two fetal positions exposed to electromagnetic wave from business portable radio close to maternal abdomen.Conf Proc IEEE Eng Med Biol Soc. 2010:734-737, 2010.**

Since the diversification of the electromagnetic (EM) environment is spreading, it is essential to estimate the EM energy absorption rate [specific absorption rate (SAR)] of a pregnant woman's body and her fetus under various exposure situations. For example, if pregnant women work in jobs where they might wear business portable radios around their abdomens, they should also be concerned about this issue, because the fetuses are in their abdomens. In this paper, in order to evaluate the SAR in the pregnant woman and her fetus when wearing the wireless radio terminal on her abdomen, the SAR distribution in the fetus is calculated using the numerical model of the pregnant woman by exposed to near-field of a normal mode helical antenna (NHA) with a metallic case at 150 MHz. In addition, the SAR in the fetus will be evaluated under two fetal positions. It was found that the fetal SARs are greatly affected by the distance and penetration path from the antenna to the fetal surface. In addition, the fetal SARs are lower than the RF safety guidelines for occupational exposure.

**Akoev IG, Mel'nikov VM, Usachev AV, Kozhokaru AF, [Modification of lethal radiation injury in mice by postradiation exposure to low-intensity centimeter-band radio frequency waves]. Radiats Biol Radioecol 34(4-5):671-674, 1994.** [Article in Russian]

A clearly pronounced modification of acute radiation injury of mice has been obtained by prolonged action (for up to 23 hours) of low-intensity (5 +/- 1.5 mu Wt/cm2) radiofrequency radiation in the ranges of 2-8, 8-18 and 19-27 GHz with a swing frequency of 12-14 Hz, applied immediately after exposure to lethal dose of gamma-radiation. Survival of mice and average life duration of killed mice were increased.

**Akoev IG, Pashovkina MS, Dolgacheva LP, Semenova TP, Kalmykov VL. [Enzymatic activity of some tissues and blood serum from animals and humans exposed to microwaves and hypothesis on the possible role of free radical processes in the nonlinear effects and modification of emotional behavior of animals] Radiats Biol Radioecol 42(3):322-330, 2002.** [Article in Russian]

The dependence of activities of actomyosin ATPase, alkaline phosphatase, aspartataminotranspherase, monoaminoxidase and that of affective rat behavior on frequency of modulation of microwaves (0.8-10 microW/cm2) was explored at short-time actions. Series of nonlinear phenomenons, inexplicable from positions of the energy approaches are revealed, The working hypothesis explaining opportunity of high performance of weak and super-weak microwaves and other revealed phenomena by resonance interaction of such electromagnetic radiofrequency radiation with paramagnetic molecules of biological tissues was proposed. This resonance interaction activate free radicals and initiate auto-supporting and auto-intensifying of chain chemical reactions. The spontaneous autocatalytic oxidation of catecholamines enlarges a common pool of free radicals, capable to participate in such enhanced generating. The protective role of monoaminoxidase is postulated. Monoaminoxidase is basically located on an outer surface of mitochondrias and it is deaminating monoamines. The deaminating prevents penetration of catecholamines inside of mitochondrias and their quinoid oxidation there with formation of free-radical semi-quinons, capable to destroy system of ATP synthesis. These inferences are obliquely confirmed by the experimentally revealed correlation between activity of monoaminoxidase and integrative activity of the rat brain.

**Aksen F, Dasdag S, Akdag MZ, Askin M, Dasdag MM. The effects of whole body cell phone exposure on the t1 relaxation times and trace elements in the serum of rats. Electromag Biol Med. 23:7-11, 2004.**

The objective of this study was to investigate the effects of radiofrequency radiation emitted from cellular phones on: (1) trace elements such as manganese, iron, copper, zinc, (2) T1 relaxation times in serum, and (3) rectal temperature of rats exposed to microwave radiation emitted from cellular phones. Sixteen Spraque–Dawley rats were separated into two groups of eight, one sham-exposed (control) and one exposed (experimental). The rats were confined in Plexiglas cages and a cellular phone was placed 0.5 cm under the cage. For the experimental group, cellular phones were

activated 20 min per day, 7 days a week, for 1 month. For the control group, a cellular phone placed beneath the cage for 20 min a day was turned off. Rectal temperatures were measured weekly. For 250-mW-radiated powers, the whole body average specified absorption rate (SAR) (rms) is 0.52 W/kg and 1-g-averaged peak SAR (rms) is 3.13 W/kg. The Mann-Whitney U test was used for statistical comparisons of groups. T1 relaxation time and the values of iron and copper in the serum of the experimental group were not changed compared to the control group ($p > 0.05$). However, manganese and zinc values in the serum of the experimental group were significantly different from the control group ($p < 0.05$). The difference in rectal temperature measured before and after exposure in the experimental groups was not statistically different from control ($p > 0.05$).

**Aksoy U, Sahin S, Ozkoc S, Ergor G. The effect of electromagnetic waves on the growth of Entamoeba histolytica and Entamoeba dispar. Saudi Med J. 26(9):1388-1390, 2005.**

OBJECTIVE: The aim of this study was to investigate the influence of electromagnetic radiation of a digital Global System for Mobile Communication mobile telephone (900 MHz) on Entamoeba histolytica (E. histolytica) and Entamoeba dispar (E. dispar) (cysts or trophozoites, or both) in a 24-hour period. METHODS: This study was carried out from April 2004 to May 2004 at the Department of Parasitology, Medical Faculty of Dokuz Eylul University in Izmir, Turkey. The cultivated isolate tubes, which were exposed to electromagnetic field at 37OC, were evaluated as study group, whereas the tubes without exposure were assessed as control group. Finally, only living parasites in all tubes were counted using a hemacytometer. The effect of the temperature was evaluated for both control and study groups. RESULTS: The influence of electromagnetic field and temperature was assessed separately for the study group. The parasite number of E. histolytica decreased after exposure at 37OC and room temperature ($p=0.009$) compared to the decrease in the control group ($p=0.009$). The parasite number of E. dispar also decreased after exposure at 37OC and room temperature ($p=0.009$). In comparison to control tubes, this was a significant decrease ($p=0.008$). In the case of exposure of E. histolytica the results did not reveal any significant difference between temperature degrees to magnetic field ($p=0.459$) and E. dispar ($p=0.172$). CONCLUSION: Our findings show that exposure to electromagnetic field for a certain period of time may cause damage that can lead to death in single-cell organisms.

**Aksu R, Uğur F, Bicer C, Menkü A, Güler G, Madenoğlu H, Canpolat DG, Boyaci A. The efficiency of pulsed radiofrequency application on L5 and l6 dorsal roots in rabbits developing neuropathic pain. Reg Anesth Pain Med. 35(1):11-15, 2010.**

**BACKGROUND:** Injury of a peripheral nerve may lead to neuropathic pain, a form of chronic pain that does not respond to traditional pain therapies. The aim of this study was to investigate the effect of pulsed radiofrequency (PRF) applied to the L5 and L6 dorsal roots on the neuropathic pain that develops after sciatic nerve injury in rabbits. **METHODS:** In this study, 18 New Zealand rabbits were used. These were divided into 3 groups. In groups 1 and 2, the left sciatic nerve was tightly ligated as a partial ligation model with 4-0 silk sutures. Group 3 was a sham group. Pulsed radiofrequency was applied to group 1 rabbits on both dorsal roots at 42 degrees C for 8 mins. The responses of all the groups to thermal and mechanical stimuli were measured for a period of 4

weeks after this process. **RESULTS:** Ten days after ligation of the left sciatic nerve and before PRF application, neuropathic pain occurred; the responses of groups 1 and 2 to the hot plate test and to the mechanical stimulus were lower ($P < 0.005$) when compared with the baseline values. There were no statistically significant differences between baseline values and group 1 rabbits' responses to the hot plate test 2 weeks after the application of PRF or to the mechanical stimulus 3 weeks after RF application. The decrease seen in group 2 persisted after 4 weeks ($P < 0.001$). **CONCLUSIONS:** The hyperalgesia that develops as a result of neuropathic pain in rabbits was observed to be reduced by PRF application.

**Akyel Y, Hunt EL, Gambrill C, Vargas C Jr, Immediate post-exposure effects of high-peak-power microwave pulses on operant behavior of Wistar rats. Bioelectromagnetics 12(3):183-195, 1991.**

Behavioral effects of high-peak-power microwave pulses on Wistar rats were studied by operant schedules. Each of twelve rats that had been trained to press a lever to receive food pellets was assigned randomly in groups of four to three different schedules of reinforcement: fixed-ratio (FR), variable-interval (VI), and differential-reinforcement-of-low-rates (DRL). After achieving a steady baseline performance, each animal was exposed for 10 min to 1.25-GHz microwave radiation at 1-MW peak-power (10-microseconds pulse width). Each pulse produced a peak whole-body SA and SAR of 2.1 J/kg and 0.21 MW/kg. Total doses (SAs) were set to 0.50, 1.5, 4.5, and 14 kJ/kg by adjusting the pulse-repetition rate. The corresponding time-averaged whole-body SARs were 0.84, 2.5, 7.6, and 23 W/kg. A microwave-transparent animal holder was used to keep the animal's body axis parallel to the E-field. Exposures at the highest dose caused an average colonic temperature rise of 2.5 degrees C and these animals failed to respond at all for about 13 minutes after the exposure. Their colonic temperatures had decreased to 1.1 degrees C, or less, above their pre-exposure (normal) temperature level when they began to respond. The FR and VI animals failed to reach their baseline levels of performance thereafter, while those on the DRL schedule displayed variable effects. No behavioral effects were found at the lower dose levels. It is concluded that the behavioral perturbations produced by pulsed microwave irradiation were thermal in nature.

**Al-Ali BM, Patzak J, Fischereder K, Pummer K, Shamloul R. Cell phone usage and erectile function. Cent European J Urol. 66(1):75-77, 2013.**

INTRODUCTION: The objective of this pilot study was to report our experience concerning the effects of cell phone usage on erectile function (EF) in men. MATERIAL AND METHODS: We recruited 20 consecutive men complaining of erectile dysfunction (ED) for at least six months (Group A), and another group of 10 healthy men with no complaints of ED (Group B). Anamnesis, basic laboratory investigations, and clinical examinations were performed. All men completed the German version of the Sexual Health Inventory for Men (SHIM) for evaluation of the International Index of Erectile Function (IIEF), as well as another questionnaire designed by our clinicians that assessed cell phone usage habits. RESULTS: There was no significant difference between both groups regarding age, weight, height, and total testosterone (Table 1). The SHIM scores of Group A were significantly lower than that of Group B, 11.2 ±5 and 24.2 ±2.3, respectively. Total time spent talking on the cell phone per week was not significantly

higher in Group A over B, 17.6 ±11.1 vs. 12.5 ±7 hours. Men with ED were found to carry their 'switched on' cell phones for a significantly longer time than those without ED, 4.4 ±3.6 vs. 1.8 ±1 hours per day. CONCLUSIONS: We found a potential correlation with cell phone usage and a negative impact on EF. Further large-scale studies confirming our initial data and exploring the mechanisms involved in this phenomenon are recommended.

**Alanko T, Hietanen M  Occupational Exposure To Radiofrequency Fields In Antenna Towers. Radiat Prot Dosimetry. 123(4):537-539,2007.**

Exposure of workers to radiofrequency fields was assessed in two medium-sized antenna towers. Towers had transmitting antennas from different networks, e.g. mobile phone networks, radio and digital TV sub-stations and amateur radio. The levels of radiofrequency fields were measured close to the ladders of the towers. All measured values were below ICNIRP occupational reference levels.

**Aldad TS, Gan G, Gao XB, Taylor HS.Fetal radiofrequency radiation exposure from 800-1900 mhz-rated cellular telephones affects neurodevelopment and behavior in mice. Sci Rep. 2:312, 2012.**

Neurobehavioral disorders are increasingly prevalent in children, however their etiology is not well understood. An association between prenatal cellular telephone use and hyperactivity in children has been postulated, yet the direct effects of radiofrequency radiation exposure on neurodevelopment remain unknown. Here we used a mouse model to demonstrate that in-utero radiofrequency exposure from cellular telephones does affect adult behavior. Mice exposed in-utero were hyperactive and had impaired memory as determined using the object recognition, light/dark box and step-down assays. Whole cell patch clamp recordings of miniature excitatory postsynaptic currents (mEPSCs) revealed that these behavioral changes were due to altered neuronal developmental programming. Exposed mice had dose-responsive impaired glutamatergic synaptic transmission onto layer V pyramidal neurons of the prefrontal cortex. We present the first experimental evidence of neuropathology due to in-utero cellular telephone radiation. Further experiments are needed in humans or non-human primates to determine the risk of exposure during pregnancy.

**Al-Damegh MA. Rat testicular impairment induced by electromagnetic radiation from a conventional cellular telephone and the protective effects of the antioxidants vitamins C and E. Clinics (Sao Paulo). 67(7):785-792, 2012.**

OBJECTIVE:  The aim of this study was to investigate the possible effects of electromagnetic radiation from conventional cellular phone use on the oxidant and antioxidant status in rat blood and testicular tissue and determine the possible protective role of vitamins C and E in preventing the detrimental effects of electromagnetic radiation on the testes. MATERIALS AND METHODS: The treatment groups were exposed to an electromagnetic field, electromagnetic field plus vitamin C (40 mg/kg/day) or electromagnetic field plus vitamin E (2.7 mg/kg/day). All groups were exposed to the same electromagnetic frequency for 15, 30, and 60 min daily for two weeks. RESULTS:

There was a significant increase in the diameter of the seminiferous tubules with a disorganized seminiferous tubule sperm cycle interruption in the electromagnetism-exposed group. The serum and testicular tissue conjugated diene, lipid hydroperoxide, and catalase activities increased 3-fold, whereas the total serum and testicular tissue glutathione and glutathione peroxidase levels decreased 3-5 fold in the electromagnetism-exposed animals. CONCLUSION: Our results indicate that the adverse effect of the generated electromagnetic frequency had a negative impact on testicular architecture and enzymatic activity. This finding also indicated the possible role of vitamins C and E in mitigating the oxidative stress imposed on the testes and restoring normality to the testes.

**Al-Dousary SH**. **Mobile phone induced sensorineural hearing loss. Saudi Med J. 28(8):1283-1286, 2007.**

The increased use of mobile phones worldwide has focused interest on the biological effects and possible health outcomes of exposure to radiofrequency fields from mobile phones, and their base stations. Various reports suggest that mobile phone use can cause health problems like fatigue, headache, dizziness, tension, and sleep disturbances; however, only limited research data is available in medical literature regarding interaction between electromagnetic fields emitted by mobile phones and auditory function; and the possible impact on hearing. We report a case of sensorineural hearing loss due to Global System for Mobile Communications mobile phone use, in a 42-year-old male.

**Alhekail ZO. Electromagnetic radiation from microwave ovens. J Radiol Prot 21(3):251-258, 2001.**

Electromagnetic radiation from microwave ovens in Saudi Arabia was investigated by means of a field measurement survey. The survey was carried out for 106 ovens used in households and restaurants in Riyadh city. Ovens were between 1 month and 14 years old with operating power ranging from 0.5 to 4.4 kW. One oven was found to leak more than the 5 mW cm(-2) limit specified in the standard. Fifteen other ovens were found to leak 1 mW cm(-2) or more, with the remaining ovens leaking less than that. Based on the survey result, previous studies and the fast decay of radiated power density with distance from the oven, the conclusion was that user exposure to RF radiation from microwave ovens is much less than the general public exposure limit set by most international standards at 2450 MHz, i.e. 1 mW cm(-2), and that a detrimental effect on health is an unlikely result of exposure to radiation from microwave ovens.

**Alhusseiny A, Al-Nimer M, Majeed A. Electromagnetic energy radiated from mobile phone alters electrocardiographic records of patients with ischemic heart disease. Ann Med Health Sci Res. 2(2):146-151, 2012.**

**BACKGROUND:** Electromagnetic energy radiated from mobile phones did not show significant effect on the blood pressure, heart rate, and electrocardiographic (ECG) parameters in animals and humans. **AIM:** This study aimed to investigate the effect of radiofrequency of mobile phone on the electrocardiographic parameters in patients with history of ischemic heart disease, taking into consideration the gender factor. **SUBJECTS**

**AND METHODS:** A total number of 356 participants (129 males and 227 females) were admitted in this study. They were grouped into: subjects without cardiac diseases (Group I), patients with ischemic heart disease (Group II), and patients with history of cardiac diseases not related to myocardial ischemia (Group III). Electrocardiogram was obtained from each patient when the mobile phone was placed at the belt level and over precordium in turn-off mode (baseline) and turn-on mode for 40 sec ringing. The records of ECG were electronically analyzed. **RESULTS:** Prolongation of QTc interval was significantly observed in male gender of Groups I and III ($P < 0.001$). Male patients of Group II showed significant QTc interval prolongation ($P = 0.01$) and changes in the voltage criteria ($P = 0.001$). These changes were not observed in female patients with ischemic heart disease. The position of mobile at the belt level or over the precordium showed effects on the heart. **CONCLUSIONS:** The radiofrequency of cell phone prolongs the QT interval in human beings and it interferes with voltage criteria of ECG records in male patients with myocardial ischemia.

**Al-Khlaiwi T, Meo SA. Association of mobile phone radiation with fatigue, headache, dizziness, tension and sleep disturbance in Saudi population. Saudi Med J. 25(6):732-736, 2004.**

OBJECTIVE: The widespread use of mobile phones has been increased over the past decade; they are now an essential part of business, commerce and society. The use of mobile phones can cause health problems. Therefore, the aim of the present study is to investigate the association of using mobile phones with fatigue, headache, dizziness, tension and sleep disturbance in the Saudi population and provide health and social awareness in using these devices. METHODS: This study was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Kingdom of Saudi Arabia during the year 2002 to 2003. In the present study, a total of 437 subjects (55.1% male and 39.9% female) were invited, they have and had been using mobile phones. A questionnaire was distributed regarding detailed history and association of mobile phones with health hazards. RESULTS: The results of the present study showed an association between the use of mobile phones and health hazards. The overall mean percentage for these clinical findings in all groups were headache (21.6%), sleep disturbance (4.%), tension (3.9%), fatigue (3%) and dizziness (2.4%). CONCLUSION: Based on the results of the present study, we conclude that the use of mobile phones is a risk factor for health hazards and suggest that long term or excessive use of mobile phones should be avoided by health promotion activities such as group discussions, public presentations and through electronic and print media sources.

**Alon L, Cho GY, Yang X, Sodickson DK, Deniz CM. A method for safety testing of radiofrequency/microwave-emitting devices using MRI. Magn Reson Med. 2014 Nov 25. doi: 10.1002/mrm.25521. [Epub ahead of print]**

PURPOSE: Strict regulations are imposed on the amount of radiofrequency (RF) energy that devices can emit to prevent excessive deposition of RF energy into the body. In this study, we investigated the application of MR temperature mapping and 10-g average specific absorption rate (SAR) computation for safety evaluation of RF-emitting devices. METHODS: Quantification of the RF power deposition was shown for an MRI-compatible dipole antenna and a non-MRI-compatible mobile phone via phantom temperature

change measurements. Validation of the MR temperature mapping method was demonstrated by comparison with physical temperature measurements and electromagnetic field simulations. MR temperature measurements alongside physical property measurements were used to reconstruct 10-g average SAR. RESULTS: The maximum temperature change for a dipole antenna and the maximum 10-g average SAR were 1.83°C and 12.4 W/kg, respectively, for simulations and 1.73°C and 11.9 W/kg, respectively, for experiments. The difference between MR and probe thermometry was <0.15°C. The maximum temperature change and the maximum 10-g average SAR for a cell phone radiating at maximum output for 15 min was 1.7°C and 0.54 W/kg, respectively. CONCLUSION: Information acquired using MR temperature mapping and thermal property measurements can assess RF/microwave safety with high resolution and fidelity.

**Al-Qahtani K. Mobile Phone Use and the Risk of Parotid Gland Tumors: A Retrospective Case-Control Study. Gulf J Oncolog. 2016 Jan;1(20):71-8.**

BACKGROUND: Mobile phones are integral part of the modern lifestyle. As they emit radio frequency electromagnetic field, their role in carcinogenesis needs to be ascertained. The goal of this study was to investigate the association between the use of cellular phones and the risk for parotid gland tumors. MATERIALS AND METHODS: A total of 26 patients diagnosed with parotid gland tumors and 61 healthy controls were enrolled through a hospital-based retrospective case-control study. The patients were referred and admitted to a tertiary hospital from January 1996 to March 2013. RESULTS: The odds of exposure were 3.47 times higher among patients compared to their controls. 95% CI suggested that the true Odds Ratio (OR) at the population level could be somewhere between 1.3 and 9.23 and so the observed OR was statistically significant at 5% level of significance. CONCLUSIONS: Overall, an association between the exposure of cellular phone use for more than 1 hour daily and parotid tumor was observed. This association should be interpreted with caution because of the relatively small sample size.

**Alsanosi AA, Al-Momani MO, Hagr AA, Almomani FM, Shami IM, Al-Habeeb SF. The acute auditory effects of exposure for 60 minutes to mobile`s electromagnetic field. Saudi Med J. 34(2):142-146, 2013.**

**OBJECTIVE:** To assess the immediate consequences of 60 minutes exposure to mobile phones on hearing function by determining changes in distortion product otoacoustic emission (DPOAE) and hearing threshold levels (HTLs). **METHODS:** This prospective control clinical trial study was carried out at the Ear, Nose and Throat Department, King Abdulaziz University Hospital, Riyadh, Kingdom of Saudi Arabia from July 2009 to July 2011. The data collected included age, symptoms experienced after exposure, and HTLs and DPOAE were recorded before, and immediately after 60 minutes of exposure to the same model of mobile phone. **RESULTS:** Heat/pain was the most commonly reported symptom. In the test-ears, significant shift ($p<0.05$) was noticed in HTLs at 1000 and 2000 Hz but not at other frequencies, while non test-ears did not reveal significant shift in HTLs. Additionally, test-ears revealed significant differences ($p<0.05$) in DPOAE at 1000

Hz, 1400 Hz, 2000 Hz, and at the average of all frequencies, while non test-ears did not show significant differences. **CONCLUSION:** Sixty minutes of close exposure to electromagnetic fields emitted by a mobile phone had an immediate effect on HTL assessed by pure-tone audiogram and inner ear (assessed by DPOAE) in young human subjects. It also caused a number of other otologic symptoms.

**Al-Serori H, Kundi M, Ferk F, Mišík M, Nersesyan A, Murbach M, Lah TT, Knasmüller S. Evaluation of the potential of mobile phone specific electromagnetic fields (UMTS) to produce micronuclei in human glioblastoma cell lines. Toxicol In Vitro. 40:264-271, 2017.**

Some epidemiological studies indicate that mobile phones cause glioblastomas in humans. Since it is known that genomic instability plays a key role in the etiology of cancer, we investigated the effects of the universal mobile telecommunications system radiofrequency (UMTS-RF) signal, which is used in "smart" phones, on micronucleus (MN) formation and other anomalies such as nuclear buds (NBUDs) and nucleoplasmatic bridges (NPBs). MN are formed by structural and numerical aberrations, NBs reflect gene amplification and NPBs are formed from dicentric chromosomes. The experiments were conducted with human glioblastoma cell lines, which differ in regard to their p53 status, namely U87 (wild-type) and U251 (mutated). The cells were cultivated for 16h in presence and absence of fetal calf serum and exposed to different SAR doses (0.25, 0.50 and 1.00W/kg), which reflect the exposure of humans, in presence and absence of mitomycin C as former studies indicate that RF may cause synergistic effects in combination with this drug. We found no evidence for induction of MN and other anomalies. However, with the highest dose, induction of apoptosis was observed in U251 cells on the basis of the morphological features of the cells. Our findings indicate that the UMTS-RF signal does not cause chromosomal damage in glioblastoma cells; the mechanisms which lead to induction of programmed cell death will be investigated in further studies.[1]

**Altamura G, Toscano S, Gentilucci G, Ammirati F, Castro A, Pandozi C, Santini M, Influence of digital and analogue cellular telephones on implanted pacemakers. Eur Heart J 18(10):1632-4161, 1997.**

The aim of this study was to find out whether digital and analogue cellular 'phones affect patients with pacemakers. The study comprised continuous ECG monitoring of 200 pacemaker patients. During the monitoring certain conditions caused by interference created by the telephone were looked for: temporary or prolonged pacemaker inhibition; a shift to asynchronous mode caused by electromagnetic interference; an increase in ventricular pacing in dual chamber pacemakers, up to the programmed upper rate. The Global System for Mobile Communications system interfered with pacing 97 times in 43 patients (21.5%). During tests on Total Access of Communication System telephones, there were 60 cases of pacing interference in 35 patients (17.5%). There were 131 interference episodes during ringing vs 26 during the on/off phase; ($P < 0.0001$); 106 at maximum sensitivity level vs 51 at the 'base' value; $P <0.0001$). Prolonged pacing inhibition (> 4 s) was seen at the pacemaker 'base' sensing value in six patients using the Global system but in only one patient using Total Access. CONCLUSION: Cellular

'phones may be dangerous for pacemaker patients. However, they can be used safely if patients do not carry the 'phone close to the pacemaker, which is the only place where high risk interference has been observed.

**Altuntas G, Sadoglu D, Ardic S, Yilmaz H, Imamoglu M, Turedi S.Acute effects of the electromagnetic waves emitted by mobile phones on attention in emergency physicians. Am J Emerg Med. 2017 Nov 13. pii: S0735-6757(17)30940-3. doi: 10.1016/j.ajem.2017.11.031.**

STUDY OBJECTIVE: The purpose of this study was to investigate the acute effects of the electromagnetic waves (EMW) emitted by mobile phones on attention in emergency physicians. METHODS: This single-center, prospective, randomized, double-blinded clinical study was performed among emergency physicians in a tertiary hospital. Thirty emergency physicians were enrolled in the study. Initial d2 test was applied in the evaluation of attention and concentration of all the physicians, who were randomly assigned into one of two groups. The control group members hold mobile phones in 'off' mode to their left ears for 15min. The members of the intervention group hold mobile phones in 'on' mode to their left ears for 15min, thus exposing them to 900-1800MHz EMW. The d2 test was re-applied to both groups after this procedure. Differences in attention and concentration levels between the groups were compared. RESULTS: Difference between initial and final d2 test in total performance (TN-E, p=0.319), in total number of figures marked (TN, p=0.177), in test performance percentile (PR, p=0.619) and in attention fluctuation (FR, p=0.083) were similar between the groups. However, difference in the number of figures missed (E1 selective attention, p=0.025), difference between numbers of incorrectly marked figures (E2, p=0,018) and difference in focus levels (E, p=0.016) were significantly in favor of the intervention group. CONCLUSION: According to our study findings, the EMW emitted by mobile phones has no deleterious effect on the attention and concentration levels of emergency physicians, and even has a positive impact on selective attention levels.

**Aly AA, Cheema MI, Tambawala M,  Laterza R, Zhou E, Rathnabharathi K, Barnes FS. Effects of 900-MHz Radio Frequencies on the Chemotaxis of Human Neutrophils in Vitro. IEEE Transactions on Biomedical Engineering, 55(2): 795-797, 2008.**

Summary: The effects of radio frequency (RF) fields on the ability of human neutrophils to follow concentration gradients of Cyclic Adenosine 3', 5'-Monophosphate (C-AMP) are reported. Blood from healthy adult donors was exposed in vitro to different temperatures and 900-MHz RF field at approximately 0.4 V/m. It was observed that the neutrophils' speed increased with increasing temperatures from 35 $^{o}$C to 40 $^{o}$C where it peaked and then decreased above 40 $^{o}$C without RF exposure. When 900-MHz RF field was applied, the speed increased above the value observed at the same temperature, and the maximum speed exceeded that measured value at any temperature by approximately 50%. The calculated temperature change resulting from the RF exposure was less than one microdegree. The direction of motion changed from along the concentration gradient and the electrical field lines to motion at right angles to the concentration gradient and the electric field. The average time for the neutrophils to respond to the effect of RF radiation was about 2.5 min.

**Ammari M, Brillaud E, Gamez C, Lecomte A, Sakly M, Abdelmelek H, de Seze R. Effect of a chronic GSM 900MHz exposure on glia in the rat brain. Biomed Pharmacother. 62(4):273-281, 2008.**

Extension of the mobile phone technology raises concern about the health effects of 900MHz microwaves on the central nervous system (CNS). In this study we measured GFAP expression using immunocytochemistry method, to evaluate glial evolution 10 days after a chronic exposure (5 days a week for 24 weeks) to GSM signal for 45min/day at a brain-averaged specific absorption rate (SAR)=1.5W/kg and for 15min/day at a SAR=6W/kg in the following rat brain areas: prefrontal cortex (PfCx), caudate putamen (Cpu), lateral globus pallidus of striatum (LGP), dentate gyrus of hippocampus (DG) and cerebellum cortex (CCx). In comparison to sham or cage control animals, rats exposed to chronic GSM signal at 6W/kg have increased GFAP stained surface areas in the brain ($p<0.05$). But the chronic exposure to GSM at 1.5W/kg did not increase GFAP expression. Our results indicated that chronic exposure to GSM 900MHz microwaves (SAR=6W/kg) may induce persistent astroglia activation in the rat brain (sign of a potential gliosis).

**Ammari M, Lecomte A, Sakly M, Abdelmelek H, de-Seze R. Exposure to GSM 900 MHz electromagnetic fields affects cerebral cytochrome c oxidase activity. Toxicology. 250(1):70-74, 2008.**

The world-wide and rapidly growing use of mobile phones has raised serious concerns about the biological and health-related effects of radio frequency (RF) radiation, particularly concerns about the effects of RFs upon the nervous system. The goal of this study was conducted to measure cytochrome oxidase (CO) levels using histochemical methods in order to evaluate regional brain metabolic activity in rat brain after exposure to a GSM 900 MHz signal for 45 min/day at a brain-averaged specific absorption rate (SAR) of 1.5 W/Kg or for 15 min/day at a SAR of 6 W/Kg over seven days. Compared to the sham and control cage groups, rats exposed to a GSM signal at 6 W/Kg showed decreased CO activity in some areas of the prefrontal and frontal cortex (infralimbic cortex, prelimbic cortex, primary motor cortex, secondary motor cortex, anterior cingulate cortex areas 1 and 2 (Cg1 and Cg2)), the septum (dorsal and ventral parts of the lateral septal nucleus), the hippocampus (dorsal field CA1, CA2 and CA3 of the hippocampus and dental gyrus) and the posterior cortex (retrosplenial agranular cortex, primary and secondary visual cortex, perirhinal cortex and lateral entorhinal cortex). However, the exposure to GSM at 1.5 W/Kg did not affect brain activity. Our results indicate that 6 W/Kg GSM 900 MHz microwaves may affect brain metabolism and neuronal activity in rats.

**Ammari M, Jacquet A, Lecomte A, Sakly M, Abdelmelek H, de Seze R. Effect of head-only sub-chronic and chronic exposure to 900-MHz GSM electromagnetic fields on spatial memory in rats. Brain Inj. 22(13-14):1021-1029, 2008.**

**PRIMARY OBJECTIVE:** This study was carried out to investigate the behavioural effects of sub-chronic and chronic head-only exposure to 900 MHz GSM (Global System for Mobile communications) in male rats. **METHODS:** Rats were exposed for 45 minutes per

day, at a brain-averaged specific absorption rate (SAR) = 1.5 W Kg(-1) or 15 minutes per day at a SAR = 6 W Kg(-1), during 8 or 24 weeks. Then, their spatial memory was tested using the radial-arm maze. In the first phase (10 days), rats were trained to visit the eight arms of the maze without returning to an arm already visited. In the second phase (8 days), a 45-minute intra-trial delay was introduced after four visited arms. **RESULTS:** Performance of exposed rats (1.5 or 6 W Kg(-1)) was compared with that of sham, negative control and positive control rats. Scopolamine treatment in the positive control rats induced deficit in spatial memory task in the second phase of the test. However, spatial memory task was unaffected in exposed rats. **CONCLUSION:** Sub-chronic and chronic head-only exposure of rats to GSM 900 MHz signal (45-minutes, SAR = 1.5 or 15-minutes, SAR = 6 W Kg(-1)) did not induce spatial memory deficit in the radial-arm maze.

**Ammari M, Gamez C, Lecomte A, Sakly M, Abdelmelek H, De Seze R. GFAP expression in the rat brain following sub-chronic exposure to a 900 MHz electromagnetic field signal. Int J Radiat Biol. 86(5):367-375, 2010.**

PURPOSE: The rapid development and expansion of mobile communications contributes to the general debate on the effects of electromagnetic fields emitted by mobile phones on the nervous system. This study aims at measuring the glial fibrillary acidic protein (GFAP) expression in 48 rat brains to evaluate reactive astrocytosis, three and 10 days after long-term head-only sub-chronic exposure to a 900 MHz electromagnetic field (EMF) signal, in male rats. METHODS: Sprague-Dawley rats were exposed for 45 min/day at a brain-averaged specific absorption rate (SAR) = 1.5 W/kg or 15 min/day at a SAR = 6 W/kg for five days per week during an eight-week period. GFAP expression was measured by the immunocytochemistry method in the following rat brain areas: Prefrontal cortex, cerebellar cortex, dentate gyrus of the hippocampus, lateral globus pallidus of the striatum, and the caudate putamen. RESULTS: Compared to the sham-treated rats, those exposed to the sub-chronic GSM (Global System for mobile communications) signal at 1.5 or 6 W/kg showed an increase in GFAP levels in the different brain areas, three and ten days after treatment. CONCLUSION: Our results show that sub-chronic exposures to a 900 MHz EMF signal for two months could adversely affect rat brain (sign of a potential gliosis).

**Amoako JK, Fletcher JJ, Darko EO. Measurement and analysis of radiofrequency radiations from some mobile phone base stations in Ghana. Radiat prot dosimetry. 135(4):256-260, 2009.**

A survey of the radiofrequency electromagnetic radiation at public access points in the vicinity of 50 cellular phone base stations has been carried out. The primary objective was to measure and analyse the electromagnetic field strength levels emitted by antennae installed and operated by the Ghana Telecommunications Company. On all the sites measurements were made using a hand-held spectrum analyser to determine the electric field level with the 900 and 1800 MHz frequency bands. The results indicated that power densities at public access points varied from as low as 0.01 microW m(-2) to as high as 10 microW m(-2) for the frequency of 900 MHz. At a transmission frequency of 1800 MHz, the variation of power densities is from 0.01 to 100 microW m(-2). The results were found to be in compliant with the International Commission on Non-ionizing Radiological

Protection guidance level but were 20 times higher than the results generally obtained for such a practice elsewhere. There is therefore a need to re-assess the situation to ensure reduction in the present level as an increase in mobile phone usage is envisaged within the next few years.

**Anane R, Geffard M, Taxile M, Bodet D, Billaudel B, Dulou PE, Veyret B. Effects of GSM-900 microwaves on the experimental allergic encephalomyelitis (EAE) rat model of multiple sclerosis. Bioelectromagnetics 24(3):211-213, 2003.**

The effects of acute exposure to GSM-900 microwaves (900 MHz, 217 Hz pulse modulation) on the clinical parameters of the acute experimental allergic encephalomyelitis (EAE) model in rats were investigated in two independent experiments: rats were either habituated or nonhabituated to the exposure restrainers. EAE was induced with a mixture of myelin basic protein and Mycobacterium tuberculosis. Female Lewis rats were divided into cage control, sham exposed, and two groups exposed either at 1.5 or 6.0 W/kg local specific absorption rate (SAR averaged over the brain) using a loop antenna placed over their heads. There was no effect of a 21-day exposure (2 h/day) on the onset, duration, and termination of the EAE crisis.

**Anane R, Dulou P-E, Taxile M, Geffard M, Crespeau F, Veyret B. Effects of GSM-900 microwaves on DMBA-induced mammary gland tumors in female Sprague-Dawley rats. Radiat Res 160:492–497, 2003.**

The aim of this investigation was to test the hypothesis that sub-chronic whole-body exposure to GSM-900 microwaves had an effect on tumor promotion and progression. Mammary tumors were induced by ingestion of a single 10-mg dose of 7,12-dimethylbenz(a)anthracene (DMBA) in female Sprague-Dawley rats (Ico:OFA-SD; IOPS Caw). In two independent experiments, DMBA-treated animals were divided into four groups: sham-exposed (16) and exposed (three groups of 16 animals). The specific absorption rates (SARs), averaged over the whole body, were 3.5, 2.2 and 1.4 W/kg in the first experiment (May–July) and 1.4, 0.7 and 0.1 W/kg in the second experiment (September–November). Exposure started 10 days after DMBA treatment and lasted 2 h/day, 5 days/week for 9 weeks. Animals were exposed to plane waves with the electric field parallel to the long axis of the animals. Body weight and the number, location and size of the tumors were recorded at regular intervals. Rats were killed humanely 3 weeks after the end of exposure. The results are negative in terms of latency, multiplicity and tumor volume. With regard to tumor incidence, in the first experiment there was an increase in the rate of incidence at 1.4 W/kg but less at 2.2 W/kg and none at 3.5 W/kg. Overall, these results, which are rather inconsistent, do not bring new evidence of a co-promoting effect of exposure to GSM-900 signals using the DMBA rat model.

**Anderson LE, Sheen DM, Wilson BW, Grumbein SL, Creim JA, Sasser LB. Two-year chronic bioassay study of rats exposed to a 1.6 GHz radiofrequency signal. Radiat Res. 162(2):201-210, 2004.**

The purpose of this study was to determine whether long-term exposure to a 1.6 GHz radiofrequency (RF) field would affect the incidence of cancer in Fischer 344 rats. Thirty-six timed-pregnant rats were randomly assigned to each of three treatment groups: two

groups exposed to a far-field RF Iridium signal and a third group that was sham exposed. Exposures were chosen such that the brain SAR in the fetuses was 0.16 W/kg. Whole-body far-field exposures were initiated at 19 days of gestation and continued at 2 h/day, 7 days/week for dams and pups after parturition until weaning (approximately 23 days old). The offspring (700) of these dams were selected, 90 males and 90 females for each near-field treatment group, with SAR levels in the brain calculated to be as follows: (1) 1.6 W/kg, (2) 0.16 W/kg and (3) near-field sham controls, with an additional 80 males and 80 females as shelf controls. Confining, head-first, near-field exposures of 2 h/day, 5 days/week were initiated when the offspring were 36 +/- 1 days old and continued until the rats were 2 years old. No statistically significant differences were observed among treatment groups for number of live pups/litter, survival index, and weaning weights, nor were there differences in clinical signs or neoplastic lesions among the treatment groups. The percentages of animals surviving at the end of the near-field exposure were not different among the male groups. In females a significant decrease in survival time was observed for the cage control group.

**Anderson V, Joyner KH, Specific absorption rate levels measured in a phantom head exposed to radio frequency transmissions from analog hand-held mobile phones. Bioelectromagnetics 16(1):60-69,1995.**

Electric fields (E-fields) induced within a phantom head from exposure to three different advanced mobile phone system (AMPS) hand-held telephones were measured using an implantable E-field probe. Measurements were taken in the eye nearest the phone and along a lateral scan through the brain from its centre to the side nearest the phone. During measurement, the phones were positioned alongside the phantom head as in typical use and were configured to transmit at maximum power (600 mW nominal). The specific absorption rate (SAR) was calculated from the in situ E-field measurements, which varied significantly between phone models and antenna configuration. The SARs induced in the eye ranged from 0.007 to 0.21 W/kg. Metal-framed spectacles enhanced SAR levels in the eye by 9-29%. In the brain, maximum levels were recorded at the measurement point closest to the phone and ranged from 0.12 to 0.83 W/kg. These SARs are below peak spatial limits recommended in the U.S. and Australian national standards [IEEE Standards Coordinating Committee 28 (1991): C95.1-1991 and Standards Australia (1990): AS2772.1-1990] and the IRPA guidelines for safe exposure to radio frequency (RF) electromagnetic fields [IRPA (1988): Health Phys 54:115-123]. Furthermore, a detailed thermal analysis of the eye indicated only a 0.022 degrees C maximum steady-state temperature rise in the eye from a uniform SAR loading of 0.21 W/kg. A more approximate thermal analysis in the brain also indicated only a small maximum temperature rise of 0.034 degrees C for a local SAR loading of 0.83 W/kg.

**Anderson V. Comparisons of peak SAR levels in concentric sphere head models of children and adults for irradiation by a dipole at 900 MHz. Phys Med Biol. 48(20):3263-3275, 2003.**

The aim of this study is to examine the scale and significance of differences in peak specific energy absorption rate (SAR) in the brains of children and adults exposed to radiofrequency emissions from mobile phones. Estimates were obtained by method of multipole analysis of a three layered (scalp/cranium/brain) spherical head exposed to a

nearby 0.4 lambda dipole at 900 MHz. A literature review of head parameters that influence SAR induction revealed strong indirect evidence based on total body water content that there are no substantive age-related changes in tissue conductivity after the first year of life. However, it was also found that the thickness of the ear, scalp and cranium do decrease on average with decreasing age, though individual variability within any age group is very high. The model analyses revealed that compared to an average adult, the peak brain 10 g averaged SAR in mean 4, 8, 12 and 16 year olds (yo) is increased by a factor of 1.31, 1.23, 1.15 and 1.07, respectively. However, contrary to the expectations of a recent prominent expert review, the UK Stewart Report, the relatively small scale of these increases does not warrant any special precautionary measures for child mobile phone users since: (a) SAR testing protocols as contained in the CENELEC (2001) standard provide an additional safety margin which ensures that allowable localized SAR limits are not exceeded in the brain; (b) the maximum worst case brain temperature rise (approximately 0.13 to 0.14 degrees C for an average 4 yo) in child users of mobile phones is well within safe levels and normal physiological parameters; and (c) the range of age average increases in children is less than the expected range of variation seen within the adult population.

**Andersson B, Berg M, Arnetz BB, Melin L, Langlet I, Lidén S. A cognitive-behavioral treatment of patients suffering from "electric hypersensitivity". Subjective effects and reactions in a double-blind provocation study. J Occup Environ Med. 38(8):752-758, 1996.**

This study tested psychological treatment of patients with "electric hypersensitivity." Seventeen patients were randomly assigned to a treatment group or a waiting-list control group in a pretest-posttest control group design. The patients were also taking part in double-blind provocation tests before and after the treatment. Subjective ratings of symptoms were registered and blood samples were taken and analyzed for "stress-related" variables, such as prolactin, cortisol, dehydroepiandrosterone, and cholesterol levels. The patients in the experimental group reduced their evaluations of the disability more than the control group did. This indicates that psychological treatment may be of value in this disease. However, none of the psychophysiological measures or the subjective reactions to the provocation test showed any significant between-group difference. The conclusion from the provocation test is that this group of alleged hypersensitive patients did not react to the electromagnetic fields.

**Andrzejak R, Poreba R, Poreba M, Derkacz A, Skalik R, Gac P, Beck B, Steinmetz-Beck A, Pilecki W. The influence of the call with a mobile phone on heart rate variability parameters in healthy volunteers. Ind Health. 46(4):409-417, 2008.**

It is possible that electromagnetic field (EMF) generated by mobile phones (MP) may have an influence on the autonomic nervous system (ANS) and modulates the function of circulatory system. The aim of the study was to estimate the influence of the call with a mobile phone on heart rate variability (HRV) in young healthy people. The time and frequency domain HRV analyses were performed to assess the changes in sympathovagal balance in a group of 32 healthy students with normal electrocardiogram (ECG) and echocardiogram at rest. The frequency domain variables were computed:

ultra low frequency (ULF) power, very low frequency (VLF) power, low frequency (LF) power, high frequency (HF) power and LF/HF ratio was determined. ECG Holter monitoring was recorded in standardized conditions: from 08:00 to 09:00 in the morning in a sitting position, within 20 min periods: before the telephone call (period I), during the call with use of mobile phone (period II), and after the telephone call (period III). During 20 min call with a mobile phone time domain parameters such as standard deviation of all normal sinus RR intervals (SDNN [ms]--period I: 73.94+/-25.02, period II: 91.63+/-35.99, period III: 75.06+/-27.62; I-II: $p<0.05$, II-III: $p<0.05$) and standard deviation of the averaged normal sinus RR intervals for all 5-mm segments (SDANN [ms]--period I: 47.78+/-22.69, period II: 60.72+/-27.55, period III: 47.12+/-23.21; I-II: $p<0.05$, II-III: $p<0.05$) were significantly increased. As well as very low frequency (VLF [ms2]--period I: 456.62+/-214.13, period II: 566.84+/-216.99, period III: 477.43+/-203.94; I-II: $p<0.05$), low frequency (LF [ms(2)]--period I: 607.97+/-201.33, period II: 758.28+/-307.90, period III: 627.09+/-220.33; I-II: $p<0.01$, II-III: $p<0.05$) and high frequency (HF [ms(2)]--period I: 538.44+/-290.63, period II: 730.31+/-445.78, period III: 590.94+/-301.64; I-II: $p<0.05$) components were the highest and the LF/HF ratio (period I: 1.48+/-0.38, period II: 1.16+/-0.35, period III: 1.46+/-0.40; I-II: $p<0.05$, II-III: $p<0.05$) was the lowest during a call with a mobile phone. The tone of the parasympathetic system measured indirectly by analysis of heart rate variability was increased while sympathetic tone was lowered during the call with use of a mobile phone. It was shown that the call with a mobile phone may change the autonomic balance in healthy subjects. Changes in heart rate variability during the call with a mobile phone could be affected by electromagnetic field but the influence of speaking cannot be excluded.

**Angelone LM, Bit-Babik G, Chou CK. Computational Electromagnetic analysis in a human head model with EEG electrodes and leads exposed to RF-field sources at 915 MHz and 1748 MHz. Radiat Res. 174(1):91-100. 2010.**

Abstract An electromagnetic analysis of a human head with EEG electrodes and leads exposed to RF-field sources was performed by means of Finite-Difference Time-Domain simulations on a 1-mm(3) MRI-based human head model. RF-field source models included a half-wave dipole, a patch antenna, and a realistic CAD-based mobile phone at 915 MHz and 1748 MHz. EEG electrodes/leads models included two configurations of EEG leads, both a standard 10-20 montage with 19 electrodes and a 32-electrode cap, and metallic and high resistive leads. Whole-head and peak 10-g average SAR showed less than 20% changes with and without leads. Peak 1-g and 10-g average SARs were below the ICNIRP and IEEE guideline limits. Conversely, a comprehensive volumetric assessment of changes in the RF field with and without metallic EEG leads showed an increase of two orders of magnitude in single-voxel power absorption in the epidermis and a 40-fold increase in the brain during exposure to the 915 MHz mobile phone. Results varied with the geometry and conductivity of EEG electrodes/leads. This enhancement confirms the validity of the question whether any observed effects in studies involving EEG recordings during RF-field exposure are directly related to the RF fields generated by the source or indirectly to the RF-field-induced currents due to the presence of conductive EEG leads.

**Anghileri LJ, Mayayo E, Domingo JL, Thouvenot P. Radiofrequency-induced**

**carcinogenesis: cellular calcium homeostasis changes as a triggering factor. InterJ RadBiol. 81(3):205-209, 2005.**

The aim was to study the effects of radiofrequency (Rf) in a mice strain characterized by age-determined carcinogenesis of lymphatic tissues. Mice were treated with a 1 h/week Rf exposure for 4 months. A group submitted to sham exposure was used as control animals. The evolution of carcinogenesis was followed up to 18 months. The maximal life span of control mice was about 24 months. All dead animals were clinically and histologically examined to give an age-determined comparative quantification of the evolving carcinogenesis. A radiocalcium tracer method permitted the evaluation of Rf effects on transmembrane transport of extracellular calcium at 1 and 24 h after exposure. The determination of induced lipid peroxidation completed this second study. The findings show that Rf provoked an earlier general lymphocyte cell infiltration, formation of lymphoblastic ascites and extranodal tumours of different histological types, as well as an increased early mortality. The results suggest that in Rf-exposed mice, carcinogenesis may be induced earlier and with different pathological forms than in control animals. The modifications in cellular calcium homeostasis and the age-determined thymus involution appear to be important factors involved in this carcinogenesis process.

**Anghileri LJ, Mayayo E, Domingo JL. Iron-radiofrequency synergism in lymphomagenesis. Immunopharmacol Immunotoxicol. 28(1):175-183, 2006.**

The parenteral **iron** administration effects on the acceleration of lymphomagenesis by radiofrequency exposure were investigated using an animal model that develops spontaneous lymphomas with ageing. Complementary studies of the in vivo uptake of 59Fe-labeled ferric gluconate and ferric-ATP complex showed differences ob absorption and excretion between both **iron** compounds. In vitro assays of their effects on calcium cellular uptake using a cell model and tissues homogenates showed a molecular structure-dependence. The current results (mortality, clinical and histopathological examinations) demonstrated a synergism between radiofrequency and ferric gluconate, and the increased risk of radiofrequency exposure when it is simultaneous to parenteral iron administration.

**Anghileri LJ, Mayayo E, Domingo JL. Aluminum, calcium ion and radiofrequency synergism in acceleration of lymphomagenesis. Immunopharmacol Immunotoxicol. 31(3):358-362. 2009**

This study that was done on lymphomagene-bearing mice indicates a synergism aluminum-radiofrequency which induces an early increase in mortality that is in concomitance with lymphoid elements proliferation and infiltration of spleen and liver. These two last phenomena were assesed by determination of the hypertrophic index (Growth Index) which is the organ weight to to the body weight ratio, as well as by the histopathological examination of the organ tissue. The importance of this synergism appears to be determined by the ionization at the physiological pH of the used aluminum complexes: much higher with lactate complex than with the citrate one. On the other hand, this dissociation appears to induce a remarkable acceleration of the mortality and the lymphoid elements-related hypertrophy of the spleen and liver at early age. Aluminum complexes are known as modifiers of the intracellular calcium homeostasis, and to verify if such process could be implicated in this synergism, the effects of calcium chloride were

assayed, in this case the calcium-overload had no effects in the presence of a workable cellular control of intracellular calcium homeostasis. This finding support the hypothesis that ionized aluminum provided by lactate may be implicated in the inhibition of the buffering and extruding extracellular calcium system.

**Anghileri LJ, Mayayo E, Domingo JL, Thouvenot P. Evaluation of health risks caused by radio frequency accelerated carcinogenesis: the importance of processes driven by the calcium ion signal. Eur J Cancer Prev. 15(3):191-195, 2006.**

The acceleration of carcinogenesis, which was induced either by radio frequency radiation from a cellular telephone or by the ferric-ATP complex, was similar in a mouse strain characterized by age-determined carcinogenesis of lymphoid tissues. Organ hypertrophy, the presence of lymphoid blood and ascites, the development of solid tumours, and mortality were very different to those found in control animals. These results emphasize the role of calcium ion signal influx in the activation of oncogenes and the failure of thymus-determined immune defences.

**Anglesio L, Benedetto A, Bonino A, Colla D, Martire F, Saudino Fusette S, d'Amore G. Population exposure to electromagnetic fields generated by radio base stations: evaluation of the urban background by using provisional model and instrumental measurements. Radiat Prot Dosimetry 97(4):355-358, 2001.**

Electromagnetic radiation, which is used by broadcasting and mobile telephone systems to transmit information, permeates the city environment. In order to properly evaluate population exposure to electromagnetic fields, knowledge of their intensity and spectral components is necessary. In this study the results of radiofrequency field monitoring carried out in Torino, a large town located in the north-west of Italy are shown: the variation of the electromagnetic field strength is evaluated as a function of the height from the ground, the location in the urban area and the frequency. separating the contributions of the different sources (broadcasting antennas and radio base stations for mobile phones). Furthermore, the contribution of the radio base stations is theoretically evaluated, adding the emissions off all installations situated in Torino and examining the field strength maps calculated, considering the orography, for different heights. The theoretical values are also compared with those measured in the frequency range of mobile telephony emissions.

**Aniolczyk H, Electromagnetic field pattern in the environment of GSM base stations. Int J Occup Med Environ Health 12(1):47-58, 1999.**

Three mobile phone systems are used in Poland: analog, operated at the 450 MHz frequency range, and two digital systems operated at 900 MHz and 1800 MHz. The GSM--Global System for Mobile Communication meets all relevant requirements, and it is most widely used throughout the world. According to the mobile phone concept, the whole communication area is divided into sub-areas (cells) where base stations are located. The base stations are provided with the transmitter units mounted on free-standing masts, high chimneys and building roofs, including those of the residential buildings. The transmitter antennas of the base stations constitute a source of 935-960 EMF radiation. This work analyses the essential characteristics of the base station antennas from the point of view of radiation intensity. The analysis is based on the results

of EMF measurements performed by experts of two relevant research institutes. For inaccessible antennas, the measurements were performed at the accredited laboratory.

**Antonopoulos A, Eisenbrandt H, Obe G, Effects of high-frequency electromagnetic fields on human lymphocytes in vitro. Mutat Res 395(2-3): 209-214, 1997.**

Human peripheral lymphocytes were incubated in the presence of high-frequency electromagnetic fields of 380, 900 and 1800 MHz. The measured endpoints were cell cycle progression and the frequencies of sister-chromatid exchanges. No differences between treated and control cultures could be found.

**Anttila K. Mycotoxins, fungus and 'electrohypersensitivity'. Med Hypotheses. 55(3):208-214, 2000.**

'Electrohypersensitivity' is often explained as a psychological syndrome. Our modern environment contains a lot of different substances and some of them are toxic. Mycotoxins are types of toxins that are biologically very active and that affect living organisms. Mycotoxins and fungi capable of producing toxins have been detected in ventilation systems, water damage and in foodstuff. Many of those displaying symptoms caused by electromagnetic fields have fungus infections or have been living in fungus-contaminated environments for long periods. In animal studies mycotoxins have shown the same effects as those seen in the 'electrohypersensitivity' syndrome. Phototoxic reactions are well known in veterinary medicine and in medical science, so the question is whether the 'electrohypersensitivity' syndrome is caused by 'phototoxic' reactions?

**Apollonio F, D'Inzeo G, Tarricone L. Energy evaluation of mw effects on Ach receptor channels with parallel computing Electromag. Biol. Med. 19:69-79, 2000.**

We present an evaluation of the effects of microwave fields on the acetylcholine (ACh) receptor channel, based on energy issues. The channel is considered a stochastic automaton, flipping randomly from one state to another, and the incident field modifies transitions among the states. The observation of some appropriate biochemical parameters demonstrates that microwave fields cause conformational changes in the receptor site. An energetic mapping of ACh conformational changes is also achieved, clearing the ground for future development of this research in the field of molecular simulations.

**Arai N, Enomoto H, Okabe S, Yuasa K, Kamimura Y, Ugawa Y. Thirty minutes mobile phone use has no short-term adverse effects on central auditory pathways. Clin Neurophysiol. 114(8):1390-1394, 2003.**

OBJECTIVE: To investigate whether pulsed high-frequency electromagnetic field (pulsed EM field) emitted by a mobile phone for 30 min has short-term adverse effects on the human central auditory system.METHODS: We studied the auditory brainstem response (ABR), the ABR recovery function and middle latency response (MLR) before and after using a mobile phone for 30 min in 15 normal hearing volunteers.RESULTS: None of the 3 measures were affected by exposure to pulsed EM field emitted by a mobile phone for

30 min.CONCLUSIONS: Based on the ABR and MLR methods utilized in the study, we conclude that 30 min mobile phone use has no short-term adverse effects on the human auditory system.

**Aran JM, Carrere N, Chalan Y, Dulou PE, Larrieu S, Letenneur L, Veyret B, Dulon D. Effects of exposure of the ear to GSM microwaves: in vivo and in vitro experimental studies. Int J Audiol. 43(9):545-554, 2004.**

The effects of mobile phone (GSM) microwaves on the ears of guinea pigs were investigated in two in vivo experiments and one in vitro experiment. In the first experiment, three groups of eight guinea pigs had their left ear exposed for 1 h/day, 5 days/week, for 2 months, to GSM microwaves (900 MHz. GSM modulated) at specific absorption rates (SARs) of 1, 2 and 4 W/kg respectively, and a fourth group was sham-exposed. Distortion-product otoacoustic emissions (DPOAEs) were measured for each ear before exposure, at the end of the 2-month exposure period, and 2 months later. In the second experiment, the same protocol was applied to eight sham-exposed and 16 exposed guinea pigs at 4W/kg, but the auditory brainstem response (ABR) thresholds were monitored. Repeated-measures ANOVA showed no difference in DPOAE amplitudes or in ABR thresholds between the exposed and non-exposed ears and between the sham-exposed and exposed groups In the course of the second experiment, acute effects were also investigated by measuring once, in all animals, ABR thresholds just before and just after the 1-h exposure: no statistically significant difference was observed. In vitro, the two organs of Corti (OCs) of newborn rats (n=15) were isolated and placed in culture. For each animal, one OC was exposed for 24-48 h to 1 W/kg GSM microwaves, and the other was sham-exposed. After 2-3 days of culture, all OCs were observed under light microscopy. They all appeared normal to naive observers at this stage of development. These results provided no evidence that microwave radiation, at the levels produced by mobile phones, caused damage to the inner ear or the auditory pathways in our experimental animals.

**Arbabi-Kalati F, Salimi S, Vaziry-Rabiee A, Noraeei M. Effect of mobile phone usage time on total antioxidant capacity of saliva and salivary immunoglobulin a. Iran J Public Health. 43(4):480-484, 2014.**

BACKGROUND: Nowadays mobile phone is very popular, causing concern about the effect it has on people's health. Parotid salivary glands are in close contact to cell phone while talking with the phone and the possibility of being affected by them. Limited studies have evaluated the effect of cell phone use on the secretions of these glands; so this study was designed to investigate the effects of duration of mobile phone use on the total antioxidant capacity of saliva. METHODS: Unstimulated saliva from 105 volunteers without oral lesions collected. The volunteers based on daily usage of mobile phones were divided into three groups then total antioxidant capacity of saliva was measured by Ferric Reducing Ability of Plasma (FRAP) method. Data were analyzed by SPSS software version 19. ANOVA was used to compare 3 groups and post-hoc Tukey test to compare between two groups. RESULTS: Average total antioxidant capacities of saliva in 3 groups were 657.91 µmol/lit, 726.77 µm/lit and 560.17 µmol/lit, respectively. The two groups had statistically significant different (P = 0.039). CONCLUSION: Over an hour

talking with a cell phone decreases total antioxidant capacity of saliva in comparison with talking less than twenty minutes.

**Ardoino L, Barbieri E, Vecchia P. Determinants of exposure to electromagnetic fields from mobile phones. Radiat Prot Dosimetry. 111(4):403-406, 2004.**

In actual conditions of use, the power radiated from cellular phones changes during conversation depending on several factors. Upon request from the radio base station (RBS), the phone in fact, reduces, its power to a level that is deemed optimum for the quality of conversation. In this study, special phones, which had been modified to allow the continuous logging of power emitted during the calls have been used. Off-line processing of recorded data allowed the analysis of the behaviour of mobile phones under real-use conditions. Further data recorded by operators at selected base stations were used for the purposes of comparison and checking of the effectiveness of the experimental method. The results indicate a high proportion of use of the highest power levels, under any circumstance. Such behaviour is mainly due to frequent handovers requested by the control software to optimise the communication traffic.

**Arendash GW, Sanchez-Ramos J, Mori T, Mamcarz M, Lin X, Runfeldt M, Wang L, Zhang G, Sava V, Tan J, Cao C. Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice. J Alzheimers Dis. 19(1):191-210, 2010.**

Despite numerous studies, there is no definitive evidence that high-frequency electromagnetic field (EMF) exposure is a risk to human health. To the contrary, this report presents the first evidence that long-term EMF exposure directly associated with cell phone use (918 MHz; 0.25 w/kg) provides cognitive benefits. Both cognitive-protective and cognitive-enhancing effects of EMF exposure were discovered for both normal mice and transgenic mice destined to develop Alzheimer's-like cognitive impairment. The cognitive interference task utilized in this study was designed from, and measure-for-measure analogous to, a human cognitive interference task. In Alzheimer's disease mice, long-term EMF exposure reduced brain amyloid-beta (Abeta) deposition through Abeta anti-aggregation actions and increased brain temperature during exposure periods. Several inter-related mechanisms of EMF action are proposed, including increased Abeta clearance from the brains of Alzheimer's disease mice, increased neuronal activity, and increased cerebral blood flow. Although caution should be taken in extrapolating these mouse studies to humans, we conclude that EMF exposure may represent a non-invasive, non-pharmacologic therapeutic against Alzheimer's disease and an effective memory-enhancing approach in general.

**Arendash GW, Mori T, Dorsey M, Gonzalez R, Tajiri N, Borlongan C. Electromagnetic Treatment to Old Alzheimer's Mice Reverses β-Amyloid Deposition, Modifies Cerebral Blood Flow, and Provides Selected Cognitive Benefit. PLoS One. 7(4):e35751, 2012.**

Few studies have investigated physiologic and cognitive effects of "long-term"

electromagnetic field (EMF) exposure in humans or animals. Our recent studies have provided initial insight into the long-term impact of adulthood EMF exposure (GSM, pulsed/modulated, 918 MHz, 0.25-1.05 W/kg) by showing 6+ months of daily EMF treatment protects against or reverses cognitive impairment in Alzheimer's transgenic (Tg) mice, while even having cognitive benefit to normal mice. Mechanistically, EMF-induced cognitive benefits involve suppression of brain β-amyloid (Aβ) aggregation/deposition in Tg mice and brain mitochondrial enhancement in both Tg and normal mice. The present study extends this work by showing that daily EMF treatment given to very old (21-27 month) Tg mice over a 2-month period reverses their very advanced brain Aβ aggregation/deposition. These very old Tg mice and their normal littermates together showed an increase in general memory function in the Y-maze task, although not in more complex tasks. Measurement of both body and brain temperature at intervals during the 2-month EMF treatment, as well as in a separate group of Tg mice during a 12-day treatment period, revealed no appreciable increases in brain temperature (and no/slight increases in body temperature) during EMF "ON" periods. Thus, the neuropathologic/cognitive benefits of EMF treatment occur without brain hyperthermia. Finally, regional cerebral blood flow in cerebral cortex was determined to be reduced in both Tg and normal mice after 2 months of EMF treatment, most probably through cerebrovascular constriction induced by freed/disaggregated Aβ (Tg mice) and slight body hyperthermia during "ON" periods. These results demonstrate that long-term EMF treatment can provide general cognitive benefit to very old Alzheimer's Tg mice and normal mice, as well as reversal of advanced Aβ neuropathology in Tg mice without brain heating. Results further underscore the potential for EMF treatment against AD.

**Arns M, Van Luijtelaar G, Sumich A, Hamilton R, Gordon E. Electroencephalographic, personality, and executive function measures associated with frequent mobile phone use. Int J Neurosci. 117(9):1341-1360, 2007.**

The present study employs standardized data acquired from the Brain Resource International Database to study the relationship between mobile phone usage, personality, and brain function (n = 300). Based on the frequency and duration of mobile phone usage, three groups were formed. The findings suggest a subtle slowing of brain activity related to mobile phone use that is not explained by differences in personality. These changes are still within normal physiological ranges. Better executive function in mobile phone users may reflect more focused attention, possibly associated with a cognitive training effect (i.e., frequently making phone calls in distracting places), rather than a direct effect of mobile phone use on cognition.

**Aslan A, İkinci A, Baş O, Sönmez OF, Kaya H, Odacı E. Long-term exposure to a continuous 900 MHz electromagnetic field disrupts cerebellar morphology in young adult male rats. Biotech Histochem. 92(5):324-330, 2017.**

The pathological effects of exposure to an electromagnetic field (EMF) during childhood and adolescence may be greater than those from exposure during adulthood. We investigated possible pathological changes in the cerebellum of adolescent rats exposed to 900 MHz EMF daily for 25 days. We used three groups of six 21-day-old male rats as follows: unexposed control group (Non-EG), sham-exposed group (Sham-EG) and an EMF-exposed group (EMF-EG). EMF-EG rats were exposed to EMF in an EMF cage for 1 h daily from postnatal days 21 through 46. Sham-EG rats were placed in the EMF cage for 1 h daily, but were not subjected to EMF. No procedures were performed on the Non-EG rats. The cerebellums of all animals were removed on postnatal day 47, sectioned and stained with cresyl violet for histopathological and stereological analyses. We found significantly fewer Purkinje cells in the EMF-EG group than in the Non-EG and Sham-EG groups. Histopathological evaluation revealed alteration of normal Purkinje cell arrangement and pathological changes including intense staining of neuron cytoplasm in the EMF-EG group. We found that exposure to continuous 900 MHz EMF for 1 h/day during adolescence can disrupt cerebellar morphology and reduce the number of Purkinje cells in adolescent rats.

**Astrain I, Bernaus J, Claverol J, Escobar A, Godoy P. [Prevalence of mobile phone use while driving vehicles] Gac Sanit 17(1):66-69, 2003.** [Article in Spanish]

Objective: To estimate the prevalence of mobile telephone use while driving vehicles in the city of Lleida (Spain).Methods: A random sample of 1536 cars passing through six intersections regulated by traffic lights in Lleida were selected (three with urban traffic and three with interurban traffic). Cyclists, motorcyclists and driving school cars were excluded. The variables studied were mobile telephone use, age, (18-40; 41-60; >61), sex, the presence of passengers, type of intersection (urban traffic/interurban traffic), day of the week (working day/weekend or holiday) and hour of the day (rush hour/non-rush hour). The prevalence of mobile telephone use was calculated in percentages with a 95% CI. The relationship among the dependent variable (mobile telephone use) and the other independent variables was studied using odds radios (OR) and 95% CI.Results: A total of 1536 direct observations were made and mobile telephone use was detected in 50 drivers. The prevalence was 3.3 (95% CI, 2.4-4.3). The prevalence was higher in men (OR = 2.2; 95% CI, 1.0-5.7), in drivers aged more than 60 years old (OR = 2.2; 95% CI, 0.5-8,4) and in those aged 18-40 years old (OR =1.5; 95% CI, 0.8-3.0), in unaccompanied drivers (OR = 3.0; 95% CI, 1.5-6.3), in urban intersections (OR = 2.7; 95% CI, 1.2-5.9), on workdays (OR = 2.0; 95% CI, 0.9-4.4) and at the rush hour (OR =1.4; 95% CI, 0.8-2.4).Conclusions: The prevalence of mobile telephone use while driving vehicles can be considered high, because of the increase in car accidents. The profile of drivers using mobile telephones corresponds to men aged 18-40 years or more than 61 years, in urban intersections, without passengers, during workdays and at the rush hour. We recommend the implementation of measures to decrease the use of mobile telephones while driving.

**Asbridge M, Brubacher JR, Chan H.Cell phone use and traffic crash risk: a culpability analysis.Int J Epidemiol. 2012 Nov 18. [Epub ahead of print]**

BACKGROUND: The use of a cell phone or communication device while driving is illegal in many jurisdictions, yet evidence evaluating the crash risk associated with cell phone use in naturalistic settings is limited. This article aims to determine whether cell phone use while driving increases motor vehicle crash culpability. METHOD: Drivers involved in crashes where police reported cell phone use (n = 312) and propensity matched drivers (age, sex, suspect alcohol/drug impairment, crash type, date, time of day, geographical location) without cell phone use (n = 936) were drawn from Insurance Corporation of British Columbia Traffic Accident System data. A standardized scoring tool, modified to account for Canadian driving conditions, was used to determine crash culpability from police reports on all drivers from the crashes. The association between crash culpability and cell phone use was determined, with additional subgroup analyses based on crash severity, driver characteristics and type of licence. RESULTS: A comparison of crashes with vs without cell phones revealed an odds ratio of 1.70 (95% confidence interval 1.22-2.36; P = 0.002). This association was consistent after adjustment for matching variables and other covariates. Subgroup analyses demonstrated an association for male drivers, unimpaired drivers, injured and non-injured drivers, and for drivers aged between 26 and 65 years. CONCLUSIONS: Crash culpability was found to be significantly associated with cell phone use by drivers, increasing the odds of a culpable crash by 70% compared with drivers who did not use a cell phone. This increased risk was particularly high for middle-aged drivers.

**Aslan A, Kırdemır V, Kocak A, Atay T, Baydar ML, Ozerdemoglu RA, Aydogan NH. Effect of 1800 MHz Electromagnetic Radiation Emitted from Cellular Phones on Fracture Healing. Arch Med Res. 2014 Feb 4. pii: S0188-4409(14)00007-1. doi: 10.1016/j.arcmed.2014.01.006. [Epub ahead of print]**

BACKGROUND AND AIMS: In this study, we aimed to investigate whether 1800 MHz frequency electromagnetic radiation (EMRs) have an effect on bone healing. METHODS: A total of 30 Wistar albino rats were divided into two equal groups. Fractures were created in the right tibias of all rats; next, intramedullary fixations with K-wire were performed. A control group (Group I) was kept under the same experimental conditions except without EMF exposure. Rats in Group II were exposed to an 1800 MHz frequency EMF for 30 min a day for 5 days a week. Next, radiological, mechanical, and histological examinations were performed to evaluate tibial fracture healing. RESULTS: Radiological, histological and mechanical scores were not significantly different between groups (respectively, p = 0.114, p = 0.184 and p = 0.083), and all of these scores were lower than those of the controls. CONCLUSIONS: EMR at 1800 MHz frequency emitted from cellular phones has no effect on bone fracture healing.

**Atasoy HI, Gunal MY, Atasoy P, Elgun S, Bugdayci G. Immunohistopathologic demonstration of deleterious effects on growing rat testes of radiofrequency waves emitted from conventional Wi-Fi devices. J Pediatr Urol. 9(2):223-229, 2013.**

OBJECTIVE: To investigate effects on rat testes of radiofrequency radiation emitted from indoor Wi-Fi Internet access devices using 802.11.g wireless standards. METHODS: Ten Wistar albino male rats were divided into experimental and control groups, with five rats

per group. Standard wireless gateways communicating at 2.437 GHz were used as radiofrequency wave sources. The experimental group was exposed to radiofrequency energy for 24 h a day for 20 weeks. The rats were sacrificed at the end of the study. Intracardiac blood was sampled for serum 8-hydroxy-2'-deoxyguanosine levels. Testes were removed and examined histologically and immunohistochemically. Testis tissues were analyzed for malondialdehyde levels and prooxidant-antioxidant enzyme activities. RESULTS: We observed significant increases in serum 8-hydroxy-2'-deoxyguanosine levels and 8-hydroxyguanosine staining in the testes of the experimental group indicating DNA damage due to exposure ($p < 0.05$). We also found decreased levels of catalase and glutathione peroxidase activity in the experimental group, which may have been due to radiofrequency effects on enzyme activity ($p < 0.05$). CONCLUSIONS: These findings raise questions about the safety of radiofrequency exposure from Wi-Fi Internet access devices for growing organisms of reproductive age, with a potential effect on both fertility and the integrity of germ cells.

**Atay T, Aksoy BA, Aydogan NH, Baydar ML, Yildiz M, Ozdemir R. Effect of electromagnetic field induced by radio frequency waves at 900 to 1800 MHz on bone mineral density of iliac bone wings. J Craniofac Surg. 20(5):1556-1560, 2009.**

OBJECTIVE: Telecommunication has gained a different meaning in daily life with the introduction of the mobile phone system. However, electromagnetic pollution has increased in parallel to this improvement. In this study, we aimed to investigate the effects of electromagnetic waves emitted from cellular phones operating at a frequency of 900 to 1800 MHz on the bone mineral density of the human iliac bone wings, which are the most common carriage sites for mobile phones. MATERIALS AND METHODS: A total of 150 male volunteer participants were included in this study. The mean age was 31.85 years, and the age range was between 21 and 57 years. The participants were separated into 2 groups based on as follows: iliac side exposed to electromagnetic wave (group 1) and unexposed side (group 2). Of the total number of participants, 122 were carrying their phones on their right iliac wings, whereas 28 were carrying their phones on their left iliac wings. The mean daily carriage duration was 14.7 hours (between 12 and 20 h), and the mean duration for cellular phone use was 6.2 years (between 4 and 9 yr). Mineral bone density was measured using dual-energy x-ray absorptiometry in the right and the left iliac wings of all the participants. The SPSS 15 software (SPSS Inc, Chicago, IL) was used for statistical analysis. In the comparison of the 2 sides, Student t test was performed and $P < 0.05$ was considered significant. RESULTS: The mean dual-energy x-ray absorptiometry values measured from group 1 were slightly lower than those from group 2, but there was no statistically significant difference between the groups ($P > 0.05$). In addition, the mean values of group 1 were not as low as those measured in osteopeny or osteoporosis cases. CONCLUSIONS: Current data may suggest that taking into consideration cellular phone use when iliac bone graft is necessary in clinical practice would constitute an important factor for more favorable outcomes.

**Atchley P, Dressel J. Conversation limits the functional field of view. Hum Factors. 46(4):664-673, 2004.**

The purpose of these two experiments is to investigate one possible mechanism that

might account for an increase in crash risk with in-car phone use: a reduction in the functional field of view. In two between-subjects experiments, college undergraduates performed a task designed to measure the functional field of view in isolation and while performing a hands-free conversational task. In both experiments, the addition of the conversational task led to large reductions in the functional field of view. Because similar reductions have been shown to increase crash risk, reductions in the functional field of view by conversation may be an important mechanism involved in increased risk for crashes with in-car phone use. Actual or potential applications of this research include improving driver performance.

**Atlı Şekeroğlu Z, Akar A, Sekeroğlu V. Evaluation of the cytogenotoxic damage in immature and mature rats exposed to 900 MHz radio frequency electromagnetic fields. Int J Radiat Biol. 2013 May 29. [Epub ahead of print]**

Abstract Purpose: One of the most important issues regarding radio frequency electromagnetic fields (RF-EMF) is their effect on genetic material. Therefore, we investigated the cytogenotoxic effects of 900 MHz radio frequency electromagnetic fields (RF-EMF) and the effect of a recovery period after exposure to RF-EMF on bone marrow cells of immature and mature rats. Materials and methods: The immature and mature rats in treatment groups were exposed to RF-EMF for 2 h/day for 45 days. Average electrical field values for immature and mature rats were 28.1±4.8 V/m and 20.0±3.2 V/m, respectively. Whole-body specific absorption rate (SAR) values for immature and mature rats were in the range of 0.38-0.78 W/kg, and 0.31-0.52 W/kg during the 45 days, respectively. Two recovery groups were kept for 15 days after RF-EMF exposure. Results: Significant differences were observed in chromosome aberrations (CA), micronucleus (MN) frequency, mitotic index (MI) and ratio of polychromatic erythrocytes (PCE) in all treatment and recovery groups. The cytogenotoxic damage in immature rats was statistically higher than the mature rats. The recovery period did not reduce the damage to the same extent as the corresponding control groups. Conclusions: The exposure of RF-EMF leads to cytotoxic and genotoxic damage in immature and mature rats. More sensitive studies are required to elucidate the possible carcinogenic risk of EMF exposure in humans, especially children.

**Augner C, Florian M, Pauser G, Oberfeld G, Hacker GW. GSM base stations: Short-term effects on well-being. Bioelectromagnetics. 30:73-80, 2009.**

The purpose of this study was to examine the effects of short-term GSM (Global System for Mobile Communications) cellular phone base station RF-EMF (radiofrequency electromagnetic fields) exposure on psychological symptoms (good mood, alertness, calmness) as measured by a standardized well-being questionnaire. Fifty-seven participants were selected and randomly assigned to one of three different exposure scenarios. Each of those scenarios subjected participants to five 50-min exposure sessions, with only the first four relevant for the study of psychological symptoms. Three exposure levels were created by shielding devices in a field laboratory, which could be installed or removed during the breaks between sessions such that double-blinded conditions prevailed. The overall median power flux densities were 5.2 microW/m(2)

during "low," 153.6 microW/m(2) during "medium," and 2126.8 microW/m(2) during "high" exposure sessions. For scenario HM and MH, the first and third sessions were "low" exposure. The second session was "high" and the fourth was "medium" in scenario HM; and vice versa for scenario MH. Scenario LL had four successive "low" exposure sessions constituting the reference condition. Participants in scenarios HM and MH (high and medium exposure) were significantly calmer during those sessions than participants in scenario LL (low exposure throughout) (P = 0.042). However, no significant differences between exposure scenarios in the "good mood" or "alertness" factors were obtained. We conclude that short-term exposure to GSM base station signals may have an impact on well-being by reducing psychological arousal.

**Augner C, Hacker GW. Are people living next to mobile phone base stations more strained? Relationship of health concerns, self-estimated distance to base station, and psychological parameters. Indian J Occup Environ Med. 13(3):141-145, 2009.**

BACKGROUND AND AIMS: Coeval with the expansion of mobile phone technology and the associated obvious presence of mobile phone base stations, some people living close to these masts reported symptoms they attributed to electromagnetic fields (EMF). Public and scientific discussions arose with regard to whether these symptoms were due to EMF or were nocebo effects. The aim of this study was to find out if people who believe that they live close to base stations show psychological or psychobiological differences that would indicate more strain or stress. Furthermore, we wanted to detect the relevant connections linking self-estimated distance between home and the next mobile phone base station (DBS), daily use of mobile phone (MPU), EMF-health concerns, electromagnetic hypersensitivity, and psychological strain parameters. DESIGN, MATERIALS AND METHODS: Fifty-seven participants completed standardized and non-standardized questionnaires that focused on the relevant parameters. In addition, saliva samples were used as an indication to determine the psychobiological strain by concentration of alpha-amylase, cortisol, immunoglobulin A (IgA), and substance P. RESULTS: Self-declared base station neighbors (DBS </= 100 meters) had significantly higher concentrations of alpha-amylase in their saliva, higher rates in symptom checklist subscales (SCL) somatization, obsessive-compulsive, anxiety, phobic anxiety, and global strain index PST (Positive Symptom Total). There were no differences in EMF-related health concern scales. CONCLUSIONS: We conclude that self-declared base station neighbors are more strained than others. EMF-related health concerns cannot explain these findings. Further research should identify if actual EMF exposure or other factors are responsible for these results.

**Augner C, Hacker GW, Oberfeld G, Florian M, Hitzl W, Hutter J, Pauser G. Effects of Exposure to GSM mobile phone base station signals on salivary cortisol, alpha-amylase, and Immunoglobulin A. Biomed Environ Sci. 23(3):199-207, 2010.**

OBJECTIVE: The present study aimed to test whether exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phone base stations may have effects on salivary alpha-amylase, immunoglobulin A (IgA), and cortisol levels.

METHODS: Fifty seven participants were randomly allocated to one of three different experimental scenarios (22 participants to scenario 1, 26 to scenario 2, and 9 to scenario 3). Each participant went through five 50-minute exposure sessions. The main RF-EMF source was a GSM-900-MHz antenna located at the outer wall of the building. In scenarios 1 and 2, the first, third, and fifth sessions were "low" (median power flux density 5.2 muW/m(2)) exposure. The second session was "high" (2126.8 muW/m(2)), and the fourth session was "medium" (153.6 muW/m(2)) in scenario 1, and vice versa in scenario 2. Scenario 3 had four "low" exposure conditions, followed by a "high" exposure condition. Biomedical parameters were collected by saliva samples three times a session. Exposure levels were created by shielding curtains. RESULTS: In scenario 3 from session 4 to session 5 (from "low" to "high" exposure), an increase of cortisol was detected, while in scenarios 1 and 2, a higher concentration of alpha-amylase related to the baseline was identified as compared to that in scenario 3. IgA concentration was not significantly related to the exposure.CONCLUSIONS: RF-EMF in considerably lower field densities than ICNIRP-guidelines may influence certain psychobiological stress markers.

**Augner C, Gnambs T, Winker R, Barth A. Acute effects of electromagnetic fields emitted by GSM mobile phones on subjective well-being and physiological reactions: a meta-analysis.Sci Total Environ. 424:11-15, 2012.**

The potential effects of radiofrequency electromagnetic fields (RF-EMF) emitted by GSM mobile phones on subjective symptoms, well-being and physiological parameters have been investigated in many studies. However, the results have been ambiguous. The current meta-analysis aims to clarify whether RF-EMF have an influence on well-being in self-reported sensitive persons, as well as in non-sensitive people. A literature search revealed 17 studies including 1174 participants. The single effects for various subjective and objective outcomes were meta-analytically combined to yield a single population parameter. Dependant variables were subjective (e.g. headaches) and objective parameters (e.g. heart rate variability) of well-being. The results show no significant impact of short-term RF-EMF exposure on any parameter. Future research should focus on the possible effects of long-term exposure.

**Auvinen A, Hietanen M, Luukkonen R, Koskela R-S, Brain tumors and salivary gland cancers among cellular telephone users Epidemiology 13:356-359, 2002.**

Background. Possible risk of cancer associated with use of cellular telephones has lately been a subject of public debate. Methods. We conducted a register-based, case-control study on cellular phone use and cancer. The study subjects were all cases of brain tumor (N = 398) and salivary gland cancer (N = 34) diagnosed in Finland in 1996, with five controls per case. Results. Cellular phone use was not associated with brain tumors or salivary gland cancers overall, but there was a weak association between gliomas and analog cellular phones. Conclusions. A register-based approach has limited value in risk assessment of cellular phone use owing to lack of information on exposure.

**Avci B, Akar A, Bilgici B, Tunçel ÖK. Oxidative stress induced by 1.8 GHz radio frequency electromagnetic radiation and effects of garlic extract in rats. Int J Radiat Biol. 88(11):799-805, 2012.**

**PURPOSE:** We aimed to study the oxidative damage induced by radiofrequency electromagnetic radiation (RF-EMR) emitted by mobile telephones and the protective effect of garlic extract used as an anti-oxidant against this damage. **MATERIALS AND METHODS:** A total of 66 albino Wistar rats were divided into three groups. The first group of rats was given 1.8 GHz, 0.4 W/kg specific absorption rate (SAR) for 1 h a day for three weeks. The second group was given 500 mg/kg garlic extract in addition to RF-EMR. The third group of rats was used as the control group. At the end of the study, blood and brain tissue samples were collected from the rats. **RESULTS:** After the RF-EMR exposed, the advanced oxidation protein product (AOPP) levels of brain tissue increased compared with the control group ($p < 0.001$). Garlic administration accompanying the RF-EMR, on the other hand, significantly reduced AOPP levels in brain tissue ($p < 0.001$). The serum nitric oxide (NO) levels significantly increased both in the first and second group ($p < 0.001$). However, in the group for which garlic administration accompanied that of RF-EMR, there was no difference in serum NO levels compared with the RF-EMR exposed group ($p > 0.05$). There was no significant difference among the groups with respect to malondialdehyde (MDA) levels in brain tissue and blood samples ($p > 0.05$). Similarly, no difference was detected among the groups regarding serum paroxonase (PON) levels ($p > 0.05$). We did not detect any PON levels in the brain tissue. **CONCLUSIONS:** The exposure of RF-EMR similar to 1.8 GHz Global system for mobile communication (GSM) leads to protein oxidation in brain tissue and an increase in serum NO. We observed that garlic administration reduced protein oxidation in brain tissue and that it did not have any effects on serum NO levels.

**Avdikos A, Karkabounas S, Metsios A, Kostoula O, Havelas K, Binolis J, Verginadis I, Hatziaivazis G, Simos I, Evangelou A. Anticancer effects on leiomyosarcoma-bearing Wistar rats after electromagnetic radiation of resonant radiofrequencies. Hell J Nucl Med. 10(2):95-101, 2007.**

In the present study, the effects of a resonant low intensity static electromagnetic field (EMF), causing no thermal effects, on Wistar rats have been investigated. Sarcoma cell lines were isolated from leiomyosarcoma tumors induced in Wistar rats by the subcutaneous (s.c) injection of 3,4-benzopyrene. Furthermore, smooth muscle cells (SMC) were isolated from the aorta of Wistar rats and cultivated. Either leiomyosarcoma cells (LSC) or SMC were used to record a number of characteristic resonant radiofrequencies, in order to determine the specific electromagnetic fingerprint spectrum for each cell line. These spectra were used to compose an appropriate algorithm, which transforms the recorded radiofrequencies to emitted ones. The isolated LSC were cultured and then exposed to a resonant low intensity radiofrequency EMF (RF-EMF), at frequencies between 10 kHz to 120 kHz of the radiowave spectrum. The exposure lasted 45 consecutive minutes daily, for two consecutive days. Three months old female Wistar rats were inoculated with exposed and non-exposed to EMF LSC (4 x 10(6) LCS for animal). Inoculated with non-exposed to EMF cells animals were then randomly separated into three Groups. The first Group was sham exposed to the resonant EMF

(control Group-CG), the second Group after the inoculation of LSC and appearance of a palpable tumor mass, was exposed to a non-resonant EMF radiation pattern, for 5 h per day till death of all animals (experimental control Group-ECG). The third Group of animals after inoculation of LSC and the appearance of a palpable tumor mass, was exposed to the resonant EMF radiation for 5 h per day, for a maximum of 60 days (experimental Group-I, EG-I). A fourth Group of animals was inoculated with LSC exposed to EMF irradiation and were not further exposed to irradiation (experimental Group-II, EG-II). Tumor induction was 100% in all Groups studied and all tumors were histologically identified as leiomyosarcomas. In the case of the EG-I, a number of tumors were completely regretted (final tumor induction: 66%). Both Groups of animals inoculated with exposed or non-exposed to the EMF LSC, (EG-I and EG-II, respectively) demonstrated a significant prolongation of the survival time and a lower tumor growth rate, in comparison to the control Group (CG) and the experimental control Group (ECG). However, the survival time of EG-I animals was found to be significantly longer and tumor growth rate significantly lower compared to EG-II animals. In conclusion, our results indicate a specific anticancer effect of resonant EMF irradiation. These results may possibly be attributed to (a) the duration of exposure of LSC and (b) the exposure of the entire animal to this irradiation.

**Avendaño C, Mata A, Sanchez Sarmiento CA, Doncel GF. Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation.Fertil Steril. 97(1):39-45, 2012.**

**OBJECTIVE:** To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa.**DESIGN:** Prospective in vitro study.**SETTING:** Center for reproductive medicine.**PATIENT(S):** Semen samples from 29 healthy donors.**INTERVENTION(S):** Motile sperm were selected by swim up. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to an internet-connected laptop by Wi-Fi for 4 hours, whereas the second aliquot (unexposed) was used as control, incubated under identical conditions without being exposed to the laptop.**MAIN OUTCOME MEASURE(S):** Evaluation of sperm motility, viability, and DNA fragmentation.**RESULT(S):** Donor sperm samples, mostly normozoospermic, exposed ex vivo during 4 hours to a wireless internet-connected laptop showed a significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation. Levels of dead sperm showed no significant differences between the two groups.**CONCLUSION(S):** To our knowledge, this is the first study to evaluate the direct impact of laptop use on human spermatozoa. Ex vivo exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation by a nonthermal effect. We speculate that keeping a laptop connected wirelessly to the internet on the lap near the testes may result in decreased male fertility. Further in vitro and in vivo studies are needed to prove this contention.

**Aweda MA, Gbenebitse S, Meidinyo RO. Effects of 2.45 GHz microwave exposures on the peroxidation status in Wistar rats. Niger Postgrad Med J. 10(4):243-246, 2003.**

One of the consequences of exposures to microwave (MW) radiations is the enhanced production of free O2, free radicals, peroxides and superoxides. The effects on the lipid peroxidation status (LPS) of whole body irradiation of 120 Wistar rats with 2.45 GHz MW at a power density of 6mWcm(-2) have been studied using the MW generator model ER6660E from Toshiba UK Ltd. The LPS in the rats was monitored for a period of 8 weeks post irradiation using thiobarbituric acid (TRA) method. The MW exposures caused an increase in the LPS from the mean control value of 4.18 x 10(-6)g 1(-1)to a maximum of 6.50 x 10(-6) g 1(-1) within the first 24 hrs, and then gradually reduced to control value after about a week. 1mg kg(-1) of ascorbic acid administered before irradiation caused a decrease in the LPS from the control value to a minimum of 2.86 x 10(-6)g 1(-1) within the first week. The value then gradually rose to a maximum of 3.96 x 10(-6)g 1(-1) within the monitoring period. 1 mg kg(-1) of a-tocopherol also administered before irradiation also caused a decrease in the LPS from the control value to a minimum of 2.10 x 10(-6) g 1(-1) within the first week. The value then gradually rose to a maximum of 3.94 x 10(-6) g 1(-1) within the monitoring period. The results obtained from this study demonstrate that MW exposures cause significant increase in the LPS and there are protective effects of the anti-oxidants ascorbic acid and alpha-tocopherol.

**Aweda MA, Ajekigbe AT, Ibitoye AZ, Evwhierhurhoma BO, Eletu OB. Potential health risks due to telecommunications radiofrequency radiation exposures in Lagos State Nigeria. Nig Q J Hosp Med. 19(1):6-14, 2009.**

BACKGROUND: The global system mobile telecommunications system (GSM) which was recently introduced in Nigeria is now being used by over 40 million people in Nigeria. The use of GSM is accompanied with exposure of the users to radiofrequency radiation (RFR), which if significant, may produce health hazards. This is the reason why many relevant national and international organizations recommended exposure limits to RFR and why it is made compulsory for GSM handsets to indicate the maximum power output as a guide to potential consumers. OBJECTIVE: This study was conducted to measure the RFR output power densities (S) from the most commonly used GSM handsets used in Lagos State and compare with the limit recommended for safety assessment. METHODS: Over 1100 most commonly used handsets of different makes and models as well as wireless phones were sampled and studied in all over the local government areas of the State. An RFR meter, Electrosmog from LESSEMF USA was used for the measurements. The handsets were assessed for health risks using the reference value of 9 Wm(-2) as recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). RESULTS: The range of the S-values obtained varied from a minimum of 1.294 0.101 Wm(-2) with Siemens model R228 to a maximum of 16.813 +/- 0.094 Wm(-2) with Samsung model C140*. The results from wireless telephones showed very low S-values ranging from a minimum of 0.024 +/- 0.001 Wm(-2) with HUAWEI and ST CDMA 1 to a maximum of 0.093 +/- 0.002 Wm(-2) with HISENSE. CONCLUSION: The results showed that the population in Lagos State may be at risk due to significant RFR exposures resulting principally from the use of GSM. Quite a number of handsets emit power above the ICNIRP recommended value. Measured RFR power close to Radio and Television masts and transmitters are within tolerable limits in most cases, only that the public should not reside or work close to RFR installations. Phone calls with GSM

should be restricted to essential ones while youths and children that are more susceptible to RFR hazards should be supervised in their use of GSM. Wireless phones are quite safe.

**Ayata A, Mollaoglu H, Yilmaz HR, Akturk O, Ozguner F, Altuntas I. Oxidative stress-mediated skin damage in an experimental mobile phone model can be prevented by melatonin. J Dermatol. 31(11):878-883, 2004.**

Most mobile phones emit 900 MHz of radiation that is mainly absorbed by the external organs. The effects of 900 MHz of radiation on fibrosis, lipid peroxidation, and anti-oxidant enzymes and the ameliorating effects of melatonin (Mel) were evaluated in rat skin. Thirty Wistar-Albino rats were used in the study. The experimental groups were the control group, the irradiated group (IR), and the irradiated+Mel treated group (IR+Mel). A dose of 900 MHz, 2 W radiation was applied to the IR group every day for 10 days (30 min/day). The IR+Mel group received 10 mg/kg/day melatonin in tap water for 10 days before the irradiation. At the end of the 10th day, a skin specimen was excised from the thoracoabdominal area. The levels of malondialdehyde (MDA) and hydroxypyroline and the activities of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) were studied in the skin samples. MDA and hydroxyproline levels and activities of CAT and GSH-Px were increased significantly in the IR group compared to the control group ($p<0.05$) and decreased significantly in the IR+Mel group ($p<0.05$). SOD activity was decreased significantly in the IR group and this decrease was not prevented by the Mel treatment. These results suggest that rats irradiated with 900 MHz suffer from increased fibrosis and lipid peroxidation (LPO). Mel treatment can reduce the fibrosis and LPO caused by radiation.

**Aydin B, Akar A. Effects of a 900-MHz electromagnetic field on oxidative stress parameters in rat lymphoid organs, polymorphonuclear leukocytes and plasma. Arch Med Res. 42(4):261-267, 2011.**

BACKGROUND AND AIMS: The present study investigated the effects of a 900-MHz electromagnetic field (EMF) for 2 h/day for 45 days on lymphoid organs (spleen, thymus, bone marrow), polymorphonuclear leukocytes (PMNs) and plasma of rats, focusing on changes in the enzymatic and nonenzymatic antioxidant system. We determined whether there is any difference between immature and mature rats in terms of oxidative damage caused by EMF and tested recovery groups to determine whether EMF-induced damage is reversible in immature and mature rats. METHODS: Twenty four immature and 24 mature rats were divided randomly and equally into six groups as follows: two control groups, immature (2 weeks old) and mature (10 weeks old); two groups were exposed to 900 MHz (28.2 ± 2.1 V/m) EMF for 2 h/day for 45 days. Two recovery groups were kept for 15 days after EMF exposure. RESULTS: Substantial, deleterious biochemical changes were observed in oxidative stress metabolism after EMF exposure. Antioxidant enzyme activity, glutathione levels in lymphoid organs and the antioxidant capacity of the plasma decreased, but lipid peroxidation and nitric oxide levels in PMNs and plasma and also myeloperoxidase activity in PMNs increased. Oxidative damage was tissue specific and improvements seen after the recovery period were limited, especially in immature rats. CONCLUSIONS: In the present study, much higher levels of irreversible oxidative damage were observed in the major lymphoid organs of immature rats than in mature

rats.

**Aydin D, Feychting M, Schüz J, Andersen TV, Poulsen AH, Prochazka M, Klæboe L, Kuehni CE, Tynes T, Röösli M. Predictors and overestimation of recalled mobile phone use among children and adolescents. Prog Biophys Mol Biol. 107(3):356-361, 2011.**

A growing body of literature addresses possible health effects of mobile phone use in children and adolescents by relying on the study participants' retrospective reconstruction of mobile phone use. In this study, we used data from the international case-control study CEFALO to compare self-reported with objectively operator-recorded mobile phone use. The aim of the study was to assess predictors of level of mobile phone use as well as factors that are associated with overestimating own mobile phone use. For cumulative number and duration of calls as well as for time since first subscription we calculated the ratio of self-reported to operator-recorded mobile phone use. We used multiple linear regression models to assess possible predictors of the average number and duration of calls per day and logistic regression models to assess possible predictors of overestimation. The cumulative number and duration of calls as well as the time since first subscription of mobile phones were overestimated on average by the study participants. Likelihood to overestimate number and duration of calls was not significantly different for controls compared to cases (OR=1.1, 95%-CI: 0.5 to 2.5 and OR=1.9, 95%-CI: 0.85 to 4.3, respectively). However, likelihood to overestimate was associated with other health related factors such as age and sex. As a consequence, such factors act as confounders in studies relying solely on self-reported mobile phone use and have to be considered in the analysis.

**Aydin D, Feychting M, Schüz J, Tynes T, Andersen TV, Schmidt LS, Poulsen AH, Johansen C, Prochazka M, Lannering B, Klæboe L, Eggen T, Jenni D, Grotzer M, Von der Weid N, Kuehni CE, Röösli M. Mobile phone use and brain tumors in children and adolescents: a multicenter case-control study. J Natl Cancer Inst. 103(16):1264-1276, 2011.**

BACKGROUND: It has been hypothesized that children and adolescents might be more vulnerable to possible health effects from mobile phone exposure than adults. We investigated whether mobile phone use is associated with brain tumor risk among children and adolescents.METHODS: CEFALO is a multicenter case-control study conducted in Denmark, Sweden, Norway, and Switzerland that includes all children and adolescents aged 7-19 years who were diagnosed with a brain tumor between 2004 and 2008. We conducted interviews, in person, with 352 case patients (participation rate: 83%) and 646 control subjects (participation rate: 71%) and their parents. Control subjects were randomly selected from population registries and matched by age, sex, and geographical region. We asked about mobile phone use and included mobile phone operator records when available. Odds ratios (ORs) for brain tumor risk and 95% confidence intervals (CIs) were calculated using conditional logistic regression models.RESULTS: Regular users of mobile phones were not statistically significantly more likely to have been diagnosed with brain tumors compared with nonusers (OR =

1.36; 95% CI = 0.92 to 2.02). Children who started to use mobile phones at least 5 years ago were not at increased risk compared with those who had never regularly used mobile phones (OR = 1.26, 95% CI = 0.70 to 2.28). In a subset of study participants for whom operator recorded data were available, brain tumor risk was related to the time elapsed since the mobile phone subscription was started but not to amount of use. No increased risk of brain tumors was observed for brain areas receiving the highest amount of exposure.CONCLUSION: The absence of an exposure-response relationship either in terms of the amount of mobile phone use or by localization of the brain tumor argues against a causal association.

**Aydin D, Feychting M, Schüz J, Andersen TV, Poulsen AH, Prochazka M, Klaeboe L, Kuehni CE, Tynes T, Röösli M. Impact of random and systematic recall errors and selection bias in case--control studies on mobile phone use and brain tumors in adolescents (CEFALO study). Bioelectromagnetics. 32(5):396-407, 2011.**

Whether the use of mobile phones is a risk factor for brain tumors in adolescents is currently being studied. Case--control studies investigating this possible relationship are prone to recall error and selection bias. We assessed the potential impact of random and systematic recall error and selection bias on odds ratios (ORs) by performing simulations based on real data from an ongoing case--control study of mobile phones and brain tumor risk in children and adolescents (CEFALO study). Simulations were conducted for two mobile phone exposure categories: regular and heavy use. Our choice of levels of recall error was guided by a validation study that compared objective network operator data with the self-reported amount of mobile phone use in CEFALO. In our validation study, cases overestimated their number of calls by 9% on average and controls by 34%. Cases also overestimated their duration of calls by 52% on average and controls by 163%. The participation rates in CEFALO were 83% for cases and 71% for controls. In a variety of scenarios, the combined impact of recall error and selection bias on the estimated ORs was complex. These simulations are useful for the interpretation of previous case-control studies on brain tumor and mobile phone use in adults as well as for the interpretation of future studies on adolescents.

**Aydogan F, Unlu I, Aydin E, Yumusak N, Devrim E, Samim EE, Ozgur E, Unsal V, Tomruk A, Ozturk GG, Seyhan N. The effect of 2100 MHz radiofrequency radiation of a 3G mobile phone on the parotid gland of rats. Am J Otolaryngol. 2014 Oct 5. pii: S0196-0709(14)00207-5. doi: 10.1016/j.amjoto.2014.10.001. [Epub ahead of print]**

PURPOSE: We aimed to evaluate the effect of 2100 MHz radiofrequency radiation on the parotid gland of rats in short and relatively long terms. MATERIAL AND METHODS: Thirty Wistar albino rats were divided into four groups. Groups A and B served as the control groups (for 10 days and 40 days, respectively), and each group included six rats. Groups C and D were composed of nine rats each, and they were the exposure groups. The rats were exposed to 2100 MHz radiofrequency radiation emitted by a generator, simulating a third generation mobile phone for 6 hours/day, 5 days/week, for 10 or 40 days. Following exposure, the rats were sacrificed and parotid glands were removed.

Histopathological and biochemical examinations were performed. RESULTS: Although there were no histopathological changes in the control groups except for two animals in group A and three animals in group B, the exposure groups C (10 days) and D (40 days) showed numerous histopathological changes regarding salivary gland damage including acinar epithelial cells, interstitial space, ductal system, vascular system, nucleus, amount of cytoplasm and variations in cell size. The histopathological changes were more prominent in group D compared to group C. There was statistically significant different parameter regarding variation in cell size between the groups B and D (p=0.036). CONCLUSION: The parotid gland of rats showed numerous histopathological changes after exposure to 2100 MHz radiofrequency radiation, both in the short and relatively long terms. Increased exposure duration led to an increase in the histopathological changes.

**Aydoğan F, Aydın E, Koca G, Özgür E, Atilla P, Tüzüner A, Demirci Ş, Tomruk A, Öztürk GG, Seyhan N, Korkmaz M, Müftüoğlu S, Samim EE. The effects of 2100-MHz radiofrequency radiation on nasal mucosa and mucociliary clearance in rats. Int Forum Allergy Rhinol. 5(7):626-632, 2015.**

BACKGROUND: Nasal mucociliary clearance has an important role in voiding the airways from inhaled foreign substances. This activity could be disturbed by environmental factors such as radiofrequency radiation. The aim of the present study was to investigate short-term and relatively long-term effects of 2100-MHz radiofrequency radiation emitted by a generator, simulating a 3G-mobile phone, on the nasal septal mucosa and mucociliary clearance in rats. METHODS: Thirty Wistar albino rats were divided into 4 groups. There were 6 rats in Group A and Group B, which served as the control groups (10-day and 40-day groups, respectively). Groups C (10-day exposure) and D (40-day exposure) were both composed of 9 rats; they comprised the radiofrequency radiation exposure groups. The rats in groups C and D were exposed to 2100-MHz radiofrequency radiation emitted by a generator, simulating a 3G-mobile phone, 6 hours/day, for 10 or 40 days, respectively. After exposure, nasal mucociliary clearance was measured by rhinoscintigraphy. After euthanization, the nasal septa of the animals were removed, and tissue samples of the nasal mucosa were examined using a transmission electron microscope. RESULTS: The differences in mucociliary clearances between groups A and C, groups B and D, and groups C and D were found to be statistically significant ($p = 0.005$, $p < 0.001$, $p < 0.001$, respectively). Although there were no histopathological abnormalities in the control groups, the exposure groups showed a number of degenerated and apoptotic cells, ciliary disorganization and ciliary loss in the epithelial cells, epithelial metaplasia, alteration of normal chromatin distribution and karyolysis in nuclei, changes in the basal cells, and lymphocytic infiltration. The histopathological changes were more severe in group D. CONCLUSION: Radiofrequency radiation at 2100 MHz damaged the nasal septal mucosa, and disturbed the mucociliary clearance. Ciliary disorganization and ciliary loss in the epithelial cells resulted in deterioration of nasal mucociliary clearance.

**Ayinmode BO, Farai IP. STUDY OF VARIATIONS OF RADIOFREQUENCY POWER DENSITY FROM MOBILE PHONE BASE STATIONS WITH DISTANCE. Radiat Prot Dosimetry. 2013 Apr 25. [Epub ahead of print]**

The variations of radiofrequency (RF) radiation power density with distance around some mobile phone base stations (BTSs), in ten randomly selected locations in Ibadan, western Nigeria, were studied. Measurements were made with a calibrated hand-held spectrum analyser. The maximum Global System of Mobile (GSM) communication 1800 signal power density was 323.91 μW $m^{-2}$ at 250 m radius of a BTS and that of GSM 900 was 1119.00 μW $m^{-2}$ at 200 m radius of another BTS. The estimated total maximum power density was 2972.00 μW $m^{-2}$ at 50 m radius of a different BTS. This study shows that the maximum carrier signal power density and the total maximum power density from a BTS may be observed averagely at 200 and 50 m of its radius, respectively. The result of this study demonstrates that exposure of people to RF radiation from phone BTSs in Ibadan city is far less than the recommended limits by International scientific bodies.

**Aynali G, Nazıroğlu M, Celik O, Doğan M, Yarıktaş M, Yasan H. Modulation of wireless (2.45 GHz)-induced oxidative toxicity in laryngotracheal mucosa of rat by melatonin. Eur Arch Otorhinolaryngol. 270(5):1695-1700, 2013.**

It is well known that oxidative stress induces larynx cancer, although antioxidants induce modulator role on etiology of the cancer. It is well known that electromagnetic radiation (EMR) induces oxidative stress in different cell systems. The aim of this study was to investigate the possible protective role of melatonin on oxidative stress induced by Wi-Fi (2.45 GHz) EMR in laryngotracheal mucosa of rat. For this purpose, 32 male rats were equally categorized into four groups, namely controls, sham controls, EMR-exposed rats, EMR-exposed rats treated with melatonin at a dose of 10 mg/kg/day. Except for the controls and sham controls, the animals were exposed to 2.45 GHz radiation during 60 min/day for 28 days. The lipid peroxidation levels were significantly ($p < 0.05$) higher in the radiation-exposed groups than in the control and sham control groups. The lipid peroxidation level in the irradiated animals treated with melatonin was significantly ($p < 0.01$) lower than in those that were only exposed to Wi-Fi radiation. The activity of glutathione peroxidase was lower in the irradiated-only group relative to control and sham control groups but its activity was significantly ($p < 0.05$) increased in the groups treated with melatonin. The reduced glutathione levels in the mucosa of rat did not change in the four groups. There is an apparent protective effect of melatonin on the Wi-Fi-induced oxidative stress in the laryngotracheal mucosa of rats by inhibition of free radical formation and support of the glutathione peroxidase antioxidant system.

**Azadi Oskouyi E, Rajaei F, Safari Variani A, Sarokhani MR, Javadi A. Effects of microwaves (950 MHZ mobile phone) on morphometric and apoptotic changes of rabbit epididymis. Andrologia. 2014 Jul 25. doi: 10.1111/and.12321. [Epub ahead of print]**

The effect of mobile phone radiation on human reproduction system is still a matter of debate. In this study, 18 male rabbits were randomly divided into two experimental groups and one control group. Experimental groups received simulated microwaves with the frequency of 950 MHz and the output power of 3 and 6 watts for 2 weeks, 2 h a day. After

a week of rest, the microscopic slides from the quada of the excised epididymis were prepared. Then, the diameter of epididymis, the height of epithelium and the number of apoptotic cells in epithelium in study groups were determined. The data were compared using spss software and one-way anova test. The epithelial height and diameter of the epididymis in 3 watt and 6 watt groups had a significant decrease compared to the control group ($P < 0.001$), while the testosterone level only in 6 watt group was significantly decreased compared to control group. The rate of apoptosis in the epithelial cells of the epididymis had a significant increase only in 6 watt group compared to the control group ($P < 0.001$). This study showed that the microwaves with the frequency of 950 MHz can have negative impacts on morphometric and apoptotic changes of rabbit epididymis.

**Azah CK, Amoako JK, Fletcher JJ. Levels of electric field strength within the immediate vicinity of FM radio stations in Accra, Ghana. Radiat Prot Dosimetry. 156(4):395-400, 2013.**

Heightened awareness of the ever-expanding use of radiofrequency (RF) techniques and technology has led to mounting concerns from the general public and the scientific community regarding the possible health effects that may arise as a consequence of exposure to RF radiations and has drawn the attention of many researchers the world over. A survey of the RF electromagnetic radiation at public access points in the vicinity of 20 frequency-modulated (FM) radio stations has been made in Accra, Ghana. The fundamental object was to determine the levels of RF fields from FM broadcast antennae within 10-200 m radius about the foot of the FM base station and at a height of 1.5 m above the ground at selected locations. A spectrum analyser and a bi-conical antenna element sensitive and effective within the frequency band of 30-300 MHz were used. Results obtained indicated that the levels of electric field strength ranged from 5.4E-04 V m(-1) at FM station 'O' to 7.4E-08 V m(-1) at FM station 'D'. At a transmission frequency range of 88-108 MHz, the variation of power densities is from 2.5E-10 to 1.5E-17 Wm(-2). These values are very low and are far below the reference level set by the International Commission on Non-Ionizing Radiation Protection and therefore do not pose any known hazard to the inhabitants of Accra, Ghana. The electric field levels presented in this work are comparable with those reported from epidemiological studies conducted elsewhere.

**Babincova M, Leszczynska D, Sourivong P, Babinec P, Selective treatment of neoplastic cells using ferritin-mediated electromagnetic hyperthermia. Med Hypotheses 54(2):177-179, 2000.**

A new method of cancer treatment is proposed, based on the unique magnetic properties of ferritin iron core which, in alternating magnetic field of frequency approximately 100 kHz, is easily heated to temperatures sufficiently high to destroy neoplastic cells containing an excess of this protein, without damaging the normal cells.

**Bachmann M, Kalda J, Lass J, Tuulik V, Säkki M, Hinrikus H. Non-linear analysis of the electroencephalogram for detecting effects of low-level electromagnetic fields. Med Biol Eng Comput. 43(1):142-149, 2005.**

The study compared traditional spectral analysis and a new scale-invariant method, the analysis of the length distribution of low-variability periods (LDLVPs), to distinguish between electro-encephalogram (EEG) signals with and without a weak stressor, a low-level modulated microwave field. During the experiment, 23 healthy volunteers were exposed to a microwave (450 MHz) of 7 Hz frequency on-off modulation. The field power density at the scalp was 0.16 mW cm(-2). The experimental protocol consisted of ten cycles of repetitive microwave exposure. Signals from frontal EEG channels FP1 and FP2 were analysed. Smooth power spectrum and length distribution curves of low-variability periods, as well as probability distribution close to normal, confirmed that stationarity of the EEG signal during recordings was achieved. The quantitative measure of LDLVPs provided a significant detection of the effect of the stressor for the six subjects exposed to the microwave field but for none of the sham recordings. The spectral analysis revealed a significant result for one subject only. A significant effect of the exposure to the EEG signal was detected in 25% of subjects, with microwave exposure increasing EEG variability. The effect was not detectable by power spectral measures.

**Bachmann M, Rubljova J, Lass J, Tomson R, Tuulik V, Hinrikus H. Adaptation of human brain bioelectrical activity to low-level microwave. Conf Proc IEEE Eng Med Biol Soc. 2007:4747-4750, 2007.**

The experiments of adaptation of the human brain bioelectrical activity were carried out on a group of 14 healthy volunteers exposed to 450 MHz microwave radiation modulated at 40 Hz frequencies. The field power density at the scalp was 0.16 mW/cm(2). Results of the study indicate that adaptation effect of human brain to low-level microwave exposure is evident. The initial increase of EEG power was compensated and even overcompensated. The adaptation phenomena were obvious in EEG alpha and beta rhythms.

**Bachmann M, Lass J, Kalda J, Säkki M, Tomson R, Tuulik V, Hinrikus H. Integration of differences in EEG analysis reveals changes in human EEG caused by microwave. Conf Proc IEEE Eng Med Biol Soc. 1:1597-1600, 2006.**

Three different methods in combination with integration of differences in signals were applied for EEG analysis to distinguish changes in EEG caused by microwave: S-parameter, power spectral density and length distribution of low variability periods. The experiments on the effect of modulated low-level microwaves on human EEG were carried out on four different groups of healthy volunteers exposed to 450 MHz microwave radiation modulated with 7 Hz, 14 Hz, 21 Hz, 40 Hz, 70 Hz, 217 or 1000 Hz frequencies. The field power density at the scalp was 0.16 mW/cm2. The EEG analysis performed for individuals with three different methods showed that statistically significant changes occur in the EEG rhythms energy and dynamics between 12% and 30% of subjects.

**Bahreyni Toossi MH, Sadeghnia HR, Mohammad Mahdizadeh Feyzabadi M, Hosseini M, Hedayati M, Mosallanejad R, Beheshti F, Alizadeh Rahvar Z. Exposure**

**to** mobile phone **(900-1800 MHz) during pregnancy: tissue oxidative stress after childbirth. J Matern Fetal Neonatal Med. 2017 Apr 23:1-6. doi: 10.1080/14767058.2017.1315657. [Epub ahead of print]**

BACKGROUND: The present study has investigated the effects of **mobile phone** (900-1800 MHz)-induced electromagnetic radiation on redox status in the heart, liver, kidney, cerebellum, and hippocampus of dams and the offspring mice.MATERIALS AND METHODS: Pregnant Balb/C were divided into two groups including the control and the experimental group. The experimental group was exposed to **mobile phone** (900-1800 MHz), during pregnancy (2 h/d for 20 d). The dams and the offspring of both groups were sacrificed and tissues of interest were harvested immediately after delivery. Malondialdehyde (MDA) concentration, total thiol groups (TTG) content, superoxide dismutase (SOD), and catalase (CAT) activities were determined in the tissues.RESULTS: In the experimental groups, MDA levels were significantly increased, while TTG, SOD, and CAT were significantly decreased in the total tissues of dams and their offspring.CONCLUSION: Exposure to **mobile phone** (900-1800 MHz) during pregnancy induced oxidative stress in tissues of dams and their offspring.

**Bak M, Dudarewicz A, Zmyślony M, Sliwinska-Kowalska M. Effects of GSM signals during exposure to event related potentials (ERPs). Int J Occup Med Environ Health. 23(2):191-199, 2010.**

Objectives: The primary aim of this work was to assess the effect of electromagnetic field (EMF) from the GSM mobile phone system on human brain function. The assessment was based on the assay of event related potentials (ERPs). Material and Methods: The study group consisted of 15 volunteers, including 7 men and 8 women. The test protocol comprised determination of P300 wave in each volunteer during exposure to the EMF. To eliminate possible effects of the applied test procedure on the final result, the test was repeated without EMF exposure. P300 latency, amplitude, and latency of the N1, N2, P2 waves were analysed. Results: The statistical analysis revealed an effect of EMF on P300 amplitude. In the experiment with EMF exposure, lower P300 amplitudes were observed only at the time in which the volunteers were exposed to EMF; when the exposure was discontinued, the values of the amplitude were the same as those observed before EMF application. No such change was observed when the experiment was repeated with sham exposure, which may be considered as an indirect proof that lower P300 amplitude values were due to EMF exposure. No statistically significant changes were noted in the latencies of the N1, N2, P2 waves that precede the P300 wave, nor in the latency of the P300 itself. Conclusions: The results suggest that exposure to GSM EMF exerts some effects on CNS, including effects on long latency ERPs.

**Bakacak M, Bostancı MS, Attar R, Yıldırım ÖK, Yıldırım G, Bakacak Z, Sayar H, Han A. The effects of electromagnetic fields on the number of ovarian primordial follicles: An experimental study. Kaohsiung J Med Sci. 31(6):287-292, 2015.**

The aim of this study was to evaluate the effect of an electromagnetic field (EMF), generated close to the ovaries, on primordial follicles. A total of 16 rats were used in this study. The study group consisted of rats exposed to an EMF in the abdominal region for 15 min/d for 15 days. Both the study and control group were composed of eight rats. After the treatment period of 15 days, the ovaries of the rats were extracted, and sections of ovarian tissue were taken for histological evaluation. The independent samples t test was used to compare the two groups. In the study group, the means of the right and left ovarian follicle numbers were 34.00 ± 10.20 and 36.00 ± 10.53, respectively. The average total ovarian follicle number was 70.00 ± 19.03. In the control group, the means of the right and left ovarian follicle numbers were 78.50 ± 25.98 and 71.75 ± 29.66, respectively, and the average total ovarian follicle number was 150.25 ± 49.53. The comparisons of the means of the right and left ovarian follicle numbers and the means of the total ovarian follicle numbers between the study and control groups indicated that the study group had significantly fewer follicles ($p < 0.001$, $p = 0.011$, and $p = 0.002$, respectively). This study found a significant decrease in the number of ovarian follicles in rats exposed to an EMF. Further clinical studies are needed to reveal the effects of EMFs on ovarian reserve and infertility.

**Bakos J, Kubinyi G, Sinay H, Thuroczy G. GSM modulated radiofrequency radiation does not affect 6-sulfatoxymelatonin excretion of rats. Bioelectromagnetics 24(8):531-534, 2003.**

In this study, the effect of exposure to 900 and 1800 MHz GSM-like radiofrequency radiation upon the urinary 6-sulfatoxymelatonin (6SM) excretion of adult male Wistar rats was studied. Seventy-two rats were used in six independent experiments, three of which were done with 900 MHz and the other three with 1800 MHz. The exposures were performed in a gigahertz transverse electromagnetic mode (GTEM) cell. The power densities of radiation were 100 and 20 microW/cm(2) at 900 and 1800 MHz frequency, respectively. The carrier frequency was modulated with 218 Hz, as in the GSM signal. The animals were exposed for 2 h between 8:00 AM and noon daily during the 14 day exposure period. The urine of rats was collected from 12:00 AM to 8:00 AM, collecting from exposed and control animal groups on alternate days. The urinary 6SM concentration was measured by (125)I radioimmunoassay and was referred to creatinine. The combined results of three experiments done with the same frequency were statistically analyzed. Statistically significant changes in the 6SM excretion of exposed rats ($n = 18$) compared to control group ($n = 18$) were not found either at 900 or 1800 MHz.

**Balakrishnan K, Murali V, Rathika C, Manikandan T, Malini RP, Kumar RA, Krishnan M. Hsp70 is an independent stress marker among frequent users of mobile phones. J Environ Pathol Toxicol Oncol. 33(4):339-347, 2014.**

The aim of this study was to measure the serum concentrations of heat shock protein (HSP) 70 and C-reactive protein (CRP) and the expression levels of the hsp70 gene among frequent users of mobile phones (FUMPs). We enrolled 120 employees of information technology (IT)/IT enabled service companies (FUMPs; IT professionals) and 102 infrequent users of mobile phones (IFUMPs; people from non-IT professions) as

controls. The serum concentrations of HSP70 and CRP were measured by enzyme-linked immunosorbant assay and hsp70 gene expression by reverse transcription polymerase chain reaction. Significantly higher concentrations of serum HSP70 ($P < 0.00012$) and CRP ($P < 0.04$) were observed among FUMPs than IFUMPs. A higher level of hsp70 gene expression (fold induction) was observed among FUMPs than IFUMPs ($P < 7.06 \times 10\text{-}13$). In contrast to the duration of exposure-dependent increase of serum concentration of CRP, the serum HSP70 concentration was found to be independent of the duration of exposure to mobile phones. Thus, the study convincingly demonstrated the role of serum HSP and CRP as systemic inflammatory biomarkers for mobile phone-induced radiation.

**Balcer-Kubiczek EK, Harrison GH. Neoplastic transformation of C3H/10T1/2 cells following exposure to 120-Hz modulated 2.45-GHz microwaves and phorbol ester tumor promoter. Radiat Res 126(1):65-72, 1991.**

Some recent epidemiological studies have shown a positive association between cancer incidence and exposure to electromagnetic (EM) fields. Evidence from in vitro studies indicates that this effect could be due to synergistic interaction between EM fields and tumor promoters. However, no dose-response data related directly to carcinogenesis have been published. In this study, actively growing cultures of C3H/10T1/2 cells were exposed for 24 h to 2.45-GHz microwaves pulse-modulated at 120 Hz. Conditions of EM-field exposure were designed to simulate low-field exposures (specific absorption rate 0.1, 1, or 4.4 W/kg; the corresponding peak amplitudes were electric field 18, 56, or 120 V/m, magnetic field 0.09, 0.27, or 0.56 muT, respectively). In separate experiments, a 24-h EM-field exposure at 4.4 W/kg was preceded or followed by X irradiation at 0.5, 1, or 1.5 Gy. Cells were assayed for cell survival and neoplastic transformation with or without post-treatment administration of 0.1 micrograms/ml of 12-O-tetradecanoylphorbol-13-acetate (TPA) for the duration of the assay. The EM fields alone had no effect on cell survival or induction of neoplastic transformation. However, enhancement of transformation due to EM fields plus TPA was highly significant and ranged up to a level equivalent to that produced by 1.5 Gy of X rays. The frequency of neoplastic transformation was dependent on the level of EM exposure and was additive with doses of X rays given as a cocarcinogen.

**Balci M, Devrim E, Durak I. Effects of mobile phones on oxidant/antioxidant balance in cornea and lens of rats. Curr Eye Res. 32(1):21-25, 2007.**

Purpose: To investigate the effects of mobile-phone-emitted radiation on the oxidant/antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C in this setting. Methods: Forty female albino Wistar rats were assigned to one of four groups containing 10 rats each. One group received a standardized daily dose of mobile phone radiation for 4 weeks. The second group received this same treatment along with a daily oral dose of vitamin C (250 mg/kg). The third group received this dose of vitamin C alone, while the fourth group received standard laboratory care and served as a control. In corneal and lens tissues, malondialdehyde (MDA) levels and activities of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) were measured with spectrophotometric methods. Results: In corneal tissue, MDA level and CAT activity

significantly increased in the mobile phone group compared with the mobile phone plus vitamin C group and the control group ($p < 0.05$), whereas SOD activity was significantly decreased ($p < 0.05$). In the lens tissues, only the MDA level significantly increased in the mobile phone group relative to mobile phone plus vitamin C group and the control groups ($p < 0.05$). In lens tissue, significant differences were not found between the groups in terms of SOD, GSH-Px, or CAT ($p > 0.05$). Conclusions: The results of this study suggest that mobile telephone radiation leads to oxidative stress in corneal and lens tissues and that antioxidants such as vitamin C can help to prevent these effects

**Balci M, Namuslu M, Devrim E, Durak I. Effects of computer monitor-emitted radiation on oxidant/antioxidant balance in cornea and lens from rats. Mol Vis. 15:2521-2525, 2009.**

PURPOSE: This study aims to investigate the possible effects of computer monitor-emitted radiation on the oxidant/antioxidant balance in corneal and lens tissues and to observe any protective effects of vitamin C (vit C). METHODS: Four groups (PC monitor, PC monitor plus vitamin C, vitamin C, and control) each consisting of ten Wistar rats were studied. The study lasted for three weeks. Vitamin C was administered in oral doses of 250 mg/kg/day. The computer and computer plus vitamin C groups were exposed to computer monitors while the other groups were not. Malondialdehyde (MDA) levels and superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and catalase (CAT) activities were measured in corneal and lens tissues of the rats. RESULTS: In corneal tissue, MDA levels and CAT activity were found to increase in the computer group compared with the control group. In the computer plus vitamin C group, MDA level, SOD, and GSH-Px activities were higher and CAT activity lower than those in the computer and control groups. Regarding lens tissue, in the computer group, MDA levels and GSH-Px activity were found to increase, as compared to the control and computer plus vitamin C groups, and SOD activity was higher than that of the control group. In the computer plus vitamin C group, SOD activity was found to be higher and CAT activity to be lower than those in the control group. CONCLUSION: The results of this study suggest that computer-monitor radiation leads to oxidative stress in the corneal and lens tissues, and that vitamin C may prevent oxidative effects in the lens.

**Baliatsas C, van Kamp I, Kelfkens G, Schipper M, Bolte J, Yzermans J, Lebret E. Non-specific physical symptoms in relation to actual and perceived proximity to mobile phone base stations and powerlines. BMC Public Health. 11:421, 2011.**

BACKGROUND: Evidence about a possible causal relationship between non-specific physical symptoms (NSPS) and exposure to electromagnetic fields (EMF) emitted by sources such as mobile phone base stations (BS) and powerlines is insufficient. So far little epidemiological research has been published on the contribution of psychological components to the occurrence of EMF-related NSPS. The prior objective of the current study is to explore the relative importance of actual and perceived proximity to base stations and psychological components as determinants of NSPS, adjusting for demographic, residency and area characteristics. METHODS: Analysis was performed on data obtained in a cross-sectional study on environment and health in 2006 in the

Netherlands. In the current study, 3611 adult respondents (response rate: 37%) in twenty-two Dutch residential areas completed a questionnaire. Self-reported instruments included a symptom checklist and assessment of environmental and psychological characteristics. The computation of the distance between household addresses and location of base stations and powerlines was based on geo-coding. Multilevel regression models were used to test the hypotheses regarding the determinants related to the occurrence of NSPS. RESULTS: After adjustment for demographic and residential characteristics, analyses yielded a number of statistically significant associations: Increased report of NSPS was predominantly predicted by higher levels of self-reported environmental sensitivity; perceived proximity to base stations and powerlines, lower perceived control and increased avoidance (coping) behavior were also associated with NSPS. A trend towards a moderator effect of perceived environmental sensitivity on the relation between perceived proximity to BS and NSPS was verified ($p = 0.055$). There was no significant association between symptom occurrence and actual distance to BS or powerlines. CONCLUSIONS: Perceived proximity to BS, psychological components and socio-demographic characteristics are associated with the report of symptomatology. Actual distance to the EMF source did not show up as determinant of NSPS.

**Baliatsas C, Van Kamp I, Lebret E, Rubin GJ. Idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF): A systematic review of identifying criteria. BMC Public Health. 2012 Aug 11;12:643. doi: 10.1186/1471-2458-12-643.**

BACKGROUND: Idiopathic environmental intolerance attributed to electromagnetic fields (IEI-EMF) remains a complex and unclear phenomenon, often characterized by the report of various, non-specific physical symptoms (NSPS) when an EMF source is present or perceived by the individual. The lack of validated criteria for defining and assessing IEI-EMF affects the quality of the relevant research, hindering not only the comparison or integration of study findings, but also the identification and management of patients by health care providers. The objective of this review was to evaluate and summarize the criteria that previous studies employed to identify IEI-EMF participants. METHODS: An extensive literature search was performed for studies published up to June 2011. We searched EMBASE, Medline, Psychinfo, Scopus and Web of Science. Additionally, citation analyses were performed for key papers, reference sections of relevant papers were searched, conference proceedings were examined and a literature database held by the Mobile Phones Research Unit of King's College London was reviewed. RESULTS: Sixty-three studies were included. "Hypersensitivity to EMF" was the most frequently used descriptive term. Despite heterogeneity, the criteria predominantly used to identify IEI-EMF individuals were: 1. Self-report of being (hyper)sensitive to EMF. 2. Attribution of NSPS to at least one EMF source. 3. Absence of medical or psychiatric/psychological disorder capable of accounting for these symptoms 4. Symptoms should occur soon (up to 24 hours) after the individual perceives an exposure source or exposed area. (Hyper)sensitivity to EMF was either generalized (attribution to various EMF sources) or source-specific. Experimental studies used a larger number of criteria than those of observational design and performed more frequently a medical examination or interview as prerequisite for inclusion. CONCLUSIONS: Considerable heterogeneity exists in the criteria used by the researchers to identify IEI-EMF, due to explicit differences in their conceptual frameworks. Further work is required to produce consensus criteria not only

for research purposes but also for use in clinical practice. This could be achieved by the development of an international protocol enabling a clearly defined case definition for IEI-EMF and a validated screening tool, with active involvement of medical practitioners.

**Balik HH, Turgut-Balik D, Balikci K, Ozcan IC. Some ocular symptoms and sensations experienced by long term users of mobile phones. Pathol Biol (Paris). 53(2):88-91, 2005.**

In this study, a survey was conducted to investigate the possible effects of long term usage of mobile phone (MP) on eyes. The studied symptoms are blurring of vision, redness on the eyes, vision disturbance, secretion of the eyes, inflammation in the eyes and lacrimation of the eyes. There is no effect on redness on the eyes and vision disturbance, but some statistical evidences are found that MP may cause blurring of vision, secretion of the eyes, inflammation in the eyes and lacrimation of the eyes. These results suggest an awareness of the symptoms and sensations.

**Balikci K, Cem Ozcan I, Turgut-Balik D, Balik HH. A survey study on some neurological symptoms and sensations experienced by long term users of mobile phones. Pathol Biol (Paris). 53(1):30-34, 2005.**

A survey study was conducted to investigate the possible effects of mobile phone on headache, dizziness, extreme irritation, shaking in the hands, speaking falteringly, forgetfulness, neuro-psychological discomfort, increase in the carelessness, decrease of the reflex and clicking sound in the ears. There is no effect on dizziness, shaking in hands, speaking falteringly and neuro-psychological discomfort, but some statistical evidences are found that mobile phone may cause headache, extreme irritation, increase in the carelessness, forgetfulness, decrease of the reflex and clicking sound in the ears.

**Balmori A. Mobile Phone Mast Effects on Common Frog (Rana temporaria) Tadpoles: The City Turned into a Laboratory. Electromagn Biol Med. 29(1-2):31-35, 2010.**

An experiment has been made exposing eggs and tadpoles of the common frog (Rana temporaria) to electromagnetic radiation from several mobile (cell) phone antennae located at a distance of 140 meters. The experiment lasted two months, from the egg phase until an advanced phase of tadpole prior to metamorphosis. Measurements of electric field intensity (radiofrequencies and microwaves) in V/m obtained with three different devices were 1.8 to 3.5 V/m. In the exposed group (n = 70), low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) was observed. Regarding the control group (n = 70) under the same conditions but inside a Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained. These results indicate that radiation emitted by phone masts in a real situation may affect the development and may cause an increase in mortality of exposed tadpoles. This research may have huge implications for the natural world, which is now exposed to high microwave radiation levels from a multitude of phone masts.

**Balode, Z, Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. Sci Total Environ 180(1):81-85, 1996.**

Previous bioindicative studies in the Skrunda Radio Location Station area have focused on the somatic influence of electromagnetic radiation on plants, but it is also important to study genetic effects. We have chosen cows as test animals for cytogenetical evaluation because they live in the same general exposure area as humans, are confined to specific locations and are chronically exposed to radiation. Blood samples were obtained from female Latvian Brown cows from a farm close to and in front of the Skrunda Radar and from cows in a control area. A simplified alternative to the Schiff method of DNA staining for identification of micronuclei in peripheral erythrocytes was applied. Microscopically, micronuclei in peripheral blood erythrocytes were round in shape and exhibited a strong red colour. They are easily detectable as the only coloured bodies in the uncoloured erythrocytes. From each individual animal 2000 erythrocytes were examined at a magnification of x 1000 for the presence of micronuclei. The counting of micronuclei in peripheral erythrocytes gave low average incidences, 0.6 per 1000 in the exposed group and 0.1 per 1000 in the control, but statistically significant ($P < 0.01$) differences were found in the frequency distribution between the control and exposed groups.

**Bamiou DE, Ceranic B, Cox R, Watt H, Chadwick P, Luxon LM. Mobile telephone use effects on peripheral audiovestibular function: A case-control study. Bioelectromagnetics.29(2):108-117,2008.**

Low level radio-frequency (RF) signals may produce disorientation, headache and nausea. This double blind study tested nine case-subjects, who complained of various symptoms after prolonged mobile telephone use and 21 control subjects. Each subject underwent a series of trials, in which a dummy mobile telephone exposure system was held to each ear for 30 min in (a) pulsed, (b) continuous RF emission or, (c) no emission test modes. In the active pulsed and continuous modes the same mean power as the output of a typical handset was delivered at a carrier frequency of 882 MHz and at a maximum specific absorption rate (SAR) value of 1.3 W kg(-1) (+/- 30%). In Experiment I (auditory), transient evoked otoacoustic emissions (TEOAE), which assess the outer hair cells in the inner ear, were conducted. In Experiment II (vestibular) the vestibulo-ocular reflex was recorded by video-oculography (VOG), at baseline and immediately post exposure. There were no significant TEOAE changes from baseline to post-exposure recording for any of the exposures and no significant differences in the TEOAEs' change from baseline to post exposure between cases and controls. The VOG did not identify any effect of the exposure on the vestibular end organ in either cases or controls. In conclusion, 30 min exposure to mobile phone RF did not show any immediate effects on vestibulocochlear function as measured by TEOAE and the VOR.

**Bamiou DE, Ceranic B, Vickers D, Zamyslowska-Szmytke E, Cox R, Chadwick P, Luxon LM. Mobile telephone use effects on perception of verticality. Bioelectromagnetics. 2014 Sep 26. doi: 10.1002/bem.21877. [Epub ahead of print]**

Low-level radiofrequency (RF) signals may produce disorientation and nausea. In experiment I, we assessed mobile phone effects on graviception in nine symptomatic subjects after mobile telephone use and 21 controls. The mobile handset was strapped to each ear for 30 min in pulsed emission, continuous RF emission, or no emission test mode, respectively. The subjective visual vertical and horizontal (SVV/SVH) were tested from min 25 of exposure. There was no exposure effect; however, there was an ear effect, with the SVV/SVH being shifted to the opposite direction of the ear exposed. This could be due to thermal or RF effects or handset weight. In experiment II, we assessed the handset weight effect on 18 normal controls. After baseline SVV/SVH, the switched off handset was strapped to either ear; the SVV/SVH was repeated 25 min later. A significant ear effect was found. We compared the observed ear effect SVV/SVH change in the experiment II group to the continuous exposure ear effect change in the experiment I group, and the difference was not significant. The ear effect was attributed to a minor head tilt due to the handset weight, or proprioceptive stimulation of neck muscle affecting the perception of verticality.

**Banaceur S, Banasr S, Sakly M, Abdelmelek H. Whole body exposure to 2.4 GHz WIFI signals: effects on cognitive impairment in adult triple transgenic mouse models of Alzheimer's disease (3xTg-AD). Behav Brain Res. 240:197-201, 2013.**

The present investigation aimed at evaluating the effects of long-term exposure to WIFI type radiofrequency (RF) signals (2.40 GHz), two hours per day during one month at a Specific Absorption Rate (SAR) of 1.60 W/kg. The effects of RF exposure were studied on wildtype mice and triple transgenic mice (3xTg-AD) destined to develop Alzheimer's-like cognitive impairment. Mice were divided into four groups: two sham groups (WT, TG; n=7) and two exposed groups (WTS, TGS; n=7). The cognitive interference task used in this study was designed from an analogous human cognitive interference task including the Flex field activity system test, the two-compartment box test and the Barnes maze test. Our data demonstrate for the first time that RF improves cognitive behavior of 3xTg-AD mice. We conclude that RF exposure may represent an effective memory-enhancing approach in Alzheimer's disease.

**Banerjee S, Singh NN, Sreedhar G, Mukherjee S. Analysis of the Genotoxic Effects of Mobile Phone Radiation using Buccal Micronucleus Assay: A Comparative Evaluation. J Clin Diagn Res. 2016 Mar;10(3):ZC82-5. doi: 10.7860/JCDR/2016/17592.7505. Epub 2016 Mar 1.**

INTRODUCTION: Micronucleus (MN) is considered to be a reliable marker for genotoxic damage and it determines the presence and the extent of the chromosomal damage. The MN is formed due to DNA damage or chromosomal disarrangements. The MN has a close association with cancer incidences. In the new era, mobile phones are constantly gaining popularity specifically in the young generation, but this device uses radiofrequency radiation that may have a possible carcinogenic effect. The available reports related to the carcinogenic effect of mobile radiation on oral mucosa are contradictory. AIM: To explore the effects of mobile phone radiation on the MN frequency in oral mucosal cells. MATERIALS AND METHODS: The subjects were divided into two

major groups: low mobile phone users and high mobile phone users. Subjects who used their mobile phone since less than five years and less than three hours a week comprised of the first group and those who used their mobile since more than five years and more than 10 hours a week comprised of the second group. Net surfing and text messaging was not considered in this study. Exfoliated buccal mucosal cells were collected from both the groups and the cells were stained with DNA-specific stain acridine orange. Thousand exfoliated buccal mucosal cells were screened and the cells which were positive for micronuclei were counted. The micronucleus frequency was represented as mean±SD, and unpaired Student t-test was used for intergroup comparisons. RESULTS: The number of micronucleated cells/ 1000 exfoliated buccal mucosal cells was found to be significantly increased in high mobile phone users group than the low mobile phone users group. The use of mobile phone with the associated complaint of warmth around the ear showed a maximum increase in the number of micronucleated cells /1000 exfoliated buccal mucosal cells. CONCLUSION: Mobile phone radiation even in the permissible range when used for longer duration causes significant genotoxicity. The genotoxicity can be avoided to some extent by the regular use of headphones.

**Baohong Wang, Jiliang H, Lifen J, Deqiang L, Wei Z, Jianlin L, Hongping D. Studying the synergistic damage effects induced by 1.8GHz radiofrequency field radiation (RFR) with four chemical mutagens on human lymphocyte DNA using comet assay in vitro. Mutat Res. 578(1-2):149-157, 2005.**

The aim of this investigation was to study the synergistic DNA damage effects in human lymphocytes induced by 1.8GHz radiofrequency field radiation (RFR, SAR of 3W/kg) with four chemical mutagens, i.e. mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiomimetic agent), methyl methanesulfonate (MMS, alkylating agent), and 4-nitroquinoline-1-oxide (4NQO, UV-mimetic agent). The DNA damage of lymphocytes exposed to RFR and/or with chemical mutagens was detected at two incubation time (0 or 21h) after treatment with comet assay in vitro. Three combinative exposure ways were used. Cells were exposed to RFR and chemical mutagens for 2 and 3h, respectively. Tail length (TL) and tail moment (TM) were utilized as DNA damage indexes. The results showed no difference of DNA damage indexes between RFR group and control group at 0 and 21h incubation after exposure ($P>0.05$). There were significant difference of DNA damage indexes between MMC group and RFR+MMC co-exposure group at 0 and 21h incubation after treatment ($P<0.01$). Also the significant difference of DNA damage indexes between 4NQO group and RFR+4NQO co-exposure group at 0 and 21h incubation after treatment was observed ($P<0.05$ or $P<0.01$). The DNA damage in RFR+BLM co-exposure groups and RFR+MMS co-exposure groups was not significantly increased, as compared with corresponding BLM and MMS groups ($P>0.05$). The experimental results indicated 1.8GHz RFR (SAR, 3W/kg) for 2h did not induce the human lymphocyte DNA damage effects in vitro, but could enhance the human lymphocyte DNA damage effects induced by MMC and 4NQO. The synergistic DNA damage effects of 1.8GHz RFR with BLM or MMS were not obvious.

**Baohong W, Lifen J, Lanjuan L, Jianlin L, Deqiang L, Wei Z, Jiliang H. Evaluating the combinative effects on human lymphocyte DNA damage induced by ultraviolet**

**ray C plus 1.8GHz microwaves using comet assay in vitro. Toxicology. 232(3):311-316, 2007.**

The objective of this study was to observe whether 1.8GHz microwaves (MW) (SAR, 3 W/kg) exposure can influence human lymphocyte DNA damage induced by ultraviolet ray C (UVC). The lymphocytes, which were from three young healthy donors, were exposed to 254 nm UVC at the doses of 0.25, 0.5, 0.75, 1.0, 1.5 and 2.0 J m(-2), respectively. The lymphocytes were irradiated by 1.8GHz MW (SAR, 3 W/kg) for 0, 1.5 and 4 h. The combinative exposure of UVC plus MW was conducted. The treated cells were incubated for 0, 1.5 and 4 h. Finally, comet assay was used to measure DNA damage of above treated lymphocytes. The results indicated that the difference of DNA damage induced between MW group and control group was not significant (P>0.05). The MTLs induced by UVC were 1.71+/-0.09, 2.02+/-0.08, 2.27+/-0.17, 2.27+/-0.06, 2.25+/-0.12, 2.24+/-0.11 microm, respectively, which were significantly higher than that (0.96+/-0.05 microm) of control (P<0.01). MTLs of some sub-groups in combinative exposure groups at 1.5-h incubation were significantly lower that those of corresponding UVC sub-groups (P<0.01 or P<0.05). However, MTLs of some sub-groups in combinative exposure groups at 4-h incubation were significantly higher that those of corresponding UVC sub-groups (P<0.01 or P<0.05). In this experiment it was found that 1.8GHz (SAR, 3 W/kg) MW exposure for 1.5 and 4 h did not enhance significantly human lymphocyte DNA damage, but could reduce and increase DNA damage of human lymphocytes induced by UVC at 1.5-h and 4-h incubation, respectively.

**Barbaro V, Bartolini P, Donato A, Militello C, Electromagnetic interference of analog cellular telephones with pacemakers. Pacing Clin Electrophysiol 19(10):1410-1418, 1996.**

The aim of this study was to verify whether there is a public health risk from the interference of analog cellular telephones with pacemakers. We used a human trunk simulator to reproduce an actual implant, and two cellular telephones working with the TACS (Total Access Communication System) standard. Results showed that the electromagnetic field radiated from the analog cellular telephones interfered with a large number of the pacemakers tested (10/25). When the telephone antenna was in close proximity to the pacemaker head, pacemaker desensitizing and sensitizing and pulse inhibition was detected at the moment of an incoming call and throughout ringing. In the worst case of pulse inhibition, the pacemaker skipped three nonconsecutive beats and then resumed its normal pacing, while the desensitizing and sensitizing phenomena persisted as long as the interfering signal was on. Pulse inhibition was also observed when the connection did not succeed. Maximum sensing threshold variation was about 186% (increase) and 62% (decrease) for desensitizing and sensitizing phenomena, respectively. It was also demonstrated that the signal emitted by analog cellular telephones during the crossing of contiguous cells could induce pacemaker pulse inhibition, but under our experimental conditions this event did not seem to pose a risk for the pacemaker patient.

**Barcal J, Cendelín J, Vozeh F, Zalud V. Effect of whole-body exposure to high-**

**frequency electromagnetic field on the brain electrogeny in neurodefective and healthy mice. Prague Med Rep. 106(1):91-100, 2005.**

A direct registration of brain cortical and hippocampal activity during a high-frequency electromagnetic field (HF EMF) exposure was performed. All experimental procedures were done under urethane anaesthesia (20%, 2 g/kg i.p.) in Lurcher mutant mice, wild type (healthy littermates) were used as controls. Experimental animals were exposed to the HF EMF with frequency corresponding to cellular phones. Our method is based on the use of gel electrodes (silicon tubes or glass microcapillaries filled with agar) where the connection with classical electrodes is located out of HF EMF space. ECoG evaluation showed a distinct shift to lower frequency components but clear effect has been observed only in wild type (healthy) mice whereas in Lurcher mutant mice only gentle differences between frequency spectra were found. Measurement of hippocampal rhythmicity showed gentle changes with increase of higher frequencies (i.e. opposite effect than in cortex) and changes in theta oscillations registered from a dentate gyrus and CA1 area in both types of animals (healthy and mutant). These findings support the idea about possible influencing the central nervous system by HF EMF exposure and support also some recent results about possible health risks resulting from cellular phones use.

**Barcal J, Vozeh F. Effect of whole-body exposure to high-frequency electromagnetic field on the brain cortical and hippocampal activity in mouse experimental model. NeuroQuantology 5:292-302, 2007.**

Evaluation of the direct registration of brain cortical and hippocampal activity during a high-frequency electromagnetic field (HF-EMF) exposure was performed. Experimental procedures were done under general anesthesia (urethane, 20%, 2g/kg i.p.) in Lurcher mutant mice, wild type (healthy littermates) were used as controls. Animals were exposed to the HF-EMF with frequency corresponding to cellular phones (900 MHz). We used of gel electrodes (silicon tubes or glass microcapillary filled with agar) where the connection with classical electrodes was located out of HF-EMF space. ECoG evaluation showed a distinct shift to lower frequency components but clear effect has been observed only in wild type (healthy) mice whereas in Lurcher mutant mice only gentle differences between frequency spectra were found. Measurement of hippocampal rhythmicity showed gentle changes with increase of higher frequencies (i.e. opposite effect than in cortex) and changes in theta oscillations registered from a dentate gyrus and CA1 area in both types of animals (healthy and mutant). These findings support an idea about possible influencing the central nervous system by HF-EMF exposure and support also some recent results about possible health risks resulting from cellular phones use.

**Barkana Y, Zadok D, Morad Y, Avni I. Visual field attention is reduced by concomitant hands-free conversation on a cellular telephone. Am J Ophthalmol. 138(3):347-353, 2004.**

PURPOSE: To quantify the central attention-diverting effect of hands-free cellular phone conversation on visual field awareness. DESIGN: Experimental study. METHODS: Twenty male and 21 female healthy participants performed a pretest and baseline

Esterman visual field examinations with the Humphrey Systems Visual Field Analyzer II. During the consequent third examination, each participant engaged in a hands-free conversation using a cellular phone. The conversation was the same for all participants. Visual field performance parameters were compared between the second (baseline) examination, and the third (test) examination for each eye. RESULTS: During phone conversation, missed points increased from mean 1.0 +/- 1.5 to 2.6 +/- 3.4 (P <==.001) in the right eye and from 1.1 +/- 1.53 to 3.0 +/- 3.4 (P <.001) in the left eye. Fixation loss increased from mean 7.8% to 27.4% (P <.0001) and from 7.2% to 34.8% (P <.0001) for the right and left eyes, respectively. Test duration increased by a mean of 0.28 seconds (15%) per stimulus (P <.0001). Approximately half of missed points were inside the central 30 degrees. There was no significant difference in the performance of male and female participants. CONCLUSION: We describe a new model for the quantification of the attention-diverting effect of cellular-phone conversation on the visual field. In the current study, cellular hands-free conversation caused some subjects to miss significantly more points, react slower to each stimulus, and perform with reduced precision. Legislative restrictions on concomitant cellular-phone conversation and driving may need to be based on individual performance rather than a general ban on cellular phone usage.

**Barker AT, Jackson PR, Parry H, Coulton LA, Cook GG, Wood SM. The effect of GSM and TETRA mobile handset signals on blood pressure, catechol levels and heart rate variability. Bioelectromagnetics.28(6):433-438, 2007.**

An acute rise in blood pressure has been reported in normal volunteers during exposure to signals from a mobile phone handset. To investigate this finding further we carried out a double blind study in 120 healthy volunteers (43 men, 77 women) in whom we measured mean arterial pressure (MAP) during each of six exposure sessions. At each session subjects were exposed to one of six different radio frequency signals simulating both GSM and TETRA handsets in different transmission modes. Blood catechols before and after exposure, heart rate variability during exposure, and post exposure 24 h ambulatory blood pressure were also studied. Despite having the power to detect changes in MAP of less than 1 mmHg none of our measurements showed any effect which we could attribute to radio frequency exposure. We found a single statistically significant decrease of 0.7 mmHg (95% CI 0.3-1.2 mmHg, P = .04) with exposure to GSM handsets in sham mode. This may be due to a slight increase in operating temperature of the handsets when in this mode. Hence our results have not confirmed the original findings of an acute rise in blood pressure due to exposure to mobile phone handset signals. In light of this negative finding from a large study, coupled with two smaller GSM studies which have also proved negative, we are of the view that further studies of acute changes in blood pressure due to GSM and TETRA handsets are not required.

**Barteri M, Pala A, Rotella S. Structural and kinetic effects of mobile phone microwaves on acetylcholinesterase activity. Biophys Chem. 113(3):245-253, 2005.**

The present study provides evidence that "in vitro" simple exposure of an aqueous solution of electric eel acetylcholinesterase (EeAChE; EC 3.1.1.7.) to cellular phone emission alters its enzymatic activity. This paper demonstrates, by combining different experimental techniques, that radio frequency (RF) radiations irreversibly affect the

structural and biochemical characteristics of an important CNS enzyme. These results were obtained by using a commercial cellular phone to reproduce the reality of the human exposition. This experimental procedure provided surprising effects collected practically without experimental errors because they were obtained comparing native and irradiated sample of the same enzyme solution. Although these results cannot be used to conclude whether exposure to RF during the use of cellular phone can lead to any hazardous health effect, they may be a significant first step towards further verification of these effects on other "ex vivo" or "in vivo" biological systems.

**Barteri M, De Carolis R, Marinelli F, Tomassetti G, Montemiglio LC. Effects of microwaves (900 MHz) on peroxidase systems: a comparison between lactoperoxidase and horseradish peroxidase. Electromagn Biol Med. 2015 Jan 12:1-7. [Epub ahead of print]**

This work shows the effects of exposure to an electromagnetic field at 900 MHz on the catalytic activity of the enzymes lactoperoxidase (LPO) and horseradish peroxidase (HRP). Experimental evidence that irradiation causes conformational changes of the active sites and influences the formation and stability of the intermediate free radicals is documented by measurements of enzyme kinetics, circular dichroism spectroscopy (CD) and cyclic voltammetry.

**Barth A, Winker R, Ponocny-Seliger E, Mayrhofer W, Ponocny I, Sauter C, Vana N. A meta-analysis for neurobehavioral effects due to electromagnetic field exposure emitted by GSM mobile phones. Occup Environ Med.65(5):342-6, 2008.**

BACKGROUND AND OBJECTIVE: Numerous studies have investigated the potential effects of electromagnetic fields (EMFs) emitted by GSM mobile phones (~900 MHz to ~1800 MHz) on cognitive functioning, but results have been equivocal. In order to try and clarify this issue, the current study carried out a meta-analysis on nineteen experimental studies. DESIGN: meta-analysis METHODS: Nineteen studies were taken into consideration. Ten of them were included in the meta-analysis as they fulfil several minimum requirements; for example, single-blind or double-blind experimental study design and documentation of means and standard deviation of the dependent variables. The meta-analysis aimed at comparing exposed with non-exposed subjects assuming that there is a common population effect so that one single effect size could be calculated. When homogeneity for single effect sizes was not given, an own population effect for each study and a distribution of population effects was assumed. RESULTS: Attention measured by the subtraction task seems to be affected in regard of decreased reaction time. Working memory measured by the N-back test seems to by affected too: Under condition 0-back target response time is lower under exposure, while under condition 2-back target response time increases. The number of errors under condition 2-back non-targets appears to be higher under exposure. CONCLUSION: Results of the meta-analysis suggest that EMFs may have a small impact on human attention and working memory.

**Barthélémy A, Mouchard A, Bouji M, Blazy K, Puigsegur R, Villégier AS. Glial markers and emotional memory in rats following acute cerebral radiofrequency exposures. Environ Sci Pollut Res Int. 2016 Sep 30. [Epub ahead of print]**

The widespread mobile phone use raises concerns on the possible cerebral effects of radiofrequency electromagnetic fields (RF EMF). Reactive astrogliosis was reported in neuroanatomical structures of adaptive behaviors after a single RF EMF exposure at high specific absorption rate (SAR, 6 W/kg). Here, we aimed to assess if neuronal injury and functional impairments were related to high SAR-induced astrogliosis. In addition, the level of beta amyloid 1-40 (Aβ 1-40) peptide was explored as a possible toxicity marker. Sprague Dawley male rats were exposed for 15 min at 0, 1.5, or 6 W/kg or for 45 min at 6 W/kg. Memory, emotionality, and locomotion were tested in the fear conditioning, the elevated plus maze, and the open field. Glial fibrillary acidic protein (GFAP, total and cytosolic fractions), myelin basic protein (MBP), and Aβ1-40 were quantified in six brain areas using enzyme-linked immunosorbent assay. According to our data, total GFAP was increased in the striatum (+114 %) at 1.5 W/kg. Long-term memory was reduced, and cytosolic GFAP was increased in the hippocampus (+119 %) and in the olfactory bulb (+46 %) at 6 W/kg (15 min). No MBP or Aβ1-40 expression modification was shown. Our data corroborates previous studies indicating RF EMF-induced astrogliosis. This study suggests that RF EMF-induced astrogliosis had functional consequences on memory but did not demonstrate that it was secondary to neuronal damage.

**Bartsch H, Bartsch C, Seebald E, Deerberg F, Dietz K, Vollrath L, Mecke D. Chronic Exposure to a GSM-like Signal (Mobile Phone) Does Not Stimulate the Development of DMBA-Induced Mammary Tumors in Rats: Results of Three Consecutive Studies. Radiat Res 157(2):183-190, 2002.**

Certain epidemiological and experimental studies raised concerns about the safety of radiofrequency (RF) electromagnetic fields because of a possible increased risk of leukemia and lymphoma. In this study, an RF field used in mobile telecommunication was tested using 7,12-dimethylbenz[a]anthracene (DMBA)-induced mammary tumors in female Sprague-Dawley rats as a model for human breast cancer. Three experiments were carried out under strictly standardized conditions and were started on the same day of three consecutive years. The field consisted of a GSM-like signal (900 MHz pulsed at 217 Hz, pulse width 577 [mu]s) of relatively low power flux density (100 [mu]W/cm(2) [plus minus] 3 dB) and was applied continuously throughout each experiment to freely moving animals. The specific absorption rates averaged over the whole body were 17.5--70 mW/kg. The highest values in young animals were at or around the exposure limit permissible for the general public (i.e. 80 mW/kg). The animals were palpated weekly for the presence of mammary tumors and were killed humanely when tumors reached a diameter of 1--2 cm to allow a reliable histopathological classification and a distinction between malignant and benign subtypes. The overall results of the three studies are that there was no statistically significant effect of RF-field exposure on tumor latency and that the cumulative tumor incidence at the end of the experiment was unaffected as well. The risk ratios were 1.08 (95% CI: 0.91--1.29) and 0.96 (95% CI: 0.85--1.07) for benign and malignant tumors, respectively. These observations are in agreement with other published findings. In the first experiment, however, the median latency for the development of the first malignant tumor in each animal was statistically significantly extended for RF-field-exposed animals compared to controls (278 days compared to 145

days, P = 0.009). No such differences were detected in the two subsequent experiments. These results show that low-level RF radiation does not appear to possess carcinogenic or cancer-promoting effects on DMBA-induced mammary tumors. To explain the mechanisms underlying the different results obtained in the three experiments, a hypothesis is presented which is based upon the neuroendocrine control mechanisms involved in the promotion of DMBA-induced mammary tumors. Despite the apparent absence of stimulatory effects of low-level RF-field exposure on the development and growth of solid tumors, it will be necessary to verify these results for leukemias and lymphomas, which may have completely different biological control mechanisms.

**Bartsch H, Küpper H, Scheurlen U, Deerberg F, Seebald E, Dietz K, Mecke D, Probst H, Stehle T, Bartsch C. Effect of chronic exposure to a GSM-like signal (mobile phone) on survival of female Sprague-Dawley rats: Modulatory effects by month of birth and possibly stage of the solar cycle. Neuro Endocrinol Lett. 31(4):457-473, 2010.**

During 1997-2008 two long-term (I and II) and two life-long (III and IV) experiments were performed analyzing the effect of chronic exposure to a low-intensity GSM-like signal (900 MHz pulsed with 217 Hz, 100 microW/cm(2) average power flux density, 38-80 mW/kg mean specific absorption rate for whole body) on health and survival of unrestrained female Sprague-Dawley rats kept under identical conditions. Radiofrequency (RF)-exposure was started at 52-70 days of age and continued for 24 (I), 17 (II) and up to 36 and 37 months, respectively (III/IV). In the first two experiments (1997-2000) 12 exposed and 12 sham-exposed animals each were observed until they were maximally 770 or 580 days old. In experiment I no adverse health effects of chronic RF-exposure were detectable, neither by macroscopic nor detailed microscopic pathological examinations. Also in experiment II no apparent macroscopic pathological changes due to treatment were apparent. Median survival time could not be estimated since in none of the groups more than 50% of the animals had died. In the course of two complete survival experiments (2002-2005; 2005-2008) 30 RF- and 30 sham-exposed animals each were followed up until their natural end or when they became moribund and had to be euthanized. A synoptical data analysis was performed. Survival data of all four groups could be fitted well by the Weibull distribution. According to this analysis median survival was significantly shortened under RF-exposure in both experiments by 9.06% (95% CI 2.7 to 15.0%) (p=0.0064); i.e by 72 days in experiment III and 77 days in experiment IV as compared to the corresponding sham-treated animals (III: 799 days; IV: 852 days). Both groups of animals of experiment III showed reduced median survival times by 6.25% (95% CI -0.3 to 12.4%) (p=0.0604) compared to the corresponding groups of experiment IV (53 days: sham-exposed animals, 48 days: RF-exposed animals) which may be due to the fact that animals of experiment III were born in October and animals of experiment IV in May indicating that the month of birth affects life span. From the results of the last two experiments it has to be concluded that chronic exposure to a low-intensity GSM-like signal may exert negative health effects and shorten survival if treatment is applied sufficiently long and the observational period covers the full life span of the animals concerned. The current data show that survival of rats kept under controlled laboratory conditions varies within certain limits

depending on the month of birth. In view of our previous observations regarding an inhibitory or no effect of RF-exposure on DMBA-induced mammary cancer during the 1997-2000 period, an additional modulatory influence on a year-to-year basis should be considered which might be related to changing solar activity during the the 11-years' sunspot cycle. These potentially complex influences of the natural environment modulating the effects of anthropogenic RF-signals on health and survival require a systematic continuation of such experiments throughout solar cycle 24 which started in 2009.

**Bas O, Odaci E, Kaplan S, Acer N, Ucok K, Colakoglu S. 900 MHz electromagnetic field exposure affects qualitative and quantitative features of hippocampal pyramidal cells in the adult female rat. Brain Res. 1265:178-185, 2009.**

The effects of electromagnetic fields (EMFs) emitted by mobile phones on humans hold special interest due to their use in close proximity to the brain. The current study investigated the number of pyramidal cells in the cornu ammonis (CA) of the 16-week-old female rat hippocampus following postnatal exposure to a 900 megahertz (MHz) EMF. In this study were three groups of 6 rats: control (Cont), sham exposed (Sham), and EMF exposed (EMF). EMF group rats were exposed to 900 MHz EMF (1 h/day for 28 days) in an exposure tube. Sham group was placed in the exposure tube but not exposed to EMF (1 h/day for 28 days). Cont group was not placed into the exposure tube nor were they exposed to EMF during the study period. In EMF group rats, the specific energy absorption rate (SAR) varied between 0.016 (whole body) and 2 W/kg (locally in the head). All of the rats were sacrificed at the end of the experiment and the number of pyramidal cells in the CA was estimated using the optical fractionator technique. Histopathological evaluations were made on sections of the CA region of the hippocampus. Results showed that postnatal EMF exposure caused a significant decrease of the pyramidal cell number in the CA of the EMF group ($P<0.05$). Additionally, cell loss can be seen in the CA region of EMF group even at qualitative observation. These results may encourage researchers to evaluate the chronic effects of 900 MHz EMF on teenagers' brains.

**Bassen HI, Moore HJ, Ruggera PS, Cellular phone interference testing of implantable cardiac defibrillators in vitro. Pacing Clin Electrophysiol 21(9):1709-1715, 1998.**

An in vitro study was undertaken to investigate the potential for cellular telephones to nterfere with representative models of presently used ICDs. Digital cellular phones (DCPs) generate strong, amplitude modulated fields with pulse repetition rates near the physiological range sensed by the ICD as an arrhythmia. DCPs with Time Division Multiple Access (TDMA) pulsed amplitude modulation caused the most pronounced effect--high voltage firing or inhibition of pacing output of the ICDs. This electromagnetic interference (EMI) occurred only when the phones were within 2.3-5.8 cm of the ICD pulse generator that was submerged 0.5 cm in 0.18% saline. ICD performance always reverted to baseline when the cellular phones were removed from the immediate proximity of the ICD. Three models of ICDs were subjected to EMI susceptibility testing using two types of digital phones and one analog cellular phone, each operating at their

respective maximum output power. EMI was observed in varying degrees from all DCPs. Inhibition of pacer output occurred in one ICD, and high voltage firing occurred in the two other ICDs, when a TDMA-11 Hz DCP was placed within 2.3 cm of the ICD. For the ICD that was most sensitive to delivering unintended therapy, inhibition followed by firing occurred at distances up to 5.8 cm. When a TDMA-50 Hz phone was placed at the minimum test distance of 2.3 cm, inhibition followed by firing was observed in one of the ICDs. EMI occurred most frequently when the lower portion of the monopole antenna of the cellular phone was placed over the ICD header.

**Baste V, Riise T, Moen BE. Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. Eur J Epidemiol.23(5):369-377,2008.**

Concern is growing about exposure to electromagnetic fields and male reproductive health. The authors performed a cross-sectional study among military men employed in the Royal Norwegian Navy, including information about work close to equipment emitting radiofrequency electromagnetic fields, one-year infertility, children and sex of the offspring. Among 10,497 respondents, 22% had worked close to high-frequency aerials to a "high" or "very high" degree. Infertility increased significantly along with increasing self-reported exposure to radiofrequency electromagnetic fields. In a logistic regression, odds ratio (OR) for infertility among those who had worked closer than 10 m from high-frequency aerials to a "very high" degree relative to those who reported no work near high-frequency aerials was 1.86 (95% confidence interval (CI): 1.46-2.37), adjusted for age, smoking habits, alcohol consumption and exposure to organic solvents, welding and lead. Similar adjusted OR for those exposed to a "high", "some" and "low" degree were 1.93 (95% CI: 1.55-2.40), 1.52 (95% CI: 1.25-1.84), and 1.39 (95% CI: 1.15-1.68), respectively. In all age groups there were significant linear trends with higher prevalence of involuntary childlessness with higher self-reported exposure to radiofrequency fields. However, the degree of exposure to radiofrequency radiation and the number of children were not associated. For self-reported exposure both to high-frequency aerials and communication equipment there were significant linear trends with lower ratio of boys to girls at birth when the father reported a higher degree of radiofrequency electromagnetic exposure.

**Baste V, Mild KH, Moen BE. Radiofrequency exposure on fast patrol boats in the Royal Norwegian Navy--an approach to a dose assessment. Bioelectromagnetics. 31(5):350-360, 2010.**

Epidemiological studies related to radiofrequency (RF) electromagnetic fields (EMF) have mainly used crude proxies for exposure, such as job titles, distance to, or use of different equipment emitting RF EMF. The Royal Norwegian Navy (RNoN) has measured RF field emitted from high-frequency antennas and radars on several spots where the crew would most likely be located aboard fast patrol boats (FPB). These boats are small, with short distance between the crew and the equipment emitting RF field. We have described the measured RF exposure aboard FPB and suggested different methods for calculations of total exposure and annual dose. Linear and spatial average in addition to percentage of ICNIRP and squared deviation of ICNIRP has been used. The methods will form the basis of a job

exposure matrix where relative differences in exposure between groups of crew members can be used in further epidemiological studies of reproductive health.

**Baste V, Moen BE, Oftedal G, Strand LA, Bjørge L, Mild KH. Pregnancy Outcomes After Paternal Radiofrequency Field Exposure Aboard Fast Patrol Boats. J Occup Environ Med. 54(4):431-438, 2012.**

OBJECTIVES: To investigate adverse reproductive outcomes among male employees in the Royal Norwegian Navy exposed to radiofrequency electromagnetic fields aboard fast patrol boats. METHODS: Cohort study of Royal Norwegian Navy servicemen linked to the Medical Birth Registry of Norway, including singleton offspring born between 1967 and 2008 (n = 37,920). Exposure during the last 3 months before conception (acute) and exposure more than 3 months before conception (nonacute) were analyzed. RESULTS: Perinatal mortality and preeclampsia increased after service aboard fast patrol boats during an acute period and also after increased estimated radiofrequency exposure during an acute period, compared with service aboard other vessels. No associations were found between nonacute exposure and any of the reproductive outcomes. CONCLUSIONS: Paternal work aboard fast patrol boats during an acute period was associated with perinatal mortality and preeclampsia, but the cause is not clear.

**Bastide M, Youbibier-Simoa BJ, Lebecq JC, Giaimis J. Toxicologic study of electromagnetic radiation emitted by television and video display screens and cellular telephones on chickens and mice. Indoor Built Environ 10:291-298, 2001.**

The effects of continuous exposure of chick embryos and young chickens to the electromagnetic fields (EMFs) emitted by video display units (VDUs) and GSM cell phone radiation, either the whole spectrum emitted or attenuated by a copper gauze, were investigated. Permanent exposure to the EMFs radiated by a VDU was associated with significantly increased fetal loss (47-68%) and markedly depressed levels of circulating specific antibodies (lgG), corticosterone and melatonin. We have also shown that under chronic exposure conditions, GSM cell phone radiation was harmful to chick embryos, stressful for healthy mice and, in this species, synergistic with cancer insofar as it depleted stress hormones. The same pathological results were observed after substan tial reduction of the microwaves radiated from the cell phone by attenuating them with a copper gauze.

**Batellier F, Couty I, Picard D, Brillard JP. Effects of exposing chicken eggs to a cell phone in "call" position over the entire incubation period. Theriogenology. 69(6):737-745,2008**

The aim of the present study was to assess the effects of exposing fertile chicken eggs to a cell phone repeatedly calling a ten-digit number at 3-min intervals over the entire period of incubation. A pre-experiment was performed first to adjust incubation conditions in an experimental chamber devoid of metallic content and without automatic turning until the overall performance of hatchability was reproducible in the absence of the cell phone. The experimental period consisted of a series of 4 incubations referred to as "replicates". For each replicate, one batch of 60 eggs was

exposed to the immediate environment (</=25cm) of a cell phone in the "call" position (exposed group), while another batch of 60 eggs, 1.5m away from the exposed group and also in the incubation chamber, was exposed to a similar cell phone in the "off" position (sham group). For each replicate, 2 other groups each of 60 eggs were also incubated, one in a standard mini-incubator ("Control I" group) and the second in a standard medium size incubator ("Control II" group). Temperature, relative humidity and electromagnetic fields in the experimental chamber were permanently monitored over the entire experiment. A significantly higher percentage of embryo mortality was observed in the "exposed" compared to the "sham" group in 2 of the 4 replicates ($p<.05$). In comparison with control groups, additional embryo mortality in the exposed group occurred mainly between Days 9 and 12 of incubation but a causal relationship between the intensity of the electric field and embryo mortality could not be established.

**Bayat M, Hemati S, Soleimani-Estyar R, Shahin-Jafari A. Effect of long-term exposure of mice to 900 MHz GSM radiation on experimental cutaneous candidiasis. Saudi J Biol Sci. 24(4):907-914, 2017.**

Mobile phones communicate with base stations using 900 MHz microwaves. The current study was aimed to survey the effects of long-term 900 MHz microwave exposure of mice on experimentally induced cutaneous candidiasis. Forty inbred, male, BALB/c mice were randomly divided into four groups. Cutaneous lesions with *Candida albicans* were experimentally induced on the lateral-back skin of the 20 mice. One group of the diseased mice were exposed (6 h per day and 7 d per week) to 900 MHz microwave radiation, while the other groups were not exposed. Two unexposed control groups were also included. The skin lesions were regularly monitored and the live candida cell density was enumerated using the colony-forming unit (CFU) assay. The process was repeated after a one week resting interval. One week later, all mice were challenged through intra tail veins using $LD_{90}$ dose of *C. albicans*. Mortality of the mice was recorded and the candida load of the kidney homogenates from died animals was counted. 900 MHz microwave exposed mice had 1.5 day and 3.7 day delays on wound healing in stages two. Live Candida inoculated Wave exposed (LCW) mice also showed higher yeast loads in skin lesions at days 5, 7 and 9 post inoculation. Survival analysis of live candida challenged mice showed the radiation exposed group is prone to death induced by systemic infection and candida enumeration from the kidney homogenates showed radiation exposed animals have had significantly higher yeast load in the tissue. In collection, long-term 900 MHz radiation exposure of mice led to longevity of skin wounds and susceptibility of the animals to systemic challenge and higher incidences of microorganisms in internal tissues.

**Beason RC, Semm P. Responses of neurons to an amplitude-modulated microwave stimulus. Neurosci Lett 333(3):175-178, 2002.**

In this study we investigated the effects of a pulsed radio frequency signal similar to the signal produced by global system for mobile communication telephones (900 MHz carrier, modulated at 217 Hz) on neurons of the avian brain. We found that such stimulation

resulted in changes in the amount of neural activity by more than half of the brain cells. Most (76%) of the responding cells increased their rates of firing by an average 3.5-fold. The other responding cells exhibited a decrease in their rates of spontaneous activity Such responses indicate potential effects on humans using hand-held cellular phones.

**Bedir R, Tumkaya L, Şehitoğlu İ, Kalkan Y, Yilmaz A, Şahin OZ. The effect of exposure of rats during prenatal period to radiation spreading from mobile phones on renal development. Ren Fail. 37(2):305-309, 2015.**

Background: The aim of this study was to investigate the effects of exposure to a 900-MHz electromagnetic field (EMF) produced by mobile phones on the renal development of prenatal rats. Histopathological changes and apoptosis in the kidneys, together with levels of urea, creatinine and electrolyte in serum were determined. METHODS: A total of 14 Sprague-Dawley rats were studied. Pregnant rats were divided into two equal groups: a control group and an EMF-exposed group. The study group was exposed to 900-MHz of EMF during the first 20 days of pregnancy, while the control group was unexposed to EMF. Sections obtained from paraffin blocks were stained for caspase-3 by immunohistochemistry, hematoxylin-eosin and Masson's trichrome. RESULTS: Mild congestion and tubular defects, and dilatation of Bowman's capsule were observed in the kidney tissues of rats in the exposed group. Apoptosis was evaluated using anti-caspase-3; stronger positive staining was observed in the renal tubular cells in the study group than those of the control group. Although there was a significant difference between the study and control groups in terms of K(+) level ($p < 0.05$), no significant difference was observed in the other parameters studied ($p > 0.05$). CONCLUSION: Our study shows that the electromagnetic waves propagated from mobile phones have harmful effects on the renal development of prenatal rats.

**Beede KE, Kass SJ. Engrossed in conversation: The impact of cell phones on simulated driving performance. Accid Anal Prev38(2):415-21, 2006.**

The current study examined the effects of cognitively distracting tasks on various measures of driving performance. Thirty-six college students with a median of 6 years of driving experience completed a driving history questionnaire and four simulated driving scenarios. The distraction tasks consisted of responding to a signal detection task and engaging in a simulated cell phone conversation. Driving performance was measured in terms of four categories of behavior: traffic violations (e.g., speeding, running stop signs), driving maintenance (e.g., standard deviation of lane position), attention lapses (e.g., stops at green lights, failure to visually scan for intersection traffic), and response time (e.g., time to step on brake in response to a pop-up event). Performance was significantly impacted in all four categories when drivers were concurrently talking on a hands-free phone. Performance on the signal detection task was poor and not significantly impacted by the phone task, suggesting that considerably less attention was paid to detecting these peripheral signals. However, the signal detection task did interact with the phone task on measures of average speed, speed variability, attention lapses, and reaction time. The findings lend further empirical support of the dangers of drivers being distracted by cell phone conversations.

**Beekhuizen J, Vermeulen R, Kromhout H, Bürgi A, Huss A. Geospatial modelling of electromagnetic fields from mobile phone base stations. Sci Total Environ. 2013 Jan 16;445-446C:202-209. doi: 10.1016/j.scitotenv.2012.12.020. [Epub ahead of print]**

There is concern that exposure to radio frequency electromagnetic fields (RF-EMF) from mobile phone base stations might lead to adverse health effects. In order to assess potential health risks, reliable exposure assessment is necessary. Geospatial exposure modelling is a promising approach to quantify ambient exposure to RF-EMF for epidemiological studies involving large populations. We modelled RF-EMF for Amsterdam, The Netherlands by using a 3D RF-EMF model (NISMap). We subsequently compared modelled results to RF-EMF measurements in five areas with differing built-up characteristics (e.g., low-rise residential, high-rise commercial). We performed, in each area, repeated continuous measurements along a predefined ~2km long path. This mobile monitoring approach captures the high spatial variability in electric field strengths. The modelled values were in good agreement with the measurements. We found a Spearman correlation of 0.86 for GSM900 and 0.85 for UMTS between modelled and measured values. The average measured GSM900 field strength was 0.21V/m, and UMTS 0.09V/m. The model underestimated the GSM900 field strengths by 0.07V/m, and slightly overestimated the UMTS field strengths by 0.01V/m. NISMap provides a reliable way of assessing environmental RF-EMF exposure for epidemiological studies of RF-EMF and health in urban areas.

**Behari J, Kunjilwar KK, and Pyne S, Interaction of low level modulated RF radiation with $Na^+$–$K^+$-ATPase. Bioelectrochem Bioenerg 47:247-252, 1998.**

The effect of low-level amplitude modulated radiofrequency radiation were studied on $Na^+$–$K^+$-ATPase activity in the brain of developing male Wistar rats of age 23 days (body weight 55–60 g). They were exposed to carrier wave (CW) frequency 147 MHz and its sub-harmonic frequencies 73.5 and 36.75 MHz amplitude modulated (AM) at 16 and 76 Hz for 30–35 days (3 h $day^{-1}$, Power density 1.47 mW $cm^{-2}$,average specific absorption rate 9.65–6.11 W $kg^{-1}$). We observed a statistically significant increase in $Na^+$–$K^+$-ATPase activity in chronically exposed rats compared to the control ones. The increase in $Na^+$–$K^+$-ATPase activity was around 19–20% in the rats exposed to CW frequencies AM at 16 Hz compared to the controls, whereas the increase in $Na^+$–$K^+$-ATPase activity was around 15–16% in rats exposed to the same set of CW frequencies but AM at 76 Hz. Though there was a difference in $Na^+$–$K^+$-ATPase activities (3–4%) in the two groups but the difference was found to be statistically insignificant. Within the group of rats exposed to CW frequencies amplitude modulated at 16 and 76 Hz, respectively, the effect on $Na^+$–$K^+$-ATPase activity was found to be independent of the magnitude of CW frequencies. An additional single short duration (20–60 min) exposure of membranes in vitro from different exposed group to the above field did not show any significant alteration on $Na^+$–$K^+$-ATPase activity. It is concluded that a low level effect of amplitude modulated radiation produces statistically significant effect on $Na^+$–$K^+$-ATPase activity but is insensitive to the carrier wave frequencies under investigation.

**Behari J, Nirala JP. Specific absorption rate variation in a brain phantom due to exposure by a 3G mobile phone: problems in dosimetry. Indian J Exp Biol. 51(12):1079-1085, 2013.**

A specific absorption rate (SAR) measurements system has been developed for compliance testing of personal mobile phone in a brain phantom material contained in a Perspex box. The volume of the box has been chosen corresponding to the volume of a small rat and illuminated by a 3G mobile phone frequency (1718.5 MHz), and the emitted radiation directed toward brain phantom .The induced fields in the phantom material are measured. Set up to lift the plane carrying the mobile phone is run by a pulley whose motion is controlled by a stepper motor. The platform is made to move at a pre-determined rate of 2 degrees per min limited up to 20 degrees. The measured data for induced fields in various locations are used to compute corresponding SAR values and inter comparison obtained. These data are also compared with those when the mobile phone is placed horizontally with respect to the position of the animal. The SAR data is also experimentally obtained by measuring a rise in temperature due to this mobile exposures and data compared with those obtained in the previous set. To seek a comparison with the safety criteria same set of measurements are performed in 10 g phantom material contained in a cubical box. These results are higher than those obtained with the knowledge of induced field measurements. It is concluded that SAR values are sensitive to the angular position of the moving platform and are well below the safety criteria prescribed for human exposure. The data are suggestive of having a fresh look to understand the mode of electromagnetic field -bio interaction.

**Behrens T, Lynge E, Cree I, Sabroe S, Lutz JM, Afonso N, Eriksson M, Guénel P, Merletti F, Morales-Suarez-Varela M, Stengrevics A, Févotte J, Llopis-González A, Gorini G, Sharkova G, Hardell L, Ahrens W. Occupational exposure to electromagnetic fields and sex-differential risk of uveal melanoma. Occup Environ Med.67(11):751-759, 2010**

Objectives The association between occupational exposure to electromagnetic fields (EMF) and the risk of uveal melanoma was investigated in a case-control study in nine European countries. Methods Incident cases of uveal melanoma and population as well as hospital controls were included and frequency matched by country, 5-year birth cohort and sex. Subjects were asked whether they had worked close to high-voltage electrical transmission installations, computer screens and various electrical machines, or in complex electrical environments. Measurements of two Scandinavian job-exposure matrices were applied to estimate lifelong cumulative EMF exposure. Unconditional logistic regression analyses, stratified by sex and eye colour were calculated, adjusting for several potential confounders. Results 293 patients with uveal melanoma and 3198 control subjects were interviewed. Women exposed to electrical transmission installations showed elevated risks (OR 5.81, 95% CI 1.72 to 19.66). Positive associations with exposure to control rooms were seen among men and women, but most risk increases were restricted to subjects with dark iris colour. Application of published EMF measurements revealed stronger risk increases among women compared to men. Again, elevated risks were restricted to subjects with dark

eye colour. Conclusion Although based on a low prevalence of exposure to potential occupational sources of EMF, our data indicate that exposed dark-eyed women may be at particular risk for uveal melanoma.

**Bellieni CV, Pinto I, Bogi A, Zoppetti N, Andreuccetti D, Buonocore G. Exposure to electromagnetic fields from laptop use of "laptop" computers. Arch Environ Occup Health. 67(1):31-36, 2012.**

Portable computers are often used at tight contact with the body and therefore are called "laptop." The authors measured electromagnetic fields (EMFs) laptop computers produce and estimated the induced currents in the body, to assess the safety of laptop computers. The authors evaluated 5 commonly used laptop of different brands. They measured EMF exposure produced and, using validated computerized models, the authors exploited the data of one of the laptop computers (LTCs) to estimate the magnetic flux exposure of the user and of the fetus in the womb, when the laptop is used at close contact with the woman's womb. In the LTCs analyzed, EMF values (range 1.8-6 μT) are within International Commission on Non-Ionizing Radiation (NIR) Protection (ICNIRP) guidelines, but are considerably higher than the values recommended by 2 recent guidelines for computer monitors magnetic field emissions, MPR II (Swedish Board for Technical Accreditation) and TCO (Swedish Confederation of Professional Employees), and those considered risky for tumor development. When close to the body, the laptop induces currents that are within 34.2% to 49.8% ICNIRP recommendations, but not negligible, to the adult's body and to the fetus (in pregnant women). On the contrary, the power supply induces strong intracorporal electric current densities in the fetus and in the adult subject, which are respectively 182-263% and 71-483% higher than ICNIRP 98 basic restriction recommended to prevent adverse health effects. Laptop is paradoxically an improper site for the use of a LTC, which consequently should be renamed to not induce customers towards an improper use.

**Belokhvostov AS, Osipovich VK, Veselova OM, Kolodiazhnaia VA. [DNA analysis of retroposon-like genetic LINE elements in blood plasma of rats exposed to radio-diapason electromagnetic waves] Radiats Biol Radioecol 35(3):356-363, 1995.** [Article in Russian]

The elevation of LINE-elements' DNA level was revealed in blood plasma of rats exposed to electromagnetic waves. The amount of full-size 5'-containing LINE-elements copies was increased especially. Connection of this effect with retrotransposon activation and genetic instability condition of organism development is supposed.

**Belousova TE, Kargina-Terent'eva RA, [Adrenergic nerve plexuses of heart and adrenal and myocardial catecholamines of spontaneously hypertensive rats under the influence of electromagnetic irradiation in the millimeter range]. Morfologiia 115(1):16-18, 1999. [Article in Russian]**

Condition of adrenergic cardiac and adrenal nervous plexuses of Kyoto-Wistar Rats (WKY) and spontaneously hypertensive rats (SHR) was examined by quantitative neurohistochemical methods before and after extremely high frequency field (EHF field)

influence of "Bayur" microwave therapy apparatus in mode 1 (42,194 MHz frequency, 7.1 mm wavelength) and in mode 3 (53,534 MHz frequency, 5.6 mm wavelength). Reduction of myocardial nervous plexus density and catecholamine luminescence intensity were detected in SHR, as well as decrease of adrenal glands relative weight and catecholamine luminescence intensity in adrenal medulla of SHR, that is indicative of suppression of sympatho-adrenal system of hypertensive animals by EHF field influence in medical operating modes.

**Belyaev IYa, Alipov YD, Shcheglov VS, Lystsov VN, Resonance effect of microwaves on the genome conformational state of E. coli cells. Z Naturforsch [C] 47(7-8):621-827, 1992.**

The effect of low intensity microwaves on the conformational state of the genome of X-irradiated E. coli cells was studied by the method of viscosity anomalous time dependencies. It has been established that within the ranges of 51.62-51.84 GHz and 41.25-41.50 GHz the frequency dependence of the observed effect has a resonance nature with a resonance half-width of the order of 100 MHz. The power dependence of the microwave effect within the range of 0.1-200 microW/cm2 has shown that a power density of 1 microW/cm2 is sufficient to suppress radiation-induced repair of the genome conformational state. The effect of microwave suppression of repair is well reproduced and does not depend on the sequence of cell exposure to X-rays and microwave radiation in the millimeter band. The results obtained indicate the role of the cell genome in the resonant interaction of cells with low intensity millimeter waves.

**Belyaev IY, Shcheglov VS, Alipov YD, Polunin VA, Resonance effect of millimeter waves in the power range from 10(-19) to 3 x 10(-3) W/cm2 on Escherichia coli cells at different concentrations. Bioelectromagnetics 17(4):312-321, 1996.**

The effect of millimeter waves (MMWs) on the genome conformational state (GCS) of E. coli AB1157 cells was studied by the method of anomalous viscosity time dependencies (AVTD) in the frequency range of 51.64-51.85 GHz. The 51.755 GHz resonance frequency of the cell reaction to MMWs did not depend on power density (PD) in the range from 10(-19) to 3 x 10(-3) W/cm2. The half-width of the resonant reaction of cells showed a sigmoid dependence on PD, changing from 3 MHz to 100 MHz. The PD dependence of the half-width had the same shape for different concentrations of exposed cells (4 x 10(7) and 4 x 10(8) cells/ml), whereas the magnitude of the 51.755 GHz resonance effect differed significantly and depended on the PD of MMW exposure. Sharp narrowing of the 51.755 GHz resonance in the PD range from 10(-4) to 10(-7) W/cm2 was followed by an emergence of new resonance frequencies. The PD dependence of the MMW effect at one of these resonance frequencies (51.674 GHz) differed markedly from the corresponding dependence at the 51.755 GHz resonance, the power window occurring in the range from 10(-16) to 10(-8) W/cm2. The results obtained were explained in the framework of a model of electron-conformational interactions. The frequency-time parameters of this model appeared to be in good agreement with experimental data.

**Belyaev IY, Hillert L, Protopopova M, Tamm C, Malmgren LO, Persson BR, Selivanova G, Harms-Ringdahl M. 915 MHz microwaves and 50 Hz magnetic field affect chromatin conformation and 53BP1 foci in human lymphocytes from hypersensitive and healthy persons. Bioelectromagnetics. 26(3):173-184, 2005.**

We used exposure to microwaves from a global system for mobile communication (GSM) mobile phone (915 MHz, specific absorption rate (SAR) 37 mW/kg) and power frequency magnetic field (50 Hz, 15 muT peak value) to investigate the response of lymphocytes from healthy subjects and from persons reporting hypersensitivity to electromagnetic field (EMF). The hypersensitive and healthy donors were matched by gender and age and the data were analyzed blind to treatment condition. The changes in chromatin conformation were measured with the method of anomalous viscosity time dependencies (AVTD). 53BP1 protein, which has been shown to colocalize in foci with DNA double strand breaks (DSBs), was analyzed by immunostaining in situ. Exposure at room temperature to either 915 MHz or 50 Hz resulted in significant condensation of chromatin, shown as AVTD changes, which was similar to the effect of heat shock at 41 degrees C. No significant differences in responses between normal and hypersensitive subjects were detected. Neither 915 MHz nor 50 Hz exposure induced 53BP1 foci. On the contrary, a distinct decrease in background level of 53BP1 signaling was observed upon these exposures as well as after heat shock treatments. This decrease correlated with the AVTD data and may indicate decrease in accessibility of 53BP1 to antibodies because of stress-induced chromatin condensation. Apoptosis was determined by morphological changes and by apoptotic fragmentation of DNA as analyzed by pulsed-field gel electrophoresis (PFGE). No apoptosis was induced by exposure to 50 Hz and 915 MHz microwaves. In conclusion, 50 Hz magnetic field and 915 MHz microwaves under specified conditions of exposure induced comparable responses in lymphocytes from healthy and hypersensitive donors that were similar but not identical to stress response induced by heat shock.

**Belyaev IY, Koch CB, Terenius O, Roxstrom-Lindquist K, Malmgren LO, H Sommer W, Salford LG, Persson BR. Exposure of rat brain to 915 MHz GSM microwaves induces changes in gene expression but not double stranded DNA breaks or effects on chromatin conformation. Bioelectromagnetics.27(4):295-306,2006.**

We investigated whether exposure of rat brain to microwaves (MWs) of global system for mobile communication (GSM) induces DNA breaks, changes in chromatin conformation and in gene expression. An exposure installation was used based on a test mobile phone employing a GSM signal at 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g. Rats were exposed or sham exposed to MWs during 2 h. After exposure, cell suspensions were prepared from brain samples, as well as from spleen and thymus. For analysis of gene expression patterns, total RNA was extracted from cerebellum. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). DNA double strand breaks (DSBs) were analyzed by pulsed-field gel electrophoresis (PFGE). Effects of MW exposure were observed on neither conformation of chromatin nor DNA DSBs. Gene expression profiles were obtained by Affymetrix U34 GeneChips representing 8800 rat genes and analyzed with the Affymetrix Microarray Suite (MAS) 5.0 software. In cerebellum from all exposed animals, 11 genes were upregulated in a range of 1.34-2.74 fold and one gene was downregulated 0.48-fold ($P < .0025$). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB), and melatonin production. The data shows that GSM MWs at 915 MHz did not

induce PFGE-detectable DNA double stranded breaks or changes in chromatin conformation, but affected expression of genes in rat brain cells

**Belyaev IY, Markovà E, Hillert L, Malmgren LO, Persson BR. Microwaves from UMTS/GSM mobile phones induce long-lasting inhibition of 53BP1/gamma-H2AX DNA repair foci in human lymphocytes. Bioelectromagnetics.30(2):129-141, 2009**

We have recently described frequency-dependent effects of mobile phone microwaves (MWs) of global system for mobile communication (GSM) on human lymphocytes from persons reporting hypersensitivity to electromagnetic fields and healthy persons. Contrary to GSM, universal global telecommunications system (UMTS) mobile phones emit wide-band MW signals. Hypothetically, UMTS MWs may result in higher biological effects compared to GSM signal because of eventual "effective" frequencies within the wideband. Here, we report for the first time that UMTS MWs affect chromatin and inhibit formation of DNA double-strand breaks co-localizing 53BP1/gamma-H2AX DNA repair foci in human lymphocytes from hypersensitive and healthy persons and confirm that effects of GSM MWs depend on carrier frequency. Remarkably, the effects of MWs on 53BP1/gamma-H2AX foci persisted up to 72 h following exposure of cells, even longer than the stress response following heat shock. The data are in line with the hypothesis that the type of signal, UMTS MWs, may have higher biological efficiency and possibly larger health risk effects compared to GSM radiation emissions. No significant differences in effects between groups of healthy and hypersensitive subjects were observed, except for the effects of UMTS MWs and GSM-915 MHz MWs on the formation of the DNA repair foci, which were different for hypersensitive ($P < 0.02$[53BP1]//0.01[gamma-H2AX]) but not for control subjects ($P > 0.05$). The non-parametric statistics used here did not indicate specificity of the differences revealed between the effects of GSM and UMTS MWs on cells from hypersensitive subjects and more data are needed to study the nature of these differences.

**Benson VS, Pirie K, Schüz J, Reeves GK, Beral V, Green J; for the Million Women Study Collaborators. Mobile phone use and risk of brain neoplasms and other cancers: prospective study. Int J Epidemiol. 2013 May 8. [Epub ahead of print]**

BACKGROUND: Results from some retrospective studies suggest a possible increased risk of glioma and acoustic neuroma in users of mobile phones. METHODS: The relation between mobile phone use and incidence of intracranial central nervous system (CNS) tumours and other cancers was examined in 791 710 middle-aged women in a UK prospective cohort, the Million Women Study. Cox regression models were used to estimate adjusted relative risks (RRs) and 95% confidence intervals (CIs). Women reported mobile phone use in 1999 to 2005 and again in 2009. RESULTS: During 7 years' follow-up, 51 680 incident invasive cancers and 1 261 incident intracranial CNS tumours occurred. Risk among ever vs never users of mobile phones was not increased for all intracranial CNS tumours (RR = 1.01, 95% CI = 0.90-1.14, P = 0.82), for specified CNS tumour types nor for cancer at 18 other specified sites. For long-term users compared with never users, there was no appreciable association for glioma (10+ years: RR = 0.78, 95% CI = 0.55-1.10, P = 0.16) or meningioma (10+ years: RR = 1.10, 95% CI = 0.66-1.84, P = 0.71). For acoustic neuroma, there was an increase in risk with long term

use vs never use (10+ years: RR = 2.46, 95% CI = 1.07-5.64, P = 0.03), the risk increasing with duration of use (trend among users, P = 0.03). CONCLUSIONS: In this large prospective study, mobile phone use was not associated with increased incidence of glioma, meningioma or non-CNS cancers.

**Berg G, Schuz J, Samkange-Zeeb F, Blettner M. Assessment of radiofrequency exposure from cellular telephone daily use in an epidemiological study: German Validation study of the international case-control study of cancers of the brain-INTERPHONE-Study. J Expo Anal Environ Epidemiol. 15(3):217-224, 2004.**

OBJECTIVE: The objective of the study is to validate self-reported cellular phone use information by comparing it with the cumulative emitted power and duration of calls measured by software-modified cellular phones (SMP). The information was obtained using a questionnaire developed for the international case-control study on the risk of the use of mobile phones in tumours of the brain or salivary gland (INTERPHONE-study). Method: The study was conducted in Bielefeld, Germany. Volunteers were asked to use SMPs instead of their own cellular phones for a period of 1 month. The SMP recorded the power emitted by the mobile phone handset during each base station contact. Information on cellular phone use for the same time period from traffic records of the network providers and from face-to-face interviews with the participants 3 months after the SMP use was assessed. Pearson's correlation coefficients and linear regression models were used to analyse the association between information from the interview and from the SMP. Results: In total, 1757 personal mobile phone calls were recorded for 45 persons by SMP and traffic records. The correlation between the self-reported information about the number and the duration of calls with the cumulative power of calls was 0.50 (P<0.01) and 0.48 (P<0.01), respectively. Almost 23% of the variance of the cumulative power was explained by either the number or the cumulative duration of calls. After inclusion of possible confounding factors in the regression model, the variance increased to 26%. Minor confounding factors were "network provider", "contract form", and "cellular phone model". Discussion: The number of calls alone is a sufficient parameter to estimate the cumulative power emitted by the handset of a cellular telephone. The cumulative power emitted by these phones is only associated with number of calls but not with possible confounding factors. Using the mobile phone while driving, mainly in cities, or mainly in rural areas is not associated with the recorded cumulative power in the SMP.

**Berg G, Spallek J, Schuz J, Schlehofer B, Bohler E, Schlaefer K, Hettinger I, Kunna-Grass K, Wahrendorf J, Blettner M. Occupational exposure to radio frequency/microwave radiation and the risk of brain tumors: Interphone Study Group, Germany. Am J Epidemiol.164(6):538-548, 2006.**

It is still under debate whether occupational exposure to radio frequency/microwave electromagnetic fields (RF/MW-EMF) contributes to the development of brain tumors. This analysis examined the role of occupational RF/MW-EMF exposure in the risk of glioma and meningioma. A population-based, case-control study including 381 meningioma cases, 366 glioma cases, and 1,494 controls aged 30-69 years was performed in three German regions in 2000-2003. An exposure matrix for occupational activity was constructed by using information on RF/MW-EMF exposure

collected in a computer-assisted personal interview. "High" exposure was defined as an occupational exposure that may exceed the RF/MW-EMF exposure limits for the general public recommended by the International Commission on Non-Ionizing Radiation Protection. Multiple conditional logistic regressions were performed separately for glioma and meningioma. No significant association between occupational exposure to RF/MW-EMF and brain tumors was found. For glioma, the adjusted odds ratio for highly exposed persons compared with persons not highly exposed was 1.21 (95% confidence interval: 0.69, 2.13); for meningioma, it was 1.34 (95% confidence interval: 0.64, 2.81). However, the slight increase in risk observed with increasing duration of exposure merits further research with larger sample sizes.

**Bergamaschi A, Magrini A, Ales G, Coppetta L, Somma G. Are thyroid dysfunctions related to stress or microwave exposure (900 MHz)? Int J Immunopathol Pharmacol. 17(2 Suppl):31-36, 2004.**

In the last decade, numerous scientific evidence suggested possible adverse health effects from exposure to electromagnetic fields (EMF's) and the use of mobile phones. According to some studies EMF induced changes of trans-membrane Ca++ flux may lead to altered metabolism and/or secretion of neurohormones including TSH, ACTH, GH, prolactin and melatonin. The aim of this research was to analyse the effects of mobile phone use on thyroid function and to evaluate the possible role of occupational stress. 2598 employees (1355 men and 1243 women) with different duties (vendors, operators and network technicians) were included in the study. Exposure to EMF's, generated by mobile phones, was assessed both by submitting a questionnaire directly to the employees and acquiring data regarding conversation times. The workers were divided into three groups on the basis of their personal mobile phone use. Moreover, a group of 160 workers with TSH values below 0.4 UI/l was characterized. No statistically significant difference regarding TSH values below 0.4 UI/l was observed among workers with different duties but there was a greater prevalence of subjects with low TSH values among 192 employees with more than 33 hrs/month conversation time; this difference was statistically significant ($p < 0.05$). On the basis of our data, it is not possible to establish whether this result is determined by exposure to EMF's from mobile phones or by the stress of using these instruments.

**Berg-Beckhoff G, Blettner M, Kowall B, Breckenkamp J, Schlehofer B, Schmiedel S, Bornkessel C, Reis U, Potthoff P, Schuz J Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. Occup Environ Med 66:124-130, 2009.**

ABSTRACT. Objective: The aim of the cross-sectional study was to test the hypothesis that exposure to continuous low-level radio frequency electromagnetic fields (RF-EMFs) emitted from mobile phone base stations was related to various health disturbances. Methods: For the investigation people living mainly in urban regions were selected from a nationwide study in 2006. In total, 3526 persons responded to a questionnaire (response rate 85%). For the exposure assessment a dosimeter measuring different RF-EMF frequencies was used. Participants answered a postal questionnaire on how mobile phone base stations affected their health and they gave information on sleep disturbances, headaches, health complaints and mental and physical health using

standardised health questionnaires. Information on stress was also collected. Multiple linear regression models were used with health outcomes as dependent variables (n=1326). Results: For the five health scores used, no differences in their medians were observed for exposed versus nonexposed participants. People who attributed adverse health effects to mobile phone base stations reported significantly more sleep disturbances and health complaints, but they did not report more headaches or less mental and physical health. Individuals concerned about mobile phone base stations did not have different wellbeing scores compared with those who were not concerned. Conclusions: In this large population-based study, measured RF-EMFs emitted from mobile phone base stations were not associated with adverse health effects.

**Bergdahl J, Tillberg A, Stenman E. Odontologic survey of referred patients with symptoms allegedly caused by electricity or visual display units. Acta Odontol Scand. 56(5):303-307, 1998.**

Twenty-eight consecutive patients with symptoms allegedly caused by electricity or visual display units were odontologically investigated according to a specially designed registration form including an anamnestic interview and a clinical protocol. The most common oral and general symptoms reported were burning mouth, craniomandibular dysfunction symptoms, skin complaints, and fatigue. Oral symptoms such as craniomandibular dysfunction and general symptoms such as eye complaints and dizziness scored highest on a visual analog scale regarding mean symptom intensity. The patients reported various numbers of medical diagnoses, such as allergic rhinitis or asthma and hypothyroidism. Various dental diseases were found; the most common were temporomandibular joint and masticatory muscle dysfunctions, lesions in the oral mucosa, and periodontal diseases. Urinary-Hg (U-Hg) analysis showed a mean U-Hg concentration of 8.5 nmol Hg/L urine, and none of the patients exceeded the limit of 50 nmol Hg/L urine. The U-Hg concentration was positively correlated with the number of amalgam fillings ($P < 0.01$) and craniomandibular disorders ($P < 0.05$). No or low secretion of the minor mucous glands was found in 43% of the patients. One patient showed hypersensitivity to gold and cobalt. The present study showed that various odontologic factors might be involved in some of these patients' suffering. Thus, it is important that professionals from other disciplines collaborate with dentistry if these patients are to be properly investigated.

**Bergqvist B, Arvidsson L, Pettersson E, Galt S, Saalman E, Hamnerius Y, Norden B, Effect of microwave radiation on permeability of liposomes. Evidence against non-thermal leakage. Biochim Biophys Acta 1201(1):51-54, 1994.**

The effect of 2.45 GHz microwave radiation on the permeability of unilamellar phosphatidylcholine liposomes has been studied. Leakage of 5(6)-carboxyfluorescein from the liposomes was measured using spectrofluorimetry after exposure to either microwaves or thermal heating for 5-20 min intervals. The exposure temperature, 37.6 +/- 0.5 degrees C, was well above the phase transition temperature of the lipid membrane. The microwave exposure did not result in any non-thermal increase in permeability above that produced by thermal heating. This study refutes the results

reported by Saalman et al. [Biochim Biophys Acta 1064(1):124-130, 1991] in which an increased liposome permeability due to microwave exposure was reported. The refined analysis in the present study shows that this increased liposome permeability was not a non-thermal microwave effect.

**Berolo S, Steenstra I, Amick BC 3rd, Wells RP. A comparison of two methods to assess the usage of mobile hand-held communication devices. J Occup Environ Hyg. 2014 Dec 1:0. [Epub ahead of print]**

Objective: The purposes of this study were to: 1) examine agreement between self-reported measures of mobile device use and direct measures of use, and 2) understand how respondents thought about their device use when they provided self-reports. Methods: Self-reports of six categories of device use were obtained using a previously developed questionnaire, and direct measures of use were collected using a custom logging application (n = 47). Bland-Altman analyses were used to examine agreement between the two measurement approaches. Interviews targeted participants' experiences completing the device use section of the questionnaire. Results: Self-reports of use on a typical day last week overestimated logged use; overestimates tended to be low at low average usage times, and became more variable as usage time increased. Self-reports of use yesterday also exceeded logged use, however the degree of overestimation was less than for a typical day last week. Six themes were identified from interviews, including the thought process used by participants to arrive at usage and the ease of reporting usage. Discussion: It is challenging for respondents of this questionnaire to provide accurate self-reports of use. The source of this challenge may be attributed to the intrinsic difficulty of estimating use, partly due to the multiple functions of the devices as well as the variability of use both within a day and a week. Conclusion: Research investigating the relationship between device use and health outcomes should include a logging application to examine exposure simultaneously with self-reports to better understand the sources of hazardous exposures.

**Besset A, Espa F, Dauvilliers Y, Billiard M, de Seze R. No effect on cognitive function from daily mobile phone use. Bioelectromagnetics. 26(2):102-108, 2005.**

The increasing use of mobiles phones (MP) has raised the problem of the effects of daily electromagnetic fields (EMF) exposure on human health. To date several studies have been published concerning the effects of acute MP exposure on psychomotor performances. This study investigated the effects of daily exposure to GSM 900 type MP on cognitive function. Fifty-five subjects (27 male and 28 female) were divided into two groups: a group with MP switched on and a group with MP switched off. The two groups were matched according to age, gender, and IQ. This double blind study lasted for 45 days and was divided in three periods: baseline (BLP, 2 days), exposure (EP, 27 days), and recovery (RP, 13 days). Subjects were exposed during EP and sham exposed during RP for 2 h/day, 5 days/week. The neuropsychological test battery composed of 22 tasks screened four neuropsychological categories: information processing, attention capacity, memory function, and executive function. This neuropsychological battery was performed four times on day 2 (BLP), day 15 (EP), day 29 (EP), and day 43 (RP). Our results indicate that daily MP use has no effect on cognitive function after a 13-h rest period.

**Betts TR, Simpson IA**, **Inhibition of temporary pacing by a mobile phone. Heart 87:130, 2002.**

A patient with no underlying rhythm was receiving transvenoustemporary pacing from an external pulse generator and bipolartemporary pacing wire on a coronary care unit. While examiningthe patient, the consultant cardiologist was telephoned on hismobile phone, carried in his jacket pocket. The electromagnetic interference generated by the ringing mobile phone caused inappropriatesensing by the pulse generator and inhibition of ventricularpacing. The image shows the resultant 2.5 second pause. Pacing recommenced when the mobile phone was moved away from the bedside.This case is a reminder that mobile phones may adversely affect electronic hospital equipment.

**Bhatt CR, Redmayne M, Billah B, Abramson MJ, Benke G. Radiofrequency-electromagnetic field exposures in kindergarten children. J Expo Sci Environ Epidemiol. 2016 Oct 19. doi: 10.1038/jes.2016.55. [Epub ahead of print]**

The aim of this study was to assess environmental and personal radiofrequency-electromagnetic field (RF-EMF) exposures in kindergarten children. Ten children and 20 kindergartens in Melbourne, Australia participated in personal and environmental exposure measurements, respectively. Order statistics of RF-EMF exposures were computed for 16 frequency bands between 88 MHz and 5.8 GHz. Of the 16 bands, the three highest sources of environmental RF-EMF exposures were: Global System for Mobile Communications (GSM) 900 MHz downlink (82 mV/m); Universal Mobile Telecommunications System (UMTS) 2100MHz downlink (51 mV/m); and GSM 900 MHz uplink (45 mV/m). Similarly, the three highest personal exposure sources were: GSM 900 MHz downlink (50 mV/m); UMTS 2100 MHz downlink, GSM 900 MHz uplink and GSM 1800 MHz downlink (20 mV/m); and Frequency Modulation radio, Wi-Fi 2.4 GHz and Digital Video Broadcasting-Terrestrial (10 mV/m). The median environmental exposures were: 179 mV/m (total all bands), 123 mV/m (total mobile phone base station downlinks), 46 mV/m (total mobile phone base station uplinks), and 16 mV/m (Wi-Fi 2.4 GHz). Similarly, the median personal exposures were: 81 mV/m (total all bands), 62 mV/m (total mobile phone base station downlinks), 21 mV/m (total mobile phone base station uplinks), and 9 mV/m (Wi-Fi 2.4 GHz). The measurements showed that environmental RF-EMF exposure levels exceeded the personal RF-EMF exposure levels at kindergartens.

**Bhatt CR, Benke G, Smith CL, Redmayne M, Dimitriadis C, Dalecki A, Macleod S, Sim MR, Croft RJ, Wolfe R, Kaufman J, Abramson MJ. Use of** mobile **and cordless** phones **and change in cognitive function: a prospective cohort analysis of Australian primary school children. Environ Health. 16(1):62, 2017.**

BACKGROUND: Some previous studies have suggested an association between children's use of mobile phones (MPs)/cordless phones (CPs) and development of cognitive function. We evaluated possible longitudinal associations between the use of MPs and CPs in a cohort of primary school children and effects on their cognitive function. METHODS: Data on children's socio-demographics, use of MPs and CPs, and

cognitive function were collected at baseline (2010-2012) and follow-up (2012-2013). Cognitive outcomes were evaluated with the CogHealth™ test battery and Stroop Color-Word test. The change in the number of MP/CP voice calls weekly from baseline to follow-up was dichotomized: "an increase in calls" or a "decrease/no change in calls". Multiple linear regression analyses, adjusting for confounders and clustering by school, were performed to evaluate the associations between the change in cognitive outcomes and change in MP and CP exposures. RESULTS: Of 412 children, a larger proportion of them used a CP (76% at baseline and follow-up), compared to a MP (31% at baseline and 43% at follow-up). Of 26 comparisons of changes in cognitive outcomes, four demonstrated significant associations. The increase in MP usage was associated with larger reduction in response time for response inhibition, smaller reduction in the number of total errors for spatial problem solving and larger increase in response time for a Stroop interference task. Except for the smaller reduction in detection task accuracy, the increase in CP usage had no effect on the changes in cognitive outcomes. CONCLUSION: Our study shows that a larger proportion of children used CPs compared to MPs. We found limited evidence that change in the use of MPs or CPs in primary school children was associated with change in cognitive function.

**Bianchi A, Phillips JG. Psychological predictors of problem mobile phone use. Cyberpsychol Behav. 8(1):39-51, 2005.**

Mobile phone use is banned or illegal under certain circumstances and in some jurisdictions. Nevertheless, some people still use their mobile phones despite recognized safety concerns, legislation, and informal bans. Drawing potential predictors from the addiction literature, this study sought to predict usage and, specifically, problematic mobile phone use from extraversion, self-esteem, neuroticism, gender, and age. To measure problem use, the Mobile Phone Problem Use Scale was devised and validated as a reliable self-report instrument, against the Addiction Potential Scale and overall mobile phone usage levels. Problem use was a function of age, extraversion, and low self-esteem, but not neuroticism. As extraverts are more likely to take risks, and young drivers feature prominently in automobile accidents, this study supports community concerns about mobile phone use, and identifies groups that should be targeted in any intervention campaigns.

**Bielski J, Sikorski M, [Disturbances of glucose tolerance in workers exposed to electromagnetic radiation]. Med Pr 47(3):227-231, 1996.** [Article in Polish]

The study group was composed of 50 workers exposed to electromagnetic radiation (radiowaves). Out of them 31 persons (62%), employed mostly in the risk zone, showed irregular glycaemia after oral administration of 75 g of glucose. At normal blood sugar before breakfast, the glycaemia level was high following administration of glucose and it did not return to starting values after 2 hours. After 30 min from glucose administration the level accounted for 155 mg%, after 60 min-180 mg%, after 90 min-153 mg% and after 120 min-124 mg%, on average. In 10 persons (32%) with glucose tolerance disturbances, disorders in bioelectric activity of the brain (abnormal EEG record) were observed.

**Bilgici B, Akar A, Avci B, Tuncel OK. Effect of 900 MHz radıofrequency radıatıon on oxıdatıve stress In rat braın and serum. Electromagn Biol Med. 32(1):20-29, 2013.**

The increasing use of mobile telephones raises the question of possible adverse effects of the electromagnetic fields (EMF) that these phones produce. In this study, we examined the oxidative stress in the brain tissue and serum of rats that resulted from exposure to a 900-MHz EMF at a whole body average specific absorption rate (SAR) of 1.08 W/kg for 1 h/day for 3 weeks. We also examined the antioxidant effect of garlic powder (500 mg/kg/day) given orally to EMF-exposed rats. We found that malondialdehyde (MDA) ($p < 0.001$) and advanced oxidation protein product (AOPP) ($p < 0.05$) increased in rat brain tissue exposed to the EMF and that garlic reduced these effects ($p < 0.05$). There was no significant difference in the nitric oxide (NO) levels in the brain. Paraoxonase (PON) was not detected in the brain. There was a significant increase in the levels of NO ($p < 0.001$) detected in the serum after EMF exposure, and garlic intake did not affect this increase in NO. Our results suggest that there is a significant increase in brain lipid and protein oxidation after electromagnetic radiation (EMR) exposure and that garlic has a protective effect against this oxidative stress.

**Billaudel B, Taxile M, Poulletier de Gannes F, Ruffie G, Lagroye I, Veyret B. Effects of exposure to DAMPS and GSM signals on Ornithine Decarboxylase (ODC) activity: II. SH-SY5Y human neuroblastoma cells. Int J Radiat Biol. 85(6):519-522, 2009.**

Purpose: An increase in Ornithine Decarboxylase (ODC) activity was reported in L929 murine fibroblast cells after exposure to a digital cellular telephone signal. This result was not confirmed by several other studies, including the one reported in a companion paper. As a partner in the Perform-B programme, we extended this study to human neuroblastoma cells (SH-SY5Y), using well-defined waveguide systems to imitate exposure to radiofrequency radiation (RFR): Digital Advanced Mobile Phone System (DAMPS) or Global System for Mobile communications (GSM) signals emitted by mobile phones. Materials and methods: Human neuroblastoma cells (SH-SY5Y) were exposed at various Specific Absorption Rates (SAR) to DAMPS or GSM signals using different set-ups. Cell ODC activities were assayed using (14)CO(2) generation from (14)C-labeled L-ornithine. Results: SH-SY5Y cells were incubated for 20 hours, and were blindly exposed to 50 Hz-modulated DAMPS-835 or 217 Hz-modulated GSM-1800 for 8 or 24 h using Information Technologies in Society (IT'IS) waveguides equipped with fans. After cell lysis, ODC activity was determined using (14)C-labeled L-ornithine. ODC activity was estimated by the (14)CO(2) generated from (14)C-labeled L-ornithine, as generated d.p.m. (14)CO(2)/h/mg protein. The results showed that, irrespective of the signal used (835 MHz/DAMPS, or 1800 MHz/GSM) and exposure conditions (duration and SAR), human SH-SY5Y neuroblastoma cells did not exhibit any alteration in ODC enzyme activity. Conclusion: This work did not show a significant effect of mobile phone RFR exposure on ODC activity in neuroblastoma cells (SH-SY5Y).

**Billaudel B, Taxile M, Ruffie G, Veyret B, Lagroye I. Effects of exposure to DAMPS and GSM signals on ornithine decarboxylase (ODC) activity: I. L-929 mouse fibroblasts. Int J Radiat Biol. 85(6):510-518, 2009.**

Purpose: A temporary increase in ornithine decarboxylase (ODC) activity was reported in lysed L-929 fibroblasts after exposure to the microwaves emitted by Digital Advanced Mobile Phone System (DAMPS-835 MHz, 2.5 W/kg, 8 hours). Confirmation of these data

was undertaken, given the suggested potential physiopathological consequences, i.e., tumour promotion. Materials and methods: Murine L-929 fibroblasts were exposed at various Specific Absorption rates (SAR) to (DAMPS) or Global System for Mobile communications (GSM) signals using different set-ups. Cell ODC activities were assayed using (14)CO(2) generation from (14)C-labeled L-ornithine. Results: ODC activity in live L-929 cells showed no significant alteration after exposure at an SAR of 2.5 W/kg, for one hour at the end of exposure to 50 Hz-modulated DAMPS-835 using Transverse Electro-Magnetic (TEM) cells. No significant alteration in ODC activity was observed at 6 W/kg, with active fans to regulate temperature (37 degrees C). Tests using cell lysed after exposure in another temperature-controlled set-up (waveguides) did not confirm the published studies reporting increased ODC activity in Radio-Frequency radiation (RFR)-exposed L-929 cells. In the second part of the study, no alteration of ODC activity was detected when L-929 cells were exposed to different RFR signals: 217 Hz modulated GSM-900 (wire-patch antenna) or GSM-1800 (waveguides), and lysed before ODC measurement. Conclusion: We conclude that under our exposure conditions, DAMPS-835 and GSM signals have no influence on ODC activity in L-929 cells.

**Bin-Meferij MM, El-Kott AF. The radioprotective effects of Moringa oleifera against mobile phone electromagnetic radiation-induced infertility in rats.Int J Clin Exp Med. 2015 Aug 15;8(8):12487-97. eCollection 2015.**

The present study has investigated the effects of mobile phone electromagnetic radiation (EMR) on fertility in rats. The purpose of this study was to explore the capability of polyphenolic-rich Moringa oleifera leaf extract in protecting rat testis against EMR-induced impairments based on evaluation of sperm count, viability, motility, sperm cell morphology, anti-oxidants (SOD & CAT), oxidative stress marker, testis tissue histopathology and PCNA immunohistochemistry. The sample consisted of sixty male Wistar rats which were divided into four equal groups. The first group (the control) received only standard diet while the second group was supplemented daily and for eight weeks with 200 mg/kg aqueous extract of Moringa leaves. The third group was exposed to 900 MHz fields for one hour a day and for (7) days a week. As for the fourth group, it was exposed to mobile phone radiation and received the Moringa extract. The results showed that the EMR treated group exhibited a significantly decrease sperm parameters. Furthermore, concurrent exposure to EMR and treated with MOE significantly enhanced the sperm parameters. However, histological results in EMR group showed irregular seminiferous tubules, few spermatogonia, giant multinucleated cells, degenerated spermatozoa and the number of Leydig cells was significantly reduced. PCNA labeling indices were significant in EMR group versus the control group. Also, EMR affects spermatogenesis and causes to apoptosis due to the heat and other stress-related EMR in testis tissue. This study concludes that chronic exposure to EMR marked testicular injury which can be prevented by Moringa oleifera leaf extract.

**Birks L, Guxens M, Papadopoulou E, Alexander J, Ballester F, Estarlich M, Gallastegi M, Ha M, Haugen M, Huss A, Kheifets L, Lim H, Olsen J, Santa-Marina L, Sudan M, Vermeulen R, Vrijkotte T, Cardis E, Vrijheid M. Maternal** cell phone **use**

**during pregnancy and child behavioral problems in five birth cohorts. Environ Int. 104:122-131, 2017.**

INTRODUCTION: Previous studies have reported associations between prenatal **cell phone** use and child behavioral problems, but findings have been inconsistent and based on retrospective assessment of **cell phone** use. This study aimed to assess this association in a multi-national analysis, using data from three cohorts with prospective data on prenatal **cell phone** use, together with previously published data from two cohorts with retrospectively collected **cell phone** use data.METHODS: We used individual participant data from 83,884 mother-child pairs in the five cohorts from Denmark (1996-2002), Korea (2006-2011), the Netherlands (2003-2004), Norway (2004-2008), and Spain (2003-2008). We categorized **cell phone** use into none, low, medium, and high, based on frequency of calls during pregnancy reported by the mothers. Child behavioral problems (reported by mothers using the Strengths and Difficulties Questionnaire or Child Behavior Checklist) were classified in the borderline/clinical and clinical ranges using validated cut-offs in children aged 5-7years. Cohort specific risk estimates were meta-analyzed.RESULTS: Overall, 38.8% of mothers, mostly from the Danish cohort, reported no **cell phone** use during pregnancy and these mothers were less likely to have a child with overall behavioral, hyperactivity/inattention or emotional problems. Evidence for a trend of increasing risk of child behavioral problems through the maternal **cell phone** use categories was observed for hyperactivity/inattention problems (OR for problems in the clinical range: 1.11, 95%CI 1.01, 1.22; 1.28, 95%CI 1.12, 1.48, among children of medium and high users, respectively). This association was fairly consistent across cohorts and between cohorts with retrospectively and prospectively collected **cell phone** use data.CONCLUSIONS: Maternal **cell phone** use during pregnancy may be associated with an increased risk for behavioral problems, particularly hyperactivity/inattention problems, in the offspring. The interpretation of these results is unclear as uncontrolled confounding may influence both maternal **cell phone** use and child behavioral problems..

**Bisht KS, Moros EG, Straube WL, Baty JD, Roti Roti JL, The Effect of 835.62 MHz FDMA or 847.74 MHz CDMA Modulated Radiofrequency Radiation on the Induction of Micronuclei in C3H 10T½ Cells. Radiat. Res. 157, 506–515, 2002.**

To determine if radiofrequency (RF) radiation induces the formation of micronuclei, C3H 10T½ cells were exposed to 835.62 MHz frequency division multiple access (FDMA) or 847.74 MHz code division multiple access (CDMA) modulated RF radiation. After the exposure to RF radiation, the micronucleus assay was performed by the cytokinesis block method using cytochalasin B treatment. The micronuclei appearing after mitosis were scored in binucleated cells using acridine orange staining. The frequency of micronuclei was scored both as the percentage of binucleated cells with micronuclei and as the number of micronuclei per 100 binucleated cells. Treatment of cells with cytochalasin B at a concentration of 2 μg/ml for 22 h was found to yield the maximum number of binucleated cells in C3H 10T½ cells. The method used

for the micronucleus assay in the present study detected a highly significant dose response for both indices of micronucleus production in the dose range of 0.1–1.2 Gy and it was sensitive enough to detect a significant ($P > 0.05$) increase in micronuclei after doses of 0.3 Gy in exponentially growing cells and after 0.9 Gy in plateau-phase cells. Exponentially growing cells or plateau-phase cells were exposed to CDMA (3.2 or 4.8 W/kg) or FDMA (3.2 or 5.1 W/kg) RF radiation for 3, 8, 16 or 24 h. In three repeat experiments, no exposure condition was found by analysis of variance to result in a significant increase relative to sham-exposed cells either in the percentage of binucleated cells with micronuclei or in the number of micronuclei per 100 binucleated cells. In this study, data from cells exposed to different RF signals at two SARs were compared to a common sham-exposed sample. We used the Dunnett's test, which is specifically designed for this purpose, and found no significant exposure-related differences for either plateau-phase cells or exponentially growing cells. Thus the results of this study are not consistent with the possibility that these RF radiations induce micronuclei.

**Bit-Babik G, Chou CK, Faraone A, Gessner A, Kanda M, Balzano Q. Estimation of the SAR in the human head and body due to radiofrequency radiation exposure from handheld mobile phones with hands-free accessories. Radiat Res 159(4):550-557, 2003.**

It was reported by others that hands-free accessories increase the absorption of RF energy in a human head compared to a handset alone. The results of this study show that the opposite is observed when proper dosimetric methods are employed. It is pointed out that for correct estimation of the exposure level it is necessary to use appropriate physical and experimental models and measurement instrumentation, following internationally recommended standards. The human phantoms used for measurements involving the hands-free accessories should include the torso; i.e., measurements should not be performed on the head phantom alone. This has a significant impact on the results because the RF energy coupled into the leads of hands-free accessories is strongly attenuated by the body. Numerical simulations using the Finite-Difference Time-Domain (FDTD) method and experimental measurements with a miniature electric-field probe are in good agreement and show a decrease, not an increase, in RF energy exposure in the human head from hands-free accessories.

**Bit-Babik, G., Guy, A. W., Chou, C-K., Faraone, A., Kanda, M., Gessner, A., Wang, J. and Fujiwara, O. Simulation of exposure and SAR estimation for adult and child heads exposed to radiofrequency energy from portable communication devices. Radiat. Res. 163: 580-590, 2005.**

The level and distribution of radiofrequency energy absorbed in a child's head during the use of a mobile phone compared to those in an adult head has been a controversial issue in recent years. It has been suggested that existing methods that are used to determine specific absorption rate (SAR) and assess compliance with exposure standards using an adult head model may not adequately account for potentially higher levels of exposure in children due to their smaller head size. The present study incorporates FDTD computations of locally averaged SAR in two different anatomically correct adult and child

head models using the IEEE standard (Std. C95.3-2002) SAR averaging algorithm. The child head models were obtained by linear scaling of the adult head model to replicate the conditions of previous studies reported in the literature and also by transforming the different adult head models based on data on the external shapes of children's heads. The tissue properties of the adult and corresponding child head models were kept the same. In addition, modeling and experimental measurements were made using three spheres filled with a tissue-equivalent mixture to approximate heads of increasing size. Results show that the peak local average SAR over 1 g and 10 g of tissue and the electromagnetic energy penetration depths are about the same in all of the head models under the same exposure conditions. When making interlaboratory comparisons, the model and the SAR averaging algorithm used must be standardized to minimize controversy.

**Blettner M, Schlehofer B, Breckenkamp J, Kowall B, Schmiedel S, Reis U, Potthoff P, Schuez J, Berg-Beckhoff G. Mobile phone base stations and adverse health effects: Phase 1: A population-based cross-sectional study in Germany. Occup Environ Med. 66(2):118-123. 2009**.

Abstract OBJECTIVE: The aim of this first phase of a cross-sectional study from Germany was to investigate whether proximity of residence to mobile phone base stations as well as risk perception is associated with health complaints. METHODS: We conducted a population-based multi-phase cross-sectional study within the context of a large panel survey regularly carried out by a private research institute in Germany. In the initial phase, which we will report on in this paper, 30,047 persons from a total of 51,444 who took part in the nationwide survey also answered questions on how mobile phone base stations affect their health. A list of 38 health complaints was used. A multiple linear regression model was used to identify predictors of health complaints including proximity of residence to mobile phone base stations and risk perception. RESULTS: Of the 30,047 participants (response rate 58.6%), 18.7% of participants were concerned about adverse health effects of mobile phone base stations, while an additional 10.3% attributed their personal adverse health effects to the exposure from them. Participants who are concerned about or attribute adverse health effects to mobile phone base stations and those living in the vicinity of a mobile phone base station (500 m) reported slightly more health complaints than others. CONCLUSIONS: A substantial proportion of the German population is concerned about adverse health effects caused by exposure from mobile phone base stations. The observed slightly higher prevalence of health complaints near base stations can however not be fully explained by attributions or concerns.

**Blick DW, Adair ER, Hurt WD, Sherry CJ, Walters TJ, Merritt JH, Thresholds of microwave-evoked warmth sensations in human skin. Bioelectromagnetics 18(6):403-409, 1997.**

We measured thresholds for microwave-evoked skin sensations of warmth at frequencies of 2.45, 7.5, 10, 35, and 94 GHz. In the same subjects, thresholds of warmth evoked by infrared radiation (IR) were also measured for comparison. Detection thresholds were measured on the skin in the middle of the back in 15 adult male human subjects at all

microwave (MW) frequencies and with IR. Long duration (10-s), large area (327-cm2) stimuli were used to minimize any differential effects of temporal or spatial summation. Sensitivity increased monotonically with frequency throughout the range of microwave frequencies tested. The threshold at 94 GHz (4.5 +/- 0.6 mW/cm2) was more than an order of magnitude less than at 2.45 GHz (63.1 +/- 6.7 mW/cm2), and it was comparable to the threshold for IR (5.34 +/- 1.07 mW/cm2).

**Bodera P, Stankiewicz W, Antkowiak B, Paluch M, Kieliszek J, Sobiech J, Zdanowski R, Wojdas A, Siwicki AK, Skopińska-Rózewska E. Suppressive effect of electromagnetic field on analgesic activity of tramadol in rats. Pol J Vet Sci. 15(1):95-100, 2012.**

The electromagnetic fields (EMFs) have been shown to alter animal and human behavior, such as directional orientation, learning, pain perception (nociception or analgesia) and anxiety-related behaviors. The aim of this study was to evaluate the influence of electromagnetic fields of high-frequency microwaves on pain perception and anti-nociceptive activity of tramadol (TRAM) - analgetic effective in the treatment of moderate to severe acute and chronic pain states. Electromagnetic fields exposures of a)1500 MHz frequency and b) modulated, 1800 MHz (which is identical to that generated by mobile phones) were applied. Paw withdrawal latency (PWL) to thermal stimulus was measured in vehicle or tramadol (TRAM) treated animals before and after 30, 60 and 90 minutes from injections. The differences in the level of pain (PWL) between control group and rats exposed to EMF alone in three measurements, were not observed. Tramadol alone significantly increased PWLs to thermal stimulus in comparison to vehicle results at 30 ($p < 0.001$) and 60 minutes ($p < 0.05$) after drug injection. EMF exposure of both frequencies transiently suppressed analgesic effect of tramadol, significantly reducing paw withdrawal latency in animals treated with this drug at 30 minutes from the drug injection.

**Bodera P, Stankiewicz W, Zawada K, Antkowiak B, Paluch M, Kieliszek J, Kalicki B, Bartosiński A, Wawer I. Changes in antioxidant capacity of blood due to mutual action of electromagnetic field (1800 MHz) and opioid drug (tramadol) in animal model of persistent inflammatory state. Pharmacol Rep. 65(2):421-428, 2013.**

Background: The biological effects and health implications of electromagnetic field (EMF) associated with cellular mobile telephones and related wireless systems and devices have become a focus of international scientific interest and world-wide public concern. It has also been proved that EMF influences the production of reactive oxygen species (ROS) in different tissues. Methods: Experiments were performed in healthy rats and in rats with persistent inflammatory state induced by Complete Freund's Adjuvant (CFA) injection, which was given 24 h before EMF exposure and drug application. Rats were injected with CFA or the same volume of paraffin oil into the plantar surface of the left hind paw. Animals were exposed to the far-field range of an antenna at 1800 MHz with the additional modulation which was identical to that generated by mobile phone GSM 1800. Rats were given 15 min exposure, or were sham-exposed with no voltage applied to the field generator in control groups. Immediately before EMF exposure, rats were injected intraperitoneally with tramadol in the 20 mg/kg dose or vehicle in the 1 ml/kg

volume. Results: Our study revealed that single EMF exposure in 1800 MHz frequency significantly reduced antioxidant capacity both in healthy animals and those with paw inflammation. A certain synergic mode of action between applied electromagnetic fields and administered tramadol in rats treated with CFA was observed. Conclusions: The aim of the study was to examine the possible, parallel/combined effects of electromagnetic radiation, artificially induced inflammation and a centrally-acting synthetic opioid analgesic drug, tramadol, (used in the treatment of severe pain) on the antioxidant capacity of blood of rats. The antioxidant capacity of blood of healthy rats was higher than that of rats which received only tramadol and were exposed to electromagnetic fields.

**Bodera P, Stankiewicz W, Antkowiak B, Paluch M, Kieliszek J, Sobiech J, Niemcewicz M. Influence of electromagnetic field (1800 MHz) on lipid peroxidation in brain, blood, liver and kidney in rats. Int J Occup Med Environ Health. 2015;28(4):751-9. doi: 10.13075/ijomeh.1896.00255**

OBJECTIVES: The aim of this study is the evaluation of the influence of repeated (5 times for 15 min) exposure to electromagnetic field (EMF) of 1800 MHz frequency on tissue lipid peroxidation (LPO) both in normal and inflammatory state, combined with analgesic treatment. MATERIAL AND METHODS: The concentration of malondialdehyde (MDA) as the end-product of the lipid peroxidation (LPO) was estimated in blood, liver, kidneys, and brain of Wistar rats, both healthy and those with complete Freund's adjuvant (CFA)-induced persistent paw inflammation. RESULTS: The slightly elevated levels of the MDA in blood, kidney, and brain were observed among healthy rats in electromagnetic field (EMF)-exposed groups, treated with tramadol (TRAM/EMF and exposed to the EMF). The malondialdehyde remained at the same level in the liver in all investigated groups: the control group (CON), the exposed group (EMF), treated with tramadol (TRAM) as well as exposed to and treated with tramadol (TRAM/EMF). In the group of animals treated with the complete Freund's adjuvant (CFA) we also observed slightly increased values of the MDA in the case of the control group (CON) and the exposed groups (EMF and TRAM/EMF). The MDA values concerning kidneys remained at the same levels in the control, exposed, and not-exposed group treated with tramadol. Results for healthy rats and animals with inflammation did not differ significantly. CONCLUSIONS: The electromagnetic field exposure (EMF), applied in the repeated manner together with opioid drug tramadol (TRAM), slightly enhanced lipid peroxidation level in brain, blood, and kidneys.

**Boehmert C, Wiedemann P, Pye J, Croft R. The Effects of Precautionary Messages about Electromagnetic Fields from Mobile Phones and Base Stations Revisited: The Role of Recipient Characteristics. Risk Anal. 2016 May 10. doi: 10.1111/risa.12634. [Epub ahead of print]**

Precautionary messages have been shown to increase recipients' threat perceptions about radio-frequency electromagnetic fields (RF-EMFs) emitted by mobile phones and mobile phone base stations. The current study explored the interplay of variables on the side of message recipients with this effect. The individual difference variables of interest

were gender, trait anxiety, personal need for structure, and personal fear of invalidity. Furthermore, the study determined whether the increased threat perception is accompanied by emotional distress. A total of 298 university students answered a survey after reading either a basic text about RF-EMFs or a text including precautionary information. Linear multiple regression with interactions analyses showed that the effect of precautionary messages differed for people with different levels of trait anxiety. How trait anxiety was related to the effect of precautionary messages in turn depended on participants' gender. Personal need for structure and personal fear of invalidity were mostly unrelated to the effect of precautionary messages. Regarding participants' emotional distress, we found no difference in state anxiety scores between those participants who received precautionary information and those who did not. The findings show that the effects of precautionary messages on threat perception depend on individual difference variables such as recipients' trait anxiety and gender. Also, the fact that precautionary communication did not result in heightened state anxiety challenges the assumption that precautionary messages induce fear or anxiety.

**Boga A, Emre M, Sertdemir Y, Akillioglu K, Binokay S, Demirhan O. The effect of 900 and 1800MHz GSM-like radiofrequency irradiation and nicotine sulfate administration on the embryonic development of Xenopus laevis. Ecotoxicol Environ Saf. 2014 Dec 19;113C:378-390. doi: 10.1016/j.ecoenv.2014.12.020. [Epub ahead of print]**

The aim of this study was to investigate the effects of GSM-like radiofrequency electromagnetic radiation (RF EMR) and nicotine sulfate (NS) exposure on Xenopus embryonic development.The developmental effects of GSM-like RF-EMR (900-1800MHz, at a SAR value of 1W/kg and NS on Xenopus laevis embryos were investigated). Following the application of radiofrequency radiation and/or NS administration, the embryos were closely examined in order to determine their possible teratogenic effects. Xenopus frogs obtained from the Department of Physiology of the Cukurova University, in accordance described by the Standard Guide of the American Society for Testing and Materials (ASTM). Following the exposure of Xenopus embryos to RF-EMR at 900 and 1800MHz (1.0W/kg) for 4, 6 and 8h; the whole body specific energy absorption rate (SAR) of the embryos was calculated. With the exception of irradiation at 1800MHz no dramatic developmental anomalies were observed in the Xenopus embryos in association with RF-EMR applications. Combined RF-EMR and NS applications resulted in dramatic abnormalities and death among the Xenopus embryos.The study results indicated that GSM-like RF-EMR (e.g. radiation from cell phones) was not as harmful to Xenopus embryos as might have been expected. However, the combined effects of GSM-like RF-EMR and NS on Xenopus embryos were more severe than the effect of RF-EMR or NS alone. In conclusion, the study results appear to suggest that the combined use of nicotine and cell phones might result in more pronounced detrimental effects on the health of smokers.

**Boga A, Emre M, Sertdemir Y, Uncu İ, Binokay S, Demirhan O. Effects of GSM-like radiofrequency irradiation during the oogenesis and spermiogenesis of Xenopus laevis. Ecotoxicol Environ Saf. 129:137-144, 2016.**

We aimed to evaluate the effect of GSM-like radiofrequency electromagnetic radiation (RF-EMR) on the oogenesis, and spermiogenesis of Xenopus laevis, and so the development of the embryos obtained from Normal Females+Normal Males (i.e. "N(F)+N(M)"); Normal Females+RF-exposed Males (i.e. "N(F)+RF(M)"); RF-exposed Female+Normal Male (i.e. "RF(F)+N(M)"); and RF-exposed Female+RF-exposed Male (i.e. "RF(F)+RF(M)". Various, assessments were performed to determine potential teratogenic effects and mortality, body growth and behavior on first generation embryos. After exposing adults frogs of both sexes to 900MHz RF-EMR (at 1.0W/kg) for 8h a day over a 5-week period, the embryos' specific energy absorption rate (SAR) was calculated. In our present study (control group; 2.2% abnormal, 0.0% dead); with the N(F)+RF(M) combination, the long-term exposure of adult males to GSM-like radiation at 900MHz (RF: 2W) for 5 week/8h/day resulted in normal, abnormal and dead embryo ratios of 88.3%, 3.3% and 8.3%, respectively ($p<0.001$). In the RF(F)+N(M) combination, long-term exposure (5 week/8h/day) of adult females led to normal, abnormal and dead embryo ratios of 76.7%, 11.7%, and 11.7%, respectively ($p<0.001$). And in the RF(F)+RF(M) combination, long-term exposure (5 week/8h/day) of both adult males and females led to normal, abnormal and dead embryo ratios of 73.3%, 11.7%, and 15%, respectively ($p<0.001$). With the exception RF(F)+RF(M) group ($p<0.001$), no significant changes were observed on body growth (lengths) in comparison to the control group. It was also observed that the offspring of female adult Xenopus exposed to RF-EMR during oogenesis exhibited a more aggressive behavior compared to the control group. Cell phones radiation can thus lead to detrimental effects in humans' male and female reproductive cells.

**Bogomazova AN, Vassina EM, Goryachkovskaya TN, Popik VM, Sokolov AS, Kolchanov NA, Lagarkova MA, Kiselev SL, Peltek SE. No DNA damage response and negligible genome-wide transcriptional changes in human embryonic stem cells exposed to terahertz radiation. Sci Rep. 2015 Jan 13;5:7749. doi: 10.1038/srep07749.**

Terahertz (THz) radiation was proposed recently for use in various applications, including medical imaging and security scanners. However, there are concerns regarding the possible biological effects of non-ionising electromagnetic radiation in the THz range on cells. Human embryonic stem cells (hESCs) are extremely sensitive to environmental stimuli, and we therefore utilised this cell model to investigate the non-thermal effects of THz irradiation. We studied DNA damage and transcriptome responses in hESCs exposed to narrow-band THz radiation (2.3 THz) under strict temperature control. The transcription of approximately 1% of genes was subtly increased following THz irradiation. Functional annotation enrichment analysis of differentially expressed genes revealed 15 functional classes, which were mostly related to mitochondria. Terahertz irradiation did not induce the formation of γH2AX foci or structural chromosomal aberrations in hESCs. We did not observe any effect on the mitotic index or morphology of the hESCs following THz exposure.

**Bohr, H, Bohr, J, Microwave enhanced kinetics observed in ORD studies of a protein. Bioelectromagnetics 21(1):68-72, 2000.**

Microwaves are shown to affect the kinetics of conformational changes of the protein beta-lactoglobulin. Microwaves can accelerate conformational changes in the direction towards the equilibrium state. This applies both for the folding and the unfolding processes. Cold denaturing thermal unfolding of the proteins is accelerated by negative temperature gradients. Microwave irradiation of the protein solution heated it by about 0.3 degree, and hence the observed acceleration of denaturing is therefore non-thermal.

**Bolshakov MA, Alekseev SI, Bursting responses of Lymnea neurons to microwave radiation. Bioelectromagnetics 13(2):119-129, 1992.**

Microelectrode and voltage-clamp techniques were modified to record spontaneous electrical activity and ionic currents of Lymnea stagnalis neurons during exposure to a 900-MHz field in a waveguide-based apparatus. The field was pulse-modulated at repetition rates ranging from 0.5 to 110 pps, or it was applied as a continuous wave (CW). When subjected to pulsed waves (PW), rapid, burst-like changes in the firing rate of neurons occurred at SARs of a few W/kg. If the burst-like irregularity was present in the firing rate under control conditions, irradiation enhanced its probability of occurrence. The effect was dependent on modulation, but not on modulation frequency, and it had a threshold SAR near 0.5 W/kg. CW radiation had no effect on the firing rate pattern at the same SAR. Mediator-induced, current activation of acetylcholine, dopamine, serotonin, or gamma-aminobutyric-acid receptors of the neuronal soma was not altered during CW or PW exposures and, hence, could not have been responsible for the bursting effect.

**Bolte JF, Eikelboom T. Personal radiofrequency electromagnetic field measurements in the Netherlands: Exposure level and variability for everyday activities, times of day and types of area. Environ Int. 48C:133-142, 2012.**

Knowledge of the exposure to radiofrequency electromagnetic fields is necessary for epidemiological studies on possible health effects. The main goal of this study is to determine the exposure level and spatial and temporal variances during 39 everyday activities in 12 frequency bands used in mobile telecommunication and broadcasting. Therefore, 24h measurements were gathered from 98 volunteers living in or near Amsterdam and Purmerend, The Netherlands. They carried an activity diary to be kept to the minute, a GPS logger sampling at an interval of 1s, and an EME Spy exposimeter with a detection limit of 0.0066mW/m(2) sampling at an interval of 10s in 12 frequency bands. The mean exposure over 24h, excluding own mobile phone use, was 0.180mW/m(2). During daytime exposure was about the same, but during night it was about half, and in the evening it was about twice as high. The main contribution to environmental exposure (calling by participant not included) is from calling with mobile phones (37.5%), from cordless DECT phones and their docking stations (31.7%), and from the base stations (12.7%). The exposure to mobile phone base stations increases with the percentage of urban ground use, which is an indication for high people density. In agreement, the highest mean exposure relates to the activities with high people density, such as travelling by public transport, visiting social events, pubs or shopping malls. Exposure at home depends mainly on exposure from people calling in the neighbourhood of the participant and thus on the number of persons in a household. In addition just the possession of DECT docking stations leads to

exposure as most models transmit continuously in stand-by. Also wireless internet routers continuously transmit in the WiFi band. Though the highest exposure peaks in the WiFi band, up to 0.265W/m(2), come from stray radiation of microwave ovens. The mean total exposure largely depends on phone calls of a high exposure level and short duration. These calls lead to potentially high contrasts as well in exposure levels between sessions of the same activity as between persons, thus posing a challenge for personal exposure prediction.

**Borbely, AA, Huber, R, Graf, T, Fuchs, B, Gallmann, E, Achermann, P, Pulsed high-frequency electromagnetic field affects human sleep and sleep electroencephalogram. Neurosci Lett 275(3):207-210, 1999.**

To investigate whether the electromagnetic field (EMF) emitted by digital radiotelephone handsets affects the brain, healthy, young subjects were exposed during an entire night-time sleep episode to an intermittent radiation schedule (900 MHz; maximum specific absorption rate 1 W/kg) consisting of alternating 15-min on-15-min off intervals. Compared with a control night with sham exposure, the amount of waking after sleep onset was reduced from 18 to 12 min. Spectral power of the electroencephalogram in non-rapid eye movement sleep was increased. The maximum rise occurred in the 10-11 Hz and 13.5-14 Hz bands during the initial part of sleep and then subsided. The results demonstrate that pulsed high-frequency EMF in the range of radiotelephones may promote sleep and modify the sleep EEG.

**Bornhausen M, Scheingraber H, Prenatal exposure to 900 MHz, cell-phone electromagnetic fields had no effect on operant-behavior performances of adult rats. Bioelectromagnetics 21(8):566-574, 2000.**

To clarify potential health risks of radio-frequency electromagnetic fields (EMFs) used in cellular telephone technology to the developing brain, Wistar rats were continuously exposed during pregnancy to a low-level (0.1 mW/cm(2)) 900 MHz, 217 Hz pulse modulated EMF that approximated the highest legal exposure of normal populations to the radiation of base antennas of the GSM digital cell-phone technology. Whole body average specific absorption rate (SAR) values for the freely roaming, pregnant animals were measured in models; they ranged between 17.5 and 75 mW/kg. The offspring of exposed and of sham-exposed dams were coded and tested later as adults in a battery of ten simultaneously operated test chambers (Skinner boxes) during night time. Eight groups of ten coded animals in each group were tested for learning deficits in a sequence of nine, computer-controlled, 15 h sessions of the food-reinforced contingency Differential Reinforcement of Rate with increasing performance requirements. Two different sets of events were recorded: The food-reinforced lever-pressing activity of the animals and the inter-response intervals (IRIs) between consecutive lever presses. IRI-occurence patterns discriminated consistently between "learners" and "non-learners". Analyses of performance scores and of IRI-patterns both showed that exposure in-utero to the GSM field did not induce any measurable cognitive deficits.

**Bornkessel C, Schubert M, Wuschek M, Schmidt P. Determination of the general public exposure around GSM and UMTS base stations. Radiat Prot Dosimetry. 124(1):40-47, 2007.**

This paper summarises two studies, in which measurement and calculation methods to determine the exposure of the general public around GSM and UMTS base stations have been developed and applied to different scenarios. The electromagnetic field variations around the stations in space and time are accounted for by appropriate maximisation techniques. Measurements show a bandwidth of exposures from 0.01% to more than 10% of field strength exposure limits. The distance to the station is not a main influencing factor, whereas the orientation to the main lobe and the sight conditions greatly influence exposure. Several commercially available numerical simulation tools were tested for their applicability on exposure forecast. In line-of-sight scenarios, all programs are able to predict the exposure accurately, whereas in non-line-of-sight situations, free space models overestimate the real exposure by some orders of magnitude.

**Bortkiewicz A, Zmyslony M, Gadzicka E, Szymczak W, [Evaluation of selected parameters of circulatory system function in various occupational groups exposed to high frequency electromagnetic fields. II. Electrocardiographic changes]. Med Pr 47(3):241-252, 1996.** [Article in Polish]

The effect of electromagnetic fields (EMF) on the circulatory and nervous systems has been the subject of great interest for many years, since electric impulses generated in these systems by outer electric and magnetic fields can theoretically disturb their functions. The only data on chronic effect of weak EMFs on the human body come from the studies carried out in the Soviet Union between the fifties and the seventies. In view of a growing number of persons exposed to EMF, there is an urgent need for verifying those data by means of modern diagnostic methods. That is the reason why our study of the EMF effect on the circulatory system has been initiated. It covered 71 workers at four AM broadcast stations, 40 workers at ten radio link stations and 42 workers at three radioservices. Workers' exposure to EMF was evaluated (see part I). Subjective and objective medical examinations were performed in all workers in order to assess their state of health, then resting electrocardiogram, Holter measurements, and high intensity ECG were taken, and variation in cardiac rhythm was analysed by a long-term recording of blood pressure. The results of the analysis of the questionnaire survey as well as the Holter and resting ECG examinations are presented. The study indicated that exposure to EMF in parameters found in AM broadcast station increased risk for electrographic disturbances (detected by means of resting ECG and a 24-hour Holter recording) by six times in comparison with that in radio link station workers not exposed to medium wave EMF. In radioservice workers this risk was twice as high as that in link station workers. It seems that in AM broadcast station workers, resting ECG should be complemented by a 24-hour Holter measurements, particularly, if workers complain of the circulatory system disturbances.

**Bortkiewicz A, Gadzicka E, Zmyslony M, Heart rate variability in workers exposed to medium-frequency electromagnetic fields. J Auton Nerv Syst 59(3):91-97, 1996**

This study was undertaken to evaluate the neurovegetative regulation of the heart in workers occupationally exposed to medium frequency (MF) electromagnetic (EM) fields. The subjects were 71 workers of MF broadcast stations, aged 20-68 (mean 47.1) with the duration of work under exposure ranging from 2-40 years and 22 workers of radio link stations, aged 21-65 (mean 46.9) who were not exposed to MF EM fields. The distribution

of age and work tenure in both groups did not differ significantly. Heart rate variability (HRV) was analysed basing on 512 normal heart evolutions registered in resting, from the body surface, using the Medea-HRV system. The analysis concerned time-domain and frequency-domain parameters of HRV using fast fourier transformation. Power spectrum in the low (0.05-0.15 Hz) and high (0.15-0.35 Hz) frequency bands (LF and HF, respectively) was determined. Statistically insignificant differences found between exposed and non-exposed groups were found either in time- or in frequency-domain parameters of HRV. No correlation between the power spectrum and the subjects age was noted. Such a relationship, however, could be observed in the control group. In the study group a statistically significant negative correlation was found between the maximum intensity of EM fields and HF power spectrum. Thus it was concluded that occupational exposure to EM fields brings about impairments in the neurovegetative regulation of the cardiovascular function.

**Bortkiewicz, A, Zmyslony, M, Gadzicka, E, Palczynski, C, Szmigielski, S, Ambulatory ECG monitoring in workers exposed to electromagnetic fields. J Med Eng Technol 21(2):41-46, 1997.**

The aim of this study was to evaluate the function of the circulatory system in workers occupationally exposed to medium frequency electromagnetic fields. The subjects were 71 workers at four AM broadcast stations [0.738-1.503 MHz] aged 20-68 (mean 46.9 +/- 13.1) years and 22 workers at radio link stations aged 23-67 (mean 48.2 +/- 17.4) years. Workers at AM broadcast stations experienced 2-40 (mean 18.6 +/- 12.1) years' exposure to electromagnetic fields (average daily exposure dose about 115 Vh m-1, maximum exposure levels during shift about 165 V m-1), workers at radio link stations had no history of regular exposure to electromagnetic fields. In all the subjects a general medical examination, resting ECG and 24 h Holter monitoring were performed. The work organization, work period structure, age, lifestyle, nutritional habits and health status in both groups remained fairly similar. The electrocardiographic abnormalities detected in the resting and/ or 24 h ECG were significantly more frequent ($p = 0.006$) in workers exposed to electromagnetic fields than in non-exposed subjects (75% versus 25%). A clear tendency for a higher number of rhythm disturbances (mostly ExV) was observed in AM broadcast station workers.

**Bortkiewicz A, Pilacik B, Gadzicka E, Szymczak W. The excretion of 6-hydroxymelatonin sulfate in healthy young men exposed to electromagnetic fields emitted by cellular phone -- an experimental study. Neuroendocrinol Lett 23 Suppl 1:88-91, 2002.**

OBJECTIVES: It is quite likely that non-visible electromagnetic fields (EMF) may affect melatonin production. Some studies confirmed this hypothesis and showed that extremely low EMF altered pineal function in animals and humans. Thus, it is reasonable to suppose that EMF emitted by cellular phones may also influence secretion of melatonin. The present study sought to evaluate possible effect of the exposure to EMF emitted by cellular phone on 6-hydroxymelatonin sulfate (6-OHMS) excretion, which reflects melatonin levels in blood. MATERIAL AND METHODS: The examined group consisted of 9 healthy males aged 19-29 years. The experiment was performed under controlled conditions (the light intensity-50 lx till midnight and 0 lx during night). Each

person was examined twice: on a day without exposure (control day, C-day) and on a day with continuous exposure (60 min. exposure from cellular phone, frequency 900 MHz, pulsed with 217 Hz, pulse with 576 micros, SAR 1.23 W/kg, E-day). From 7 p.m. to 8 p.m. they used a cellular phone. The subjects did not know which day was E-day, and which was C-day. From 8 p.m. till midnight the subjects listened to music and than they slept till 7 a.m. next day. Urine samples were collected at 7 p.m., at midnight, and at 7 a.m. in the same way in C-day as in E-day. Sample were frozen for later ELISA analysis of 6-OHMS. The 6-OHMS ELISA kit from Immuno-Biological Laboratories (Hamburg) was used for measurement of 6-OHMS. The data were analysed using Wilcoxon matched-pairs signed-ranks test for each subject and for the whole group. We compared 6-OHMS level on the E-day and on the C-day separately for 3 time-points - 7 p.m., midnight, 7 a.m. RESULTS: Mean 6-OHMS level in both experiments did not differ significantly for any of the respective time points. Circadian variations of 6-OHMS level were detected in all subjects. CONCLUSIONS: The results of our investigation has demonstrated that EMF emitted by cellular phones has no distinct influence on the melatonin level.

**Bortkiewicz A, Zmyslony M, Szyjkowska A, Gadzicka E. [Subjective symptoms reported by people living in the vicinity of cellular phone base stations: a review of the studies] Med Pr. 55(4):345-351, 2004.** [Article in Polish]

The problem of health effects of electromagnetic fields (EMF) emitted by cellular phone base stations evokes much interest in view of the fact that people living in their vicinity are fated to continuous exposure to EMF. None of the studies carried out throughout the world have revealed excessive values of standards adopted by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). A questionnaire was used as a study tool. The results of the questionnaire survey reveal that people living in the vicinity of base stations report various complaints mostly of the circulatory system, but also of sleep disturbances, irritability, depression, blurred vision, concentration difficulties, nausea, lack of appetite, headache and vertigo. The performed studies showed the relationship between the incidence of individual symptoms, the level of exposure, and the distance between a residential area and a base station. This association was observed in both groups of persons, those who linked their complaints with the presence of the base station and those who did not notice such a relation. Further studies, clinical and those based on questionnaires, are needed to explain the background of reported complaints.

**Bortkiewicz A, Gadzicka E, Szyjkowska A, Politański P, Mamrot P, Szymczak W, Zmyślony M. Subjective complaints of people living near mobile phone base stations in Poland. Int J Occup Med Environ Health. 25(1):31-40, 2012.**

OBJECTIVES: The aim of our study was to assess the health conditions and subjective symptoms of the inhabitants living in the base stations vicinity and to analyse the relationship between the complaints and level of exposure to electromagnetic fields (EMF).MATERIALS AND METHODS: Our study was performed in housing estates located in five regions of Łódź. The electric field measurements were performed in the buildings located closest to the azimuth of the antennas. Respondents were selected by trained interviewers using an uniform procedure. The number of the households to be examined was set at a minimum of 420. The questionnaire contained: demographic data, occupational and environmental exposure to EMF, health condition, subjective

complaints. Results were adjusted for confounders (age, gender, EMF at the workplace and EMF emitted by household equipment) using multiple regression model.RESULTS: 181 men and 319 women from 500 households were examined. Electric field above 0.8 V/m was recorded in 12% of flats. There was no significant correlation between electric field strength and the distance of examined flats from the base stations. To make possible comparison with relevant literature, we analysed also the frequency of the reported symptoms vs. the distance. Headache was declared by 57% people, most frequently (36.4%) living 100-150 m away from the base station compared to people living at longer distances (p = 0.013). 24.4% subjects, mostly living at a distance above 150 m, declared impaired memory. Difference was statistically significant in comparison with people living at other distances (p = 0.004).CONCLUSIONS: The explanation why we did not find any correlation between the electric field strength and frequency of subjective symptoms but found a correlation between subjective symptoms and distance from base station needs further studies. Maybe new metrics of exposure assessment should be adopted for this purpose.

**Bortkiewicz A, Gadzicka E, Szymczak W, Zmyślony M. Changes in tympanic temperature during the exposure to electromagnetic fields emitted by mobile phone. Int J Occup Med Environ Health. 25(2): 145-150, 2012.**

OBJECTIVE: Mobile phones generate microwave radiation which is absorbed by exposed tissue and converted into heat. It may cause detrimental health effects. The aim of the experiment was to check if exposure to EMF emitted by mobile phone influenced the tympanic temperature.MATERIAL AND METHODS: Human volunteer study was performed on ten healthy young men, aged 22.1±4.7 years, examined three times: 1. on a day with 2×60 min of no exposure (sham day), 2. on a day with continuous, 60 min exposure and 60 min of no exposure, 3. on a day with intermittent exposure (4×15 min "on" and 4×15 min "off"). Exposure was generated by mobile phone (frequency 900 MHz, SAR 1.23 W/kg). The study was double-blind, performed under controlled conditions (at 24°C and 70% humidity). The tympanic temperature (T(ty)) was monitored every 10 sec by a thermistor probe placed close to the aural canal membrane in the ear opposite the one in contact with mobile phone (contralateral position). Multivariate repeated-measures analysis of variance was used to calculate the results.RESULTS: The mean T(ty) in the whole group during continuous exposure was significantly higher than during sham exposure (p = 0.0001). During intermittent exposure the temperature was lower than during sham day (difference was up to 0.11°C). Within an hour after continuous exposure, T(ty) was higher by 0.03°C and after intermittent exposure T(ty) was lower by 0.18°C in comparison with sham day. Two hours after exposure T(ty) was significantly lower (p = 0.0001) than after sham exposure (0.06°C and 0.26°C respectively). The trends in T(ty) during experiment differed significantly in relation to exposure conditions (p < 0.05).CONCLUSIONS: The results of this analysis indicate that the physiological response to EMF exposure from mobile phone was mostly related to type of exposure (continuous or intermittent).

**Bortkiewicz A, Gadzicka E, Szymczak W, Zmyślony M. Heart rate variability (HRV) analysis in radio and TV broadcasting stations workers. Int J Occup Med Environ Health. 25(4):446-455, 2012.**

**OBJECTIVES:** The aim of the study was to assess the mechanism of cardiovascular impairments in workers exposed to UHF-VHF radio frequency electromagnetic fields (EMF). **MATERIALS AND METHODS:** Heart rate variability (HRV) was analysed using 512 normal heart beats registered at rest. The analysis concerned time-domain (STD R-R) and frequency-domain (VLF, LF, HF) parameters of HRV. Fifty nine workers (group I) with low-level and 12 workers (group II) with high-level exposure were examined. The mean age of the subjects was 47 ± 9 years and 41 ± 14 years, and mean exposure duration 19.1 ± 8.8 years and 13 ± 4 years, in groups I and II, respectively. The groups were divided according to: E(max), E(dose), E(mean) for frequencies UHF, VHF and UHF+VHF: The control group consisted of 42 non-exposed subjects, aged 49 ± 8 years. Statistical analysis comprised one-way analysis of variance, covariance analysis and logistic regression models. **RESULTS:** In the exposed groups, the heart rate was higher than in the control one. Standard deviation of R-R intervals (STD R-R) was found to be significantly ($p = 0.0285$) lower in group I (42.5 ± 24.7 ms) compared to the control group (62.9 ± 53.5 ms). The risk of lowered STD R-R was significantly increased (OR = 2.37, $p = 0.023$) in group II. Both exposed groups presented significantly higher VLF and LF values than the control group ($p = 0.005$ and $p = 0.0025$, respectively). The EMF-exposed groups were characterised by the dominance of the sympathetic system (LF/HF 1.3 ± 0.35). **CONCLUSIONS:** The results indicate that exposure to radiofrequency EMF may affect the neurovegetative regulation.

**Boscol P, Di Sciascio MB, D'Ostilio S, Del Signore A, Reale M, Conti P, Bavazzano P, Paganelli R, Di Gioacchino M. Effects of electromagnetic fields produced by radiotelevision broadcasting stations on the immune system of women. Sci Total Environ 273(1-3):1-10, 2001.**

The object of this study was to investigate the immune system of 19 women with a mean age of 35 years, for at least 2 years (mean = 13 years) exposed to electromagnetic fields (ELMFs) induced by radiotelevision broadcasting stations in their residential area. In September 1999, the ELMFs (with range 500 KHz-3 GHz) in the balconies of the homes of the women were (mean +/- S.D.) 4.3 +/- 1.4 V/m. Forty-seven women of similar age, smoking habits and atopy composed the control group, with a nearby resident ELMF exposure of < 1.8 V/m. Blood lead and urinary trans-trans muconic acid (a metabolite of benzene), markers of exposure to urban traffic, were higher in the control women. The ELMF exposed group showed a statistically significant reduction of blood NK CD16+-CD56+, cytotoxic CD3(-)-CD8+, B and NK activated CD3(-)-HLA-DR+ and CD3(-)-CD25+ lymphocytes. 'In vitro' production of IL-2 and interferon-gamma (INF-gamma) by peripheral blood mononuclear cells (PBMC) of the ELMF exposed group, incubated either with or without phytohaemoagglutinin (PHA), was significantly lower; the 'in vitro' production of IL-2 was significantly correlated with blood CD16+-CD56+ lymphocytes. The stimulation index (S.I.) of blastogenesis (ratio between cell proliferation with and without PHA) of PBMC of ELMF exposed women was lower than that of the control

subjects. The S.I. of blastogenesis of the ELMF exposed group (but not blood NK lymphocytes and the 'in vitro' production of IL-2 and INF-gamma by PBMC) was significantly correlated with the ELMF levels. Blood lead and urinary trans-trans muconic acid were barely correlated with immune parameters: the urinary metabolite of benzene of the control group was only correlated with CD16+-CD56+ cells indicating a slight effect of traffic on the immune system. In conclusion, this study demonstrates that high frequency ELMFs reduce cytotoxic activity in the peripheral blood of women without a dose-response effect.

**Bouji M, Lecomte A, Hode Y, de Seze R, Villégier AS. Effects of 900MHz radiofrequency on corticosterone, emotional memory and neuroinflammation in middle-aged rats. Exp Gerontol.47(6): 444-451, 2012.**

The widespread use of mobile phones raises the question of the effects of electromagnetic fields (EMF, 900MHz) on the brain. Previous studies reported increased levels of the glial fibrillary acidic protein (GFAP) in the rat's brain after a single exposure to 900MHz global system for mobile (GSM) signal, suggesting a potential inflammatory process. While this result was obtained in adult rats, no data is currently available in older animals. Since the transition from middle-age to senescence is highly dependent on environment and lifestyle, we studied the reactivity of middle-aged brains to EMF exposure. We assessed the effects of a single 15min GSM exposure (900MHz; specific absorption rate (SAR)=6W/kg) on GFAP expression in young adults (6week-old) and middle-aged rats (12month-old). Brain interleukin (IL)-1β and IL-6, plasmatic levels of corticosterone (CORT), and emotional memory were also assessed. Our data indicated that, in contrast to previously published work, acute GSM exposure did not induce astrocyte activation. Our results showed an IL-1β increase in the olfactory bulb and enhanced contextual emotional memory in GSM-exposed middle-aged rats, and increased plasmatic levels of CORT in GSM-exposed young adults. Altogether, our data showed an age dependency of reactivity to GSM exposure in neuro-immunity, stress and behavioral parameters. Reproducing these effects and studying their mechanisms may allow a better understanding of mobile phone EMF effects on neurobiological parameters.

**Bouji M, Lecomte A, Gamez C, Blazy K, Villégier AS. Neurobiological effects of repeated radiofrequency exposures in male senescent rats. Biogerontology. 17(5-6):841-857, 2016.**

The increasing use of mobile phones by aging people raises issues about the effects of radiofrequency electromagnetic fields (RF-EMF) on the aging central nervous system. Here, we tested if mobile phone RF-EMF exposures could exacerbate senescence-typical neurobiological deficits. Thus, aged (22-24 months) and young (4-6 months) adult male rats were subjected to head RF-EMF exposures (900 MHz, specific absorption rate (SAR) of 6 W/kg, 45 min/day for 1 month in restraint rockets). To assess senescence-typical neurobiological deficits, spatial memory, emotional memory, anxiety-related behavior, locomotor activity, interleukins (IL)-1β and 6, glial fibrillary acidic protein and corticosterone were measured. Aged rats presented deficits in spatial learning, exploration, anxiety-related behaviors, and increased hippocampal ILs and cortical IL-1β.

Results showed that senescence-typical neurobiological deficits were not modified by RF-EMF exposures. RF-EMF-exposed rats (young and aged adults pooled) had decreased anxiety-related behaviors in the elevated plus maze. This study which is the first to assess RF-EMF exposures during late aging did not support the hypothesis of a specific cerebral vulnerability to RF-EMF during senescence. More investigations using longer RF-EMF exposures should be performed to conclude regarding the inoffensiveness of RF-EMF exposures.

**Bourdineaud JP, Šrut M, Štambuk A, Tkalec M, Brèthes D, Malarić K, Klobučar GIV. Electromagnetic fields at a mobile phone frequency (900 MHz) trigger the onset of general stress response along with DNA modifications in Eisenia fetida earthworms. Arh Hig Rada Toksikol. 68(2):142-152, 2017.**

Eisenia fetida earthworms were exposed to electromagnetic field (EMF) at a mobile phone frequency (900 MHz) and at field levels ranging from 10 to 120 V m-1 for a period of two hours (corresponding to specific absorption rates ranging from 0.13 to 9.33 mW kg-1). Potential effects of longer exposure (four hours), field modulation, and a recovery period of 24 h after two hours of exposure were addressed at the field level of 23 V m-1. All exposure treatments induced significant DNA modifications as assessed by a quantitative random amplified polymorphic DNA-PCR. Even after 24 h of recovery following a two hour-exposure, the number of probe hybridisation sites displayed a significant two-fold decrease as compared to untreated control earthworms, implying a loss of hybridisation sites and a persistent genotoxic effect of EMF. Expression of genes involved in the response to general stress (HSP70 encoding the 70 kDa heat shock protein, and MEKK1 involved in signal transduction), oxidative stress (CAT, encoding catalase), and chemical and immune defence (LYS, encoding lysenin, and MYD, encoding a myeloid differentiation factor) were up-regulated after exposure to 10 and modulated 23 V m-1 field levels. Western blots showing an increased quantity of HSP70 and MTCO1 proteins confirmed this stress response. HSP70 and LYS genes were up-regulated after 24 h of recovery following a two hour-exposure, meaning that the effect of EMF exposure lasted for hours.

**Bourthoumieu S, Joubert V, Marin B, Collin A, Leveque P, Terro F, Yardin C. Cytogenetic studies in human cells exposed in vitro to GSM-900 MHz radiofrequency radiation using R-banded karyotyping. Radiat Res 174:712-718, 2010.**

It is important to determine the possible effects of exposure to radiofrequency (RF) radiation on the genetic material of cells since damage to the DNA of somatic cells may be linked to cancer development or cell death and damage to germ cells may lead to genetic damage in next and subsequent generations. The objective of this study was to investigate whether exposure to radiofrequency radiation similar to that emitted by mobile phones of second-generation standard Global System for Mobile Communication (GSM) induces genotoxic effects in cultured human cells. The cytogenetic effects of GSM-900 MHz (GSM-900) RF radiation were investigated using R-banded karyotyping after in vitro exposure of human cells (amniotic cells) for 24 h. The average specific absorption rate

(SAR) was 0.25 W/kg. The exposures were carried out in wire-patch cells (WPCs) under strictly controlled conditions of temperature. The genotoxic effect was assessed immediately or 24 h after exposure using four different samples. One hundred metaphase cells were analyzed per assay. Positive controls were provided by using bleomycin. We found no direct cytogenetic effects of GSM-900 either 0 h or 24 h after exposure. To the best of our knowledge, our work is the first to study genotoxicity using complete R-banded karyotyping, which allows visualizing all the chromosomal rearrangements, either numerical or structural.

**Bourthoumieu S, Terro F, Leveque P, Collin A, Joubert V, Yardin C. Aneuploidy studies in human cells exposed in vitro to GSM-900 MHz radiofrequency radiation using FISH. Int J Radiat Biol 87:400-408, 2011.**

PURPOSE: Since previous research found an increase in the rate of aneuploidies in human lymphocytes exposed to radiofrequencies, it seems important to perform further studies. The objective of this study was then to investigate whether the exposure to RF (radiofrequency) radiation similar to that emitted by mobile phones of a second generation standard, i.e., Global System for Mobile communication (GSM) may induce aneuploidy in cultured human cells. MATERIALS AND METHODS: The potential induction of genomic instability by GSM-900 MHz radiofrequency (GSM-900) was investigated after in vitro exposure of human amniotic cells for 24 h to average-specific absorption rates (SAR) of 0.25, 1, 2 and 4 W/kg in the temperature range of 36.3-39.7°C. The exposures were carried out in a wire-patch cell (WPC). The rate of aneuploidy of chromosomes 11 and 17 was determined by interphase FISH (Fluorescence In Situ Hybridisation) immediately after independent exposure of three different donors for 24 h. At least 100 interphase cells were analysed per assay. RESULTS: No significant change in the rate of aneuploidy of chromosomes 11 and 17 was found following exposure to GSM-900 for 24 h at average SAR up to 4 W/kg. CONCLUSION: Our study did not show any in vitro aneuploidogenic effect of GSM using FISH and is not in agreement with the results of previous research.

**Bourthoumieu S, Magnaudeix A, Terro F, Leveque P, Collin A, Yardin C. Study of p53 expression and post-transcriptional modifications after GSM-900 radiofrequency exposure of human amniotic cells.Bioelectromagnetics. 2012 Jul 5. doi: 10.1002/bem.21744. [Epub ahead of print]**

The potential effects of radiofrequency (RF) exposure on the genetic material of cells are very important to determine since genome instability of somatic cells may be linked to cancer development. In response to genetic damage, the p53 protein is activated and can induce cell cycle arrest allowing more time for DNA repair or elimination of damaged cells through apoptosis. The objective of this study was to investigate whether the exposure to RF electromagnetic fields, similar to those emitted by mobile phones of the second generation standard, Global System for Mobile Communications (GSM), may induce expression of the p53 protein and its activation by post-translational modifications in cultured human cells. The potential induction of p53 expression and activation by GSM-900 was investigated after in vitro exposure of human amniotic cells for 24 h to average specific absorption rates (SARs) of 0.25, 1, 2, and 4 W/kg in the temperature range of

36.3-39.7 °C. The exposures were carried out using a wire-patch cell (WPC) under strictly controlled conditions of temperature. Expression and activation of p53 by phosphorylation at serine 15 and 37 were studied using Western blot assay immediately after three independent exposures of cell cultures provided from three different donors. Bleomycin-exposed cells were used as a positive control. According to our results, no significant changes in the expression and activation of the p53 protein by phosphorylation at serine 15 and 37 were found following exposure to GSM-900 for 24 h at average SARs up to 4 W/kg in human embryonic cells.

**Brande FV, Martens P. A false positive arrhythmia on electrocardiogram induced by a cell phone. Eur J Emerg Med. 10(4):357-360, 2003.**

A case report.

**Braune, S, Wrocklage, C, Raczek, J, Gailus, T, Lucking, CH, Resting blood pressure increase during exposure to a radio-frequency electromagnetic field. Lancet 351(9119):1857-1858, 1998.**

Exposure of the right hemisphere to a radiofrequency EMF for 35 min causes in human subjects an increase in sympathetic efferent activity with increases the resting blood pressure between 5-10 mm Hg. The effect is likely caused by vasoconstriction.

**Braune S, Riedel A, Schulte-Monting J, Raczek J. Influence of a radiofrequency electromagnetic field on cardiovascular and hormonal parameters of the autonomic nervous system in healthy individuals. Radiat Res 158(3):352-356, 2002.**

The potential health risks of radiofrequency electromagnetic fields (EMFs) emitted by mobile phones are of considerable public interest. The present study investigated the hypothesis, based on the results of our previous study, that exposure to EMFs can increase sympathetic vasoconstrictor activity. Forty healthy young males and females underwent a single-blind, placebo-controlled protocol once on each of two different days. Each investigation included successive periods of placebo and EMF exposure, given in a randomized order. The exposure was implemented by a GSM-like signal (900 MHz, pulsed with 217 Hz, 2 W) using a mobile phone mounted on the right-hand side of the head in a typical telephoning position. Each period of placebo exposure and of EMF exposure consisted of 20 min of supine rest, 10 min of 70 degrees upright tilt on a tilt table, and another 20 min of supine rest. Blood pressure, heart rate and cutaneous capillary perfusion were measured continuously. In addition, serum levels of norepinephrine, epinephrine, cortisol and endothelin were analyzed in venous blood samples taken every 10 min. Similar to the previous study, systolic and diastolic blood pressure each showed slow, continuous, statistically significant increases of about 5 mmHg during the course of the protocol. All other parameters either decreased in parallel or remained constant. However, analysis of variance showed that the changes in blood pressure and in all other parameters were independent of the EMF exposure. These findings do not support the assumption of a nonthermal influence of EMFs emitted by mobile phones on the cardiovascular autonomic nervous system in healthy humans.

**Brautbar N. Rapid development of brain tumors in 2 cellular phone testers. Arch Environ Health. 58(9):606, 2003.**

Two case reports. Comment on [Richter ED, Berman T, Levy O. Brain cancer with induction periods of less than 10 years in young military radar workers. Arch Environ Health. 2002 Jul-Aug;57(4):270-272.]

**Breckenkamp J, Blettner M, Schüz J, Bornkessel C, Schmiedel S, Schlehofer B, Berg-Beckhoff G. Residential characteristics and radiofrequency electromagnetic field exposures from bedroom measurements in Germany. Radiat Environ Biophys. 51(1):85-92, 2012.**

The objectives of this study were to assess total exposure to radiofrequency electromagnetic fields (RF-EMF) in bedrooms and the contribution of different radioservices (FM radio, analogue TV and DVB-T, TETRA, GSM900 downlink, GSM1800 downlink, UMTS downlink, DECT, and wireless LAN and blue tooth) to the total exposure. Additional aims were to describe the proportion of measuring values above the detection limit of the dosimeters and to characterize the differences in exposure patterns associated with self-reported residential characteristics. Exposure to RF sources in bedrooms was measured using Antennessa(®) EME Spy 120 dosimeters in 1,348 households in Germany; 280 measures were available for each frequency band per household. Mean electrical field strengths and power flux densities were calculated. Power flux densities allow the calculation of proportions of different radioservices on total exposure. Exposure was often below the detection limit (electrical field strength: 0.05 V/m) of the dosimeter. Total exposure varied, depending on residential characteristics (urban vs. rural areas and floor of a building the measurement took place). Major sources of exposure were cordless phones (DECT standard) and wireless LAN/blue tooth contributing about 82% of total exposure (20.5 µW/m(2)). Exposure to RF-EMF is ubiquitous, but exposure levels are-if at all measurable-very low and far below the ICNIRP's exposure reference levels.

**Brescia F, Sarti M, Massa R, Calabrese ML, Sannino A, Scarfì MR. Reactive oxygen species formation is not enhanced by exposure to UMTS 1950 MHz radiation and co-exposure to ferrous ions in Jurkat cells. Bioelectromagnetics.30(7):525-535, 2009.**

This study was designed to assess if radiofrequency (RF) radiation induces oxidative stress in cultured mammalian cells when given alone or in combination with ferrous ions (FeSO(4)). For this purpose the production of reactive oxygen species (ROS) was measured by flow cytometry in human lymphoblastoid cells exposed to 1950 MHz signal used by the third generation wireless technology of the Universal Mobile Telecommunication System (UMTS) at Specific Absorption Rate of 0.5 and 2.0 W/kg. Short (5-60 min) or long (24 h) duration exposures were carried out in a waveguide system under strictly controlled conditions of both dosimetry and environment. Cell viability was also measured after 24 h RF exposure using the Resazurin and Neutral Red assays. Several co-exposure protocols were applied to test if RF radiation is able to alter ROS formation induced by FeSO(4) (RF given before or concurrently to FeSO(4)). The results obtained indicate that non-thermal RF exposures do not increase spontaneous ROS formation in any of the experimental conditions

investigated. Consistent with the lack of ROS production, no change in cell viability was observed in Jurkat cells exposed to RF radiation for 24 h. Similar results were obtained when co-exposures were considered: combined exposures to RF radiation and FeSO(4) did not increase ROS formation induced by the chemical treatment alone. In contrast, in cultures treated with FeSO(4) as positive control, a dose-dependent increase in ROS formation was recorded, validating the sensitivity of the method employed.

**Brezitskaia HV, Timchenko OI, [On the mechanism of cytogenetic effect of electromagnetic radiation: a role of oxidation homeostasis]. Radiats Biol Radioecol 40(2):149-153, 2000.** [Article in Russian]

It was established in the experiments on rats that the changes in free radical oxidation under the influence of non-ionizing radiation had a wavy character. It was revealed that the changes in oxidation homeostasis preceded development of cytogenetic effects and could be their reason.

**Briggs D, Beale L, Bennett J, Toledano MB, de Hoogh K. A geographical model of radio-frequency power density around mobile phone masts. Sci Total Environ.426:233-243, 2012.**

Public concern about possible health effects of EMF radiation from mobile phone masts has led to an increase of epidemiological studies and health risk assessments which, in turn, require adequate methods of exposure estimation. Difficulties in exposure modelling are exacerbated both by the complexity of the propagation processes, and the need to obtain estimates for large study populations in order to provide sufficient statistical power to detect or exclude the small relative risks that might exist. Use of geographical information system (GIS) techniques offers the means to make such computations efficiently. This paper describes the development and field validation of a GIS-based exposure model (Geomorf). The model uses a modified Gaussian formulation to represent spatial variations in power densities around mobile phone masts, on the basis of power output, antenna height, tilt and the surrounding propagation environment. Obstruction by topography is allowed for, through use of a visibility function. Model calibration was done using field data from 151 measurement sites (1510 antenna-specific measurements) around a group of masts in a rural location, and 50 measurement sites (658 antenna-specific measurements) in an urban area. Different parameter settings were found to be necessary in urban and rural areas to obtain optimum results. The calibrated models were then validated against independent sets of data gathered from measurement surveys in rural and urban areas, and model performance was compared with that of two commonly used path-loss models (the COST-231 adaptations of the Hata and Walfisch-Ikegami models). Model performance was found to vary somewhat between the rural and urban areas, and at different measurement levels (antenna-specific power density, total power density), but overall gave good estimates (R(2)=0.641 and 0.615, RMSE=10.7 and 6.7dBm at the antenna and site-level respectively). Performance was considerably better than that of both path loss models.

**Brillaud E, Piotrowski A, de Seze R. Effect of an acute 900MHz GSM exposure on glia in the rat brain: A time-dependent study. Toxicology.238(1):23-33,2007.**

Because of the increasing use of mobile phones, the possible risks of radio frequency electromagnetic fields adverse effects on the human brain has to be evaluated. In this work we measured GFAP expression, to evaluate glial evolution 2, 3, 6 and 10 days after a single GSM exposure (15min, brain averaged SAR=6W/kg, 900MHz signal) in the rat brain. A statistically significant increase of GFAP stained surface area was observed 2 days after exposure in the frontal cortex and the caudate putamen. A smaller statistically significant increase was noted 3 days after exposure in the same areas and in the cerebellum cortex. Our results confirm the Mausset-Bonnefont et al. study [Mausset-Bonnefont, A.L., Hirbec, H., Bonnefont, X., Privat, A., Vignon, J., de Seze, R., 2004. Acute exposure to GSM 900MHz electromagnetic fields induces glial reactivity and biochemical modifications in the rat brain. Neurobiol. Dis. 17, 445-454], showing the existence of glial reactivity after a 15min GSM acute exposure at a brain averaged SAR of 6W/kg. We conclude to a temporary effect, probably due to a hypertrophy of glial cells, with a temporal and a spatial modulation of the effect. Whether this effect could be harmful remains to be studied.

**Brown HD, Chattopadhyay SK, Ouabain inhibition of kidney ATPase is altered by 9.14 GHz radiation. Bioelectromagnetics 12(3):137-143, 1991.**

At each of several stabilized temperatures between 7.0 and 43.8 degrees C, increases in dog-kidney, Na(+)-, K(+)-ATPase catalytic activity were usually observed in association with exposure for 5 min to 9.14 GHz CW microwave radiation in a thin tubular reactor. However, at 24.9 degrees C, a 23% decrease occurred. Comparisons of activity of ouabain-inhibited reactions revealed that the efficacy of the cardiac glycoside as an inhibitor of ATPase activity was severely diminished by the microwave field. The ouabain-site control mechanism may be a specific microwave target at this exposure frequency. Experimental results can be interpreted in terms of molecular structural changes or direct energy input. The estimated SAR of energy that was incident on preparations is 20 W/kg.

**Brown DO, Lu ST, Elson EC, Characteristics of microwave evoked body movements in mice. Bioelectromagnetics 15(2):143-161, 1994.**

Microwave evoked body movements were studied in mice. A resonant cavity was used to provide head and neck exposure of the mouse to pulsed and gated continuous wave (CW) 1.25 GHz microwaves. No difference in response to pulsed and gated CW stimuli of equal average power was found. The incidence of the microwave evoked body movements increased proportionally with specific absorption (dose) when the whole-body average specific absorption rate was at a constant level (7300 W/kg). Under a constant average specific absorption rate, the response incidence reached a plateau at 0.9 kJ/kg. For doses higher than 0.9 kJ/kg, response incidence was proportional to the specific absorption rate and reached a plateau at 900 W/kg. Body movements could be evoked by a single microwave pulse. The lowest whole-body specific absorption (SA) tested was 0.18 kJ/kg, and the corresponding brain SA was 0.29 kJ/kg. Bulk heating potentials of these SAs were less than 0.1 degree C. For doses higher than 0.9 kJ/kg, the response incidence was also proportional to subcutaneous temperature increment and subcutaneous heating rate. The extrapolated absolute thresholds (0% incidence) were

1.21 degrees C temperature increment and 0.24 degree C/s heating rate. Due to high subcutaneous heating rates, these microwaves must be perceived by the mouse as an intense thermal sensation but not a pain sensation because the temperature increment was well below the threshold for thermal pain. Results of the present study should be considered in promulgation of personnel protection guideline against high peak power but low average power microwaves.

**Buckner CA, Buckner AL, Koren SA, Persinger MA, Lafrenie RM. Exposure to a specific time-varying electromagnetic field inhibits cell proliferation via cAMP and ERK signaling in cancer cells. Bioelectromagnetics. 2017 Nov 10. doi: 10.1002/bem.22096.**

Exposure to specific electromagnetic field (EMF) patterns can affect a variety of biological systems. We have shown that exposure to Thomas-EMF, a low-intensity, frequency-modulated (25-6 Hz) EMF pattern, inhibited growth and altered cell signaling in malignant cells. Exposure to Thomas-EMF for 1 h/day inhibited the growth of malignant cells including B16-BL6 mouse melanoma cells, MDA-MB-231, MDA-MB-468, BT-20, and MCF-7 human breast cancer and HeLa cervical cancer cells but did not affect non-malignant cells. The Thomas-EMF-dependent changes in cell proliferation were mediated by adenosine 3',5'-cyclic monophosphate (cAMP) and extracellular-signal-regulated kinase (ERK) signaling pathways. Exposure of malignant cells to Thomas-EMF transiently changed the level of cellular cAMP and promoted ERK phosphorylation. Pharmacologic inhibitors (SQ22536) and activators (forskolin) of cAMP production both blocked the ability of Thomas-EMF to inhibit cell proliferation, and an inhibitor of the MAP kinase pathway (PD98059) was able to partially block Thomas-EMF-dependent inhibition of cell proliferation. Genetic modulation of protein kinase A (PKA) in B16-BL6 cells also altered the effect of Thomas-EMF on cell proliferation. Cells transfected with the constitutively active form of PKA (PKA-CA), which interfered with ERK phosphorylation, also interfered with the Thomas-EMF effect on cell proliferation. The non-malignant cells did not show any EMF-dependent changes in cAMP levels, ERK phosphorylation, or cell growth. These data indicate that exposure to the specific Thomas-EMF pattern can inhibit the growth of malignant cells in a manner dependent on contributions from the cAMP and MAP kinase pathways.

**Buckus R, Strukcinskiene B, Raistenskis J, Stukas R. Modelling and assessment of the electric field strength caused by mobile phone to the human head. Vojnosanit Pregl. 73(6):538-543, 2016.**

BACKGROUND/AIM: Electromagnetic field exposure is the one of the most important physical agents that actively affects live organisms and environment. Active use of mobile phones influences the increase of electromagnetic field radiation. The aim of the study was to measure and assess the electric field strength caused by mobile phones to the human head. METHODS: In this paper the software "COMSOL Multiphysics" was used to establish the electric field strength created by mobile phones around the head. RESULTS: The second generation (2G) Global System for Mobile (GSM) phones that

operate in the frequency band of 900 MHz and reach the power of 2 W have a stronger electric field than (2G) GSM mobile phones that operate in the higher frequency band of 1,800 MHz and reach the power up to 1 W during conversation. The third generation of (3G) UMTS smart phones that effectively use high (2,100 MHz) radio frequency band emit the smallest electric field strength values during conversation. The highest electric field strength created by mobile phones is around the ear, i.e. the mobile phone location. The strength of mobile phone electric field on the phantom head decreases exponentially while moving sidewards from the center of the effect zone (the ear), and constitutes 1-12% of the artificial head's surface.CONCLUSION: The highest electric field strength values of mobile phones are associated with their higher power, bigger specific energy absorption rate (SAR) and lower frequency of mobile phone. The stronger electric field emitted by the more powerful mobile phones takes a higher percentage of the head surface. The highest electric field strength created by mobile phones is distributed over the user's ear.

**Budak GG**, **Muluk NB**, **Budak B**, **Oztürk GG**, **Apan A**, **Seyhan N**. **Effects of GSM-like radiofrequency on distortion product otoacoustic emissions of rabbits: comparison of infants versus adults. Int J Pediatr Otorhinolaryngol. 73(8):1143-1147, 2009.**

OBJECTIVES: The aim of this study is to investigate the potential hazardous effects of 1800 MHz Global System for Mobile Communications-like (GSM-like) Radiofrequency (RF) exposure on the cochlear functions of female infant and adult rabbits by measuring Distortion Product Otoacoustic Emission (DPOAE) response amplitudes. METHODS: Eighteen each one-month-old New Zealand White female rabbits and eighteen each 13-month-old adult rabbits were included into the study. They were randomly divided into four groups. Nine infant rabbits (Group 1) were not exposed to 1800 MHz GSM-like RF (Infant Control, C-In). Nine infant rabbits (Group 2) were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days after they reached one-month of age (Infant RF, RF-In). Nine adult rabbits were not exposed to 1800 MHz GSM-like RF, 15 min daily for 7 (Adult Control, C-Ad). Nine adult rabbits were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days (Adult RF, RF-Ad). Cochlear functions were assessed by DPOAEs at 1.0-8.0 kHz. RESULTS: At 1.0-2.0 and 6.0 kHz, the mean DPOAE values of Group 2 were significantly higher than that of Group 1. At 3.0-8.0 kHz, the mean DPOAE values of Group 4 were significantly lower than that of Group 1. At 6.0-8.0 kHz, the mean DPOAE values of Group 2 were significantly higher than that of Group 3. At 1.0-8.0 kHz, the mean DPOAE values of Group 4 were significantly lower than that of Group 2. At 1.0-8.0 kHz, the mean DPOAE values of Group 4 were significantly lower than that of Group 3. CONCLUSION: Harmful effects of GSM-like 1800 MHz RF exposure was detected more in the adult female rabbits than infant female rabbits by DPOAE measurement. Prolonged exposure and hyperthermia related to the power density of applied RFR, increasing the temperature in the ear canal, may decrease the DPOAE amplitudes. Water containing medium in the middle ear of infant rabbits may play the protective role from the RF damage.

**Budak GG**, **Muluk NB**, **Oztürk GG**, **Budak B**, **Apan A**, **Seyhan N**, **Sanli C**. **Effects of GSM-like radiofrequency on distortion product otoacoustic emissions in pregnant**

**adult rabbits. Clin Invest Med. 32(2):E112-116, 2009**.

OBJECTIVES: To determine the effects of 1800 MHz GSM-like Radiofrequency (RFR) on the cochlear functions of pregnant adult rabbits by Distortion Product Otoacoustic Emissions (DPOAEs). METHODS: Eighteen 13-month-old pregnant and eighteen 13-month-old non-pregnant New Zealand White rabbits were studied. They were randomly divided into four groups. Nine pregnant rabbits (Group 2) and nine non-pregnant rabbits (Group 4) were exposed to 1800 MHz GSM-like RFR 15 min daily for 7 days. Nine pregnant (Group 1) and nine non-pregnant rabbits (Group 3) were not exposed to GSM like RFR. Cochlear functions were assessed by DPOAEs at 1.0-8.0 kHz. RESULTS: In all pregnant groups except 2.0 kHz, DPOAE amplitudes were not different in Group 2 and Group1. In Group 4, DPOAE amplitudes at 1.0-4.0 kHz (-1.68 dB SPL at 1.0 kHz, 3.05 dB SPL at 1.5 kHz, 2.96 dB SPL at 2.0 kHz, 1.30 dB SPL at 3.0 kHz and 12.22 dB SPL at 4.0 kHz) were lower than Group 3 (8.67 dB SPL at 1.0 kHz, 17.67 dB SPL at 1.5 kHz, 26.10 dB SPL at 2.0 kHz, 18.10 dB SPL at 3.0 kHz and 35.13 dB SPL at 4.0 kHz) ($P < 0.0125$). In the pregnant group, harmful effects of GSM-like RFR were less than in the non-pregnant group. CONCLUSION: GSM-like RFR caused decreases in DPOAE amplitudes mainly in non-pregnant adult rabbits. Prolonged exposure may affect the DPOAE amplitude. Recommendations are given to prevent the potential hazardous effects of RF in humans.

**Budak GG**, **Muluk NB**, **Budak B**, **Oztürk GG**, **Apan A**, **Seyhan N**. **Effects of intrauterine and extrauterine exposure to GSM-like radiofrequency on distortion product otoacoustic emissions in infant male rabbits. Int J Pediatr Otorhinolaryngol. 73(3):391-399, 2009.**

OBJECTIVES: The aim of this study was to investigate the potential hazardous effects of intrauterine (IU) and/or extrauterine (EU) exposure to 1800 MHz Global System for Mobile Communications-like (GSM-like) radiofrequency (RF) on the cochlear functions of infant rabbits by measuring distortion product otoacoustic emission (DPOAE) response amplitudes. METHODS: Thirty-six white infant male New Zealand rabbits each 1-month-old were included in the study. The animals were randomly divided into four groups. Nine infant rabbits (Group 1) were not exposed to 1800 MHz GSM-like RF (Control-C). Nine infant rabbits (Group 2) were exposed to 1800 MHz GSM-like RF, 15 min daily for 14 days after they reached 1-month of age (extrauterine-EU). Nine infant rabbits (Group 3) were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days in the intrauterine period (between 15th and 22nd days of the gestational period) (intrauterine-IU). Nine infant rabbits (Group 4) were exposed to 1800 MHz GSM-like RF, 15 min daily for 7 days in the intrauterine period (between 15th and 22nd days of the gestational period) and 15 min daily for 14 days after they reached to 1-month of age (IU+EU). The cochlear functions were assessed by DPOAEs at 1.0-8.0 kHz. RESULTS: At 1.5 kHz, the mean DPOAE amplitude of Group 3 was higher than that of the controls and Group 2; and the mean DPOAE value of Group 4 was higher than that of the controls and Group 2. At 2.0 kHz, the mean DPOAE amplitude of Group 4 was higher than that of Group 2. At 3.0 kHz, the mean DPOAE amplitude of Group 4 was higher than that of the controls and Group 2. At 4.0 kHz, the mean DPOAE amplitude of Group 2 was lower than that of the controls, while the mean value of Group 4 was higher than the mean value of the controls and Group 2. At 6.0 kHz, the mean DPOAE amplitude of Group 2 was lower than that of the

control group; however, the mean value of Group 4 was higher than that of Group 2. At 1.0 and 8.0 kHz, no significant differences were found among the four groups. CONCLUSION: Prolonged exposure and hyperthermia related to the power density of applied RF, increasing the temperature in the ear canal, may affect DPOAE amplitudes. Harmful effects of RF are mainly observed as a decrease in DPOAE amplitudes at 4.0-6.0 kHz during extrauterine exposure in infancy. During the intrauterine period, the water content of the middle and inner ear and amnion fluid may play a protective role. Therefore, children must be protected from RF exposure. The use of mobile phones at short distances from the ear of the infants should be avoided because of the lower thickness of the anatomical structure in infancy.

**Budinscak V, Goldoni J, Saric M, [Hematologic changes in workers exposed to radio wave radiation]. Arh Hig Rada Toksikol 42(4):367-373, 1991.** [Article in Serbo-Croatian (Roman)]

Haematological parameters were measured in 43 radar operators employed in air traffic control occupationally exposed to microwave radiation of low intensity over a period of four years. Exposure to heat, soft X-ray radiation and noise were within maximally allowed limits. The haematological changes included a decreased number of erythrocytes, reticulocytes, platelets, segmented granulocytes and monocytes, and an increased number of leucocytes and lymphocytes. The changes were not pathologically significant and most of them were reversible.

**Burch JB, Reif JS, Noonan CW, Ichinose T, Bachand AM, Koleber TL, Yost MG. Melatonin metabolite excretion among cellular telephone users. Int J Rad Biol 78: 1029-1036, 2002.**

**Abstract:** Purpose: The relationship between cellular telephone use and excretion of the melatonin metabolite 6-hydroxymelatonin sulfate (6-OHMS) was evaluated in two populations of male electric utility workers (Study 1, n=149; Study 2, n=77). Materials and methods: Participants collected urine samples and recorded cellular telephone use over 3 consecutive workdays. Personal 60-Hz magnetic field (MF) and ambient light exposures were characterized on the same days using EMDEX II meters. A repeated measures analysis was used to assess the effects of cellular telephone use, alone and combined with MF exposures, after adjustment for age, participation month and light exposure. Results: No change in 6-OHMS excretion was observed among those with daily cellular telephone use >25 min in Study 1 (5 worker-days). Study 2 workers with >25 min cellular telephone use per day (13 worker-days) had lower creatinine-adjusted mean nocturnal 6-OHMS concentrations (p=0.05) and overnight 6-OHMS excretion (p=0.03) compared with those without cellular telephone use. There was also a linear trend of decreasing mean nocturnal 6-OHMS/creatinine concentrations (p=0.02) and overnight 6-OHMS excretion (p=0.08) across categories of increasing cellular telephone use. A combined effect of cellular telephone use and occupational 60-Hz MF exposure in reducing 6-OHMS excretion was also observed in Study 2. Conclusions: Exposure-related reductions in 6-OHMS excretion were observed in Study 2, where daily cellular telephone use of >25min was more prevalent. Prolonged use of cellular telephones may lead to reduced melatonin production, and elevated 60-Hz MF exposures may potentiate the effect.

**Burch JB, Clark M, Yost MG, Fitzpatrick CT, Bachand AM, Ramaprasad J, Reif JS.**

**Radio frequency nonionizing radiation in a community exposed to radio and television broadcasting. Environ Health Perspect. 114(2):248-253, 2006.**

Exposure to radio frequency (RF) nonionizing radiation from telecommunications is pervasive in modern society. Elevated disease risks have been observed in some populations exposed to radio and television transmissions, although findings are inconsistent. This study quantified RF exposures among 280 residents living near the broadcasting transmitters for Denver, Colorado. RF power densities outside and inside each residence were obtained, and a global positioning system (GPS) identified geographic coordinates and elevations. A viewshed model within a geographic information system (GIS) characterized the average distance and percentage of transmitters visible from each residence. Data were collected at the beginning and end of a 2.5-day period, and some measurements were repeated 8-29 months later. RF levels logged at 1-min intervals for 2.5 days varied considerably among some homes and were quite similar among others. The greatest differences appeared among homes within 1 km of the transmitters. Overall, there were no differences in mean residential RF levels compared over 2.5 days. However, after a 1- to 2-year follow-up, only 25% of exterior and 38% of interior RF measurements were unchanged. Increasing proximity, elevation, and line-of-sight visibility were each associated with elevated RF exposures. At average distances from > 1-3 km, exterior RF measurements were 13-30 times greater among homes that had > 50% of the transmitters visible compared with homes with </= 50% visibility at those distances. This study demonstrated that both spatial and temporal factors contribute to residential RF exposure and that GPS/GIS technologies can improve RF exposure assessment and reduce exposure misclassification. Key words: broadcasting, electromagnetic fields, exposure assessment, GIS, nonionizing radiation, radio, television.

**Bürgi A , Scanferla D, Lehmann H. Time Averaged Transmitter Power and Exposure to Electromagnetic Fields from Mobile Phone Base Stations. Int. J. Environ. Res. Public Health 11(8), 8025-8037, 2014.**

Models for exposure assessment of high frequency electromagnetic fields from mobile phone base stations need the technical data of the base stations as input. One of these parameters, the *Equivalent Radiated Power* (ERP), is a time-varying quantity, depending on communication traffic. In order to determine temporal averages of the exposure, corresponding averages of the ERP have to be available. These can be determined as *duty factors,* the ratios of the time-averaged power to the maximum output power according to the transmitter setting. We determine duty factors for UMTS from the data of 37 base stations in the Swisscom network. The UMTS base stations sample contains sites from different regions of Switzerland and also different site types (rural/suburban/urban/hotspot). Averaged over all regions and site types, a UMTS duty factor for the 24 h-average is obtained, *i.e.*, the average output power corresponds to about a third of the maximum power. We also give duty factors for GSM based on simple approximations and a lower limit for LTE estimated from the base load on the signalling channels.

**Burlaka A, Tsybulin O, Sidorik E, Lukin S, Polishuk V, Tsehmistrenko S, Yakymenko I. Overproduction of free radical species in embryonal cells exposed to**

**low intensity radiofrequency radiation. Exp Oncol. 2013 Sep;35(3):219-225.**

Aim: Long-term exposure of humans to low intensity radiofrequency electromagnetic radiation (RF-EMR) leads to a statistically significant increase in tumor incidence. Mechanisms of such the effects are unclear, but features of oxidative stress in living cells under RF-EMR exposure were previously reported. Our study aims to assess a production of initial free radical species, which lead to oxidative stress in the cell. Materials and Methods: Embryos of Japanese quails were exposed in ovo to extremely low intensity RF-EMR of GSM 900 MHz (0.25 μW/cm2) during 158-360 h discontinuously (48 c - ON, 12 c - OFF) before and in the initial stages of development. The levels of superoxide (O2·-), nitrogen oxide (NO·), thiobarbituric acid reactive substances (TBARS), 8-oxo-2'-deoxyguanosine (8-oxo-dG) and antioxidant enzymes' activities were assessed in cells/tissues of 38-h, 5- and 10-day RF-EMR exposed and unexposed embryos. Results: The exposure resulted in a significant persistent overproduction of superoxide and nitrogen oxide in embryo cells during all period of analyses. As a result, significantly increased levels of TBARS and 8-oxo-dG followed by significantly decreased levels of superoxide dismutase and catalase activities were developed in the exposed embryo cells. Conclusion: Exposure of developing quail embryos to extremely low intensity RF-EMR of GSM 900 MHz during at least one hundred and fifty-eight hours leads to a significant overproduction of free radicals/reactive oxygen species and oxidative damage of DNA in embryo cells. These oxidative changes may lead to pathologies up to oncogenic transformation of cells.

**Burlaka A, Selyuk M, Gafurov M, Lukin S, Potaskalova V, Sidorik E. Changes in mitochondrial functioning with electromagnetic radiation of ultra high frequency as revealed by electron paramagnetic resonance methods. Int J Radiat Biol. 2014 Mar 6. [Epub ahead of print]**

Purpose: To study the effects of electromagnetic radiation (EMR) of ultra high frequency (UHF) in the doses equivalent to the maximal permitted energy load for the staffs of the radar stations on the biochemical processes that occur in the cell organelles. Materials and Methods: Liver, cardiac and aorta tissues from the male rats exposed to non-thermal UHF EMR in pulsed and continuous modes were studied during 28 days after the irradiation by the electron paramagnetic resonance (EPR) methods including a spin trapping of superoxide radicals. Results: The qualitative and quantitative disturbances in electron transport chain (ETC) of mitochondria are registered. A formation of the iron-nitrosyl complexes of nitric oxide (NO) radicals with the iron-sulphide (FeS) proteins, the decreased activity of FeS-protein N2 of NADH-ubiquinone oxidoreductase complex and flavo ubisemiquinone growth combined with the increased rates of superoxide production are obtained. Conclusions: (1) Abnormalities in the mitochondrial ETC of liver and aorta cells are more pronounced for animals radiated in a pulsed mode. (2) The alterations in the functioning of the mitochondrial ETC cause increase of superoxide radicals generation rate in all samples, formation of cellular hypoxia, and intensification of the oxide-initiated metabolic changes. (3) Electron paramagnetic resonance methods could be used to

track the qualitative and quantitative changes in the mitochondrial ETC caused by the UHF EMR.

**Busljeta I, Trosic I, Milkovic-Kraus S. Erythropoietic changes in rats after 2.45 GJz nonthermal irradiation. Int J Hyg Environ Health.207(6):549-554, 2004.**

The purpose of this study was to observe the erythropoietic changes in rats subchronically exposed to radiofrequency microwave (RF/MW) irradiation at nonthermal level. Adult male Wistar rats (N=40) were exposed to 2.45 GHz continuous RF/MW fields for 2 hours daily, 7 days a week, at 5-10 mW/cm2. Exposed animals were divided into four subgroups (n=10 animals in each subgroup) in order to be irradiated for 2, 8, 15 and 30 days. Animals were sacrified on the final irradiation day of each treated subgroup. Unexposed rats were used as control (N=24). Six animals were included into the each control subgroup. Bone marrow smears were examined to determine absolute counts of anuclear cells and erythropoietic precursor cells. The absolute erythrocyte count, haemoglobin and haematocrit values were observed in the peripheral blood by an automatic cell counter. The bone marrow cytogenetic analysis was accomplished by micronucleus (MN) tests. In the exposed animals erythrocyte count, haemoglobin and haematocrit were increased in peripheral blood on irradiation days 8 and 15. Concurrently, anuclear cells and erythropoietic precursor cells were significantly decreased ($p < 0.05$) in the bone marrow on day 15, but micronucleated cells' frequency was increased. In the applied experimental condition, RF/MW radiation might cause disturbance in red cell maturation and proliferation, and induce micronucleus formation in erythropoietic cells.

**Buttiglione M, Roca L, Montemurno E, Vitiello F, Capozzi V, Cibelli G. Radiofrequency radiation (900 MHz) induces Egr-1 gene expression and affects cell-cycle control in human neuroblastoma cells. J Cell Physiol. 213(3):759-767, 2007.**

Many environmental signals, including ionizing radiation and UV rays, induce activation of Egr-1 gene, thus affecting cell growth and apoptosis. The paucity and the controversial knowledge about the effect of electromagnetic fields (EMF) exposure of nerve cells prompted us to investigate the bioeffects of radiofrequency (RF) radiation on SH-SY5Y neuroblastoma cells. The effect of a modulated RF field of 900 MHz, generated by a wire patch cell (WPC) antenna exposure system on Egr-1 gene expression, was studied as a function of time. Short-term exposures induced a transient increase in Egr-1 mRNA level paralleled with activation of the MAPK subtypes ERK1/2 and SAPK/JNK. The effects of RF radiations on cell growth rate and apoptosis were also studied. Exposure to RF radiation had an anti-proliferative activity in SH-SY5Y cells with a significant effect observed at 24 h. RF radiation impaired cell cycle progression, reaching a significant G2-M arrest. In addition, the appearance of the sub-G1 peak, a hallmark of apoptosis, was highlighted after a 24-h exposure, together with a significant decrease in mRNA levels of Bcl-2 and survivin genes, both interfering with signaling between G2-M arrest and apoptosis. Our results

provide evidence that exposure to a 900 MHz-modulated RF radiation affect both Egr-1 gene expression and cell regulatory functions, involving apoptosis inhibitors like Bcl-2 and survivin, thus providing important insights into a potentially broad mechanism for controlling in vitro cell viability.

**Byun YH, Ha M, Kwon HJ, Hong YC, Leem JH, Sakong J, Kim SY, Lee CG, Kang D, Choi HD, Kim N.Mobile phone use, blood lead levels, and attention deficit hyperactivity symptoms in children: a longitudinal study. PLoS One. 2013;8(3):e59742.**

BACKGROUND: Concerns have developed for the possible negative health effects of radiofrequency electromagnetic field (RF-EMF) exposure to children's brains. The purpose of this longitudinal study was to investigate the association between mobile phone use and symptoms of Attention Deficit Hyperactivity Disorder (ADHD) considering the modifying effect of lead exposure. METHODS: A total of 2,422 children at 27 elementary schools in 10 Korean cities were examined and followed up 2 years later. Parents or guardians were administered a questionnaire including the Korean version of the ADHD rating scale and questions about mobile phone use, as well as socio-demographic factors. The ADHD symptom risk for mobile phone use was estimated at two time points using logistic regression and combined over 2 years using the generalized estimating equation model with repeatedly measured variables of mobile phone use, blood lead, and ADHD symptoms, adjusted for covariates. RESULTS: The ADHD symptom risk associated with mobile phone use for voice calls but the association was limited to children exposed to relatively high lead. CONCLUSIONS:The results suggest that simultaneous exposure to lead and RF from mobile phone use was associated with increased ADHD symptom risk, although possible reverse causality could not be ruled out.

**Cabot E, Christ A, Bühlmann B, Zefferer M, Chavannes N, Bakker JF, van Rhoon GC, Kuster N. Quantification Of RF-exposure of the Fetus Using Anatomical CAD-Models in Three Different Gestational Stages. Health Phys. 107(5):369-381, 2014.**

This study analyzes the exposure of pregnant women and their fetuses in three different gestational stages to electromagnetic radiation in the radio frequency range in the near- and the far-field using numerical modeling. For far-field exposure, the power density at which the basic restriction for the whole body SAR is reached is calculated for both the mother and the fetus at whole body resonance and at frequencies between 450 MHz and 2,450 MHz. The near-field exposure is assessed at 450 MHz, 900 MHz, and 2,450 MHz using half wavelength dipoles as generic sources located at different locations around the abdomen of the mother. For the investigated cases, the exposure of the mother is always below or on the order of magnitude of the basic restriction for exposure at the reference level. When applying the reference levels for the general public, the fetus is sufficiently shielded by the mother. However, the basic restrictions for general public exposure can be exceeded in the fetus when the mother is exposed at reference levels for occupational conditions. For plane wave exposure at occupational levels, the whole body SAR in the fetus can exceed the basic restrictions for the general population by at least 1.8 dB, and

in the near-field of professional devices, the 10 g SAR can be non-compliant with the product standard for the general public by > 3.5 dB.

**Cain CD, Thomas DL, Adey WR, Focus formation of C3H/10T1/2 cells and exposure to a 836.55 MHz modulated radiofrequency field. Bioelectromagnetics 18(3):237-243, 1997.**

Disruption of communication between transformed cells and normal cells is involved in tumor promotion. We have tested the hypothesis that exposures to radiofrequency (RF) fields using a form of digital modulation (TDMA) and a chemical tumor promoter, 12-O-tetradecanoylphorbol-13-acetate (TPA), are copromoters that enhance focus formation of transformed cells in coculture with parental C3H/10T1/2 murine fibroblasts. RF field exposures did not influence TPA's dose-dependent promotion of focus formation in coculture. Cell cultures were exposed to an 836.55 MHz TDMA-modulated field in TEM transmission line chambers, with incident energies that simulated field intensities at a user's head. Specific absorption rates (SARs) of 0.15, 1.5, and 15 muW/g were used during each digital packet, and the packet frequency was 50/s. The TEM chambers were placed in a commercial incubator at 37 degrees C and 95% humidity/5% CO2. The RF field exposures were in a repeating cycle, 20 min on, 20 min off, 24 h/day for 28 days. At 1.5 muW/g, TPA-induced focus formation (at 10, 30, and 50 ng/ml) was not significantly different in RF-exposed cultures compared to parallel sham-exposed cultures in ten independent experiments in terms of the number, density, and area of foci. Similarly, at 0.15 and 15.0 muW/g, in two and four experiments, respectively, RF exposure did not alter TPA-induced focus formation. The findings support a conclusion that repeated exposures to this RF field do not influence tumor promotion in vitro, based on the RF field's inability to enhance TPA-induced focus formation.

**Calabrò E, Condello S, Currò M, Ferlazzo N, Caccamo D, Magazù S, Ientile R. Modulation of heat shock protein response in SH-SY5Y by mobile phone microwaves. World J Biol Chem. 3(2):34-40, 2012.**

AIM: To investigate putative biological damage caused by GSM mobile phone frequencies by assessing electromagnetic fields during mobile phone working. METHODS: Neuron-like cells, obtained by retinoic-acid-induced differentiation of human neuroblastoma SH-SY5Y cells, were exposed for 2 h and 4 h to microwaves at 1800 MHz frequency bands. RESULTS: Cell stress response was evaluated by MTT assay as well as changes in the heat shock protein expression (Hsp20, Hsp27 and Hsp70) and caspase-3 activity levels, as biomarkers of apoptotic pathway. Under our experimental conditions, neither cell viability nor Hsp27 expression nor caspase-3 activity was significantly changed. Interestingly, a significant decrease in Hsp20 expression was observed at both times of exposure, whereas Hsp70 levels were significantly increased only after 4 h exposure. CONCLUSION: The modulation of the expression of Hsps in neuronal cells can be an early response to radiofrequency microwaves.

**Calabrò E, Magazù S.The α-helix alignment of proteins in water solution toward a high-frequency electromagnetic field: A FTIR spectroscopy study. Electromagn Biol Med. 36(3):279-288, 2017.**

The aim of this article was to study the effects of mobile phone electromagnetic waves at 1750 MHz on the Amide I and Amide II vibration bands of some proteins in bidistilled water solution by means of Fourier transform infrared (FTIR) spectroscopy and Fourier self-deconvolution (FSD) analysis. The proteins that were used for the experiment were hemoglobin, myoglobin, bovine serum albumin and lysozyme. The exposure system consisted of microwaves emitted by an operational mobile phone at the frequency at 1750 MHz at the average power density of 1 $W/m^2$. Exposed and control samples were analyzed using FTIR spectroscopy and FSD analysis. The main result was that Amide I band of the proteins that were used increased significantly ($p < 0.05$) after 4 h of exposure to MWs, whereas Amide II band did not change significantly. This result can be explained assuming that the α-helix structure of the proteins aligned itself with the direction of the electromagnetic field due to the alignment of C = O stretching and N - H bending ligands that are oriented along with the α-helix axis that give rise to the Amide I mode.

**Calcagnini G, Floris M, Censi F, Cianfanelli P, Scavino G, Bartolini P. Electromagnetic interference with infusion pumps from GSM mobile phones. Health Phys. 90(4):357-360, 2006.**

Electromagnetic interference with critical medical care devices has been reported by various groups. Previous studies have demonstrated that volumetric and syringe pumps are susceptible to false alarm buzzing and blocking when exposed to various electromagnetic sources. The risk of electromagnetic interference depends on several factors such as the phone-emitted power, distance, and carrier frequency. The aim of this study was to assess the risk of GSM phone-induced electromagnetic interference with volumetric and syringe pumps, at various distances and emitted powers. Malfunctions were observed in 6 out of 8 volumetric pumps and in 1 out of 4 syringe pumps exposed to mobile phones at their maximum output, at distances up to 30 cm. The maximum power that did not induce any malfunction at zero distance was 50 mW at 900 MHz and 2.5 mW at 1,800 MHz. In state-of-the-art pumps, the presence of moderate-good base station coverage would significantly reduce the risk of electromagnetic interference.

**Calderón C, Addison D, Mee T, Findlay R, Maslanyj M, Conil E, Kromhout H, Lee AK, Sim MR, Taki M, Varsier N, Wiart J, Cardis E. Assessment of extremely low frequency magnetic field exposure from GSM mobile phones. Bioelectromagnetics. 2013 Nov 6. doi: 10.1002/bem.21827. [Epub ahead of print]**

Although radio frequency (RF) electromagnetic fields emitted by mobile phones have received much attention, relatively little is known about the extremely low frequency (ELF) magnetic fields emitted by phones. This paper summarises ELF magnetic flux density measurements on global system for mobile communications (GSM) mobile phones, conducted as part of the MOBI-KIDS epidemiological study. The main challenge is to identify a small number of generic phone models that can be used to classify the ELF exposure for the different phones reported in the study. Two-dimensional magnetic flux density measurements were performed on 47 GSM mobile phones at a distance of 25 mm. Maximum resultant magnetic flux density values at 217 Hz had a geometric mean of 221 (+198/-104) nT. Taking into account harmonic data, measurements suggest that mobile phones could make a substantial

contribution to ELF exposure in the general population. The maximum values and easily available variables were poorly correlated. However, three groups could be defined on the basis of field pattern indicating that manufacturers and shapes of mobile phones may be the important parameters linked to the spatial characteristics of the magnetic field, and the categorization of ELF magnetic field exposure for GSM phones in the MOBI-KIDS study may be achievable on the basis of a small number of representative phones. Such categorization would result in a twofold exposure gradient between high and low exposure based on type of phone used, although there was overlap in the grouping.

**Calvente I, Fernández MF, Pérez-Lobato R, Dávila-Arias C, Ocón O, Ramos R, Ríos-Arrabal S, Villalba-Moreno J, Olea N, Núñez MI. Outdoor characterization of radio frequency electromagnetic fields in a Spanish birth cohort. Environ Res. 2015 Feb 20;138C:136-143. doi: 10.1016/j.envres.2014.12.013. [Epub ahead of print]**

There is considerable public concern in many countries about the possible adverse effects of exposure to non-ionizing radiation electromagnetic fields, especially in vulnerable populations such as children. The aim of this study was to characterize environmental exposure profiles within the frequency range 100kHz-6GHz in the immediate surrounds of the dwellings of 123 families from the INMA-Granada birth cohort in Southern Spain, using spot measurements. The arithmetic mean root mean-square electric field ($E_{RMS}$) and power density ($S_{RMS}$) values were, respectively, 195.79mV/m (42.3% of data were above this mean) and 799.01μW/m$^2$ (30% of values were above this mean); median values were 148.80mV/m and 285.94μW/m$^2$, respectively. Exposure levels below the quantification limit were assigned a value of 0.01V/m. Incident field strength levels varied widely among different areas or towns/villages, demonstrating spatial variability in the distribution of exposure values related to the surface area population size and also among seasons. Although recorded values were well below International Commission for Non-Ionizing Radiation Protection reference levels, there is a particular need to characterize incident field strength levels in vulnerable populations (e.g., children) because of their chronic and ever-increasing exposure. The effects of incident field strength have not been fully elucidated; however, it may be appropriate to apply the precautionary principle in order to reduce exposure in susceptible groups.

**Calvente I, Pérez-Lobato R, Núñez MI, Ramos R, Guxens M, Villalba J, Olea N, Fernández MF. Does exposure to environmental radiofrequency electromagnetic fields cause cognitive and behavioral effects in 10-year-old boys? Bioelectromagnetics. 37(1):25-36, 2016.**

The relationship between exposure to electromagnetic fields from non-ionizing radiation and adverse human health effects remains controversial. We aimed to explore the association of environmental radiofrequency-electromagnetic fields (RF-EMFs) exposure with neurobehavioral function of children. A subsample of 123 boys belonging to the Environment and Childhood cohort from Granada (Spain), recruited at birth from 2000 through 2002, were evaluated at the age of 9-11 years. Spot electric field measurements within the 100 kHz to 6 GHz frequency range, expressed as both root mean-square

(SRMS ) and maximum power density (SMAX ) magnitudes, were performed in the immediate surrounds of childreńs dwellings. Neurocognitive and behavioral functions were assessed with a comprehensive battery of tests. Multivariate linear and logistic regression models were used, adjusting for potential confounders. All measurements were lower than reference guideline limits, with median SRMS and SMAX values of 285.94 and 2759.68 μW/m(2) , respectively. Most of the cognitive and behavioral parameters did not show any effect, but children living in higher RF exposure areas (above median SRMS levels) had lower scores for verbal expression/comprehension and higher scores for internalizing and total problems, and obsessive-compulsive and post-traumatic stress disorders, in comparison to those living in areas with lower exposure. These associations were stronger when SMAX values were considered. Although some of our results may suggest that low-level environmental RF-EMF exposure has a negative impact on cognitive and/or behavior development in children; given limitations in the study design and that the majority of neurobehavioral functioning tasks were not affected, definitive conclusions cannot be drawn.

**Cam ST, Seyhan N. Single-strand DNA breaks in human hair root cells exposed to mobile phone radiation. Int J Radiat Biol.88(5):420-424, 2012.**

Abstract. Purpose: To analyze the short term effects of radiofrequency radiation (RFR) exposure on genomic deoxyribonucleic acid (DNA) of human hair root cells. Subjects and methods: Hair samples were collected from 8 healthy human subjects immediately before and after using a 900-MHz GSM (Global System for Mobile Communications) mobile phone for 15 and 30 minutes. Single-strand DNA breaks of hair root cells from the samples were determined using the 'comet assay'. Results: The data showed that talking on a mobile phone for 15 or 30 minutes significantly increased ($p < .05$) single-strand DNA breaks in cells of hair roots close to the phone. Comparing the 15-min and 30-min data using the paired t-test also showed that significantly more damages resulted after 30 minutes than after 15 minutes of phone use. Conclusions: A short-term exposure (15 and 30 minutes) to RFR (900-MHz) from a mobile phone caused a significant increase in DNA single-strand breaks in human hair root cells located around the ear which is used for the phone calls.

**Cam ST, Seyhan N, Kavaklı C, Celikbıçak O. Effects of 900 MHz Radiofrequency Radiation on Skin Hydroxyproline Contents. Cell Biochem Biophys. 2014 Apr 24. [Epub ahead of print]**

The present study aimed to investigate the possible effect of pulse-modulated radiofrequency radiation (RFR) on rat skin hydroxyproline content, since skin is the first target of external electromagnetic fields. Skin hydroxyproline content was measured using liquid chromatography mass spectrometer method. Two months old male wistar rats were exposed to a 900 MHz pulse-modulated RFR at an average whole body specific absorption rate (SAR) of 1.35 W/kg for 20 min/day for 3 weeks. The radiofrequency (RF) signals were pulse modulated by rectangular pulses with a repetition frequency of 217 Hz and a duty cycle of 1:8 (pulse width 0.576 ms). A skin biopsy was taken at the upper part of the abdominal costa after the exposure. The data indicated that whole body exposure to a pulse-modulated RF radiation that is similar to that emitted by

the global system for mobile communications (GSM) mobile phones caused a statistically significant increase in the skin hydroxyproline level (p = 0.049, Mann-Whitney U test). Under our experimental conditions, at a SAR less than the International Commission on Non-Ionizing Radiation Protection safety limit recommendation, there was evidence that GSM signals could alter hydroxyproline concentration in the rat skin.

**Cammaerts MC, De Doncker P, Patris X, Bellens F, Rachidi Z, Cammaerts D. GSM 900 MHz radiation inhibits ants' association between food sites and encountered cues. Electromagn Biol Med. 31(2):151-165, 2012.**

The kinetics of the acquisition and loss of the use of olfactory and visual cues were previously obtained in six experimental colonies of the ant Myrmica sabuleti meinert 1861, under normal conditions. In the present work, the same experiments were conducted on six other naive identical colonies of M. sabuleti, under electromagnetic radiation similar to those surrounding GSM and communication masts. In this situation, no association between food and either olfactory or visual cues occurred. After a recovery period, the ants were able to make such an association but never reached the expected score. Such ants having acquired a weaker olfactory or visual score and still undergoing olfactory or visual training were again submitted to electromagnetic waves. Not only did they lose all that they had memorized, but also they lost it in a few hours instead of in a few days (as under normal conditions when no longer trained). They kept no visual memory at all (instead of keeping 10% of it as they normally do). The impact of GSM 900 MHz radiation was greater on the visual memory than on the olfactory one. These communication waves may have such a disastrous impact on a wide range of insects using olfactory and/or visual memory, i.e., on bees.

**Cammaerts MC, Debeir O, Cammaerts R. Changes in Paramecium caudatum (protozoa) near a switched-on GSM telephone. Electromagn Biol Med. 30(1):57-66, 2011.**

The protozoan Paramecium caudatum was examined under normal conditions versus aside a switched-on GSM telephone (900 MHz; 2 Watts). Exposed individuals moved more slowly and more sinuously than usual. Their physiology was affected: they became broader, their cytopharynx appeared broader, their pulse vesicles had difficult in expelling their content outside the cell, their cilia less efficiently moved, and trichocysts became more visible. All these effects might result from some bad functioning or damage of the cellular membrane. The first target of communication electromagnetic waves might thus be the cellular membrane.

**Cammaerts MC, Rachidi Z, Bellens F, De Doncker P. Food collection and response to pheromones in an ant species exposed to electromagnetic radiation. Electromagn Biol Med. 2013 Jan 15. [Epub ahead of print]**

We used the ant species Myrmica sabuleti as a model to study the impact of electromagnetic waves on social insects' response to their pheromones and their food

collection. We quantified M. sabuleti workers' response to their trail, area marking and alarm pheromone under normal conditions. Then, we quantified the same responses while under the influence of electromagnetic waves. Under such an influence, ants followed trails for only short distances, no longer arrived at marked areas and no longer orientated themselves to a source of alarm pheromone. Also when exposed to electromagnetic waves, ants became unable to return to their nest and recruit congeners; therefore, the number of ants collecting food increases only slightly and slowly. After 180 h of exposure, their colonies deteriorated. Electromagnetic radiation obviously affects social insects' behavior and physiology.

**Cammaerts M-C, Vandenbosch GAE, Volski V. Effect of short-term GSM radiation at representative levels in society on a biological model: the ant Myrmica sabuleti. J Insect Beh. 27(4):514-526. 2014.**

Well-controlled electromagnetic exposure conditions were set up at a representative societal GSM radiation intensity level, 1.5 V/m, which is the legally allowed level in Brussels. Two nests of the ant species Myrmica sabuleti were repeatedly irradiated during 10 min. before their behavior was observed, based on the analysis of the ant trajectories. Under these exposure conditions, behavioral effects were detected. The ants' locomotion slightly changed. The ants' orientation towards their attractive alarm pheromone statistically became of lower quality. The ants still presented their trail following behavior but less efficiently. In this controversial issue, ants could be considered as possible bioindicators.

**Campisi A, Gulino M, Acquaviva R, Bellia P, Raciti G, Grasso R, Musumeci F, Vanella A, Triglia A. Reactive oxygen species levels and DNA fragmentation on astrocytes in primary culture after acute exposure to low intensity microwave electromagnetic field. Neurosci Lett.31 473(1):52-55, 2010.**

The exposure of primary rat neocortical astroglial cell cultures to acute electromagnetic fields (EMF) in the microwave range was studied. Differentiated astroglial cell cultures at 14 days in vitro were exposed for 5, 10, or 20min to either 900MHz continuous waves or 900MHz waves modulated in amplitude at 50Hz using a sinusoidal waveform and 100% modulation index. The strength of the electric field (rms value) at the sample position was 10V/m. No change in cellular viability evaluated by MTT test and lactate dehydrogenase release was observed. A significant increase in ROS levels and DNA fragmentation was found only after exposure of the astrocytes to modulated EMF for 20min. No evident effects were detected when shorter time intervals or continuous waves were used. The irradiation conditions allowed the exclusion of any possible thermal effect. Our data demonstrate, for the first time, that even acute exposure to low intensity EMF induces ROS production and DNA fragmentation in astrocytes in primary cultures, which also represent the principal target of modulated EMF. Our findings also suggest the hypothesis that the effects could be due to hyperstimulation of the glutamate receptors, which play a crucial role in acute and chronic brain damage. Furthermore, the results show the importance of the amplitude modulation in the interaction

between EMF and neocortical astrocytes.

**Canseven AG, Esmekaya MA, Kayhan H, Tuysuz MZ, Seyhan N. Effects of microwave exposure and Gemcitabine treatment on apoptotic activity in Burkitt's lymphoma (Raji) cells. Electromagn Biol Med. 2014 Jun 5:1-5. [Epub ahead of print]**

We investigated the effects of 1.8 MHz Global System for Mobile Communications (GSM)-modulated microwave (MW) radiation on apoptotic level and cell viability of Burkitt's lymphoma (Raji) cells with or without Gemcitabine, which exhibits cell phase specificity, primarily killing cells undergoing DNA synthesis (S-phase). Raji cells were exposed to 1.8 GHz GSM-modulated MW radiation at a specific absorption rate (SAR) of 0.350 W/kg in a $CO_2$ incubator. The duration of the exposure was 24 h. The amount of apoptotic cells was analyzed using Annexin V-FITC and propidium iodide (PI) staining with flow cytometer. The apoptotic activity of MW exposed Raji cells was increased significantly. In addition, cell viability of exposed samples was significantly decreased. Combined exposure of MW and Gemcitabine increased the amount of apoptotic cells than MW radiation alone. Moreover, viability of MW + Gemcitabine exposed cells was lower than that of cells exposed only to MW. These results demonstrated that MW radiation exposure and Gemcitabine treatment have a synergistic effect on apoptotic activity of Raji cells.

**Cao G, Liu LM, Cleary SF, Cell cycle alterations induced by isothermal 27 MHz radio-frequency radiation exposure. Bioelectrochem Bioenerg 37(2):131-140, 1995.**

The purpose of this study was to test the hypothesis that 27 MHz continuous-wave radio-frequency radiation can alter the mammalian cell cycle in the absence of radiation-induced heating. Relative effects of r.f. radiation on specific phases of the cell cycle were determined by exposing synchronized Chinese hamster ovary (CHO) cells in $G_0/G_1$ -, S- or $G_0/G_1$ -phase. The dose-rate dependence of r.f. radiation-induced direct cell-cycle alterations was investigated by exposing CHO cells for 2 h to 5 or 25 W $kg^{-1}$ under isothermal conditions in vitro. Cell cycle alterations were determined by flow cytofluorometric DNA determinations conducted over a period of 4 days after exposure. The DNA distributions of r.f.- or sham-exposed CHO cell samples were compared qualitatively by direct comparison of overlaid and difference distribution. A quantitative measure of the magnitude of the r.f.-induced CHO cell-cycle alterations was obtained by summation of the absolute value of the difference in the number of cells in all regions of the DNA distribution. The precision of the cytoflorometric assay was determined by comparison of DNA distributions of replicate CHO cell samples. The r.f. exposure induced time- and dose-rate-dependent cell cycle alterations. Maximum responses occurred 3 days after exposure at a specific absorption rate (SAR) of 25 W $kg^{-1}$. Comparison of temporal responses of cells exposed to 5 W $kg^{-1}$ vs. 25 W $kg^{-1}$ indicated an interaction of r.f. exposure intensity with cell cycle phase. In contrast to r.f.-radiation-induced alterations in the cycles of CHO cells exposed during $G_0/G_1$ - or S-phase, there were minimal effects on $G_2/M$ -phase CHO cells at either SAR, indicating lessened sensitivity of this cell cycle phase. Whereas $G_0/G_1$ - or S-phase cells exposed to either SAR approached

baseline levels of alteration by 4 days after exposure, there was a statistically significant increased alteration in cells exposed at 25 W $kg^{-1}$ relative to cells exposed at 5 W $kg^{-1}$. This indicated an r.f.-dose-rate-dependent effect on the duration of cell cycle alterations.

**Cao H, Qin F, Liu X, Wang J, Cao Y, Tong J, Zhao H. Circadian Rhythmicity of Antioxidant Markers in Rats Exposed to 1.8 GHz Radiofrequency Fields. Int J Environ Res Public Health. 12(2):2071-2087, 2015.**

BACKGROUND: The potential health risks of exposure to Radiofrequency Fields (RF) emitted by mobile phones are currently of considerable public interest, such as the adverse effects on the circadian rhythmicities of biological systems. To determine whether circadian rhythms of the plasma antioxidants (Mel, GSH-Px and SOD) are affected by RF, we performed a study on male Sprague Dawley rats exposed to the 1.8 GHz RF. METHODS: All animals were divided into seven groups. The animals in six groups were exposed to 1.8 GHz RF (201.7 μW/cm2 power density, 0.05653 W/kg specific absorption rate) at a specific period of the day (3, 7, 11, 15, 19 and 23 h GMT, respectively), for 2 h/day for 32 consecutive days. The rats in the seventh group were used as sham-exposed controls. At the end of last RF exposure, blood samples were collected from each rat every 4 h (total period of 24 h) and also at similar times from sham-exposed animals. The concentrations of three antioxidants (Mel, GSH-Px and SOD) were determined. The data in RF-exposed rats were compared with those in sham-exposed animals. RESULTS: circadian rhythms in the synthesis of Mel and antioxidant enzymes, GSH-Px and SOD, were shifted in RF-exposed rats compared to sham-exposed animals: the Mel, GSH-Px and SOD levels were significantly decreased when RF exposure was given at 23 and 3 h GMT. CONCLUSION: The overall results indicate that there may be adverse effects of RF exposure on antioxidant function, in terms of both the daily antioxidative levels, as well as the circadian rhythmicity.

**Cao XZ, Zhao ML, Wang DW, Dong B. [Apoptosis of human lung carcinoma cell line GLC-82 induced by high power electromagnetic pulse] Ai Zheng 21(9):929-933, 2002.** [Article in Chinese]

BACKGROUND & OBJECTIVE: Electromagnetic pulse (EMP) could be used for sterilization of food and the efficiency is higher than 2450 MHz continuous microwave done. This study was designed to evaluate the effect of electromagnetic pulse (EMP) on apoptosis of human lung carcinoma cell line GLC-82, so that to explore and develop therapeutic means for cancer. METHODS: The injury changes in GLC-82 cells after irradiated with EMP (electric field intensity was 60 kV/m, 5 pulses/2 min) were analyzed by cytometry, MTT chronometry, and flow cytometry. The immunohistochemical SP staining was used to determine the expressions of bcl-2 protein and p53 protein. The stained positive cells were analyzed by CMIAS-II image analysis system at a magnification 400. All data were analyzed by SPSS8.0 software. RESULTS: EMP could obviously inhibited proliferation and activity of lung carcinoma cell line GLC-82. The absorbance value (A570) of MTT decreased immediately, at 0 h, 1 h, and 6 h after the GLC-82 cells irradiated by EMP as compared with control group. The highest apoptosis rate was found to reach 13.38% by flow cytometry at 6 h after EMP irradiation. Down-

regulation of bcl-2 expression and up-regulation of p53 expression were induced by EMP. CONCLUSION: EMP promotes apoptosis of GLC-82 cells. At same time, EMP can down-regulate bcl-2 expression and up-regulate p53 expression in GLC-82 cells. The bcl-2 and the p53 protein may involve the apoptotic process.

**Cao Y, Xu Q, Lu MX, Jin ZD, DU HB, Li JX, Nie JH, Tong J. [Antagonistic effect of microwave on hematopoietic damage of mice induced by gamma-ray irradiation.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):525-529, 2009.** [Article in Chinese]

OBJECTIVE: To investigate antagonistic effect of microwave on hematopoietic damage of mice induced by gamma-ray irradiation. METHODS: Male healthy Kunning mice were treated with low dose microwave radiation before exposure to (60)Co gamma-ray irradiation of 8.0 Gy. The 30-day survival rate and average survival time of the mice after the treatment were examined. Peripheral blood parameters and the organ indexes of thymus and spleen were also observed in the irradiated mice. After exposure to 5.0 Gy gamma irradiation, indexes of hematopoietic foci formation of bone marrow cells (CFU-GM) and the proliferation activity of BMNCs were examined. The serum concentration of hemopoietic factors (GM-CSF and IL-3) were detected by ELISA kits. RESULTS: Pre-exposure with 120 microW/cm(2) 900 MHz microwave increased the 30-day survival rate ($P < 0.05$) and the number of white blood cells of gamma-ray treated mice. The increases of the organ indexes of thymus and spleen, proliferation activity of BMNCs and CFU-GM hematopoietic foci numbers, as well as the higher serum concentration of GM-CSF and IL-3 were observed in the microwave pre-exposure group. CONCLUSION: Low dose microwave radiation may exert potential antagonistic effects on hematopoietic injuries induced by ionizing radiation. The underlying mechanisms might be related with stimulation of hematopoietic growth factors expression, promotion of HSCs/HPCs proliferation, suppression on the reduction of HSCs/HPCs caused by (60)Co gamma-ray, and enhanced construction of the hematopoietic system.

**Cao Y, Zhang W, Lu MX, Xu Q, Meng QQ, Nie JH, Tong J. 900-MHz microwave radiation enhances gamma-ray adverse effects on SHG44 cells. J Toxicol Environ Health A. 72(11):727-732, 2009.**

Mobile phones are widely used globally. However, the biological effects due to exposure to electromagnetic fields (EMF) produced by mobile phones are largely unknown. Environmental and occupational exposure of humans to gamma-rays is a biologically relevant phenomenon. Consequently studies were undertaken to examine the interactions between gamma-rays and EMF on human health. In this study, exposure to 900-MHz EMF expanded gamma-ray damage to SHG44 cells. Preexposure EMF enhanced the decrease in cell proliferation induced by gamma-ray irradiation and the rate of apoptosis. The combination of EMF and gamma-ray exposure resulted in a synergistic effect by triggering stress response, which increased reactive oxygen species, but the expression of hsp70 at both mRNA and protein levels remained unaltered. Data indicate that the adverse effects of gamma-rays on cellular functions are strengthened by EMF.

**Cao Y, Xu Q, Lu MX, Jin ZD, DU HB, Li JX, Nie JH, Tong J. [Antagonistic effect of microwave on hematopoietic damage of mice induced by gamma-ray**

**irradiation.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):525-529, 2009.** [Article in Chinese]

OBJECTIVE: To investigate antagonistic effect of microwave on hematopoietic damage of mice induced by gamma-ray irradiation. METHODS: Male healthy Kunning mice were treated with low dose microwave radiation before exposure to (60)Co gamma-ray irradiation of 8.0 Gy. The 30-day survival rate and average survival time of the mice after the treatment were examined. Peripheral blood parameters and the organ indexes of thymus and spleen were also observed in the irradiated mice. After exposure to 5.0 Gy gamma irradiation, indexes of hematopoietic foci formation of bone marrow cells (CFU-GM) and the proliferation activity of BMNCs were examined. The serum concentration of hemopoietic factors (GM-CSF and IL-3) were detected by ELISA kits. RESULTS: Pre-exposure with 120 microW/cm(2) 900 MHz microwave increased the 30-day survival rate ($P < 0.05$) and the number of white blood cells of gamma-ray treated mice. The increases of the organ indexes of thymus and spleen, proliferation activity of BMNCs and CFU-GM hematopoietic foci numbers, as well as the higher serum concentration of GM-CSF and IL-3 were observed in the microwave pre-exposure group. CONCLUSION: Low dose microwave radiation may exert potential antagonistic effects on hematopoietic injuries induced by ionizing radiation. The underlying mechanisms might be related with stimulation of hematopoietic growth factors expression, promotion of HSCs/HPCs proliferation, suppression on the reduction of HSCs/HPCs caused by (60)Co gamma-ray, and enhanced construction of the hematopoietic system.

**Cao Y, Xu Q, Jin ZD, Zhang J, Lu MX, Nie JH, Tong J. Effects of 900-MHz microwave radiation on gamma-ray-induced damage to mouse hematopoietic system. J Toxicol Environ Health A. 73(7):507-513, 2010.**

Exposure of humans simultaneously to microwave and gamma-ray irradiation may be a commonly encountered phenomenon. In a previous study data showed that low-dose microwave radiation increased the survival rate of mice irradiated with 8Gy gamma-ray; however, the mechanisms underlying these findings remain unclear. Consequently, studies were undertaken to examine the effects of microwave exposure on hematopoietic system adversely altered by gamma-ray irradiation in mice. Preexposure to low-dose microwaves attenuated the damage produced by gamma-ray irradiation as evidenced by less severe pathological alterations in bone marrow and spleen. The protective effects of microwaves were postulated to be due to up-expression of some hematopoietic growth factors, stimulation of proliferation of the granulocyte-macrophages in bone marrow, and inhibition of the gamma-ray induced suppression of hematopoietic stem cells/hematopoietic progenitor cells. Data thus indicate that prior exposure to microwaves may be beneficial in providing protection against injuries produced by gamma-ray on the hematopoietic system in mice.

**Cao Y, Xu Q, Jin ZD, Zhou Z, Nie JH, Tong J. Induction of adaptive response: pre-exposure of mice to 900 MHz radiofrequency fields reduces hematopoietic damage**

**caused by subsequent exposure to ionising radiation. Int J Radiat Biol. 87(7):720-728, 2011.**

PURPOSE: To investigate whether an adaptive response can be induced in mice which were pre-exposed to 900 MHz radiofrequency fields. MATERIALS AND METHODS: Adult male Kunming mice were exposed to 900 MHz radiofrequency fields (RF) at power intensities of 12, 120 and 1200 μW/cm(2) for 1 h/day for 14 days and then subjected to whole body gamma-irradiation. The results were compared with those in unexposed control animals and those exposed to gamma-irradiation alone (without pre-exposure to RF). The extent of survival and hematopoietic tissue damage (assessed in the form of nucleated colony forming cells in the bone marrow and colony forming cells in the spleen of lethally irradiated 'recipient' mice) as well as the expression of cell cycle-related genes were investigated. RESULTS: The results indicated a significant increase in survival time, reduction in the hematopoietic tissue damage in RF pre-exposed mice which were gamma-irradiated (as compared with those exposed to gamma-radiation alone). This was accompanied by significantly increased expression of cell cycle-related genes, namely, cyclin-D1, cyclin-E, cyclin-DK4 and cyclin-DK2 in hematopoietic cells. CONCLUSIONS: Pre-exposure of mice to 900 MHz radiofrequency fields has resulted in a significant reduction in hematopoietic damage caused by subsequent exposure to ionising radiation. This phenomenon appears to be similar to that of the 'adaptive response' which is well documented in scientific literature.

**Cao Z, Liu J, Li S, Zhao X. [Effects of electromagnetic radiation from handsets of cellular telephone on neurobehavioral function] Wei Sheng Yan Jiu 29(2):102-103, 2000.** [Article in Chinese]

In order to study the effects of electromagnetic radiation from handsets of cellular telephone on neurobehavioral function, 81 staff with handsets of cellular telephone and 63 staff without handsets of cellular telephone from corporations were selected as the subjects. The subjects were investigated by questionnaire on their general health, lifestyle habit, suppress of spirit, handset using of cellular telephone, environmental exposure, morbidity, and the neurobehavioral core test battery(NCTB). The data was analyzed by chi-square, stepwise regression analysis and covariance statistics. The results showed that the average reaction time in user's group was longer than that in control group ($P < 0.01$). The time of using handset was negatively associated with corrected reaction number ($P < 0.01$). The fast reaction time and the slowest reaction time were positively associated with the length of handset using ($P < 0.01$, $P < 0.05$). The results suggested that the handset using could cause adverse health effects in neurobehavioral function.

**Capri M, Scarcella E, Bianchi E, Fumelli C, Mesirca P, Agostini C, Remondini D, Schuderer J, Kuster N, Franceschi C, Bersani F.1800 MHz radiofrequency (mobile phones, different global system for mobile communication modulations) does not affect apoptosis and heat shock protein 70 level in peripheral blood mononuclear cells from young and old donors. Int J Radiat Biol. 80(6):389-397, 2004.**

PURPOSE: To study if prolonged in vitro exposure to 1800MHz radiofrequency (RF) could exert an effect on human peripheral blood mononuclear cells (PBMC) from young

and elderly donors by affecting apoptosis, mitochondrial membrane potential and heat shock protein (HSP) 70 levels. MATERIALS AND METHODS: Endpoints were analysed in the presence or absence of the apoptosis-inducing agent 2-deoxy-D-ribose. Three different signal modulations typical of the Global System for Mobile communication (GSM) system were applied. The modulations are widely used in mobile telephony (GSM Basic, discontinuous transmission [DTX] and Talk) at specific absorption rates of 1.4 and 2.0 W kg(-1). RESULTS: In all conditions and for all endpoints tested, there was no significant difference between RF- and sham-exposed cells. CONCLUSION: 1800MHz RF could not induce apoptosis by itself or affect the apoptotic phenomenon when induced by an apoptotic agent. Moreover, RF did not modify the mitochondrial functionality and the expression of HSP 70.

**Capri M, Scarcella E, Fumelli C, Bianchi E, Salvioli S, Mesirca P, Agostini C, Antolini A, Schiavoni A, Castellani G, Bersani F, Franceschi C. In vitro exposure of human lymphocytes to 900 MHz CW and GSM modulated radiofrequency: studies of proliferation, apoptosis and mitochondrial membrane potential. Radiat Res. 162(2):211-218, 2004**.

The aim of this study was to investigate the nonthermal effects of radiofrequency (RF) fields on human immune cells exposed to a Global System for Mobile Communication (GSM) signal generated by a commercial cellular phone and by a sinusoidal non-modulated signal. To assess whether mobile phone RF-field exposure affects human immune cell functions, peripheral blood mononuclear cells (PBMCs) from healthy donors were exposed in vitro to a 900 MHz GSM or continuous-wave (CW) RF field 1 h/day for 3 days in a transverse electromagnetic mode (TEM) cell system (70-76 mW/kg average specific absorption rate, SAR). The cells were cultured for 48 or 72 h, and the following end points were studied: (1) mitogen-induced proliferation; (2) cell cycle progression; (3) spontaneous and 2-deoxy-D-ribose (dRib)-induced apoptosis; (4) mitochondrial membrane potential modifications during spontaneous and dRib-induced-apoptosis. Data obtained from cells exposed to a GSM-modulated RF field showed a slight decrease in cell proliferation when PBMCs were stimulated with the lowest mitogen concentration and a slight increase in the number of cells with altered distribution of phosphatidylserine across the membrane. On the other hand, cell cycle phases, mitochondrial membrane potential and susceptibility to apoptosis were found to be unaffected by the RF field. When cells were exposed to a CW RF field, no significant modifications were observed in comparison with sham-exposed cells for all the end points investigated.

**Capri M, Salvioli S, Altilia S, Sevini F, Remondini D, Mesirca P, Bersani F, Monti D, Franceschi CAge-Dependent Effects of in Vitro Radiofrequency Exposure (Mobile Phone) on CD95+ T Helper Human Lymphocytes. Ann N Y Acad Sci. 1067:493-499, 2006.**

.Recent studies on "nonthermal" effects of mobile phone radiofrequency (RF) suggest that RF can interact with cellular functions and molecular pathways. To study the possible RF effects on human lymphocyte activation, we analyzed CD25, CD95, CD28 molecules in unstimulated and stimulated CD4+ e CD8+ T cells in vitro. Peripheral blood mononuclear cells (PBMCs) from young and elderly donors were exposed or sham-exposed to RF (1,800 MHz, Specific Absorption Rate 2 W/kg) with or without mitogenic

stimulation. No significant changes in the percentage of these cell subsets were found between exposed and sham-exposed lymphocytes in both young and elderly donors. Nevertheless, after RF exposure we observed a slight, but significant, downregulation of CD95 expression in stimulated CD4+ T lymphocytes from elderly, but not from young donors. This age-related result is noteworthy given the importance of such a molecule in regulation of the immune response.

**Caraglia M, Marra M, Mancinelli F, D'Ambrosio G, Massa R, Giordano A, Budillon A, Abbruzzese A, Bismuto E. Electromagnetic fields at mobile phone frequency induce apoptosis and inactivation of the multi-chaperone complex in human epidermoid cancer cells. J Cell Physiol. 204(2):539-548, 2005.**

The exposure to non-thermal microwave electromagnetic field (MW-EMF) at 1.95 MHz, a frequency used in mobile communication, affects the refolding kinetics of eukaryotic proteins (Mancinelli et al., 2004). On these basis we have evaluated the in vivo effect of MW-EMF in human epidermoid cancer KB cells. We have found that MW-EMF induces time-dependent apoptosis (45% after 3 h) that is paralleled by an about 2.5-fold decrease of the expression of ras and Raf-1 and of the activity of ras and Erk-1/2. Although also the expression of Akt was reduced its activity was unchanged likely as a consequence of the increased expression of its upstream activator PI3K. In the same experimental conditions an about 2.5-fold increase of the ubiquitination of ras and Raf-1 was also found and the addition for 12 h of proteasome inhibitor lactacystin at 10 microM caused an accumulation of the ubiquitinated isoforms of ras and Raf-1 and counteracted the effects of MW-EMF on ras and Raf-1 expression suggesting an increased proteasome-dependent degradation induced by MW-EMF. The exposure of KB cells to MW-EMF induced a differential activation of stress-dependent pathway with an increase of JNK-1 activity and HSP70 and 27 expression and with a reduction of p38 kinase activity and HSP90 expression. The overexpression of HSP90 induced by transfection of KB cells with a plasmid encoding for the factor completely antagonized the apoptosis and the inactivation of the ras --> Erk-dependent survival signal induced by MW-EMF. Conversely, the inhibition of Erk activity induced by 12 h exposure to 10 mM Mek-1 inhibitor U0126 antagonized the effects induced by HSP90 transfection on apoptosis caused by MW-EMF. In conclusion, these results demonstrate for the first time that MW-EMF induces apoptosis through the inactivation of the ras --> Erk survival signaling due to enhanced degradation of ras and Raf-1 determined by decreased expression of HSP90 and the consequent increase of proteasome dependent degradation.

**Carballo-Quintás M, Martínez-Silva I, Cadarso-Suárez C, Alvarez-Figueiras M, Ares-Pena FJ, López-Martín E. A study of neurotoxic biomarkers, c-fos and GFAP after acute exposure to GSM radiation at 900 MHz in the picrotoxin model of rat brains. Neurotoxicology. 32(4):478-494, 2011.**

The acute effects of microwave exposure from the Global System for Mobile Communication (GSM) were studied in rats, using 900MHz radiation at an intensity similar to mobile phone emissions. Acute subconvulsive doses of picrotoxin were then administered to the rats and an experimental model of seizure-proneness was created from the data. Seventy-two adult male Sprague-Dawley rats underwent immunochemical testing of relevant anatomical areas to measure induction of the c-

fos neuronal marker after 90min and 24h, and of the glial fibrillary acidic protein (GFAP) 72h after acute exposure to a 900MHz electromagnetic field (EMF). The experimental set-up facilitated measurement of absorbed power, from which the average specific absorption rate was calculated using the finite-difference time-domain (FDTD) 2h after exposure to EMF radiation at 1.45W/kg in picrotoxin-treated rats and 1.38W/kg in untreated rats. Ninety minutes after radiation high levels of c-fos expression were recorded in the neocortex and paleocortex along with low hippocampus activation in picrotoxin treated animals. Most brain areas, except the limbic cortical region, showed important increases in neuronal activation 24h after picrotoxin and radiation. Three days after picrotoxin treatment, radiation effects were still apparent in the neocortex, dentate gyrus and CA3, but a significant decrease in activity was noted in the piriform and entorhinal cortex. During this time, glial reactivity increased with every seizure in irradiated, picrotoxin-treated brain regions. Our results reveal that c-fos and glial markers were triggered by the combined stress of non-thermal irradiation and the toxic effect of picrotoxin on cerebral tissues.

**Carlberg M, Hardell L. Decreased Survival of Glioma Patients with Astrocytoma Grade IV (Glioblastoma Multiforme) Associated with Long-Term Use of Mobile and Cordless Phones. Int J Environ Res Public Health. 11(10):10790-10805, 2014.**

On 31 May 2011 the WHO International Agency for Research on Cancer (IARC) categorised radiofrequency electromagnetic fields (RF-EMFs) from mobile phones, and from other devices that emit similar non-ionising electromagnetic fields, as a Group 2B, i.e., a "possible", human carcinogen. A causal association would be strengthened if it could be shown that the use of wireless phones has an impact on the survival of glioma patients. We analysed survival of 1678 glioma patients in our 1997-2003 and 2007-2009 case-control studies. Use of wireless phones in the >20 years latency group (time since first use) yielded an increased hazard ratio (HR) = 1.7, 95% confidence interval (CI) = 1.2-2.3 for glioma. For astrocytoma grade IV (glioblastoma multiforme; n = 926) mobile phone use yielded HR = 2.0, 95% CI = 1.4-2.9 and cordless phone use HR = 3.4, 95% CI = 1.04-11 in the same latency category. The hazard ratio for astrocytoma grade IV increased statistically significant per year of latency for wireless phones, HR = 1.020, 95% CI = 1.007-1.033, but not per 100 h cumulative use, HR = 1.002, 95% CI = 0.999-1.005. HR was not statistically significant increased for other types of glioma. Due to the relationship with survival the classification of IARC is strengthened and RF-EMF should be regarded as human carcinogen requiring urgent revision of current exposure guidelines.

**Carlberg M, Hardell L. Evaluation of Mobile Phone and Cordless Phone Use and Glioma Risk Using the Bradford Hill Viewpoints from 1965 on Association or Causation. Biomed Res Int. 2017:9218486, 2017.**

*Objective.* Bradford Hill's viewpoints from 1965 on association or causation were used on glioma risk and use of mobile or cordless phones. *Methods.* All nine viewpoints were evaluated based on epidemiology and laboratory studies. *Results.* Strength: meta-

analysis of case-control studies gave odds ratio (OR) = 1.90, 95% confidence interval (CI) = 1.31-2.76 with highest cumulative exposure. Consistency: the risk increased with latency, meta-analysis gave in the 10+ years' latency group OR = 1.62, 95% CI = 1.20-2.19. Specificity: increased risk for glioma was in the temporal lobe. Using meningioma cases as comparison group still increased the risk. Temporality: highest risk was in the 20+ years' latency group, OR = 2.01, 95% CI =1.41-2.88, for wireless phones. Biological gradient: cumulative use of wireless phones increased the risk. Plausibility: animal studies showed an increased incidence of glioma and malignant schwannoma in rats exposed to radiofrequency (RF) radiation. There is increased production of reactive oxygen species (ROS) from RF radiation. Coherence: there is a change in the natural history of glioma and increasing incidence. Experiment: antioxidants reduced ROS production from RF radiation. Analogy: there is an increased risk in subjects exposed to extremely low-frequency electromagnetic fields. *Conclusion.* RF radiation should be regarded as a human carcinogen causing glioma.

**Cardis E, Deltour I, Mann S, Moissonnier M, Taki M, Varsier N, Wake K, Wiart J. Distribution of RF energy emitted by mobile phones in anatomical structures of the brain. Phys Med Biol. 53(11):2771-2783, 2008.**

The rapid worldwide increase in mobile phone use in the last decade has generated considerable interest in possible carcinogenic effects of radio frequency (RF). Because exposure to RF from phones is localized, if a risk exists it is likely to be greatest for tumours in regions with greatest energy absorption. The objective of the current paper was to characterize the spatial distribution of RF energy in the brain, using results of measurements made in two laboratories on 110 phones used in Europe or Japan. Most (97-99% depending on frequency) appears to be absorbed in the brain hemisphere on the side where the phone is used, mainly (50-60%) in the temporal lobe. The average relative SAR is highest in the temporal lobe (6-15%, depending on frequency, of the spatial peak SAR in the most exposed region of the brain) and the cerebellum (2-10%) and decreases very rapidly with increasing depth, particularly at higher frequencies. The SAR distribution appears to be fairly similar across phone models, between older and newer phones and between phones with different antenna types and positions. Analyses of risk by location of tumour are therefore important for the interpretation of results of studies of brain tumours in relation to mobile phone use.

**Carlberg M, Hardell L. On the association between glioma, wireless phones, heredity and ionising radiation. Pathophysiology. 19(4):243-252, 2012.**

We performed two case-control studies on brain tumours diagnosed during 1 January 1997 to 30 June 2000 and 1 July 2000 to 31 December 2003, respectively. Living cases and controls aged 20-80 years were included. An additional study was performed on deceased cases with a malignant brain tumour using deceased controls. Pooled results for glioma yielded for ipsilateral use of mobile phone odds ratio (OR)=2.9, 95% confidence interval (CI)=1.8-4.7 in the >10 years latency group. The corresponding result for cordless phone was OR=3.8, 95% CI=1.8-8.1. OR increased statistically significant for

cumulative use of wireless phones per 100h and per year of latency. For high-grade glioma ipsilateral use of mobile phone gave OR=3.9, 95% CI=2.3-6.6 and cordless phone OR=5.5, 95% CI=2.3-13 in the >10 years latency group. Heredity for brain tumour gave OR=3.4, 95% CI=2.1-5.5 for glioma. There was no interaction with use of wireless phones. X-ray investigation of the head gave overall OR=1.3, 95% CI=1.1-1.7 for glioma without interaction with use of wireless phones or heredity. In conclusion use of mobile and cordless phone increased the risk for glioma with highest OR for ipsilateral use, latency >10 years and third tertile of cumulative use in hours. In total, the risk was highest in the age group <20 years for first use of a wireless phone.

**Carlberg M, Hardell L. Pooled analysis of Swedish case-control studies during 1997-2003 and 2007-2009 on meningioma risk associated with the use of mobile and cordless phones. Oncol Rep. 33(6):3093-3098, 2015.**

A pooled analysis of two case-control studies on meningioma with patients diagnosed during 1997-2003 and 2007-2009 was conducted. Both genders were included, aged 20-80 and 18-75 years, respectively, at the time of diagnosis. Population-based controls, matched according to age and gender, were enrolled. Exposure was assessed by questionnaire. In the entire study, cases with all brain tumor types were included. The whole reference group was used in the unconditional logistic regression analysis on meningioma, with adjustments for gender, age, year of diagnosis and socio-economic index (SEI). In total, 1,625 meningioma cases and 3,530 controls were analyzed. Overall no association with use of mobile or cordless phones was found. In the fourth quartile of use (>1,436 h) somewhat increased risk was found for mobile phones yielding an odds ratio (OR)=1.2, 95% confidence intervals (CI)=0.9-1.6 and cordless phones OR=1.7, 95% CI=1.3-2.2. Higher risk was calculated in the highest decile (>3,358 h), OR=1.5, 95% CI=0.99-2.1 and OR=2.0, 95% CI=1.4-2.8, respectively. In addition, the longest latency time gave somewhat increased risk for both phone types although the result was not statistically significant. There was no association for ipsilateral use or anatomical tumor location. The present study showed a somewhat increased risk among heavy users of mobile and cordless phones. Since meningioma is generally a slow-growing tumor, longer latency period is necessary for definitive conclusions.

**Carlberg M, Söderqvist F, Hansson Mild K, Hardell L. Meningioma patients diagnosed 2007--2009 and the association with use of mobile and cordless phones: a case--control study. Environ Health. 2013 Jul 19;12(1):60. [Epub ahead of print]**

BACKGROUND: To study the association between use of wireless phones and meningioma. METHODS: We performed a case--control study on brain tumour cases of both genders aged 18--75 years and diagnosed during 2007--2009. One population-based control matched on gender and age was used to each case. Here we report on meningioma cases including all available controls. Exposures were assessed by a questionnaire. Unconditional logistic regression analysis was performed. RESULTS: In total 709 meningioma cases and 1,368 control subjects answered the questionnaire. Mobile phone use in total produced odds ratio (OR) = 1.0, 95% confidence interval (CI) =

0.7-1.4 and cordless phone use gave OR = 1.1, 95% CI = 0.8-1.5. The risk increased statistically significant per 100 h of cumulative use and highest OR was found in the fourth quartile (>2,376 hours) of cumulative use for all studied phone types. There was no statistically significant increased risk for ipsilateral mobile or cordless phone use, for meningioma in the temporal lobe or per year of latency. Tumour volume was not related to latency or cumulative use in hours of wireless phones. CONCLUSIONS: No conclusive evidence of an association between use of mobile and cordless phones and meningioma was found. An indication of increased risk was seen in the group with highest cumulative use but was not supported by statistically significant increasing risk with latency. Results for even longer latency periods of wireless phone use than in this study are desirable.[1]

**Carrubba S, Frilot C 2nd, Chesson AL Jr, Marino AA. Mobile-phone pulse triggers evoked potentials. Neurosci Lett. 469(1):164-168, 2010.**

If mobile-phone electromagnetic fields (EMFs) are hazardous, as suggested in the literature, processes or mechanisms must exist that allow the body to detect the fields. We hypothesized that the low-frequency pulses produced by mobile phones (217Hz) were detected by sensory transduction, as evidenced by the ability of the pulses to trigger evoked potentials (EPs). Electroencephalograms (EEGs) were recorded from six standard locations in 20 volunteers and analyzed to detect brain potentials triggered by a pulse of the type produced by mobile phones. Evoked potentials having the expected latency were found in 90% of the volunteers, as assessed using a nonlinear method of EEG analysis. Evoked potentials were not detected when the EEG was analyzed using time averaging. The possibility of systematic error was excluded by sham-exposure analyses. The results implied that mobile-phones trigger EP at the rate of 217Hz during ordinary phone use. Chronic production of the changes in brain activity might be pertinent

**Cassel JC, Cosquer B, Galani R, Kuster N. Whole-body exposure to 2.45 GHz electromagnetic fields does not alter radial-maze performance in rats. Behav Brain Res. 155(1):37-43, 2004.**

Mobile communication is based on utilization of electromagnetic fields (EMFs) in the frequency range of 0.3-300GHz. Human and animal studies suggest that EMFs, which are in the 0.1MHz-300GHz range, might interfere with cognitive processes. In 1994, a report by Lai et al. [Bioelectromagnetics 15 (1994) 95-104] showed that whole-body exposure of rats to pulsed 2.45GHz microwaves (2micros pulse width, 500pps, and specific absorption rate [SAR] 0.6W/kg) for 45min resulted in altered spatial working memory assessed in a 12-arm radial-maze task. Surprisingly, there has been only one attempt to replicate this experiment so far [Bioelectromagnetics 25 (2004) 49-57]; confirmation of the Lai et al. experiment failed. In the present study, rats were tested in a 12-arm radial-maze subsequently to a daily exposure to 2.45GHz microwaves (2micros pulse width, 500pps, and SAR 0.6W/kg) for 45min. The performance of exposed rats was comparable to that found in sham-exposed or in naive rats (no contact with the exposure system). Regarding the methodological details provided by Lai et al. on their testing

protocol, our results might suggest that the microwave-induced behavioral alterations measured by these authors might have had more to do with factors liable to performance bias than with spatial working memory per se.

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**Cecil S, Neubauer G, Rauscha F, Stix G, Müller W, Breithuber C, Glanzer M. Possible risks due to exposure of workers and patients with implants by TETRA transmitters. Bioelectromagnetics. 2014 Jan 16. doi: 10.1002/bem.21839. [Epub ahead of print]**

Several studies have demonstrated that mobile telephones that use different technologies, such as Global System for Mobile Communication (GSM) or Universal Mobile Telecommunication System (UMTS), have the potential to influence the functionality of active electronic implants, including cardiac pacemakers. According to these studies, a few safety measures, such as maintaining minimum distances of 25 cm between implants and transmitters, are sufficient to avoid such effects. Terrestrial Trunked Radio (TETRA) has become a well-established communication standard in many countries, including Germany and Austria. TETRA transmitters are typically used by police forces and emergency services. Employees and volunteers working for such institutions are often in close contact with patients, causing TETRA transmitters to potentially have an impact on the functionality of the implants of patients. Therefore, the main focus of our study was to investigate the functionality of several types of implants when exposed to TETRA transmitters. Moreover, we investigated the difference in the degree of exposure of users of TETRA transmitters when they carry the devices in different locations near the body, and when they use them in different positions near the head. Our results show that a compliance distance of 30 cm between implant and transmitter is sufficient to exclude any influence on the examined implants. All examined exposure conditions demonstrated

that the levels were well below recommended limits. If a user wants to minimize their exposure, use of transmitters in front of the mouth leads to somewhat lower exposure when compared to typical mobile phone like use.

**Celik O, Hascalik S. Effect of electromagnetic field emitted by cellular phones on fetal heart rate patterns. Eur J Obstet Gynecol Reprod Biol. 112(1):55-56, 2004.**

The study was planned to determine the effects of electromagnetic fields produced by cellular phones on baseline fetal heart rate, acceleration and deceleration. Forty pregnant women undergoing non-stress test were admitted to the study. Non-stress test was obtained while the subjects were holding the CP on stand by mode and on dialing mode, each for 5 min. Similar recordings were taken while there were no phones around for 10 min. Electromagnetic fields produced by cellular phones do not cause any demonstrable affect in fetal heart rate, acceleration and deceleration.

**Celik S, Aridogan IA, Izol V, Erdoğan S, Polat S, Doran S. An Evaluation of the effects of long-term cell phone use on the testes via light and electron microscope analysis. Urology. 79(2):346-350, 2012**

Abstract. OBJECTIVE: To investigate whether the low-intensity electromagnetic waves transmitted by cell phones cause histopathological or ultrastructural changes in the testes of rats. MATERIALS AND METHODS: Wistar-Kyoto male rats were placed into either a control group or a group that was exposed to an electromagnetic field (EMF). Two cell phones with Specific Absorbation Rate values of 1.58 were placed and left off in cages that housed 15 rats included in the control group, and four cell phones were placed and left on in cages that housed 30 rats included in the experimental group. After 3 months, weights, seminiferous tubule diameters, and spermatogenic cell conditions of all testes of the rats were evaluated. One half of each testis was examined also under an electron microscope. RESULTS: No significant differences were observed between the testis weights, seminiferous tubule diameters, and histopathological evaluations between rats that had and had not been exposed to EMF. Electron microscope analysis revealed that the membrana propria thickness and the collagen fiber contents were increased and the capillary veins extended in the experimental group. Common vacuolization in the cytoplasm of the Sertoli cells, growth of electron-dense structures, and existence of large lipid droplets were noted as the remarkable findings of this study.

**Çeliker M, Özgür A, Tümkaya L, Terzi S, Yılmaz M, Kalkan Y, Erdoğan E. Effects of exposure to 2100MHz GSM-like radiofrequency electromagnetic field on auditory system of rats. Braz J Otorhinolaryngol. 2016 Nov 5. pii: S1808-8694(16)30222-1. doi: 10.1016/j.bjorl.2016.10.004. [Epub ahead of print]**

INTRODUCTION: The use of mobile phones has become widespread in recent years. Although beneficial from the communication viewpoint, the electromagnetic fields (EMF) generated by mobile phones may cause unwanted biological changes in the human body. OBJECTIVE: In this study, we aimed to evaluate the effects of 2100MHz Global System for Mobile communication (GSM-like) electromagnetic field (EMF), generated by an EMF generator, on the auditory system of rats by using electrophysiological,

histopathologic and immunohistochemical methods. METHODS: Fourteen adult Wistar albino rats were included in the study. The rats were divided randomly into two groups of seven rats each. The study group was exposed continuously for 30days to a 2100MHz EMF with a signal level (power) of 5.4dBm (3.47mW) to simulate the talk mode on a mobile phone. The control group was not exposed to the aforementioned EMF. After 30days, the Auditory Brainstem Responses (ABRs) of both groups were recorded and the rats were sacrificed. The cochlear nuclei were evaluated by histopathologic and immunohistochemical methods. RESULTS: The ABR records of the two groups did not differ significantly. The histopathologic analysis showed increased degeneration signs in the study group (p=0.007). In addition, immunohistochemical analysis revealed increased apoptotic index in the study group compared to that in the control group (p=0.002). CONCLUSION: The results support that long-term exposure to a GSM-like 2100MHz EMF causes an increase in neuronal degeneration and apoptosis in the auditory system.

**Celikozlu SD, Ozyurt MS, Cimbiz A, Yardimoglu MY, Cayci MK, Ozay Y. The effects of long-term exposure of magnetic field via 900-MHz GSM radiation on some biochemical parameters and brain histology in rats. Electromagn Biol Med. 31(4):344-355, 2012.**

The aim of this study is to determine the effects of magnetic field via cell phones on some blood parameters and neurons in the brain of rats. Animals have been classified into three groups: control, Magnetic Field (MF), and F2 groups. Throughout this study, cell phones were placed on the wall of the cages. Rats were exposed to the effects of cell phones during prenatal and postnatal periods until they were 80 days old. During the study, the exposure procedure of rats was that the phone was in standby mode for a whole day and in talking mode for 30 min per day. The waves of cell phones caused an increased blood glucose level from 96.52 ± 5.64 mg/dl to 132.14 ± 5.93 mg/dl and an increased serum protein level from 131.14 ± 6.19 mg/dl to 319.29 ± 6.73 mg/dl compared to control. Statistically, significant differences wasn't observed in the blood cholesterol concentration between the groups compared to the control. Weekly weight gain decreased in all groups compared to the control. MF exposure decreased pyramidal neuron numbers 51.15% and increased ischemic neuron numbers 73% at cortex region of brain. In addition, vascular dilatations have increased clearly in group F2.Whereas the procedure of MF did not have any effects on hippocampal pyramidal cell numbers, magnetic fields increased the amount of ischemic neurons three-fold compared to the control. In conclusion, MF affected some biochemical parameters, especially the cortex region of the brain.

1 **Cervellati F, Valacchi G, Lunghi L, Fabbri E, Valbonesi P, Marci R, Biondi C, Vesce F. 17-β-estradiol counteracts the effects of high frequency electromagnetic fields on trophoblastic connexins and integrins. Oxid Med Cell Longev. 2013;2013:280850. doi: 10.1155/2013/280850.**

We investigated the effect of high-frequency electromagnetic fields (HF-EMFs) and 17-β-estradiol on connexins (Cxs), integrins (Ints), and estrogen receptor (ER) expression, as well as on ultrastructure of trophoblast-derived HTR-8/SVneo cells.

HF-EMF, 17-β-estradiol, and their combination induced an increase of Cx40 and Cx43 mRNA expression. HF-EMF decreased Int alpha1 and β 1 mRNA levels but enhanced Int alpha5 mRNA expression. All the Ints mRNA expressions were increased by 17-β-estradiol and exposure to both stimuli. ER-β mRNA was reduced by HF-EMF but augmented by 17-β-estradiol alone or with HF-EMF. ER-β immunofluorescence showed a cytoplasmic localization in sham and HF-EMF exposed cells which became nuclear after treatment with hormone or both stimuli. Electron microscopy evidenced a loss of cellular contact in exposed cells which appeared counteracted by 17-β-estradiol. We demonstrate that 17-β-estradiol modulates Cxs and Ints as well as ER-β expression induced by HF-EMF, suggesting an influence of both stimuli on trophoblast differentiation and migration.

**Cetin H, Nazıroğlu M, Celik O, Yüksel M, Pastacı N, Ozkaya MO. Liver antioxidant stores protect the brain from electromagnetic radiation (900 and 1800 MHz)-induced oxidative stress in rats during pregnancy and the development of offspring. J Matern Fetal Neonatal Med. 2014 Mar 3. [Epub ahead of print]**

Objectives: The present study determined the effects of mobile phone (900 and 1800 MHz)-induced electromagnetic radiation (EMR) exposure on oxidative stress in the brain and liver as well as the element levels in growing rats from pregnancy to 6 weeks of age. Methods: Thirty-two rats and their offspring were equally divided into 3 different groups: the control, 900 MHz, and 1800 MHz groups. The 900 MHz and 1800 MHz groups were exposed to EMR for 60 min/day during pregnancy and neonatal development. At the 4th, 5th, and 6th weeks of the experiment, brain samples were obtained. Results: Brain and liver glutathione peroxidase (GSH-Px) activities, as well as liver vitamin A and β-carotene concentrations decreased in the EMR groups, although brain iron, vitamin A, and β-carotene concentrations increased in the EMR groups. In the 6th week, selenium concentrations in the brain decreased in the EMR groups. There were no statistically significant differences in glutathione, vitamin E, chromium, copper, magnesium, manganese, and zinc concentrations between the 3 groups. Conclusion: EMR-induced oxidative stress in the brain and liver was reduced during the development of offspring. Mobile phone-induced EMR could be considered as a cause of oxidative brain and liver injury in growing rats.

**Çetkin M, Demirel C, Kızılkan N, Aksoy N, Erbağcı H. Evaluation of the** mobile phone **electromagnetic radiation on serum iron parameters in rats. Afr Health Sci. 17(1):186-190, 2017.**

BACKGROUND: Electromagnetic fields (EMF) created by **mobile phones** during communication have harmful effects on different organs. OBJECTIVES: It was aimed to investigate the effects of an EMF created by a **mobile phone** on serum iron level, ferritin, unsaturated iron binding capacity and total iron binding capacity within a rat experiment model. METHODS: A total of 32 male Wistar albino rats were randomly divided into the control, sham, **mobile phone** speech (2h/day) and stand by (12 h/day) groups. The speech and stand by groups were subjected to the EMF for a total of 10 weeks. RESULTS: No statistically significant difference was observed between the serum iron and ferritin values of the rats in the speech and stand by groups than the control and

sham groups (p>0.05). The unsaturated iron binding capacity and total iron capacity values of the rats in the speech and stand by groups were significantly lower in comparison to the control group (p<0.01). CONCLUSION: It was found that exposure to EMF created by **mobile phones** affected unsaturated iron binding capacity and total iron binding capacity negatively.

**Ceyhan AM, Akkaya VB, Güleçol ŞC, Ceyhan BM, Özgüner F, Chen W. Protective effects of β-glucan against oxidative injury induced by 2.45-GHz electromagnetic radiation in the skin tissue of rats. Arch Dermatol Res. 304(7):521-527, 2012.**

In recent times, there is widespread use of 2.45-GHz irradiation-emitting devices in industrial, medical, military and domestic application. The aim of the present study was to investigate the effect of 2.45-GHz electromagnetic radiation (EMR) on the oxidant and antioxidant status of skin and to examine the possible protective effects of β-glucans against the oxidative injury. Thirty-two male Wistar albino rats were randomly divided into four equal groups: control; sham exposed; EMR; and EMR + β-glucan. A 2.45-GHz EMR emitted device from the experimental exposure was applied to the EMR group and EMR + β-glucan group for 60 min daily, respectively, for 4 weeks. β-glucan was administered via gavage at a dose of 50 mg/kg/day before each exposure to radiation in the treatment group. The activities of antioxidant enzymes, superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) and catalase (CAT), as well as the concentration of malondialdehyde (MDA) were measured in tissue homogenates of the skin. Exposure to 2.45-GHz EMR caused a significant increase in MDA levels and CAT activity, while the activities of SOD and GSH-Px decreased in skin tissues. Systemic β-glucan significantly reversed the elevation of MDA levels and the reduction of SOD activities. β-glucan treatment also slightly enhanced the activity of CAT and prevented the depletion of GSH-Px activity caused by EMR, but not statistically significantly. The present study demonstrated the role of oxidative mechanisms in EMR-induced skin tissue damages and that β-glucan could ameliorate oxidative skin injury via its antioxidant properties.

**Chandel S, Kaur S, Singh HP, Batish DR, Kohli RK. Exposure to 2100 MHz electromagnetic field radiations induces reactive oxygen species generation in Allium cepa roots. Journal of Microscopy and Ultrastructure, 5(4):225-229, 2017.**

During the last few decades there has been an enormous increase in the usage of cell phones as these are one of the most convenient gadgets and provide excellent mode of communication without evoking any hindrance to movement. However, these are significantly adding to the electromagnetic field radiations (EMF-r) in the environment and thus, are required to be analysed for their impacts on living beings. The present study investigated the role of cell phone EMF-r in inciting oxidative damage in onion (Allium cepa) roots at a frequency of 2100 MHz. Onion roots were exposed to continuous wave homogenous EMF-r for 1, 2 and 4 h for single day and generation of reactive oxygen species (ROS) in terms of malondialdehyde (MDA), hydrogen peroxide (H2O2) and superoxide anion (O2−) content and changes in the activities of antioxidant enzymes-superoxide dismutases (SOD) and catalases (CAT) were measured. The results showed

that EMF-r exposure enhanced the content of MDA, H2O2 and O2−. Also, there was an upregulation in the activity of antioxidant enzymes− SOD and CAT− in onion roots. The study concluded that 2100 MHz cell phone EMF-r incite oxidative damage in onion roots by altering the oxidative metabolism.

**Chagnaud JL, Veyret B In vivo exposure of rats to GSM-modulated microwaves: flow cytometry analysis of lymphocyte subpopulations and of mitogen stimulation. Int J Radiat Biol 75(1):111-113, 1999.**

The effects of GSM-modulated microwaves on lymphocyte sub-populations of Sprague-Dawley rats and their normal mitogenic responses were investigated using flow cytometry analysis and a colorimetric method. No alterations were found in the surface phenotype of splenic lymphocytes or in their mitogenic activity, indicating that low-level pulsed microwaves do not seem to affect the integrity of the immune system.

**Chagnaud, JL, Moreau, JM, Veyret, B, No effect of short-term exposure to GSM-modulated low-power microwaves on benzo(a)pyrene-induced tumours in rat. Int J Radiat Biol 75(10):1251-1256, 1999**.

PURPOSE: In view of current interest in the biological effects of amplitude-modulated microwaves arising from the rapid development of mobile communications, the effects of low-level microwaves on cancer development were investigated using a rat sarcoma model. MATERIALS AND METHODS: Two-month-old female Sprague-Dawley rats were treated by injection of benzo(a)pyrene and irradiated with GSM (Global System for Mobile)-modulated 900-MHz microwaves in an anechoic chamber at 55 or 200 microW cm(-2) (75 and 270 mW kg(-1) average whole-body SAR, 2h daily for 2 weeks). Rats were exposed from day 20, 40 or 75 after carcinogen injection. Additional groups of rats were sham-exposed in a second anechoic chamber. Anti-phosphatidylinositol autoantibody levels were evaluated in sera to monitor malignant transformation. RESULTS: Microwave exposure had no effect on the development of tumours. No acceleration or delays in tumour onset were observed. Animal survival was not modified and serum autoantibody levels were similar in exposed and sham-exposed groups. CONCLUSION: Low-level GSM microwave exposure of rat bearing benzo(a)pyrene-induced tumours had no effect on auto-antibody levels, tumour appearance and survival. The low exposure levels used here correspond to exposure limits for whole-body exposure of humans.

**Chang SK, Choi JS, Gil HW, Yang JO, Lee EY, Jeon YS, Lee ZW, Lee M, Hong MY, Ho Son T, Hong SY. Genotoxicity evaluation of electromagnetic fields generated by 835-MHz mobile phone frequency band. Eur J Cancer Prev. 14(2):175-179, 2005.**

It is still unclear whether the exposure to electromagnetic fields (EMFs) generated by mobile phone radiation is directly linked to cancer. We examined the biological effects of an EMF at 835 MHz, the most widely used communication frequency band in Korean CDMA mobile phone networks, on bacterial reverse mutation (Ames assay) and DNA stability (in vitro DNA degradation). In the Ames assay, tester strains alone or combined with positive mutagen were applied in an artificial mobile phone frequency EMF generator with continuous waveform at a specific absorption rate (SAR) of 4 W/kg for 48 h. In the presence of the 835-MHz EMF radiation, incubation with positive mutagen 4-

nitroquinoline-1-oxide and cumene hydroxide further increased the mutation rate in Escherichia coli WP2 and TA102, respectively, while the contrary results in Salmonella typhimurium TA98 and TA1535 treated with 4-nitroquinoline-1-oxide and sodium azide, respectively, were shown as antimutagenic. However, these mutagenic or co-mutagenic effects of 835-MHz radiation were not significantly repeated in other relevant strains with same mutation type. In the DNA degradation test, the exposure to 835-MHz EMF did not change the rate of degradation observed using plasmid pBluescript SK(+) as an indicator. Thus, we suggest that 835-MHz EMF under the conditions of our study neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro.

**Chapman S, Azizi L, Luo Q, Sitas F. Has the incidence of brain cancer risen in Australia since the introduction of mobile phones 29 years ago? Cancer Epidemiology. Available online May 5, 2016. doi:10.1016/j.canep.2016.04.010**

Background. Mobile phone use in Australia has increased rapidly since its introduction in 1987 with whole population usage being 94% by 2014. We explored the popularly hypothesised association between brain cancer incidence and mobile phone use. Study methods. Using national cancer registration data, we examined age and gender specific incidence rates of 19,858 male and 14,222 females diagnosed with brain cancer in Australia between 1982 and 2012, and mobile phone usage data from 1987 to 2012. We modelled expected age specific rates (20–39, 40–59, 60–69, 70–84 years), based on published reports of relative risks (RR) of 1.5 in ever-users of mobile phones, and RR of 2.5 in a proportion of 'heavy users' (19% of all users), assuming a 10-year lag period between use and incidence. Summary answers. Age adjusted brain cancer incidence rates (20–84 years, per 100,000) have risen slightly in males ($p < 0.05$) but were stable over 30 years in females ($p > 0.05$) and are higher in males 8.7 (CI = 8.1–9.3) than in females, 5.8 (CI = 5.3–6.3). Assuming a causal RR of 1.5 and 10-year lag period, the expected incidence rate in males in 2012 would be 11.7 (11–12.4) and in females 7.7 (CI = 7.2–8.3), both $p < 0.01$; 1434 cases observed in 2012, vs. 1867 expected. Significant increases in brain cancer incidence were observed (in keeping with modelled rates) only in those aged ≥70 years (both sexes), but the increase in incidence in this age group began from 1982, before the introduction of mobile phones. Modelled expected incidence rates were higher in all age groups in comparison to what was observed. Assuming a causal RR of 2.5 among 'heavy users' gave 2038 expected cases in all age groups. Limitations. This is an ecological trends analysis, with no data on individual mobile phone use and outcome. What this study adds. The observed stability of brain cancer incidence in Australia between 1982 and 2012 in all age groups except in those over 70 years compared to increasing modelled expected estimates, suggests that the observed increases in brain cancer incidence in the older age group are unlikely to be related to mobile phone use. Rather, we hypothesize that the observed increases in brain cancer incidence in Australia are related to the advent of improved diagnostic procedures when computed tomography and related imaging technologies were introduced in the early 1980s.

**Charlton SG. Perceptual and attentional effects on drivers' speed selection at curves. Accid Anal Prev. 36(5):877-884, 2004.**

This paper describes an experiment comparing the relative effectiveness of various types of warnings on drivers' speed selection at curves. The experiment compared three types of curve warnings across three different curve types in a driving simulator. All of the warnings worked reasonably well for severe curves (45 km/h), regardless of demands from a secondary (cell phone) task. For less demanding curves, only those warnings with a strong perceptual component (i.e., implicit cues) were effective in reducing drivers' curve speeds in the presence of the cell phone task. The design implications of these data appear straightforward; curve warnings that contain perceptual components or emphasise the physical features of the curve work best, particularly in cognitively demanding situations. The cell phone task added to driver workload and drivers became less responsive to primary task demands (i.e., speeds were elevated and reaction times were longer).

**Chattopadhyay SK, Toews KA, Butt S, Barlett R, Brown HD, Reverse-micelle model: pH, electromagnetic field and inhibitor enzyme interaction. Cancer Biochem Biophys 15:245-255, 1997.**

The reverse micelle is one of many models thought to have properties more nearly resembling the biological cellular environment, than does the traditional dilute-solution biochemical reaction system. In order to evaluate the results of EMF perturbation of enzyme-catalyzed reactions, the description of the AOT reverse-micelle model, with respect to its internal pH, effect of chemical inhibitors, temperature, and electromagnetic-field perturbation has herein been extended. Acetylcholinesterase and NADPH cytochrome-P450 reductase, reacting within the AOT reverse-micelle, exhibit a temperature vs. activity profile equivalent to the same reaction in a buffered dilute-solution environment. In reverse micelles, some inhibitors of AChE (propidium, and d-tubocurarine) have much less effect upon indophenol-acetate hydrolysis than they do in a dilute solution environment. Other inhibitors act in the same manner within the structured environment of the reverse micelle as in the conventional dilute solution reaction model. These differences are explicable in terms of mechanism of action of the individual inhibitors. Perturbation by low-intensity microwave fields has a similar inhibitory effect upon dilute-solution reactions, as those in the 'low-water-activity' environment of the reverse micelle. However, the interactions between physical and chemical perturbants are differently limited by the structure of the aqueous phase of the reverse micelle. pH of the 'internal' reverse-micelle environment is a function of the availability of H-ions supplied by system components. Use of indicator dyes show that the low-molarity buffers which are compatible with reverse-micelle stability, are often insufficient to maintain a constant pH. Too, in the reverse micelle, reaction rate, for proton yielding reactions, is dramatically greater than the rate of the same reaction in dilute solution at the same acidic pH.

**Chaturvedi CM, Singh VP, Singh P, Basu P, Singaravel M, Shukla RK, Dhawan A, Pati AK, Gangwar RK, and Singh SP, "," *Progress In Electromagnetics Research B*, Vol. 29, 23-42, 2011.**

Present study examines biological effects of 2.45 GHz microwave radiation in Parkes strain mice. Forty-day-old mice were exposed to CW (continuous wave) microwave radiation (2 h/day for 30 days). Locomotor activity was recorded on running wheel for 12 days prior to microwave exposure (pre-exposure), 7 days during the first week of exposure (short-term exposure) and another 7-day spell during the last week of the 30-

day exposure period (long-term exposure). Morris water maze test was performed from 17th to 22nd day of exposure. At the termination of the exposure, blood was processed for hematological parameters, brain for comet assay, epididymis for sperm count and motility and serum for SGOT (serum glutamate oxaloacetate transaminase) and SGPT (serum glutamate  pyruvate transaminase). The results show that long-term radiation-exposed group exhibited a positive ψ□(phase angle difference) for the onset of activity with reference to lights-off timing and most of the activity occurred within the light fraction of the LD (light: dark) cycle. Microwave radiation caused an increase in erythrocyte and leukocyte counts, a significant DNA strand break in brain cells and the loss of spatial memory in mice. This report for the first time provides experimental evidence that continuous exposure to low intensity microwave radiation may have an adverse effect on the brain function by altering circadian system and rate of DNA damage.

**Chauhan V, Mariampillai A, Bellier PV, Qutob SS, Gajda GB, Lemay E, Thansandote A, McNamee JP. Gene expression analysis of a human lymphoblastoma cell line exposed in vitro to an intermittent 1.9 GHz pulse-modulated radiofrequency field. Radiat Res. 165(4):424-429, 2006.**

This study was designed to determine whether radiofrequency (RF) fields of the type used for wireless communications could elicit a cellular stress response. As general indicators of a cellular stress response, we monitored changes in proto-oncogene and heat-shock protein expression. Exponentially growing human lymphoblastoma cells (TK6) were exposed to 1.9 GHz pulse-modulated RF fields at average specific absorption rates (SARs) of 1 and 10 W/kg. Perturbations in the expression levels of the proto-oncogenes FOS, JUN and MYC after exposure to sham and RF fields were assessed by real-time RT-PCR. In addition, the transcript levels of the cellular stress proteins HSP27 and inducible HSP70 were also monitored. We demonstrated that transcript levels of these genes in RF-field-exposed cells showed no significant difference in relation to the sham treatment group. However, concurrent positive (heat-shock) control samples displayed a significant elevation in the expression of HSP27, HSP70, FOS and JUN. Conversely, the levels of MYC mRNA were found to decline in the positive (heat-shock) control. In conclusion, our study found no evidence that the 1.9 GHz RF-field exposure caused a general stress response in TK6 cells under our experimental conditions.

**Chauhan V, Mariampillai A, Gajda GB, Thansandote A, McNamee JP. Analysis of proto-oncogene and heat-shock protein gene expression in human derived cell-lines exposed in vitro to an intermittent 1.9 GHz pulse-modulated radiofrequency field. Int J Radiat Biol. 82(5):347-354, 2006.**

Purpose: Several studies have reported that radiofrequency (RF) fields, as emitted by mobile phones, may cause changes in gene expression in cultured human cell-lines. The current study was undertaken to evaluate this possibility in two human-derived immune cell-lines.Materials and methods: HL-60 and Mono-Mac-6 (MM6) cells were individually exposed to intermittent (5 min on, 10 min off) 1.9 GHz pulse-modulated RF fields at a average specific absorption rate (SAR) of 1 and 10 W/kg at 37 +/- 0.5 degrees C for 6 h. Concurrent negative and positive (heat-shock for 1 h at 43 degrees C) controls were conducted with each experiment. Immediately following RF field exposure (T = 6 h) and

18 h post-exposure (T = 24 h), cell pellets were collected from each of the culture dishes and analyzed for transcript levels of proto-oncogenes (c-jun, c-myc and c-fos) and the stress-related genes (heat shock proteins (HSP) HSP27 and HSP70B) by quantitative reverse transcriptase polymerase chain reaction (RT-PCR).Results: No significant effects were observed in mRNA expression of HSP27, HSP70, c-jun, c-myc or c-fos between the sham and RF-exposed groups, in either of the two cell-lines. However, the positive (heat-shock) control group displayed a significant elevation in the expression of HSP27, HSP70, c-fos and c-jun in both cell-lines at T = 6 and 24 h, relative to the sham and negative control groups.Conclusion: This study found no evidence that exposure of cells to non-thermalizing levels of 1.9 GHz pulse-modulated RF fields can cause any detectable change in stress-related gene expression.

**Chauhan V, Qutob SS, Lui S, Mariampillai A, Bellier PV, Yauk CL, Douglas GR, Williams A, McNamee JP. Analysis of gene expression in two human-derived cell lines exposed in vitro to a 1.9 GHz pulse-modulated radiofrequency field. Proteomics. 7(21):3896-3905, 2007.**

There is considerable controversy surrounding the biological effects of radiofrequency (RF) fields, as emitted by mobile phones. Previous work from our laboratory has shown no effect related to the exposure of 1.9 GHz pulse-modulated RF fields on the expression of 22,000 genes in a human glioblastoma-derived cell-line (U87MG) at 6 h following a 4 h RF field exposure period. As a follow-up to this study, we have now examined the effect of RF field exposure on the possible expression of late onset genes in U87MG cells after a 24 h RF exposure period. In addition, a human monocyte-derived cell-line (Mono-Mac-6, MM6) was exposed to intermittent (5 min ON, 10 min OFF) RF fields for 6 h and then gene expression was assessed immediately after exposure and at 18 h postexposure. Both cell lines were exposed to 1.9 GHz pulse-modulated RF fields for 6 or 24 h at specific absorption rates (SARs) of 0.1-10.0 W/kg. In support of our previous results, we found no evidence that nonthermal RF field exposure could alter gene expression in either cultured U87MG or MM6 cells, relative to nonirradiated control groups. However, exposure of both cell-lines to heat-shock conditions (43 degrees C for 1 h) caused an alteration in the expression of a number of well-characterized heat-shock proteins.

**Chauhan V, Mariampillai A, Kutzner BC, Wilkins RC, Ferrarotto C, Bellier PV, Marro L, Gajda GB, Lemay E, Thansandote A, McNamee JP. Evaluating the biological effects of intermittent 1.9 GHz pulse-modulated radiofrequency fields in a series of human-derived cell lines. Radiat Res. 167(1):87-93, 2007.**

Several recent studies have suggested that radiofrequency (RF) fields may cause changes in a variety of cellular functions that may eventually lead to potential long-term health effects. In the present study, we have assessed the ability of non-thermal RF-field exposure to affect a variety of biological processes (including apoptosis, cell cycle progression, viability and cytokine production) in a series of human-derived cell lines (TK6, HL60 and Mono-Mac-6). Exponentially growing cells were exposed to intermittent (5 min on, 10 min off) 1.9 GHz pulse-modulated RF fields for 6 h at mean specific absorption rates (SARs) of 0, 1 and 10 W/kg. Concurrent negative (incubator)

and positive (heat shock for 1 h at 43 degrees C) controls were included in each experiment. Immediately after the 6-h exposure period and 18 h after exposure, cell pellets were collected and analyzed for cell viability, the incidence of apoptosis, and alterations in cell cycle kinetics. The cell culture supernatants were assessed for the presence of a series of human inflammatory cytokines (TNFA, IL1B, IL6, IL8, IL10, IL12) using a cytometric bead array assay. No detectable changes in cell viability, cell cycle kinetics, incidence of apoptosis, or cytokine expression were observed in any of RF-field-exposed groups in any of the cell lines tested, relative to the sham controls. However, the positive (heat-shock) control samples displayed a significant decrease in cell viability, increase in apoptosis, and alteration in cell cycle kinetics (G(2)/M block). Overall, we found no evidence that non-thermal RF-field exposure could elicit any detectable biological effect in three human-derived cell lines.

**Chauvin S, Gibergues ML, Wüthrich G, Picard D, Desreumaux JP, Bouillet JC. Occupational exposure to ambient electromagnetic fields of technical operational personnel working for a mobile telephone operator.Radiat Prot Dosimetry.136(3):185-195, 2009.**

In order to investigate the exposure of operational personnel to radiofrequency electromagnetic fields when working for a mobile telephone operator, exposimeters were used to make individual records on 23 Technical Operations personnel (mobile telephone maintenance staff) and also on 22 Other Workers. The exposure densities, to which each of the 45 subjects was subjected, were quantified using 229 exposure indicators. Cluster analysis techniques were applied to the data, in an attempt to show that they would re-emerge as belonging to one of the two groups, i.e. the Technical Operational Personnel group or the Other Workers group. This exploratory investigation has shown that the cluster analysis does not reveal a sufficiently reliable emergence of the two groups, even though certain exposure indicators were significantly different for the two groups. In addition, the use of a Learning Group method does not lead to the discovery of a predictive law that could identify the Technical Operational Personnel as a sub-group within the overall group.

**Chavdoula ED, Panagopoulos DJ, Margaritis LH. Comparison of biological effects between continuous and intermittent exposure to GSM-900-MHz mobile phone radiation: detection of apoptotic cell-death features. Mutat Res. 700(1-2):51-61, 2010.**

In the present study we used a 6-min daily exposure of dipteran flies, Drosophila melanogaster, to GSM-900MHz (Global System for Mobile Telecommunications) mobile phone electromagnetic radiation (EMR), to compare the effects between the continuous and four different intermittent exposures of 6min total duration, and also to test whether intermittent exposure provides any cumulative effects on the insect's reproductive capacity as well as on the induction of apoptotic cell death. According to our previous experiments, a 6-min continuous exposure per day for five days to GSM-900MHz and DCS-1800MHz (Digital Cellular System) mobile phone radiation, brought about a large decrease in the insect's reproductive capacity, as defined by the number of F(1) pupae.

This decrease was found to be non thermal and correlated with an increased percentage of induced fragmented DNA in the egg chambers' cells at early- and mid-oogenesis. In the present experiments we show that intermittent exposure also decreases the reproductive capacity and alters the actin cytoskeleton network of the egg chambers, another known aspect of cell death that was not investigated in previous experiments, and that the effect is also due to DNA fragmentation. Intermittent exposures with 10-min intervals between exposure sessions proved to be almost equally effective as continuous exposure of the same total duration, whereas longer intervals between the exposures seemed to allow the organism the time required to recover and partly overcome the above-mentioned effects of the GSM exposure.

**Cheever KL, Swearengin TF, Edwards RM, Nelson BK, Werren DW, Conover DL, DeBord DG. 2-Methoxyethanol metabolism, embryonic distribution, and macromolecular adduct formation in the rat: the effect of radiofrequency radiation-induced hyperthermia. Toxicol Lett 122(1):53-67, 2001.**

Exposure of pregnant rats to the solvent 2-methoxyethanol (2ME) and radiofrequency (RF) radiation results in greater than additive fetal malformations (Nelson, B.K., Conover, D.L., Brightwell, W.S., Shaw, P.B., Werren, D.W., Edwards, R.M., Lary, J.M., 1991. Marked increase in the teratogenicity of the combined administration of the industrial solvent 2-methoxyethanol and radiofrequency radiation in rats. Teratology 43, 621-34; Nelson, B.K., Conover, D.L., Shaw, P.B., Werren, D.W., Edwards, R.M., Hoberman, A.M., 1994. Interactive developmental toxicity of radiofrequency radiation and 2-methoxyethanol in rats. Teratology 50, 275-93). The current study evaluated the metabolism of 14C-labeled 2ME and the distribution of methoxyacetic acid (MAA) in maternal and embryonic tissues of pregnant Sprague-Dawley rats either exposed to 10 MHz RF radiation or sham conditions. Additionally, adduct formation for both plasma and embryonic protein was tested as a possible biomarker for the observed 2ME/RF teratogenicity. Rats were administered [ethanol-1,2-(14)C]-2ME (150 mg/kg, 161 &mgr;Ci/rat average) by gavage on gestation day 13 immediately before RF radiation sufficient to elevate body temperature to 42 degrees C for 30 min. Concurrent sham- and RF-exposed rats were sacrificed at 3, 6, 24 or 48 h for harvest of maternal blood, urine, embryos and extra-embryonic fluid. Tissues were either digested for determination of radioactivity or deproteinized with TCA and analyzed by HPLC for quantification of 2ME metabolites. Results show the presence of 2ME and seven metabolites, with the major metabolite, MAA, peaking at 6 h in the tissues tested. MAA, the proximal teratogen, was detectable in maternal serum, urine, embryo and extraembryonic fluid 48 h after dosing. Clearance of total body 14C was significantly reduced for the RF-exposed animals ($P<0.05$) for the 24-48 h period, but MAA values for serum, embryos and extraembryonic fluid were similar for both sham- and RF-exposed rats. Additionally, no difference was noted for 2ME metabolite profiles in urine or tissue for sham- or RF-exposed rats, thus eliminating an effect of RF radiation on MAA production as a possible explanation for the reported RF-2ME synergism. Subsequently, serum and embryo protein-bound adducts were evaluated by analysis of covalently bound radioactivity. Serum protein binding was significantly higher for sham than RF rats at 3- and 6-h - highest for sham rats at 6 h (519+/-95 &mgr;g as parent 2ME/g of protein) whereas RF serum values were highest at 24 h (266+/-79 &mgr;g/g protein). Embryonic protein binding was significantly higher for

sham rats at 6 h, but binding was highest for both groups at 24 h (sham=229+/-71 &mgr;g/g, RF=185+/-48 &mgr;g/g). Formation of protein adducts after 2ME is thought to be related to levels of methoxyacetaldehyde, a reactive intermediate in the formation of MAA. These results suggest that no direct relationship exists for covalent binding in the embryo which would explain RF-2ME synergistic malformations. In comparison with urinary metabolites, the relatively slow elimination of adducted serum 2ME indicates that analysis of protein-bound concentrations could be a potential tool for long- term biomonitoring of worker exposure.

**Chemeris NK, Gapeyev AB, Sirota NP, Gudkova OY, Kornienko NV, Tankanag AV, Konovalov IV, Buzoverya ME, Suvorov VG, Logunov VA. DNA damage in frog erythrocytes after in vitro exposure to a high peak-power pulsed electromagnetic field. Mutat Res. 558(1-2):27-34, 2004.**

Till the present time, the genotoxic effects of high peak-power pulsed electromagnetic fields (HPPP EMF) on cultured cells have not been studied. We investigated possible genotoxic effects of HPPP EMF (8.8GHz, 180ns pulse width, peak power 65kW, repetition rate 50Hz) on erythrocytes of the frog Xenopus laevis. We used the alkaline comet assay, which is a highly sensitive method to assess DNA single-strand breaks and alkali-labile lesions. Blood samples were exposed to HPPP EMF for 40min in rectangular wave guide. The specific absorption rate (SAR) calculated from temperature kinetics was about 1.6kW/kg (peak SAR was about 300MW/kg). The temperature rise in the blood samples at steady state was [Formula: see text] degrees C. The data show that the increase in DNA damage after exposure of erythrocytes to HPPP EMF was induced by the rise in temperature in the exposed cell suspension. This was confirmed in experiments in which cells were incubated for 40min under the corresponding temperature conditions. The results allow us to conclude that HPPP EMF-exposure at the given modality did not cause any a-thermal genotoxic effect on frog erythrocytes in vitro.

**Chen C, Ma Q, Liu C, Deng P, Zhu G, Zhang L, He M, Lu Y, Duan W, Pei L, Li M, Yu Z, Zhou Z. Exposure to 1800 MHz radiofrequency radiation impairs neurite outgrowth of embryonic neural stem cells. Sci Rep. 2014 May 29;4:5103. doi: 10.1038/srep05103.**

A radiofrequency electromagnetic field (RF-EMF) of 1800 MHz is widely used in mobile communications. However, the effects of RF-EMFs on cell biology are unclear. Embryonic neural stem cells (eNSCs) play a critical role in brain development. Thus, detecting the effects of RF-EMF on eNSCs is important for exploring the effects of RF-EMF on brain development. Here, we exposed eNSCs to 1800 MHz RF-EMF at specific absorption rate (SAR) values of 1, 2, and 4 W/kg for 1, 2, and 3 days. We found that 1800 MHz RF-EMF exposure did not influence eNSC apoptosis, proliferation, cell cycle or the mRNA expressions of related genes. RF-EMF exposure also did not alter the ratio of eNSC differentiated neurons and astrocytes. However, neurite outgrowth of eNSC differentiated neurons was inhibited after 4 W/kg RF-EMF exposure for 3 days. Additionally, the mRNA and protein expression of the proneural genes Ngn1 and NeuroD, which are crucial for neurite outgrowth, were decreased after RF-EMF exposure. The expression of their inhibitor Hes1 was upregulated by RF-EMF exposure. These results together suggested that 1800 MHz RF-EMF exposure impairs neurite outgrowth of

eNSCs. More attention should be given to the potential adverse effects of RF-EMF exposure on brain development.

**Chen G, Lu D, Chiang H, Leszczynski D, Xu Z. Using model organism Saccharomyces cerevisiae to evaluate the effects of ELF-MF and RF-EMF exposure on global gene expression. Bioelectromagnetics. 33(7):550-560, 2012.**

The potential health hazard of exposure to electromagnetic fields (EMF) continues to cause public concern. However, the possibility of biological and health effects of exposure to EMF remains controversial and their biophysical mechanisms are unknown. In the present study, we used Saccharomyces cerevisiae to identify genes responding to extremely low frequency magnetic fields (ELF-MF) and to radiofrequency EMF (RF-EMF) exposures. The yeast cells were exposed for 6 h to either 0.4 mT 50 Hz ELF-MF or 1800 MHz RF-EMF at a specific absorption rate of 4.7 W/kg. Gene expression was analyzed by microarray screening and confirmed using real-time reverse transcription-polymerase chain reaction (RT-PCR). We were unable to confirm microarray-detected changes in three of the ELF-MF responsive candidate genes using RT-PCR ($P > 0.05$). On the other hand, out of the 40 potential RF-EMF responsive genes, only the expressions of structural maintenance of chromosomes 3 (SMC3) and aquaporin 2 (AQY2 (m)) were confirmed, while three other genes, that is, halotolerance protein 9 (HAL9), yet another kinase 1 (YAK1) and one function-unknown gene (open reading frame: YJL171C), showed opposite changes in expression compared to the microarray data ($P < 0.05$). In conclusion, the results of this study suggest that the yeast cells did not alter gene expression in response to 50 Hz ELF-MF and that the response to RF-EMF is limited to only a very small number of genes. The possible biological consequences of the gene expression changes induced by RF-EMF await further investigation.

**Chen L, Qin F, Chen Y, Sun J, Tong J.[Chronotoxicity of 1800 MHz microwave radiation on sex hormones and spermatogenesis in male mice]. Wei Sheng Yan Jiu. 43(1):110-115, 2014.[Article in Chinese]**

OBJECTIVE: To study the chronotoxicity of 1800 MHz micrwave radiation on the male reproductive system. METHODS: Sixty healthy male C57 mice with circadian rhythm in a 12:12 h light-dark photoperiod were divided into false radiation group (Sham) and microwave radiation (MR) group exposed to 1800 MHz RF at 208 microW/cm2 power (SAR: 0 .2221 W/kg) density at different zeitgeber times of a day (ZT01:00, ZT05:00, ZT09 : 00, ZT13: 00, ZT17 : 00, ZT21 : 00) for continuous 32 days with 2 h/d. The testicular sperm head was counted with a microscope, and serum testosterone (T) and estradiol (E2) levels were measured by ELISA method. RESULTS: Compared with the sham group,microwave radiation induced reduced level in testicular sperm head count and serum testosterone, while the level of serum estradiol increased. Also, the circadian rhythms of testicular sperm head count and estradiol disappeared after the microwave radiation. CONCLUSION: 1800 MH2 microwave radiation may disturb the level as well as circadian rhythmicity of the reproductive functions in male mice.

**Chen Q, Xu G, Lang L, Yang A, Li S, Yang L, Li C, Huang H, Li T. ECG changes in factory workers exposed to 27.2 MHz radiofrequency radiation. Bioelectromagnetics. 2012 Dec 31. doi: 10.1002/bem.21771. [Epub ahead of print]**

To research the effect of 27.2 MHz radiofrequency radiation on electrocardiograms (ECG), 225 female workers operating radiofrequency machines at a shoe factory were chosen as the exposure group and 100 female workers without exposure from the same factory were selected as the control group. The 6 min electric field strength that the female workers were exposed to was 64.0 ± 25.2 V/m (mean ± SD), which exceeded 61 V/m, the International Commission on Non-Ionizing Radiation Protection reference root mean square levels for occupational exposure. A statistical difference was observed between the exposed group and the control group in terms of the rate of sinus bradycardia ($\chi(2) = 11.48$, $P = 0.003$). When several known risk factors for cardiovascular disease were considered, including smoking, age, alcohol ingestion habit, and so on, the exposure duration was not an effective factor for ECG changes, sinus arrhythmia, or sinus bradycardia according to $\alpha = 0.05$, while $P = 0.052$ for sinus arrhythmia was very close to 0.05. We did not find any statistical difference in heart rate, duration of the QRS wave (ventricular depolarization), or corrected QT intervals (between the start of the Q wave and end of the T wave) between the exposed and control groups. Occupational exposure to radiofrequency radiation was not found to be a cause of ECG changes after consideration of the confounding factors.

**Chen WH, Lau CP, Leung SK, Ho DS, Lee IS, Interference of cellular phones with implanted permanent pacemakers. Clin Cardiol 19(11):881-886, 1996.**

BACKGROUND AND HYPOTHESIS: Occasional reports have suggested that cellular phones may interfere with permanent pacemakers. Our investigation sought to determine systematically the effects of commercially available cellular phones on the performances of different pacing modes and sensing lead configurations of permanent implanted pacemakers. METHODS: We conducted the study in 29 patients implanted with single- or dual-chamber bipolar rate-adaptive permanent pacemakers (a total of nine different models and six different sensors: minute ventilation, activity sensing using either accelerometer or piezoelectric crystal, QT and oxygen saturation sensing) from four different manufacturers. Three different cellular phones with analog or digital coding with maximum power from 0.6 to 2 W were used to assess the effect of pacemaker interference. Each cellular phone was positioned at (1) above the pacemaker pocket, (2) the ear level ipsilateral to the pacemaker pocket, and (3) the contralateral ear level. Surface electrocardiograms, intracardiac electrograms, and marker channels were recorded where possible during the following maneuvers at each position: (1) calls made by a stationary phone to cellular phone, and (2) calls made from the cellular phone to a stationary phone. A total of eight different pacing modes [DDD(R), VDD(R), AAI(R) and VVI(R)] in both unipolar and bipolar sensing configurations was tested. RESULTS: Interference was demonstrated during cellular phone operation in 74 of 2,418 (3.1%) episodes in eight patients. Three types of interference were observed: inhibition of pacing output, rapid ventricular tracking in DDD(R) or VDD(R) mode, and asynchronous pacing. All were observed only with the cellular phone positioned above the pacemaker pocket. Interference occurred prior to and after the termination of the ringing tone of the cellular

phone in 57% of cases. Cellular phones with either digital or analog technology could cause interference. Unipolar atrial lead was most susceptible to interference (relative frequency of interference: unipolar 1.8%, bipolar 0.4%, $p < 0.05$; atrial 2.9%, ventricular 1%, $p < 0.05$). There was no sensor-driven rate acceleration during all tests. In all patients, reprogramming of the sensitivity level successfully prevented cellular phone interference. CONCLUSIONS: Commercially available cellular phones can cause reversible interference to implanted single- or dual-chamber permanent pacemakers. The effect is maximal with high atrial unipolar sensitivity, especially in single pass VDD(R) systems. Both digital and analog cellular phones can lead to interference. Pacemaker interference can occur prior to a warning sign (ringing tone) of the phone and may have significant implications in patient safety.

**Chen YB, Li J, Qi Y, Miao X, Zhou Y, Ren D, Guo GZ. The effects of electromagnetic pulses (EMP) on the bioactivity of insulin and a preliminary study of mechanism. Int J Radiat Biol. 86(1):22-26, 2010.**

PURPOSE: To investigate the effects of electromagneticpulse (EMP) exposure on the bioactivity of insulin and a preliminary mechanism for these effects.MATERIALS AND METHODS: A tapered parallel plate Gigahertz Transverse Electromagnetic (GTEM) cell with a flared rectangular coaxial transmission line was used to expose the insulin solution to EMP. Concurrent sham-exposed insulin solutions were used as a control. The effect of EMP-exposed insulin on fasting blood glucose levels of type I diabetes model mice, the effect of EMP on binding affinity between insulin and its receptor and the effect of EMP on insulin's fluorescence intensity were detected, respectively.RESULTS: (i) After EMP exposure, compared with sham-exposed insulin, the bioactivity of insulin in decreasing fasting blood glucose levels in type I diabetes model mice was reduced significantly ($p = 0.023$). (ii) Compared with sham-exposed insulin group, the percentage fluorescein isothiocyannate (FITC) labelling of HL-7702 cells was significantly reduced in the EMP-exposed insulin group (22.7-13.8%, respectively). (iii) Compared with sham-exposed insulin, the fluorescence intensity was significantly reduced in EMP-exposed insulin ($p < 0.001$).CONCLUSIONS: EMP exposure significantly decreased the bioactivity of insulin to reduce the blood glucose levels in type I diabetic mice. This could be due to a decreased binding affinity between insulin and its receptor. This mechanism could involve an alteration of insulin's' conformation caused by EMP exposure.

**Chen YB, Li J, Liu JY, Zeng LH, Wan Y, Li YR, Ren D, Guo GZ.Effect of Electromagnetic Pulses (EMP) on associative learning in mice and a preliminary study of mechanism. Int J Radiat Biol. 87(12):1147-1154, 2011.**

PURPOSE: To investigate the effects of electromagnetic pulses (EMP) on associative learning in mice and test a preliminary mechanism for these effects. MATERIALS AND METHODS: A tapered parallel plate gigahertz transverse electromagnetic (GTEM) cell with a flared rectangular coaxial transmission line was used to expose male BALB/c mice to EMP (peak-intensity 400 kV/m, rise-time 10 ns, pulse-width 350 ns, 0.5 Hz and total 200 pulses). Concurrent sham-exposed mice were used as a control. Associative learning, oxidative stress in the brain, serum chemistry and the protective action of tocopherol monoglucoside (TMG) in mice were measured, respectively. RESULTS: (1)

Twelve hour and 1 day post EMP exposure associative learning was reduced significantly compared with sham control ($p<0.05$) but recovered at 2 d post EMP exposure. (2) Compared with the sham control, lipid peroxidation of brain tissue and chemiluminescence (CL) intensity increased significantly ($p<0.05$), while the activity of the antioxidant enzymes Superoxide Dismutase [SOD], Glutathione [GSH], Glutathione Peroxidase [GSH-Px], Catalase [CAT]) decreased significantly ($p<0.05$) at 3 h, 6 h, 12 h and 1 d post EMP exposure. All these parameters recovered at 2 d post EMP exposure. (3) No significant differences between the sham control group and EMP exposed group were observed in serum cholesterol and triglycerides. (4) Pretreatment of mice with TMG showed protective effects to EMP exposure. CONCLUSIONS: EMP exposure significantly decreased associative learning in mice and TMG acted as an effective protective agent from EMP exposure. This mechanism could involve an increase of oxidative stress in brain by EMP exposure.

**Chen ZJ, He JL. [Mutagenic, carcinogenic and teratogenic effects induced by radiofrequency electromagnetic field of mobile phone.] Zhejiang Da Xue Xue Bao Yi Xue Ban. 37(1):97-102, 2008.** [Article in Chinese].

OBJECTIVE: The extensive use of mobile phones causes increasing public concern on health effects of exposure to radiofrequency (RF) electromagnetic fields. Conflicting results are found in publications on the mutagenic, carcinogenic and teratogenic effects of RF electromagnetic fields. The overwhelming findings do not support the assumption that RF exposure may induce mutagenic, carcinogenic or teratogenic effects. However, health effects from low level RF exposure need to be further studied.

**Chia SE, Chia HP, Tan JS, Prevalence of headache among handheld cellular telephone users in singapore: A community study. Environ Health Perspect 108(11):1059-1062, 2000.**

We carried out a cross-sectional community study in Singapore to determine the prevalence of specific central nervous system (CNS) symptoms among hand-held cellular telephone (HP) users compared to nonusers and to study the association of risk factors and CNS symptoms among HP users. A total of 808 men and women between 12 and 70 years of age, who lived in one community, were selected using one-stage cluster random sampling and responses to a structured questionnaire. The prevalence of HP users was 44.8%. Headache was the most prevalent symptom among HP users compared to non-HP users, with an adjusted prevalence rate ratio of 1.31 [95% confidence interval, 1.00-1.70]. There is a significant increase in the prevalence of headache with increasing duration of usage (in minutes per day). Prevalence of headache was reduced by more than 20% among those who used hand-free equipment for their cellular telephones as compared to those who never use the equipment. The use of HPs is not associated with a significant increase of CNS symptoms other than headache.

**Chiabrera A, Bianco B, Moggia E, Kaufman JJ, Zeeman-Stark modeling of the RF EMF interaction with ligand binding. Bioelectromagnetics 21(4):312-324, 2000.**

The influence of radiofrequency electromagnetic exposure on ligand binding to hydrophobic receptor proteins is a plausible early event of the interaction mechanism. A comprehensive quantum Zeeman-Stark model has been developed which takes into account the energy losses of the ligand ion due to its collisions inside the receptor crevice, the attracting nonlinear endogenous force due to the potential energy of the ion in the binding site, the out of equilibrium state of the ligand-receptor system due to the basal cell metabolism, and the thermal noise. The biophysical "output" is the change of the ligand binding probability that, in some instances, may be affected by a suitable low intensity exogenous electromagnetic "input" exposure, e.g., if the depth of the potential energy well of a putative receptor protein matches the energy of the radiofrequency photon. These results point toward both the possibility of the electromagnetic control of biochemical processes and the need for a new database of safety standards.

**Chiang H, Microwave and ELF electromagnetic field effects on intercellular communication, Proceedings of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society 20:2798-2801, 1998.**

Gap junctional intercellular communication (GJIC) plays an essential role in regulation of cell growth, differentiation and wound healing. Microwave irradiation may down-regulate GJIC and the effect is strongly influenced by modulation frequency. Many studies have demonstrated that GJIC could be suppressed by ELF magnetic field (MF) and the suppression is related to the intensity of magnetic flux density and the exposure duration. Pulsed MF is more effective than sinusoidal MF in inhibiting GJIC. Inhibiting GJIC by electromagnetic field in some cases could be beneficial or detrimental. The mechanism of GJIC inhibition by ELF MF has also been studied and found that the inhibition may be mainly due to hyperphosphorylation of gap junctional connexins by PKC rather than its transcriptional or translational disregulation.

**Chiladakis JA, Davlouros P, Agelopoulos G, Manolis AS. In-vivo testing of digital cellular telephones in patients with implantable cardioverter-defibrillators. Eur Heart J 22(15):1337-1342, 2001.**

Aims To investigate the susceptibility of implantable cardioverter defibrillators to electromagnetic interference generated by digital cellular telephones, functioning in both international transmission technologies: the Global System for Mobile Communication (GSM) and the Digital Cellular System (DCS 1800).Methods and Results In 36 patients with transvenous implantable cardioverter defibrillators from two manufacturers (Medtronic and Guidant/CPI), cellular telephones with different levels of minimal and maximal power output were tested in the transmitting and receiving mode. Evaluation was performed in activated implantable defibrillators during spontaneous cardiac activity and continuous VVI or DDD pacing to assess possible electromagnetic interference. In two patients, appropriateness of ventricular fibrillation detection and therapy was judged during telephone testing. There was no damage, reprogramming, inappropriate shock therapy or pacing inhibition during the tests. In seven pre-pectoral Medtronic implantable defibrillators, transient electromagnetic interference caused 19 erroneous sensing events, when the operating phone was held in close vicinity to the programmer head. These 'pseudo-oversensing' events, which did not result in logging of arrhythmia episodes in the device counter, were interpreted as an adverse interaction between the telephone and

the programming device.Conclusion Digital cellular telephones do not represent a risk to Medtronic and Guidant/CPI recipients of the specific implantable defibrillator models herein tested.

**Chiu CT, Chang YH, Chen CC, Ko MC, Li CY. Mobile phone use and health symptoms in children. J Formos Med Assoc. 2014 Aug 9. pii: S0929-6646(14)00207-1. doi: 10.1016/j.jfma.2014.07.002. [Epub ahead of print]**

BACKGROUND/PURPOSE: To investigate the mobile phone (MP) use for talking in relation to health symptoms among 2042 children aged 11-15 years in Taiwan. METHODS: A nationwide, cross-sectional study, using the computer assisted telephone interview (CATI) technique, was conducted in 2009 to collect information on children's utilization of MPs and the perceived health symptoms reported by their parents. RESULTS: The overall prevalence of MP use in the past month was estimated at 63.2% [95% confidence interval (CI) = 61.1-65.3%]. MP use was associated with a significantly increased adjusted odds ratio (AOR) for headaches and migraine (1.42, 95% CI = 1.12-1.81) and skin itches (1.84, 95% CI = 1.47-2.29). Children who regularly used MPs were also considered to have a health status worse than it was 1 year ago (β = 0.27, 95% CI = 0.17-0.37). CONCLUSION: Although the cross-sectional design precludes the causal inference for the observed association, our study tended to suggest a need for more cautious use of MPs in children, because children are expected to experience a longer lifetime exposure to radiofrequency electromagnetic fields (RF-EMF) from MPs.

**Choi KH, Ha M, Ha EH, Park H, Kim Y, Hong YC, Lee AK, Hwa Kwon J, Choi HD, Kim N, Kim S, Park C. Neurodevelopment for the first three years following prenatal** mobile phone **use, radio frequency radiation and lead exposure. Environ Res. 156:810-817, 2017.**

BACKGROUND: Studies examining prenatal exposure to **mobile phone** use and its effect on child neurodevelopment show different results, according to child's developmental stages. OBJECTIVES: To examine neurodevelopment in children up to 36 months of age, following prenatal **mobile phone** use and radiofrequency radiation (RFR) exposure, in relation to prenatal lead exposure.METHODS: We analyzed 1198 mother-child pairs from a prospective cohort study (the Mothers and Children's Environmental Health Study). Questionnaires were provided to pregnant women at ≤20 weeks of gestation to assess **mobile phone** call frequency and duration. A personal exposure meter (PEM) was used to measure RFR exposure for 24h in 210 pregnant women. Maternal blood lead level (BLL) was measured during pregnancy. Child neurodevelopment was assessed using the Korean version of the Bayley Scales of Infant Development-Revised at 6, 12, 24, and 36 months of age. Logistic regression analysis applied to groups classified by trajectory analysis showing neurodevelopmental patterns over time.RESULTS: The psychomotor development index (PDI) and the mental development index (MDI) at 6, 12, 24, and 36 months of age were not significantly associated with maternal **mobile phone** use during pregnancy. However, among children exposed to high maternal BLL in utero, there was a significantly increased risk of having a low PDI up to 36 months of age, in relation to an increasing average calling time (p-trend=0.008). There was also a risk of having decreasing MDI up to 36 months of age, in

relation to an increasing average calling time or frequency during pregnancy (p-trend=0.05 and 0.007 for time and frequency, respectively). There was no significant association between child neurodevelopment and prenatal RFR exposure measured by PEM in all subjects or in groups stratified by maternal BLL during pregnancy.CONCLUSIONS: We found no association between prenatal exposure to RFR and child neurodevelopment during the first three years of life; however, a potential combined effect of prenatal exposure to lead and **mobile phone** use was suggested.

**Choi SB, Kwon MK, Chung JW, Park JS, Chung K, Kim DW. Effects of short-term radiation emitted by WCDMA mobile phones on teenagers and adults. BMC Public Health 14:438, 2014. doi:10.1186/1471-2458-14-438. Published: 10 May 2014**

Background. With the rapid increasing use of third generation (3 G) mobile phones, social concerns have arisen concerning the possible health effects of radio frequency-electromagnetic fields (RF-EMFs) emitted by wideband code division multiple access (WCDMA) mobile phones in humans. The number of people, who complain of various symptoms such as headache, dizziness, and fatigue, has also increased. Recently, the importance of researches on teenagers has been on the rise. However, very few provocation studies have examined the health effects of WCDMA mobile phone radiation on teenagers. Methods. In this double-blind study, two volunteer groups of 26 adults and 26 teenagers were simultaneously investigated by measuring physiological changes in heart rate, respiration rate, and heart rate variability for autonomic nervous system (ANS), eight subjective symptoms, and perception of RF-EMFs during sham and real exposure sessions to verify its effects on adults and teenagers. Experiments were conducted using a dummy phone containing a WCDMA module (average power, 250 mW at 1950 MHz; specific absorption rate, 1.57 W/kg) within a headset placed on the head for 32 min. Results. Short-term WCDMA RF-EMFs generated no significant changes in ANS, subjective symptoms or the percentages of those who believed they were being exposed in either group. Conclusions. Considering the analyzed physiological data, the subjective symptoms surveyed, and the percentages of those who believed they were being exposed, 32 min of RF radiation emitted by WCDMA mobile phones demonstrated no effects in either adult or teenager subjects.

**Choi Y-J, Choi Y-S. Effects of Electromagnetic Radiation from Smartphones on Learning Ability and Hippocampal Progenitor Cell Proliferation in Mice. Osong Public Health and Research Perspectives. 7(1):12-17. February 2016. doi:10.1016/j.phrp.2015.12.009**

Objectives Nonionizing radiation is emitted from electronic devices, such as smartphones. In this study, we intended to elucidate the effect of electromagnetic radiation from smartphones on spatial working memory and progenitor cell proliferation in the hippocampus. Methods Both male and female mice were randomly separated into two groups (radiated and control) and the radiated group was exposed to electromagnetic radiation for 9 weeks and 11 weeks for male and female mice, respectively. Spatial working memory was examined with a Y maze, and proliferation of hippocampal

progenitor cells were examined by 5-bromo-2′-deoxyuridine administration and immunohistochemical detection. Results When spatial working memory on a Y maze was examined in the 9th week, there was no significant difference in the spontaneous alternation score on the Y maze between the two groups. In addition, there was no significant difference in hippocampal progenitor cell proliferation. However, immunoreactivity to glial fibrillary acidic protein was increased in exposed animals. Next, to test the effect of recovery following chronic radiation exposure, the remaining female mice were further exposed to electromagnetic radiation for 2 more weeks (total 11 weeks), and spontaneous alternation was tested 4 weeks later. In this experiment, although there was no significant difference in the spontaneous alternation scores, the number of arm entry was significantly increased. Conclusion These data indicate that although chronic electromagnetic radiation does not affect spatial working memory and hippocampal progenitor cell proliferation it can mediate astrocyte activation in the hippocampus and delayed hyperactivity-like behavior.

**Chou CK, Guy AW, Kunz LL, Johnson RB, Crowley JJ, Krupp JH, Long-term, low-level microwave irradiation of rats. Bioelectromagnetics 13(6):469-496, 1992.**

Our goal was to investigate effects of long-term exposure to pulsed microwave radiation. The major emphasis was to expose a large sample of experimental animals throughout their lifetimes and to monitor them for effects on general health and longevity. An exposure facility was developed that enabled 200 rats to be maintained under specific-pathogen-free (SPF) conditions while housed individually in circularly-polarized waveguides. The exposure facility consisted of two rooms, each containing 50 active waveguides and 50 waveguides for sham (control) exposures. The experimental rats were exposed to 2,450-MHz pulsed microwaves at 800 pps with a 10-microseconds pulse width. The pulsed microwaves were square-wave modulated at 8-Hz. Whole body calorimetry, thermographic analysis, and power-meter analysis indicated that microwaves delivered at 0.144 W to each exposure waveguide resulted in an average specific absorption rate (SAR) that ranged from 0.4 W/kg for a 200-g rat to 0.15 W/kg for an 800-g rat. Two hundred male, Sprague-Dawley rats were assigned in equal numbers to radiation-exposure and sham-exposure conditions. Exposure began at 8 weeks of age and continued daily, 21.5 h/day, for 25 months. Animals were bled at regular intervals and blood samples were analyzed for serum chemistries, hematological values, protein electrophoretic patterns, thyroxine, and plasma corticosterone levels. In addition to daily measures of body mass, food and water consumption by all animals, O2 consumption and CO2 production were periodically measured in a sub-sample (N = 18) of each group. Activity was assessed in an open-field apparatus at regular intervals throughout the study. After 13 months, 10 rats from each group were euthanized to test for immunological competence and to permit whole-body analysis, as well as gross and histopathological examinations. At the end of 25 months, the survivors (11 sham-exposed and 12 radiation-exposed rats) were euthanized for similar analyses. The other 157 animals were examined histopathologically when they died spontaneously or were terminated in extremis.

**Chou CK, McDougall JA, Can KW, Absence of radiofrequency heating from**

**auditory implants during magnetic resonance imaging. Bioelectromagnetics 16(5):307-316, 1995.**

The possibility of tissue heating due to an auditory brainstem implant (ABI) or a modified cochlear implant (CI) during magnetic resonance imaging (MRI) of the head was tested on a full-sized human phantom using a realistic phantom head consisting of simulated skull, brain, and muscle. Dielectric properties of the brain, muscle, and bone materials were similar to those of human tissues at 64 MHz. The body consisted of homogeneous phantom muscle enclosed in a human-shaped fiberglass shell. Thermographic and fiber-optic temperature measurements were conducted to reveal any heating. Thermograms of sagittal, frontal, and horizontal planes of the head with the ABI and CI electrodes were taken immediately before and after a 26 min MRI scan. The MRI sequence was set at 94 excitations and 25 ms echo time to induce maximum radiofrequency heating, as suggested by the General Electric Company. The difference of these two thermograms gives the heating results. In two uncut phantom heads. Teflon tubes were placed along the implanted ABI and CI, and temperature data were recorded via fiber-optic probes before, during, and after the MRI. Results showed no observable heating associated with the ABI and the modified CI during worst-case MRI of the head.

**Christ A, Chavannes N, Nikoloski N, Gerber HU, Pokovic K, Kuster N. A numerical and experimental comparison of human head phantoms for compliance testing of mobile telephone equipment. Bioelectromagnetics. 26(2):125-137, 2005.**

A new human head phantom has been proposed by CENELEC/IEEE, based on a large scale anthropometric survey. This phantom is compared to a homogeneous Generic Head Phantom and three high resolution anatomical head models with respect to specific absorption rate (SAR) assessment. The head phantoms are exposed to the radiation of a generic mobile phone (GMP) with different antenna types and a commercial mobile phone. The phones are placed in the standardized testing positions and operate at 900 and 1800 MHz. The average peak SAR is evaluated using both experimental (DASY3 near field scanner) and numerical (FDTD simulations) techniques. The numerical and experimental results compare well and confirm that the applied SAR assessment methods constitute a conservative approach.

**Christ A, Kuster N. Differences in RF energy absorption in the heads of adults and children. Bioelectromagnetics. Suppl 7:S31-44. 2005.**

There has been a long and controversial debate on possible differences in electromagnetic (EM) energy absorption between adults and children during cell phone usage. Some published studies report higher specific absorption rate (SAR) in children and explain this based on smaller head size. More recently, age dependent changes of the dielectric tissue parameters have again ignited the discussion. This study intends to give a comprehensive review of the current state of knowledge about the parameters and mechanisms affecting the exposure of the mobile phone user with special focus on the exposure of children. Discussed are the absorption mechanism, tissue parameters, the effect of the pinna, and the uncertainties associated with head models based on spheroids, scaled adult heads, and magnetic resonance imaging (MRI) data of children. The conclusions of the review do not support the assumption that the energy exposure increases due to smaller heads, but identifies open issues regarding the dielectric tissue

parameters and the thickness of the pinna.

**Christ A, Samaras T, Klingenböck A, Kuster N. Characterization of the electromagnetic near-field absorption in layered biological tissue in the frequency range from 30 MHz to 6000 MHz Phys. Med. Biol.51: 4951-4965, 2006.**

Abstract. Currently, standards for the compliance testing of wireless devices are being extended to cover a wider frequency band and different usage patterns of mobile phones as well as of novel body-worn and handheld devices. As a consequence, not only the head but also strongly varying tissue distributions of the body are exposed to electromagnetic radiation. Several authors have reported changes in the SAR absorption of body tissue due to the presence of a low permittivity fat layer. This paper identifies two different effects which can lead to increased SAR in layered tissue in comparison to the SAR assessed using homogeneous tissue simulating liquid: (1) for larger distances between the tissue and the antenna, standing wave effects occur depending on the frequency and fat layer thickness. (2) In the very close near-field (distances approximately λ/40), reactive E-field components lead to high local absorption in the skin. The latter effect occurs at lower frequencies and depends on the antenna type. Modification of the parameters of the homogeneous liquids cannot compensate for these effects. However, a conservative exposure estimate can be obtained by applying a multiplication factor between 1 and 3 to the values assessed using current experimental dosimetric techniques.

**Christ A, Gosselin MC, Christopoulou M, Kühn S, Kuster N. Age-dependent tissue-specific exposure of cell phone users. Phys Med Biol. 55(7):1767-1783, 2010.**

The peak spatial specific absorption rate (SAR) assessed with the standardized specific anthropometric mannequin head phantom has been shown to yield a conservative exposure estimate for both adults and children using mobile phones. There are, however, questions remaining concerning the impact of age-dependent dielectric tissue properties and age-dependent proportions of the skull, face and ear on the global and local absorption, in particular in the brain tissues. In this study, we compare the absorption in various parts of the cortex for different magnetic resonance imaging-based head phantoms of adults and children exposed to different models of mobile phones. The results show that the locally induced fields in children can be significantly higher (>3 dB) in subregions of the brain (cortex, hippocampus and hypothalamus) and the eye due to the closer proximity of the phone to these tissues. The increase is even larger for bone marrow (>10 dB) as a result of its significantly high conductivity. Tissues such as the pineal gland show no increase since their distances to the phone are not a function of age. This study, however, confirms previous findings saying that there are no age-dependent changes of the peak spatial SAR when averaged over the entire head.

**Christensen HC , Schüz J, Kosteljanetz M, Poulsen HS, Thomsen J, Johansen J. Cellular telephone use and risk of acoustic neuroma Am J Epidemiol 159:277-283, 2004.**

Despite limited evidence, cellular telephones have been claimedto cause cancer,

especially in the brain. In this Danish study,the authors examined the possible association between use ofcellular telephones and development of acoustic neuroma. Between2000 and 2002, they ascertained 106 incident cases and matchedthese persons with 212 randomly sampled, population-based controlson age and sex. The data obtained included information on useof cellular telephones from personal interviews, data from medicalrecords, and the results of radiologic examinations. The authorsobtained information on socioeconomic factors from StatisticsDenmark. The overall estimated relative risk of acoustic neuromawas 0.90 (95% confidence interval: 0.51, 1.57). Use of a cellphone for 10 years or more did not increase acoustic neuromarisk over that of short-term users. Furthermore, tumors didnot occur more frequently on the side of the head on which thetelephone was typically used, and the size of the tumor didnot correlate with the pattern of cell phone use. The resultsof this prospective, population-based, nationwide study, whichincluded a large number of long-term users of cellular telephones,do not support an association between cell phone use and riskof acoustic neuroma.

**Christensen, HC; Schüz, J; Kosteljanetz, M; Poulsen, HS; Boice, JD. Jr; McLaughlin, JK; Johansen, C. Cellular telephones and risk for brain tumors: A population-based, incident case-control study. Neurology 64: 1189-1195, 2005.**

Objective: To evaluate a possible association of glioma or meningioma with use of cellular telephones, using a nationwide population-based case-control study of incident cases of meningioma and glioma. Methods: The authors ascertained all incident cases of glioma and meningioma diagnosed in Denmark between September 1, 2000, and August 31, 2002. They enrolled 252 persons with glioma and 175 persons with meningioma aged 20 to 69. The authors also enrolled 822 randomly sampled, population-based controls matched for age and sex. Information was obtained from personal interviews, medical records containing diagnoses, and the results of radiologic examinations. For a small number of cases and controls, the authors obtained the numbers of incoming and outgoing calls. They evaluated the memory of the respondents with the Mini-Mental State Examination and obtained data on socioeconomic factors from Statistics Denmark.Results: There were no material socioeconomic differences between cases and controls or participants and non-participants. Use of cellular telephone was associated with a low risk for high-grade glioma (OR, 0.58; 95% CI, 0.37 to 0.90). The risk estimates were closer to unity for low-grade glioma (1.08; 0.58 to 2.00) and meningioma (1.00; 0.54 to 1.28).Conclusion: The results do not support an association between use of cellular telephones and risk for glioma or meningioma.

**Ciaravino V, Meltz ML, Erwin DN, Absence of a synergistic effect between moderate-power radio-frequency electromagnetic radiation and adriamycin on cell-cycle progression and sister-chromatid exchange. Bioelectromagnetics 12(5):289-298, 1991.**

In our laboratories we are conducting investigations of potential interactions between radio-frequency electromagnetic radiation (RFR) and chemicals that are toxic by different mechanisms to mammalian cells. The RFR is being tested at frequencies in the

microwave range and at different power levels. We report here on the 1) ability of simultaneous RFR exposures to alter the distribution of cells in first and second mitoses from that after treatment by adriamycin alone, and 2) on the ability of simultaneous RFR exposure to alter the extent of sister chromatid exchanges (SCEs) induced by adriamycin alone. This chemical was selected because of its reported mechanism of action and because it is of interest in the treatment of cancer. In our studies, Chinese hamster ovary (CHO) cells were exposed for 2 h simultaneously to adriamycin and pulsed RFR at a frequency of 2,450 MHz and a specific absorption rate of 33.8 W/Kg. The maximal temperature (in the tissue-culture medium) was 39.7 +/- 0.2 degrees C. The experiments were controlled for chemical and RFR exposures, as well as for temperature. Verified statistically, the data indicate that the RFR did not affect changes in cell progression caused by adriamycin, and the RFR did not change the number of SCEs that were induced by the adriamycin, which adriamycin is known to affect cells by damaging their membranes and DNA.

**Çiğ B, Nazıroğlu M. Investigation of the effects of distance from sources on apoptosis, oxidative stress and cytosolic calcium accumulation via TRPV1 channels induced by mobile phones and Wi-Fi in breast cancer cells. Biochim Biophys Acta. 2015 Feb 19. pii: S0005-2736(15)00053-X. doi: 10.1016/j.bbamem.2015.02.013. [Epub ahead of print]**

TRPV1 is a $Ca^{2+}$ permeable channel and gated by noxious heat, oxidative stress and capsaicin (CAP). Some reports have indicated that non-ionized electromagnetic radiation (EMR)-induces heat and oxidative stress effects. We aimed to investigate the effects of distance from sources on calcium signaling, cytosolic ROS production, cell viability, apoptosis, plus caspase-3 and -9 values induced by mobile phones and Wi-Fi in breast cancer cells MCF-7 human breast cancer cell lines were divided into A, B, C and D groups as control, 900, 1800 and 2450MHz groups, respectively. Cells in Group A were used as control and were kept in cell culture conditions without EMR exposure. Groups B, C and D were exposed to the EMR frequencies at different distances (0cm, 1cm, 5cm, 10cm, 20cm and 25cm) for 1h before CAP stimulation. The cytosolic ROS production, $Ca^{2+}$ concentrations, apoptosis, caspase-3 and caspase-9 values were higher in groups B, C and D than in A group at 0cm, 1cm and 5cm distances although cell viability (MTT) values were increased by the distances. There was no statistically significant difference in the values between control, 20 and 25cm. Wi-Fi and mobile phone EMR placed within 10cm of the cells induced excessive oxidative responses and apoptosis via TRPV1-induced cytosolic $Ca^{2+}$ accumulation in the cancer cells. Using cell phones and Wi-Fi sources which are farther away than 10cm may provide useful protection against oxidative stress, apoptosis and overload of intracellular $Ca^{2+}$. This article is part of a Special Issue entitled: Membrane channels and transporters in cancers.

**Cinel C, Boldini A, Russo R, Fox E. Effects of mobile phone electromagnetic fields on an auditory order threshold task. Bioelectromagnetics.28(6):493-496,2007.**

The effect of acute exposure to radio frequency electromagnetic fields (RF EMF) generated by mobile phones on an auditory threshold task was investigated. 168

participants performed the task while exposed to RF EMF in one testing session (either global system for mobile communication (GSM) or unmodulated signals) while in a separate session participants were exposed to sham signals. Lateralization effects were tested by exposing participants either on the left side or on the right side of the head. No significant effect of exposure to RF EMF was detected, suggesting that acute exposure to RF EMFs does not affect performance in the order threshold task.

**Cinel C, Russo R, Boldini A, Fox E. Exposure to mobile phone electromagnetic fields and subjective symptoms: a double-blind study. Psychosom Med. 70(3):345-348, 2008.**

OBJECTIVES: The objective of this study was to examine whether acute exposure to radio frequency electromagnetic fields (REFs) emitted by mobile phone may affect subjective symptoms. METHODS: Three large groups of volunteers (total 496) were exposed to REFs emitted by mobile phones in one session and sham signals in a different session. REF and sham exposure sessions were counterbalanced and double blinded. Participants were exposed to either Global System for Mobile Communication (GSM) or unmodulated signals, and the mobile phone was positioned either on the left or on the right side of the head. Before and after REF and sham exposure participants completed a questionnaire to rate five symptoms. Any changes in the severity of the symptoms after REF exposure were compared with changes after sham exposure. RESULTS: For one group of participants (N = 160), it was found that dizziness was affected by GSM exposure, but this was not consistently found with the other two groups of participants. No other significant effects were found. CONCLUSIONS: We did not find consistent evidence suggesting that exposure to mobile phone REFs affect subjective symptoms.Even though we acknowledge that more research is needed, we believe that our results give an important contribution to the research on mobile phone use and subjective symptoms.

**Clark ML, Burch JB, Yost MG, Zhai Y, Bachand AM, Fitzpatrick CT, Ramaprasad J, Cragin LA, Reif JS. Biomonitoring of estrogen and melatonin metabolites among women residing near radio and television broadcasting transmitters.J Occup Environ Med. 49(10):1149-1156, 2007.**

**OBJECTIVES:** Metabolites of estrogen (estrone-3-glucuronide [E1G]) and melatonin (6-hydroxymelatonin sulfate [6-OHMS]) were characterized among women living in a community with increased radiofrequency (RF) exposure from radio and television transmitters. **METHODS:** RF spot measurements, and personal 60-Hz magnetic field and residential parameters were collected. Overnight urine samples were assayed for E1G and 6-OHMS excretion. **RESULTS:** Among premenopausal women, there were no associations between RF or 60-Hz nonionizing radiation and E1G or 6-OHMS excretion. Among postmenopausal women, increased residential RF exposures, transmitter proximity and visibility, and temporally stable 60-Hz exposures were significantly associated with increased E1G excretion. This association was strongest among postmenopausal women with low overnight 6-OHMS levels. **CONCLUSIONS:** RF and temporally stable 60-Hz exposures were associated with increased E1G excretion among

postmenopausal women. Women with reduced nocturnal 6-OHMS excretion may represent a sensitive subgroup.

**Cleary SF, Liu LM, Merchant RE, In vitro lymphocyte proliferation induced by radio-frequency electromagnetic radiation under isothermal conditions. Bioelectromagnetics 11(1):47-56, 1990.**

Whole human blood was exposed or sham-exposed in vitro for 2 h to 27 or 2,450 MHz radio-frequency electromagnetic (RF) radiation under isothermal conditions (i.e., 37 +/- 0.2 degrees C). Immediately after exposure, mononuclear cells were separated from blood by Ficoll density-gradient centrifugation and cultured for 3 days at 37 degrees C with or without mitogenic stimulation by phytohemagglutinin (PHA). Lymphocyte proliferation was assayed at the end of the culture period by 6 h of pulse labeling with 3H-thymidine (3H-TdR). Exposure to radiation at either frequency at specific absorption rates (SARs) below 50 W/kg resulted in a dose-dependent, statistically significant increase of 3H-TdR uptake in PHA-activated or unstimulated lymphocytes. Exposure at 50 W/kg or higher suppressed 3H-TdR uptake relative to that of sham-exposed cells. There were no detectable effects of RF radiation on lymphocyte morphology or viability. Notwithstanding the characteristic temperature dependence of lymphocyte activation in vitro, the isothermal exposure conditions of this study warrant the conclusion that the biphasic, dose-dependent effects of the radiation on lymphocyte proliferation were not dependent on heating.

**Cleary, SF, Cao, G, Liu, LM, Egle, PM, Shelton, KR, Stress proteins are not induced in mammalian cells exposed to radiofrequency or microwave radiation. Bioelectromagnetics 18(7):499-505, 1997.**

The induction of stress proteins in HeLa and CHO cells was investigated following a 2 h exposure to radiofrequency (RF) or microwave radiation. Cells were exposed or sham exposed in vitro under isothermal (37 +/- 0.2 degrees C) conditions. HeLa cells were exposed to 27- or 2450 MHz continuous wave (CW) radiation at a specific absorption rate (SAR) of 25 W/kg. CHO cells were exposed to CW 27 MHz radiation at a SAR of 100 W/kg. Parallel positive control studies included 2 h exposure of HeLa or CHO cells to 40 degrees C or to 45 microM cadmium sulfate. Stress protein induction was assayed 24 h after treatment by electrophoresis of whole-cell extracted protein labeled with [35S]-methionine. Both cell types exhibited well-characterized responses to the positive control stresses. Under these exposure conditions, neither microwave nor RF radiation had a detectable effect on stress protein induction as determined by either comparison of RF-exposed cells with sham-exposed cells or comparison with heat-stressed or Cd++ positive control cells.

**Cleary, SF, Du, Z, Cao, G, Liu, LM, McCrady, C, Effect of isothermal radiofrequency radiation on cytolytic T lymphocytes. FASEB J 10(8):913-919. 1996.**

Previous in vitro studies provide evidence that RF electromagnetic radiation modulates proliferation of human glioma, lymphocytes, and other cell types. The mechanism of RF radiation cell proliferation modulation, as well as mechanisms for effects on other cell

physiologic endpoints, are not well understood. To obtain insight regarding interaction mechanisms, we investigated effects of RF radiation exposure on interleukin 2 (IL-2) - dependent proliferation of cytolytic T lymphocytes (CTLL-2). After exposure to RF radiation in the presence or absence of IL-2 cells were cultured at various physiological concentrations of IL-2. Treatment effects on CTLL-2 proliferation were determined by tritiated thymidine incorporation immediately or 24 h after exposure. Exposure to 2450 MHz RIF radiation at specific absorption rates (SARs) of greater than 25 W/kg (induced E-field strength 98.4 V/m) induced a consistent, statistically significant reduction in CTLL-2 proliferation, especially at low IL-2 concentrations. At lower SARs, 2450 MHz exposure increased CTLL-2 proliferation immediately after exposure but reduced 24 h postexposure proliferation. RF radiation effects depended on the mitotic stateof the cells at the time of exposure. Comparison of the effects of temperature elevation and RF radiation indicated significant qualitative and quantitative differences.

**Cobb BL, Jauchem JR, Mason PA, Dooley MP, Miller SA, Ziriax JM, Murphy MR, Neural and behavioral teratological evaluation of rats exposed to ultra-wideband electromagnetic fields. Bioelectromagnetics 21(7):524-537, 2000.**

Several investigators have reported teratologic effects of electromagnetic field exposure. The majority of these studies have been performed at levels of exposure that could produce substantial heating of the animals. New and unique sources of ultra-wideband (UWB) electromagnetic fields are currently being developed and tested that are capable of generating nonthermalizing, high-peak-power, microwave(MW) pulses with nanosecond (ns) pulse widths, picosecond (ps) rise times, and an UWB of frequencies. Our study was performed to determine if teratological changes occur in rat pups as a result of (i) daily UWB exposures during gestation days 3-18, or (ii) as a result of both prenatal and postnatal (10 days) exposures. Dams were exposed either to (i) UWB irradiation from a Kentech system that emitted a 55 kV/m-peak E field, 300 ps rise time, and a 1.8 ns pulse width, average whole-body specific absorption rate 45 mW/kg; (ii) sham irradiation; or (iii) a positive control, lead (Pb) acetate solution (2000 mug/ml) continuously available in the drinking water. Offspring were examined for ontogeny (litter size, sex-ratios, weights, coat appearance, tooth-eruption, eye-opening, air-righting, and ultrasonic stress vocalizations). Male pups were tested on various performance measures (locomotor, water-maze learning, and fertilization capabilities). The pups postnatally exposed were examined for hippocampal morphology and operant behavior. Behavioral, functional, and morphological effects of UWB exposure were unremarkable with these exceptions: (i) The UWB-exposed pups emitted significantly more stress vocalizations than the sham-exposed pups; (ii) the medial-to-lateral length of the hippocampus was significantly longer in the UWB-exposed pups than in the sham-exposed animals; (iii) male offspring exposed in utero to UWB mated significantly less frequently than sham-exposed males, but when they did mate there was no difference in fertilization and offspring numbers from the sham group. There does not appear to be a unifying physiological or behavioral relationship among the significant differences observed, and our findings could be due to the expected spurious results derived when a large number of statistical comparisons are made. Significant effects found between our positive-controls and other groups on numerous measures indicates that the techniques used were sensitive enough to detect teratological effects.

**Cobb BL, Jauchem JR, Adair ER. Radial arm maze performance of rats following repeated low level microwave radiation exposure. Bioelectromagnetics. 25(1): 49-57, 2004.**

We examined the possibility of changes in "working" memory of rats following whole body exposure to microwave (MW) radiation. During each of 10 days, we exposed rats within circularly polarized waveguides for 45 min to 2450 MHz fields at whole body SARs of 0.6 W/kg (2 micros pulses, 500 pps), followed by testing in a 12 arm, radial arm maze (RAM). Rats received a preexposure injection of one of three psychoactive compounds or saline, to determine whether a compound would interact with MW exposure to affect performance in the maze. Error rate, i.e., reentry into arms already visited, and time to criterion data for 10 consecutive days of testing were analyzed by a three way analysis of variance (ANOVA) using main effects of "exposure" and "drug" and a repeated factor of "test day." Our alpha limit for significance was P <.05. Analyzes of error rates revealed no significant exposure effect, no significant drug effect and no significant interaction between the two main factors. There was a significant difference in test days, as expected, with repeated test-trial days, which indicates that learning was accomplished. There was no significant interaction of test day and the other two factors. The results of our analyzes of time to criterion data included no significant exposure effect, a significant drug effect, a significant test day effect, and a significant interaction between drug and test day factors. Post hoc analyzes of the drug factor revealed that rats treated with either physostigmine or nalrexone hydrochloride, took significantly longer to complete the maze task than rats pretreated with saline or with naloxone methodide. We conclude that there is no evidence from the current study that exposure to of MW radiation under parameters examined caused decrements in the ability of rats to learn the spatial memory task.

**Cohen JT, Graham JD. A revised economic analysis of restrictions on the use of cell phones while driving. Risk Anal 23(1):5-17, 2003.**

Evidence that cell phone use while driving increases the risk of being involved in a motor vehicle crash has led policymakers to consider prohibitions on this practice. However, while restrictions would reduce property loss, injuries, and fatalities, consumers would lose the convenience of using these devices while driving. Quantifying the risks and benefits associated with cell phone use while driving is complicated by substantial uncertainty in the estimates of several important inputs, including the extent to which cell phone use increases a driver's risk of being involved in a crash, the amount of time drivers spend using cell phones (and hence their aggregate contribution to crashes, injuries, and fatalities), and the incremental value to users of being able to make calls while driving. Two prominent studies that have investigated cell phone use while driving have concluded that the practice should not be banned. One finds that the benefits of calls made while driving substantially exceed their costs while the other finds that other interventions could reduce motor vehicle injuries and fatalities (measured in terms of quality adjusted life years) at a lower cost. Another issue is that cell phone use imposes increased (involuntary) risks on other roadway users. This article revises the assumptions used in the two previous analyses to make them consistent and updates them using recent data. The result is a best estimate of zero for the net benefit of cell phone use while driving, a finding that differs substantially from the previous study. Our revised cost-effectiveness estimate for cell phone use while driving moves in the other direction,

finding that the cost per quality adjusted life year increases modestly compared to the previous estimate. Both estimates are very uncertain.

**Colak C, Parlakpinar H, Ermis N, Tagluk ME, Colak C, Sarihan E, Dilex OF, Turan B, Bakir S, Acet A. Effects of electromagnetic radiation from 3G mobile phone on heart rate, blood pressure and ECG parameters in rats. Toxicol Ind Health.28(7):629-638, 2012.**

Effects of electromagnetic energy radiated from mobile phones (MPs) on heart is one of the research interests. The current study was designed to investigate the effects of electromagnetic radiation (EMR) from third-generation (3G) MP on the heart rate (HR), blood pressure (BP) and ECG parameters and also to investigate whether exogenous melatonin can exert any protective effect on these parameters. In this study 36 rats were randomized and evenly categorized into 4 groups: group 1 (3G-EMR exposed); group 2 (3G-EMR exposed + melatonin); group 3 (control) and group 4 (control + melatonin). The rats in groups 1 and 2 were exposed to 3G-specific MP's EMR for 20 days (40 min/day; 20 min active (speech position) and 20 min passive (listening position)). Group 2 was also administered with melatonin for 20 days (5 mg/kg daily during the experimental period). ECG signals were recorded from cannulated carotid artery both before and after the experiment, and BP and HR were calculated on 1st, 3rd and 5th min of recordings. ECG signals were processed and statistically evaluated. In our experience, the obtained results did not show significant differences in the BP, HR and ECG parameters among the groups both before and after the experiment. Melatonin, also, did not exhibit any additional effects, neither beneficial nor hazardous, on the heart hemodynamics of rats. Therefore, the strategy (noncontact) of using a 3G MP could be the reason for ineffectiveness; and use of 3G MP, in this perspective, seems to be safer compared to the ones used in close contact with the head. However, further study is needed for standardization of such an assumption.

**Col-Araz N. Evaluation of factors affecting birth weight and preterm birth in southern Turkey. J Pak Med Assoc. 2013 Apr;63(4):459-62.**

OBJECTIVE: To identify factors affecting birth weight and pre-term birth, and to find associations with electromagnetic devices such as television, computer and mobile phones. METHODS:  The study was conducted in Turkey at Gazintep University, Faculty of Medicine's Outpatient Clinic at the Paediatric Ward. It comprised 500 patients who presented at the clinic from May to December 2009. All participants were administered a questionnaire regarding their pregnancy history. SPSS 13 was used for statistical analysis. RESULTS: In the study, 90 (19%) patients had pre-term birth, and 64 (12.9%) had low birth weight rate Birth weight was positively correlated with maternal age and baseline maternal weight ($r = 0.115$, $p < 0.010$; $r = 0.168$, $p < 0.000$, respectively). Pre-term birth and birth weight less than 2500g were more common in mothers with a history of disease during pregnancy ($p < 0.046$ and $p < 0.008$, respectively). The habit of watching television and using mobile phones and computer by mothers did not demonstrate any relationship with birth weight. Mothers who used mobile phones or computers during pregnancy had more deliveries before 37 weeks ($p < 0.018$, $p < 0.034$;

respectively). Similarly, pregnancy duration was shorter in mothers who used either mobile phone or computers during pregnancy ($p < 0.005$, $p < 0.048$, respectively). CONCLUSION: Mobile phones and computers may have an effect on pre-term birth.

**Colletti V, Mandalà M, Manganotti P, Ramat S, Sacchetto L, Colletti L. Intraoperative observation of changes in cochlear nerve action potentials during exposure to electromagnetic fields generated by mobile phones. J Neurol Neurosurg Psychiatry.82(7):766-71, 2010**

Background The rapid spread of devices generating electromagnetic fields (EMF) has raised concerns as to the possible effects of this technology on humans. The auditory system is the neural organ most frequently and directly exposed to electromagnetic activity owing to the daily use of mobile phones. In recent publications, a possible correlation between mobile phone usage and central nervous system tumours has been detected. Very recently a deterioration in otoacoustic emissions and in the auditory middle latency responses after intensive and long-term magnetic field exposure in humans has been demonstrated. Methods To determine with objective observations if exposure to mobile phone EMF affects acoustically evoked cochlear nerve compound action potentials, seven patients suffering from Ménière's disease and undergoing retrosigmoid vestibular neurectomy were exposed to the effects of mobile phone placed over the craniotomy for 5 min. Results All patients showed a substantial decrease in amplitude and a significant increase in latency of cochlear nerve compound action potentials during the 5 min of exposure to EMF. These changes lasted for a period of around 5 min after exposure. Discussion The possibility that EMF can produce relatively long-lasting effects on cochlear nerve conduction is discussed and analysed in light of contrasting previous literature obtained under non-surgical conditions. Limitations of this novel approach, including the effects of the anaesthetics, craniotomy and surgical procedure, are presented in detail.

**Conover DL, Moss CE, Murray WE, Edwards RM, Cox C, Grajewski B, Werren DM, Smith JM, Foot currents and ankle SARs induced by dielectric heaters. Bioelectromagnetics 13(2):103-110, 1992.**

Data are presented on ankle-specific SARs and foot currents as a function of strengths of radio-frequency electromagnetic fields encountered by operators of dielectric heaters. The determination of foot currents was based on near-field exposures in which reactive coupling dominates, and which can result in substantial SARs in exposed workers. The operators were located less than one wavelength from--usually within one meter of--the dielectric heaters, which generated fields at frequencies from 6.5 to 65 MHz. At distances normally assumed by workers, maximal strengths of electric fields ranged from 10(4) to 2.4 x 10(6) V2/m2; maximal strengths of magnetic fields ranged from 5.0 x 10(-3) to 33.3 A2/m2. Currents through both feet to ground were measured while operators stood where they normally worked. Maximal currents ranged from 3 to 617 mA, rms. Nearly 27 percent of the dielectric heaters induced foot currents that exceeded the 200-mA limit that has been proposed for a new ANSI C95.1 standard. Twenty percent of the heaters induced foot currents

that exceeded 350 mA. SARs in ankles were calculated from foot currents, and they approximated 5 W/kg at 100 mA, 29 W/kg at 250 mA, and 57 W/kg at 350 mA. The maximal SAR in the ankle was approximately 176 W/kg at 617 mA.

**Consiglio W, Driscoll P, Witte M, Berg WP. Effect of cellular telephone conversations and other potential interference on reaction time in a braking response. Accid Anal Prev 35(4):495-500, 2003.**

This experiment studied the effect of phone conversations and other potential interference on reaction time (RT) in a braking response. Using a laboratory station which simulated the foot activity in driving, 22 research participants were requested to release the accelerator pedal and depress the brake pedal as quickly as possible following the activation of a red brake lamp. Mean reaction time was determined for five conditions: (a) control, (b) listening to a radio, (c) conversing with a passenger, (d) conversing using a hand-held phone, and (e) conversing using a hands-free phone. Results indicated that conversation, whether conducted in-person or via a cellular phone caused RT to slow, whereas listening to music on the radio did not.

**Cook A, Woodward A, Pearce N, Marshall C. Cellular telephone use and time trends for brain, head and neck tumours. N Z Med J. 116(1175):U457, 2003.**

AIM: The objective of this study was to determine whether incidence rates of head and neck malignancies in New Zealand have varied since the introduction of cellular telephones in 1987. In particular, we sought to compare trends in tumour rates in anatomical sites that receive high, medium and low levels of cellular telephone radiation (based on dosimetry data). METHODS: We investigated whether trends in tumour incidence rates in New Zealand have varied since the introduction of cellular telephones in 1987. The exposure measure used was the proportion of cellular telephone subscribers within the national population, calculated using the number of subscribers over the study period. RESULTS: The graphs for high, medium and low exposure sites did not display any significant changes in trend patterns for either gender over the years 1986 to 1998. CONCLUSIONS: Incidence rates for malignancies arising in the head and neck, including those sites that hypothetically receive the highest levels of radio frequency radiation during cellular telephone use, have not changed materially since the introduction of cellular telephones to New Zealand. However, ecological studies of this nature are limited in many ways and a stronger study design is clearly needed to establish more exactly any elevation in risk.

**Cooke R, Laing S, Swerdlow AJ. A case-control study of risk of leukaemia in relation to mobile phone use. Br J Cancer.103(11):1729-1735,2010.**

Background:Mobile phone use is now ubiquitous, and scientific reviews have recommended research into its relation to leukaemia risk, but no large studies have been conducted.Methods:In a case-control study in South East England to investigate the relation of acute and non-lymphocytic leukaemia risk to mobile phone use, 806 cases with leukaemia incident 2003-2009 at ages 18-59 years (50% of those identified as eligible) and 585 non-blood relatives as controls (provided by 392 cases) were interviewed about mobile phone use and other potentially aetiological variables.Results:No association was found between regular mobile phone use and

risk of leukaemia (odds ratio (OR)=1.06, 95% confidence interval (CI)=0.76, 1.46). Analyses of risk in relation to years since first use, lifetime years of use, cumulative number of calls and cumulative hours of use produced no significantly raised risks, and there was no evidence of any trends. A non-significantly raised risk was found in people who first used a phone 15 or more years ago (OR=1.87, 95% CI=0.96, 3.63). Separate analyses of analogue and digital phone use and leukaemia subtype produced similar results to those overall.Conclusion:This study suggests that use of mobile phones does not increase leukaemia risk, although the possibility of an effect after long-term use, while biologically unlikely, remains open.

**Cooper PJ, Zheng Y. Turning gap acceptance decision-making: the impact of driver distraction. J Safety Res 33(3):321-335, 2002.**

PROBLEM: A number of studies have found that use of in-car phones by drivers can interfere with the cognitive processing necessary for making appropriate and timely vehicle control decisions. However, the specific linkage between communication-based distraction and unsafe decision-making has not been sufficiently explored. METHOD: In a closed-course driving experiment, 39 subjects were exposed to approximately 100 gaps each in a circulating traffic stream of eight vehicles on an instrumented test track that was wet about half the time. The subjects were at the controls of an instrumented car, which was oriented in a typical left-turn configuration (traffic-crossing situation in North America) and with parking brake on and the transmission in neutral. The subjects were instructed to press on the accelerator pedal when they felt that a gap was safe to accept. Their performances were monitored and incentives were provided for balancing safe decision-making with expeditious completion of the task. For half of the gap exposures (randomly assigned), each subject was required to listen and respond to a complex verbal message. RESULTS: When not distracted, the subjects' gap acceptance judgment was found to be significantly influenced by their age, the gap size, the speed of the trailing vehicle, the level of "indecision," and the condition of the track surface. However, when distracted, the subjects did not factor pavement surface condition into the decision process. On wet pavement, the subjects were judged to have initiated twice the level of potential collisions when distracted by the messages that they did when not distracted. DISCUSSION: Listening/responding to verbal messages may reduce the capacity of drivers to process adequately all the important information necessary for safe decision-making. The effects of the messages in our study seemed to cause the subjects to misjudge gap size and speed information when operating under the additional disadvantage of adverse pavement condition. SUMMARY: Attention to complex messages while making decisions about turning through gaps in an on-coming vehicle stream was associated with significantly increased unsafe decision making by subjects in our experiment when the additional complexity of wet surface condition was introduced. IMPACT ON INDUSTRY: While the results reflected a somewhat artificial situation where the measure was signaled intention to act rather than the act itself, nevertheless, they do strongly suggest a scenario in which mental distraction could contribute to crash risk. With the rapid proliferation of telematics in the vehicle market, even with the laudable objectives represented by the Intelligent Transportation Systems initiative, there is a danger of the primary task of the driver being subordinated to a perceived need to enhance information flow to/from the external "world." Industry and governments need to work together to ensure that

apparently desirable in-vehicle communication improvements do not compromise safety.

**Cooper TG, Mann SM, Khalid M, Blackwell RP. Public exposure to radio waves near GSM microcell and picocell base stations. J Radiol Prot. 26:199-211, 2006.**

**Abstract.** Exposures of the general public to radio waves at locations near 20 randomly selected GSM microcell and picocell base stations in the UK have been assessed in the context of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Compliance distances were calculated for the antennas of the base stations from their reported radiated powers. Under pessimistic assumptions that would maximise exposures, the minimum height at which the general public reference level could potentially be exceeded near any of the base station antennas was calculated to be 2.4 m above ground level. The power densities of the broadcast carriers transmitted by the base stations have been measured and scaled to include all other possible carriers. Exposures were generally in the range 0.002–2% of the ICNIRP general public reference level, and the greatest exposure quotient near any of the base stations was 8.6%. Exposures close to microcell base stations were found to be generally greater than those close to macrocell base stations.

**Copty AB, Neve-Oz Y, Barak I, Golosovsky M, Davidov D. Evidence for a specific microwave radiation effect on the green fluorescent protein. Biophys J. 91(4):1413-1423, 2006.**

We have compared the effect of microwave irradiation and of conventional heating on the fluorescence of solution-based green fluorescent protein. A specialized near-field 8.5 GHz microwave applicator operating at 250 mW input microwave power was used. The solution temperature, the intensity, and the spectrum of the green fluorescent protein fluorescence 1), under microwave irradiation and 2), under conventional heating, were measured. In both cases the fluorescence intensity decreases and the spectrum becomes red-shifted. Although the microwave irradiation heats the solution, the microwave-induced changes in fluorescence cannot be explained by heating alone. Several possible scenarios are discussed.

**Cosquer B, Galani R, Kuster N, Cassel JC. Whole-body exposure to 2.45 GHz electromagnetic fields does not alter anxiety responses in rats: a plus-maze study including test validation. Behav Brain Res. 156(1):65-74, 2005.**

In a first phase of this investigation, a validation of our elevated plus-maze apparatus was performed in male Sprague-Dawley rats by testing anxiety response at various ambient light intensities (200, 30, 10 and 2.5 lux), as well as the effects of diazepam treatment (0.5 and 1.0 mg/kg, i.p. at 30 lux). Anxiety responses were found to decrease with decreasing light intensity and to be attenuated by diazepam treatment. Subsequently, a separate set of rats was exposed to 2.45 GHz EMFs (2 micros pulse width, 500 pulses per second, whole-body and time averaged of SAR 0.6 W/kg +/-2 dB, brain-averaged SAR of 0.9 W/kg +/-3 dB) for 45 min to assess whether EMF exposure altered anxiety responses in the same apparatus. As we made no a priori hypothesis on whether the effects would be anxiogenic or anxiolytic, part of the rats were tested under an ambient light intensity of 2.5 lux, the other one being tested at 30 lux. The low intensity level set the behavioural baseline for the detection of anxiogenic effects, while the higher one corresponded to the

detection of anxiolytic effects. Sham-exposed and naive rats were used as controls. Whatever light intensity was used, EMF exposure failed to induce any significant effect on anxiety responses in the plus maze. The present experiment demonstrates that exposure to EMFs, which was previously found to increase the number of benzodiazepine receptors in the rat cortex [Lai H, Carino MA, Horita A, Guy AW. Single vs. repeated microwave exposure: effects on benzodiazepine receptors in the brain of the rat. Bioelectromagnetics 1992;13(1):57-66], does not alter anxiety responses assessed in the elevated plus maze.

**Cosquer B, Kuster N, Cassel JC. Whole-body exposure to 2.45GHz electromagnetic fields does not alter 12-arm radial-maze with reduced access to spatial cues in rats. Behav Brain Res. 161(2):331-334, 2005.**

Lai et al. [Lai H, Horita A, Guy AW. Microwave irradiation affects radial-arm maze performance in the rat. Bioelectromagnetics 1994;15(2):95-104] reported that exposure of rats to pulsed 2.45GHz microwaves altered maze performance. Their maze was bordered by 20cm high opaque walls. Using a maze test based on unrestrained access to spatial cues (no walls), we could not replicate this result [Cassel JC, Cosquer B, Galani R, Kuster N. Whole-body exposure to 2.45GHz electromagnetic fields does not alter radial-maze performance in rats. Behav Brain Res 2004;155:37-43]. Here, we attempted another replication using a maze apparatus bordered by 30cm high opaque walls. Performance of exposed rats was normal. These results show that microwave exposure as used herein does not alter spatial working memory, when access to spatial cues is reduced.

**Cosquer B, Vasconcelos AP, Frohlich J, Cassel JC. Blood-brain barrier and electromagnetic fields: Effects of scopolamine methylbromide on working memory after whole-body exposure to 2.45GHz microwaves in rats. Behav Brain Res. 161(2):229-237, 2005.**

We first verified that our 12-arm radial maze test enabled demonstration of memory deficits in rats treated with the muscarinic antagonist scopolamine hydrobromide (0.5mg/kg, i.p.). We then investigated whether a systemically-injected quaternary-ammonium derivate of this antagonist (scopolamine methylbromide; MBR), which poorly crosses the blood-brain barrier (BBB), altered maze performance after a 45-min exposure to 2.45GHz electromagnetic field (EMF; 2mus pulse width, 500pps, whole-body specific energy absorption rate [SAR] of 2.0W/kg, +/-2dB and brain averaged SAR of 3.0W/kg, +/-3dB); if observed, such an alteration would reflect changes in BBB permeability. The drug was injected before or after exposure. Controls were naive rats (no experience of the exposure device) and sham-exposed rats (experience of the exposure device without microwaves). In a final approach, rats were subjected to i.v. injections of Evans blue, a dye binding serum albumin, before or after EMF exposure. Whether scopolamine MBR was injected before or after exposure, the exposed rats did not perform differently from their naive or sham-exposed counterparts. Thus, EMFs most probably failed to disrupt the BBB. This conclusion was further supported by the absence of Evans blue extravasation into the brain parenchyma of our exposed rats.

**Costa FP, de Oliveira AC, Meirelles R, Machado MC, Zanesco T, Surjan R, Chammas MC, de Souza Rocha M, Morgan D, Cantor A, Zimmerman J, Brezovich I,**

**Kuster N, Barbault A, Pasche B. Treatment of advanced hepatocellular carcinoma with very low levels of amplitude-modulated electromagnetic fields.Br J Cancer. 105(5):640-648, 2011.**

**BACKGROUND:** Therapeutic options for patients with advanced hepatocellular carcinoma (HCC) are limited. There is emerging evidence that the growth of cancer cells may be altered by very low levels of electromagnetic fields modulated at specific frequencies.**METHODS:** A single-group, open-label, phase I/II study was performed to assess the safety and effectiveness of the intrabuccal administration of very low levels of electromagnetic fields amplitude modulated at HCC-specific frequencies in 41 patients with advanced HCC and limited therapeutic options. Three-daily 60-min outpatient treatments were administered until disease progression or death. Imaging studies were performed every 8 weeks. The primary efficacy end point was progression-free survival 6 months. Secondary efficacy end points were progression-free survival and overall survival.**RESULTS:** Treatment was well tolerated and there were no NCI grade 2, 3 or 4 toxicities. In all, 14 patients (34.1%) had stable disease for more than 6 months. Medianprogression-free survival was 4.4 months (95% CI 2.1-5.3) and median overall survival was 6.7 months (95% CI 3.0-10.2). There were three partial and one near complete responses.**CONCLUSION:** Treatment with intrabuccally administered amplitude-modulated electromagnetic fields is safe, well tolerated, and shows evidence of antitumour effects in patients with advanced HCC.

**Court-Kowalski S, Finnie JW, Manavis J, Blumbergs PC, Helps SC, Vink R. Effect of long-term (2 years) exposure of mouse brains to global system for mobile communication (GSM) radiofrequency fields on astrocytic immunoreactivity. Bioelectromagnetics. 2015 Feb 20. doi: 10.1002/bem.21891. [Epub ahead of print]**

This study was designed to determine whether long-term (2 years) brain exposure to mobile telephone radiofrequency (RF) fields produces any astrocytic activation as these glia react to a wide range of neural perturbations by astrogliosis. Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate of 4 W/kg on five successive days per week for 104 weeks. Control mice were sham-exposed or freely mobile in a cage to control any stress caused by immobilization in the exposure module. Brains were perfusion-fixed with 4% paraformaldehyde and three coronal levels immunostained for glial fibrillary acidic protein (GFAP). These brain slices were then examined by light microscopy and the amount of this immunomarker quantified using a color deconvolution method. There was no change in astrocytic GFAP immunostaining in brains after long-term exposure to mobile telephony microwaves compared to control (sham-exposed or freely moving caged mice). It was concluded that long-term (2 years) exposure of murine brains to mobile telephone RF fields did not produce any astrocytic reaction (astrogliosis) detectable by GFAP immunostaining

**Cox RA, Luxton LM, Cerebral symptoms from mobile telephones. Occup Environ Med 57(6):431, 2000. (letter to the editor)**

Mobile phones affect the inner ear in 5-8% of users leading to dizziness, disorientation, nausea, headache and transient confusion.

**Crabtree DPE, Herrera BJ, Kang S.The response of human bacteria to static magnetic field and radiofrequency electromagnetic field. J Microbiol. 55(10):809-815,2017.**

Cell phones and electronic appliances and devices are inseparable from most people in modern society and the electromagnetic field (EMF) from the devices is a potential health threat. Although the direct health effect of a cell phone and its radiofrequency (RF) EMF to human is still elusive, the effect to unicellular organisms is rather apparent. Human microbiota, including skin microbiota, has been linked to a very significant role in the health of a host human body. It is important to understand the response of human skin microbiota to the RF-EMF from cell phones and personal electronic devices, since this may be one of the potential mechanisms of a human health threat brought about by the disruption of the intimate and balanced host-microbiota relationship. Here, we investigated the response of both laboratory culture strains and isolates of skin bacteria under static magnetic field (SMF) and RF-EMF. The growth patterns of laboratory cultures of Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus epidermidis under SMF were variable per different species. The bacterial isolates of skin microbiota from 4 subjects with different cell phone usage history also showed inconsistent growth responses. These findings led us to hypothesize that cell phone level RF-EMF disrupts human skin microbiota. Thus, the results from the current study lay ground for more comprehensive research on the effect of RF-EMF on human health through the human-microbiota relationship.

**Cranfield CG, Wood AW, Anderson V, Menezes KG. Effects of mobile phone type signals on calcium levels within human leukaemic T-cells (Jurkat cells). Int J Radiat Biol 77(12):1207-1217, 2001.**

PURPOSE: To test whether exposure to simulated GSM mobile phone signals (915 MHz, 2 W kg(-1)) influences the concentration of calcium or calcium signalling patterns in a human lymphocyte cell line. MATERIALS AND METHODS: The radiofrequency (RF) energy was delivered via a coaxial applicator to a perfused chamber where cells adherent to a thin glass coverslip were imaged by laser scanning confocal microscopy. Cell calcium concentration, estimated from Fluo-3 fluorescence, was monitored over two 10-min periods; control followed by exposed/sham, with exposure status assigned in a blind and randomized fashion. Both continuous wave (CW) and pulsed wave (PW) RF (on both phytohaemagglutanin-activated and unactivated cells) were studied (with an equal number of sham exposures) on 100 cells per category (total 800 cells). RESULTS: No significant changes were noted for the following: regression slope of calcium fluorescence; mean calcium concentration; number of calcium 'spikes' in each 10 min; or mean height of these 'spikes'. The average frequency from Fourier spectra of these periods showed significant alteration in one category only: PW exposure of activated cells. CONCLUSIONS: There is no clear indication that RF emissions from mobile

phones are associated with any changes in calcium levels or calcium signalling in lymphocytes.

**Cranfield C, Wieser HG, Al Madan J, Dobson J. Preliminary evaluation of nanoscale biogenic magnetite-based ferromagnetic transduction mechanisms for mobile phone bioeffects. IEEE Trans Nanobioscience. 2(1):40-43, 2003.**

Ferromagnetic transduction models have been proposed as a potential mechanism for mobile phone bioeffects. These models are based on the coupling of RF and pulsed electromagnetic emissions to biogenic magnetite (Fe3O4) present in the human brain via either ferromagnetic resonance or mechanical activation of cellular ion channels. We have tested these models experimentally for the first time using a bacterial analogue (Magnetospirillum magnetotacticum) which produces intracellular biogenic magnetite similar to that present in the human brain. Experimental evaluation revealed that exposure to mobile phone emissions resulted in a consistent and significantly higher proportion of cell death in exposed cultures versus sham exposure ($p = 0.037$). Though there appears to be a repeatable trend toward higher cell mortality in magnetite-producing bacteria exposed to mobile phone emissions, it is not yet clear that this would extrapolate to a deleterious health effect in humans.

**Cranfield CG, Wieser HG, Dobson J. Exposure of magnetic bacteria to simulated mobile phone-type RF radiation has no impact on mortality. IEEE Trans Nanobioscience. 2(3):146-149, 2003.**

The interaction of mobile phone RF emissions with biogenic magnetite in the human brain has been proposed as a potential mechanism for mobile phone bioeffects. This is of particular interest in light of the discovery of magnetite in human brain tissue. Previous experiments using magnetite-containing bacteria exposed directly to emissions from a mobile phone have indicated that these emissions might be causing greater levels of cell death in these bacterial populations when compared to sham exposures. A repeat of these experiments examining only the radio frequency (RF) global system for mobile communication (GSM) component of the mobile phone signal in a well-defined waveguide system (REFLEX), shows no significant change in cell mortality compared to sham exposures. A nonmagnetite containing bacterial cell strain (CC-26) with similar genotype and phenotype to the magnetotactic bacteria was used as a control. These also showed no significant change in cell mortality between RF and sham exposed samples. Results indicate that the RF components of mobile phone exposure do not appear to be responsible for previous findings indicating cell mortality as a result of direct mobile phone exposure. A further mobile phone emission component that should be investigated is the 2-Hz magnetic field pulse generated by battery currents during periods of discontinuous transmission.

**Crespo-Valero P, Christopoulou M, Zefferer M, Christ A, Achermann P, Nikita KS, Kuster N. Novel methodology to characterize electromagnetic exposure of the brain. Phys Med Biol. 56(2):383-396, 2010.**

Abstract. Due to the greatly non-uniform field distribution induced in brain tissues by radio frequency electromagnetic sources, the exposure of anatomical and functional regions of the brain may be a key issue in interpreting laboratory findings and

epidemiological studies concerning endpoints related to the central nervous system. This paper introduces the Talairach atlas in characterization of the electromagnetic exposure of the brain. A hierarchical labeling scheme is mapped onto high-resolution human models. This procedure is fully automatic and allows identification of over a thousand different sites all over the brain. The electromagnetic absorption can then be extracted and interpreted in every region or combination of regions in the brain, depending on the characterization goals. The application examples show how this methodology enhances the dosimetry assessment of the brain based on results obtained by either finite difference time domain simulations or measurements delivered by test compliance dosimetry systems. Applications include, among others, the detailed dosimetric analysis of the exposure of the brain during cell phone use, improved design of exposure setups for human studies or medical diagnostic and therapeutic devices using electromagnetic fields or ultrasound.

**Croft R, Chandler J, Burgess A, Barry R, Williams J, Clarke A. Acute mobile phone operation affects neural function in humans. Clin Neurophysiol 113(10):1623, 2002.**

OBJECTIVES: Mobile phones (MP) are used extensively and yet little is known about the effects they may have on human physiology. There have been conflicting reports regarding the relation between MP use and the electroencephalogram (EEG). The present study suggests that this conflict may be due to methodological differences such as exposure durations, and tests whether exposure to an active MP affects EEG as a function of time.METHODS: Twenty-four subjects participated in a single-blind fully counterbalanced cross-over design, where both resting EEG and phase-locked neural responses to auditory stimuli were measured while a MP was either operating or turned off.RESULTS: MP exposure altered resting EEG, decreasing 1-4Hz activity (right hemisphere sites), and increasing 8-12Hz activity as a function of exposure duration (midline posterior sites). MP exposure also altered early phase-locked neural responses, attenuating the normal response decrement over time in the 4-8Hz band, decreasing the response in the 1230Hz band globally and as a function of time, and increasing midline frontal and lateral posterior responses in the 30-45Hz band.CONCLUSIONS: Active MPs affect neural function in humans and do so as a function of exposure duration. The temporal nature of this effect may contribute to the lack of consistent results reported in the literature.

**Croft RJ, Hamblin DL, Spong J, Wood AW, McKenzie RJ, Stough C. The effect of mobile phone electromagnetic fields on the alpha rhythm of human electroencephalogram. Bioelectromagnetics.29(1):1-10,2008.**

Mobile phones (MP) emit low-level electromagnetic fields that have been reported to affect neural function in humans; however, demonstrations of such effects have not been conclusive. The purpose of the present study was to test one of the strongest findings in the literature; that of increased "alpha" power in response to MP-type radiation. Healthy participants (N = 120) were tested using a double-blind counterbalanced crossover design, with each receiving a 30-min Active and a 30-min Sham Exposure 1 week apart, while electroencephalogram (EEG) data were recorded. Resting alpha power (8-12 Hz) was then derived as a function of time, for periods both during and following exposure. Non-parametric analyses were employed

as data could not be normalized. Previous reports of an overall alpha power enhancement during the MP exposure were confirmed (relative to Sham), with this effect larger at ipsilateral than contralateral sites over posterior regions. No overall change to alpha power was observed following exposure cessation; however, there was less alpha power contralateral to the exposure source during this period (relative to ipsilateral). Employing a strong methodology, the current findings support previous research that has reported an effect of MP exposure on EEG alpha power.

**Croft RJ, Leung S, McKenzie RJ, Loughran SP, Iskra S, Hamblin DL, Cooper NR. Effects of 2G and 3G mobile phones on human alpha rhythms: Resting EEG in adolescents, young adults, and the elderly. Bioelectromagnetics.31(6):434-444,2010.**

The present study was conducted to determine whether adolescents and/or the elderly are more sensitive to mobile phone (MP)-related bioeffects than young adults, and to determine this for both 2nd generation (2G) GSM, and 3rd generation (3G) W-CDMA exposures. To test this, resting alpha activity (8-12 Hz band of the electroencephalogram) was assessed because numerous studies have now reported it to be enhanced by MP exposure. Forty-one 13-15 year olds, forty-two 19-40 year olds, and twenty 55-70 year olds were tested using a double-blind crossover design, where each participant received Sham, 2G and 3G exposures, separated by at least 4 days. Alpha activity, during exposure relative to baseline, was recorded and compared between conditions. Consistent with previous research, the young adults' alpha was greater in the 2G compared to Sham condition, however, no effect was seen in the adolescent or the elderly groups, and no effect of 3G exposures was found in any group. The results provide further support for an effect of 2G exposures on resting alpha activity in young adults, but fail to support a similar enhancement in adolescents or the elderly, or in any age group as a function of 3G exposure.

**Crouzier D, Debouzy JC, Bourbon F, Collin A, Perrin A, Testylier G. Neurophysiologic effects at low level 1.8 GHz radiofrequency field exposure: a multiparametric approach on freely moving rats. Pathol Biol (Paris).55(3-4):134-142, 2007.**

Deleterious effects on healthcare and particularly disruption of the cholinergic system have been reported after exposure to radiofrequency field at low power density. This work presents a 72 hours multiparametric study, where cholinergic system was investigated using a neurochemical, electrophysiological and physiological approaches. Free moving rats were exposed 24 hours to RF GSM signal at 1.8 GHz at low power density (1.2 and 9 W/m(2)). Acetylcholine (ACh) release in the hippocampus was simultaneously monitored using the microdialysis technique, electroencephalogram (EEG), electromyogram (EMG) and subcutaneous temperature. A spectral analysis of EEG was also performed and sleep stages were determined. After experimental time, the animals were sacrificed and a NMR study was performed on lipid brain extract. No significant parameters modification was observed under RF exposure. The only significant difference was the lack of increase in time spent in REM sleep, the third day, for the 1.2 W/m(2) group. This observation appeared difficult to explain and could not be reasonably related with RF exposure.

Similarly, the NMR study also failed to show any effect of RF.

**Curcio G, Ferrara M, De Gennaro L, Cristiani R, D'Inzeo G, Bertini M. Time-course of electromagnetic field effects on human performance and tympanic temperature. Neuroreport. 15(1):161-164, 2004.**

The study aimed to investigate the time-course of electromagnetic field (EMF)-induced effects on human cognitive and behavioral performance and on tympanic temperature. Subjects were randomly assigned to two groups, exposed to a 902.40 MHz EMF before the testing session, or to the same signal during the data collecting session. Following a double-blind paradigm, subjects were tested on four performance tasks: an acoustic simple-reaction time task, a visual search task, an arithmetic descending subtraction task and an acoustic choice-reaction time task. Moreover, tympanic temperature was collected five times during each session. Results indicated an improvement of both simple- and choice-reaction times and an increase of local temperature on the exposed region under the active exposure. There was a clear time-course of the reaction time and temperature data, indicating that performance and physiological measures need a minimum of 25 min of EMF exposure to show appreciable changes.

**Curcio G, Ferrara M, Moroni F, D'Inzeo G, Bertini M, De Gennaro L. Is the brain influenced by a phone call? An EEG study of resting wakefulness. Neurosci Res. 53(3):265-270, 2005.**

We recorded the resting electroencephalogram of 20 healthy subjects in order to investigate the effect of electromagnetic field (EMF) exposure on EEG waking activity and its temporal development. The subjects were randomly assigned to two groups and exposed, in double-blind conditions, to a typical mobile phone signal (902.40MHz, modulated at 217Hz, with an average power of 0.25W) before or during the EEG recording session. The results show that, under real exposure as compared to baseline and sham conditions, EEG spectral power was influenced in some bins of the alpha band. This effect was greater when the EMF was on during the EEG recording session than before it. The present data lend further support to the idea that pulsed high-frequency electromagnetic fields can affect normal brain functioning, also if no conclusions can be drawn about the possible health effects.

**Curcio G, Valentini E, Moroni F, Ferrara M, De Gennaro L, Bertini M Psychomotor performance is not influenced by brief repeated exposures to mobile phones. Bioelectromagnetics.29(3):237-241,2008.**

The present study investigated the presence of a cumulative effect of brief and repeated exposures to a GSM mobile phone (902.40 MHz, 217 Hz modulated; peak power of 2 W; average power of 0.25 W; SAR = 0.5 W/kg) on psychomotor functions. To this end, after each of 3 15-min exposures, both an acoustic simple reaction time task (SRTT) and a sequential finger tapping task (SFTT) were administered to 24 subjects. The present study was unable to detect the cumulative effects of brief and repeated EMF exposure on human psychomotor performance, although there was a non-statistical trend to shorter reaction times. In summary, these data show an absence of effects with these particular exposure conditions; however, possible cognitive effects induced by different signal characteristics cannot be excluded.

**Curcio G, Ferrara M, Limongi T, Tempesta D, Di Sante G, De Gennaro L, Quaresima V, Ferrari M. Acute mobile phones exposure affects frontal cortex hemodynamics as evidenced by functional near-infrared spectroscopy. J Cereb Blood Flow Metab.29(5):903-910, 2009.**

This study aimed to evaluate by functional near-infrared spectroscopy (fNIRS), the effects induced by an acute exposure (40 mins) to a GSM (Global System for Mobile Communications) signal emitted by a mobile phone (MP) on the oxygenation of the frontal cortex. Eleven healthy volunteers underwent two sessions (Real and Sham exposure) after a crossover, randomized, double-blind paradigm. The whole procedure lasted 60 mins: 10-mins baseline (Bsl), 40-mins (Exposure), and 10-mins recovery (Post-Exp). Together with frontal hemodynamics, heart rate, objective and subjective vigilance, and self-evaluation of subjective symptoms were also assessed. The fNIRS results showed a slight influence of the GSM signal on frontal cortex, with a linear increase in [HHb] as a function of time in the Real exposure condition ($F(4,40)=2.67$; $P=0.04$). No other measure showed any GSM exposure-dependent changes. These results suggest that fNIRS is a convenient tool for safely and noninvasively investigating the cortical activation in MP exposure experimental settings. Given the short-term effects observed in this study, the results should be confirmed on a larger sample size and using a multichannel instrument that allows the investigation of a wider portion of the frontal cortex.

**Curcio G, Mazzucchi E, Marca GD, Vollono C, Rossini PM. Electromagnetic fields and EEG spiking rate in patients with focal epilepsy. Clin Neurophysiol. 2014 Aug 11. pii: S1388-2457(14)00404-0. doi: 10.1016/j.clinph.2014.07.013. [Epub ahead of print]**

OBJECTIVE: Despite the increase in mobile telephone technology use and possible effects on brain excitability, no studies have investigated the impact of GSM like (Global System for Mobile Communications) signal on the ongoing spiking activity in human epileptic patients. METHODS: Brain electrical (electroencephalogram, EEG) activity of 12 patients with focal epilepsy has been recorded under both Real and Sham exposure following a double-blind, crossover, counterbalanced design: before the exposure (pre-exposure/baseline session), during the Real or Sham 45min exposure (during-exposure session), and after the exposure (post-exposure session). As dependent variables both spiking activity (spikes count) and EEG quantitative indices (spectral power and coherence data) have been considered. RESULTS: Spiking activity tended to be lower under Real than under Sham exposure. EEG spectral content analysis indicated a significant increase of Gamma band under Real exposure, mainly evident in Parieto-occipital and Temporal areas. Connectivity data indicated increased interhemispheric (left temporal to right frontal Regions of Interest, ROIs) instantaneous coherence, in the Beta frequency band during-exposure with respect to baseline session. No significant modification of lagged coherence was observed. CONCLUSIONS: Acute GSM exposure in epileptic patients slightly influences their EEG properties, without reaching any clinical relevance. SIGNIFICANCE: No signs were found of an increased risk of incoming seizures for these patients as a consequence of using mobile phones.

**Czerska EM, Elson EC, Davis CC, Swicord ML, Czerski P, Effects of continuous and pulsed 2450-MHz radiation on spontaneous lymphoblastoid transformation of human lymphocytes in vitro. Bioelectromagnetics 13(4):247-259, 1992.**

Normal human lymphocytes were isolated from the peripheral blood of healthy donors. One-ml samples containing (10(6)) cells in chromosome medium 1A were exposed for 5 days to conventional heating or to continuous wave (CW) or pulsed wave (PW) 2450-MHz radiation at non-heating (37 degrees C) and various heating levels (temperature increases of 0.5, 1.0, 1.5, and 2 degrees C). The pulsed exposures involved 1-microsecond pulses at pulse repetition frequencies from 100 to 1,000 pulses per second at the same average SAR levels as the CW exposures. Actual average SARs ranged to 12.3 W/kg. Following termination of the incubation period, spontaneous lymphoblastoid transformation was determined with an image analysis system. The results were compared among each of the experimental conditions and with sham-exposed cultures. At non-heating levels, CW exposure did not affect transformation. At heating levels both conventional and CW heating enhanced transformation to the same extent and correlate with the increases in incubation temperature. PW exposure enhanced transformation at non-heating levels. This finding is significant (P less than .002). At heating levels PW exposure enhanced transformation to a greater extent than did conventional or CW heating. This finding is significant at the .02 level. We conclude that PW 2450-MHz radiation acts differently on the process of lymphoblastoid transformation in vitro compared with CW 2450-MHz radiation at the same average SARs.

**Czyz J, GuanK, ZengQ, NikolovaT, MeisterA, SchönbornF, SchudererJ, KusterN, WobusAM, High frequency electromagnetic fields (GSM signals) affect gene expression levels in tumor suppressor p53-deficient embryonic stem cells. Bioelectromagnetics 25:296-307, 2004.**

Effects of electromagnetic fields (EMF) simulating exposure to the Global System for Mobile Communications (GSM) signals were studied using pluripotent embryonic stem (ES) cells in vitro. Wild-type ES cells and ES cells deficient for the tumor suppressor p53 were exposed to pulse modulated EMF at 1.71 GHz, lower end of the uplink band of GSM 1800, under standardized and controlled conditions, and transcripts of regulatory genes were analyzed during in vitro differentiation. Two dominant GSM modulation schemes (GSM-217 and GSM-Talk), which generate temporal changes between GSM-Basic (active during talking phases) and GSM-DTX (active during listening phases thus simulating a typical conversation), were applied to the cells at and below the basic safety limits for local exposures as defined for the general public by the International Commission on Nonionizing Radiation Protection (ICNIRP). GSM-217 EMF induced a significant upregulation of mRNA levels of the heat shock protein, hsp70 of p53-deficient ES cells differentiating in vitro, paralleled by a low and transient increase of c-jun, c-myc, and p21 levels in p53-deficient, but not in wild-type cells. No responses were observed in either cell type after EMF exposure to GSM-Talk applied at similar slot-averaged specific absorption rates (SAR), but at lower time-averaged SAR values. Cardiac differentiation and cell cycle characteristics were not affected in embryonic stem and embryonic carcinoma cells after exposure to GSM-217 EMF signals. Our data indicate that the genetic background determines cellular responses to GSM modulated EMF.

**Dabouis V, Arvers P, Debouzy JC, Sebbah C, Crouzier D, Perrin A.First epidemiological study on occupational radar exposure in the French Navy: a 26-year cohort study. Int J Environ Health Res. 2015 Jul 28:1-14. [Epub ahead of print]**

This retrospective cohort study deals with the causes of death among 57,000 military personnel who served in the French Navy surface vessels and were observed over the period 1975-2000. We successively compared the mortality rate and the specific causes of death between two groups differing in their potential exposure levels to radar. Occupational exposure was defined according to the on-board workplace (radar and control groups). The age-adjusted death ratios of the navy personnel were compared. For all causes of death, the results showed that 885 deaths in the radar group and 299 in the control group occurred (RR = 1.00 (95 % CI: 0.88-1.14)). RRs were 0.92 (95 % CI: 0.69-1.24) for neoplasms. For the duration of follow-up, the results did not show an increased health risk for military personnel exposed to higher levels of radio frequencies in the radar group, but the number of deaths was very small for some cancer sites.

**Dabrowski MP, Stankiewicz W, Kubacki R, Sobiczewska E, Szmigielski S. Immunotropic Effects in Cultured Human Blood Mononuclear Cells Pre-exposed to Low-Level 1300 MHz Pulse-Modulated Microwave Field Electromag. Biol. Med. 22:1-13, 2003.**

The samples of mononuclear cells isolated from peripheral blood of healthy donors (N = 16) were exposed to 1300 MHz pulse-modulated microwaves at 330 pps with 5 μs pulse width. The samples were exposed in an anechoic chamber at the average value of power density of S = 10 W/m$^2$ (1 mW/cm$^2$). The average specific absorption rate (SAR) was measured in rectangular waveguide and the value of SAR = 0.18 W/kg was recorded. Subsequently, the exposed and control cells were assessed in the microculture system for several parameters characterizing their proliferative and immunoregulatory properties. Although the irradiation decreased the spontaneous incorporation of 3H-thymidine, the proliferative response of lymphocytes to phytohemagglutinin (PHA) and to Con A as well as the T-cell suppressive activity (SAT index) and the saturation of IL-2 receptors did not change. Nevertheless, the lymphocyte production of interleukin (IL)-10 increased (P < .001) and the concentration of IFNγ remained unchanged or slightly decreased in the culture supernatants. Concomitantly, the microwave irradiation modulated the monokine production by monocytes. The production of IL-1β increased significantly (P < .01), the concentration of its antagonist (IL-1ra) dropped by half (P < .01) and the tumor necrosis factor (TNF-α) concentration remained unchanged. These changes of monokine proportion (IL-1β vs. IL-1ra) resulted in significant increase of the value of LM index (P < .01), which reflects the activation of monocyte immunogenic function. The results indicate that pulse-modulated microwaves represent the potential of immunotropic influence, stimulating preferentially the immunogenic and proinflammatory activity of monocytes at relatively low levels of exposure.

**Dahmen N**, **Ghezel-Ahmadi D**, **Engel A**. **Blood laboratory findings in patients suffering from self-perceived electromagnetic hypersensitivity (EHS). Bioelectromagnetics. 30(4):299-306, 2009.**

Risks from electromagnetic devices are of considerable concern. Electrohypersensitive (EHS) persons attribute a variety of rather unspecific symptoms to exposure to electromagnetic fields. The pathophysiology of EHS is unknown and therapy remains a challenge. We hypothesized that some electrosensitive individuals are suffering from common somatic health problems. Toward this end we analysed clinical laboratory parameters including thyroid-stimulating hormone (TSH), alanine transaminase (ALT), aspartate transaminase (AST), creatinine, hemoglobine, hematocrit and c-reactive protein (CRP) in subjects suffering from EHS and in controls that are routinely used in clinical medicine to identify or screen for common somatic disorders. One hundred thirty-two patients (n = 42 males and n = 90 females) and 101 controls (n = 34 males and n = 67 females) were recruited. Our results identified laboratory signs of thyroid dysfunction, liver dysfunction and chronic inflammatory processes in small but remarkable fractions of EHS sufferers as potential sources of symptoms that merit further investigation in future studies. In the cases of TSH and ALT/AST there were significant differences between cases and controls. The hypotheses of anaemia or kidney dysfunction playing a major role in EHS could be unambiguously refuted. Clinically it is recommended to check for signs of treatable somatic conditions when caring for individuals suffering from self-proclaimed EHS.

**d'Ambrosio G, MassaR, Scarfi MR, Zeni O, Cytogenetic damage in human lymphocytes following GMSK phase modulated microwave exposure. Bioelectromagnetics 23:7-13, 2002.**

The present study investigated, using in vitro experiments on human lymphocytes, whether exposure to a microwave frequency used for mobile communication, either unmodulated or in presence of phase only modulation, can cause modification of cell proliferation kinetics and/or genotoxic effects, by evaluating the cytokinesis block proliferation index and the micronucleus frequency. In the GSM 1800 mobile communication systems the field is both phase (Gaussian minimum shift keying, GMSK) and amplitude (time domain multiple access, TDMA) modulated. The present study investigated only the effects of phase modulation, and no amplitude modulation was applied. Human peripheral blood cultures were exposed to 1.748 GHz, either continuous wave (CW) or phase only modulated wave (GMSK), for 15 min. The maximum specific absorption rate (~5 W/kg) was higher than that occurring in the head of mobile phone users; however, no changes were found in cell proliferation kinetics after exposure to either CW or GMSK fields. As far as genotoxicity is concerned, the micronucleus frequency result was not affected by CW exposure; however, a statistically significant micronucleus effect was found following exposure to phase modulated field. These results would suggest a genotoxic power of the phase modulation per se.

**D'Andrea JA, DeWitt JR, Portuguez LM, Gandhi OP. Reduced exposure to microwave radiation by rats: frequency specific effects. Prog Clin Biol Res. 257:289-308, 1988.**

Previous research has shown that SAR "hotspots" are induced within the laboratory rat and that the resulting thermal hotspots are not entirely dissipated by bloodflow. Two experiments were conducted to determine if hotspot formation in the body and tail of the rat, which is radiation frequency specific, would have behavioral consequences. In the

first experiment rats were placed in a plexiglas cage one side of which, when occupied by the rat, commenced microwave radiation exposure; occupancy of the other side terminated exposure. Groups of rats were tested during a baseline period to determine the naturally preferred side of the cage. Subsequent exposure to 360-MHz, 700-MHz or 2450-MHz microwave radiation was made contingent on preferred-side occupancy. A significant reduction in occupancy of the preferred side of the cage, and hence, microwaves subsequently occurred. Reduced exposure to 360-MHz and 2450-MHz microwaves at 1, 2, 6 and 10 W/kg were significantly different from 700-MHz microwaves. In the second experiment semichronic exposures revealed the threshold for reduced exposure of 2450-MHz microwaves to be located between whole-body SAR's of 2.1 and 2.8 W/kg.

**D'Andrea JA, Thomas A, Hatcher DJ, Rhesus monkey behavior during exposure to high-peak-power 5.62-GHz microwave pulses. Bioelectromagnetics 15(2):163-176, 1994.**

Limits on the exposure to high-peak-power, short-duration microwave pulses have only recently been adopted. Additional data, however, are needed to understand the effects that may be produced by exposure to high-peak-power pulsed microwaves. Four male rhesus monkeys (Macaca mulatta) were trained on an operant task for food pellet reward to investigate the behavioral effects of very high-peak-power 5.62 GHz microwaves. The operant task required monkeys to pull one plastic lever on a variable interval schedule (VI-25 s) and then respond to color signals and pull a second lever to obtain food. The monkeys were conditioned to perform a color discrimination task using one of three colors displayed by a fiber-optic cable. A red signal was the discriminative stimulus for responding on the first lever. A response on the second lever when a green signal was presented (1 s duration) delivered a food pellet. If a response on the second lever was made in the presence of a white signal, a 30-s timeout occurred. While performing the behavioral task, the monkeys were exposed to microwave pulses produced by either a military radar (FPS-26A) operating at 5.62 GHz or the same radar coupled to a Stanford linear energy doubler (SLED) pulse-forming device (ITT-2972) that enhanced peak power by a factor of nine by adding a high power pulse to the radar pulse. The effects of both types of pulses were compared to sham exposure. Peak field power densities tested were 518, 1270, and 2520 W/cm2 for SLED pulses and 56, 128, and 277 W/cm2 for the radar pulses. The microwave pulses (radar or SLED) were delivered at 100 pps (2.8 microseconds radar pulse duration; approximately 50 ns SLED pulse duration) for 20 min and produced averaged whole-body SARs of 2, 4, or 6 W/kg. Compared to sham exposures, significant alterations of lever responding, reaction time, and earned food pellets occurred during microwave exposure at 4 and 6 W/kg but not at 2 W/kg. There were no differences between radar or SLED pulses in producing behavioral effects.

**Danese E, Lippi G, Buonocore R, Benati M, Bovo C, Bonaguri C, Salvagno GL, Brocco G, Roggenbuck D, Montagnana M.** Mobile phone **radiofrequency exposure has no effect on DNA double strand breaks (DSB) in human lymphocytes. Ann Transl Med. 5(13):272, 2017.**

BACKGROUND: The use of **mobile phones** has been associated with an increased risk of developing certain type of cancer, especially in long term users. Therefore, this study

was aimed to investigate the potential genotoxic effect of **mobile phone** radiofrequency exposure on human peripheral blood mononuclear cells in vitro.METHODS: The study population consisted in 14 healthy volunteers. After collection of two whole blood samples, the former was placed in a plastic rack, 1 cm from the chassis of a commercial **mobile phone** (900 MHz carrier frequency), which was activated by a 30-min call. The second blood sample was instead maintained far from **mobile phones** or other RF sources. The influence of **mobile phone** RF on DNA integrity was assessed by analyzing γ-H2AX foci in lymphocytes using immunofluorescence staining kit on AKLIDES. RESULTS: No measure of γ-H2AX foci was significantly influenced by **mobile phone** RF exposure, nor **mobile phone** exposure was associated with significant risk of genetic damages in vitro (odds ratio comprised between 0.27 and 1.00). CONCLUSIONS: The results of this experimental study demonstrate that exposure of human lymphocytes to a conventional 900 MHz RF emitted by a commercial **mobile phone** for 30 min does not significantly impact DNA integrity.

**Daniels WM, Pitout IL, Afullo TJ, Mabandla MV. The effect of electromagnetic radiation in the mobile phone range on the behaviour of the rat. Metab Brain Dis. 24(4):629-641, 2009**

Electromagnetic radiation (EMR) is emitted from electromagnetic fields that surround power lines, household appliances and mobile phones. Research has shown that there are connections between EMR exposure and cancer and also that exposure to EMR may result in structural damage to neurons. In a study by Salford et al. (Environ Health Perspect 111:881-883, 2003) the authors demonstrated the presence of strongly stained areas in the brains of rats that were exposed to mobile phone EMR. These darker neurons were particularly prevalent in the hippocampal area of the brain. The aim of our study was to further investigate the effects of EMR. Since the hippocampus is involved in learning and memory and emotional states, we hypothesised that EMR will have a negative impact on the subject's mood and ability to learn. We subsequently performed behavioural, histological and biochemical tests on exposed and unexposed male and female rats to determine the effects of EMR on learning and memory, emotional states and corticosterone levels. We found no significant differences in the spatial memory test, and morphological assessment of the brain also yielded non-significant differences between the groups. However, in some exposed animals there were decreased locomotor activity, increased grooming and a tendency of increased basal corticosterone levels. These findings suggested that EMR exposure may lead to abnormal brain functioning.

**Daniells, C, Duce, I, Thomas, D, Sewell, P, Tattersall, J, de Pomerai, D, Transgenic nematodes as biomonitors of microwave-induced stress. Mutat Res 399:55-64, 1998.**

Transgenic nematodes (Caenorhabditis elegans strain PC72), carrying a stress-inducible reporter gene (Escherichia coli beta-galactosidase) under the control of a C. elegans hsp16 heat-shock promoter, have been used to monitor toxicant responses both in water and soil. Because these transgenic nematodes respond both to heat and toxic chemicals by synthesising an easily detectable reporter product, they afford a useful preliminary

screen for stress responses (whether thermal or non-thermal) induced by microwave radiation or other electromagnetic fields. We have used a transverse electromagnetic (TEM) cell fed from one end by a source and terminated at the other end by a matched load. Most studies were conducted using a frequency of 750 MHz, at a nominal power setting of 27 dBm. The TEM cell was held in an incubator at 25 degrees C inside a shielded room; corresponding controls were shielded and placed in the same 25 degrees C incubator; additional baseline controls were held at 15 degrees C (worm growth temperature). Stress responses were measured in terms of beta-galactosidase (reporter) induction above control levels. The time-course of response to continuous microwave radiation showed significant differences from 25 degrees C controls both at 2 and 16 h, but not at 4 or 8 h. Using a 5 x 5 multiwell plate array exposed for 2 h, the 25 microwaved samples showed highly significant responses compared with a similar control array. The wells most strongly affected were those in the rows closest to the source, whereas the most distant row did not rise above control levels, suggesting a shadow effect. These differential responses are difficult to reconcile with general heating effects, although localised power absorption affords a possible explanation. Experiments in which the frequency and/or power settings were varied suggested a greater response at 21 than at 27 dBm, both at 750 and 300 MHz, although extremely variable responses were observed at 24 dBm and 750 MHz. Thus, lower power levels tended, if anything, to induce larger responses (with the above-mentioned exception), which is opposite to the trend anticipated for any simple heating effect. These results are reproducible and data acquisition is both rapid and simple. The evidence accrued to date suggests that microwave radiation causes measurable stress to transgenic nematodes, presumably reflecting increased levels of protein damage within cells (the common signal thought to trigger hsp gene induction). The response levels observed are comparable to those observed with moderate concentrations (ppm) of metal ions such as Zn2+ and Cu2+. We conclude that this approach deserves further and more detailed investigation, but that it has already demonstrated clear biological effects of microwave radiation in terms of the activation of cellular stress responses (hsp gene induction).

**Danker-Hopfe H, Dorn H, Bahr A, Anderer P, Sauter C. Effects of electromagnetic fields emitted by mobile phones (GSM 900 and WCDMA/UMTS) on the macrostructure of sleep. J Sleep Res.20(1 Pt 1):73-81, 2010.**

Summary In the present double-blind, randomized, sham-controlled cross-over study, possible effects of electromagnetic fields emitted by Global System for Mobile Communications (GSM) 900 and Wideband Code-Division Multiple Access (WCDMA)/Universal Mobile Telecommunications System (UMTS) cell-phones on the macrostructure of sleep were investigated in a laboratory environment. An adaptation night, which served as screening night for sleep disorders and as an adjustment night to the laboratory environment, was followed by 9 study nights (separated by a 2-week interval) in which subjects were exposed to three exposure conditions (sham, GSM 900 and WCDMA/UMTS). The sample comprised 30 healthy male subjects within the age range 18-30 years (mean +/- standard deviation: 25.3 +/- 2.6 years). A cell-phone usage at maximum radio frequency (RF) output power was simulated and the transmitted power was adjusted in order to approach, but not to exceed, the specific absorption rate (SAR) limits of the International Commission on Non-Ionizing

Radiation Protection (ICNIRP) guidelines for general public exposure (SAR(10g) = 2.0 W kg(-1)). In this study, possible effects of long-term (8 h) continuous RF exposure on the central nervous system were analysed during sleep, because sleep is a state in which many confounding intrinsic and extrinsic factors (e.g. motivation, personality, attitude) are eliminated or controlled. Thirteen of 177 variables characterizing the initiation and maintenance of sleep in the GSM 900 and three in the WCDMA exposure condition differed from the sham condition. The few significant results are not indicative of a negative impact on sleep architecture. From the present results there is no evidence for a sleep-disturbing effect of GSM 900 and WCDMA exposure.

**Danker-Hopfe H, Dorn H, Bornkessel C, Sauter C. Do mobile phone base stations affect sleep of residents? Results from an experimental double-blind sham-controlled field study. Am J Hum Biol. 22(5):613-618, 2010.**

OBJECTIVES: The aim of the present double-blind, sham-controlled, balanced randomized cross-over study was to disentangle effects of electromagnetic fields (EMF) and non-EMF effects of mobile phone base stations on objective and subjective sleep quality. METHODS: In total 397 residents aged 18-81 years (50.9% female) from 10 German sites, where no mobile phone service was available, were exposed to sham and GSM (Global System for Mobile Communications, 900 MHz and 1,800 MHz) base station signals by an experimental base station while their sleep was monitored at their homes during 12 nights. Participants were randomly exposed to real (GSM) or sham exposure for five nights each. Individual measurement of EMF exposure, questionnaires on sleep disorders, overall sleep quality, attitude towards mobile communication, and on subjective sleep quality (morning and evening protocols) as well as objective sleep data (frontal EEG and EOG recordings) were gathered. RESULTS: Analysis of the subjective and objective sleep data did not reveal any significant differences between the real and sham condition. During sham exposure nights, objective and subjective sleep efficiency, wake after sleep onset, and subjective sleep latency were significantly worse in participants with concerns about possible health risks resulting from base stations than in participants who were not concerned. CONCLUSIONS: The study did not provide any evidence for short-term physiological effects of EMF emitted by mobile phone base stations on objective and subjective sleep quality. However, the results indicate that mobile phone base stations as such (not the electromagnetic fields) may have a significant negative impact on sleep quality.

**Danker-Hopfe H, Dorn H, Bahr A, Anderer P, Sauter C. Effects of electromagnetic fields emitted by mobile phones (GSM 900 and WCDMA/UMTS) on the macrostructure of sleep.J Sleep Res. 20(1 Pt 1):73-81, 2011.**

In the present double-blind, randomized, sham-controlled cross-over study, possible effects of electromagnetic fields emitted by Global System for Mobile Communications (GSM) 900 and Wideband Code-Division Multiple Access (WCDMA)/Universal Mobile Telecommunications System (UMTS) cell-phones on the macrostructure of sleep were investigated in a laboratory environment. An adaptation night, which served as screening night for sleep disorders and as an adjustment night

to the laboratory environment, was followed by 9 study nights (separated by a 2-week interval) in which subjects were exposed to three exposure conditions (sham, GSM 900 and WCDMA/UMTS). The sample comprised 30 healthy male subjects within the age range 18-30 years (mean ± standard deviation: 25.3 ± 2.6 years). A cell-phone usage at maximum radio frequency (RF) output power was simulated and the transmitted power was adjusted in order to approach, but not to exceed, the specific absorption rate (SAR) limits of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for general public exposure (SAR(10g) = 2.0 W kg(-1)). In this study, possible effects of long-term (8 h) continuous RF exposure on the central nervous system were analysed during sleep, because sleep is a state in which many confounding intrinsic and extrinsic factors (e.g. motivation, personality, attitude) are eliminated or controlled. Thirteen of 177 variables characterizing the initiation and maintenance of sleep in the GSM 900 and three in the WCDMA exposure condition differed from the sham condition. The few significant results are not indicative of a negative impact on sleep architecture. From the present results there is no evidence for a sleep-disturbing effect of GSM 900 and WCDMA exposure.

**Danker-Hopfe H, Dorn H, Bolz T, Peter A, Hansen ML, Eggert T, Sauter C. Effects of mobile phone exposure (GSM 900 and WCDMA/UMTS) on polysomnography based sleep quality: An intra- and inter-individual perspective. Environ Res. 145:50-60, 2015.**

BACKGROUND: Studies on effects of radio frequency-electromagnetic fields (RF-EMF) on the macrostructure of sleep so far yielded inconsistent results. This study investigated whether possible effects of RF-EMF exposure differ between individuals. OBJECTIVE: In a double-blind, randomized, sham-controlled cross-over study possible effects of electromagnetic fields emitted by pulsed Global System for Mobile Communications (GSM) 900 and Wideband Code-Division Multiple Access (WCDMA)/Universal Mobile Telecommunications System (WCDMA/UMTS) devices on sleep were analysed. METHODS: Thirty healthy young men (range 18-30 years) were exposed three times per exposure condition while their sleep was recorded. Sleep was evaluated according to the American Academy of Sleep Medicine standard and eight basic sleep variables were considered. RESULTS: Data analyses at the individual level indicate that RF-EMF effects are observed in 90% of the individuals and that all sleep variables are affected in at least four subjects. While sleep of participants was affected in various numbers, combinations of sleep variables and in different directions, showing improvements but also deteriorations, the only consistent finding was an increase of stage R sleep under GSM 900MHz exposure (9 of 30 subjects) as well as under WCDMA/UMTS exposure (10 of 30 subjects). CONCLUSIONS: The results underline that sleep of individuals can be affected differently. The observations found here may indicate an underlying thermal mechanism of RF-EMF on human REM sleep. Nevertheless, the effect of an increase in stage R sleep in one third of the individuals does not necessarily indicate a disturbance of sleep.

**Das S, Chakraborty S, Mahanta B. A study on the effect of prolonged** mobile phone **use on pure tone audiometry thresholds of medical students of Sikkim. J Postgrad Med. 63(4):221-225, 2017.**

INTRODUCTION: **Mobile phones** have become indispensable for daily activities, and people are exposed to them from an early age. There is, however, concern about the harmful effect of the electromagnetic radiation emitted from the **mobile phones**.OBJECTIVE: The objective of the study was to study the effect of **mobile phone** on average pure tone audiometry (PTA) threshold of the person and to study the changes in the pure tone threshold at high frequencies such as 2 kHz, 4 kHz, and 8 kHz among the students with prolonged exposure to **mobile phones**.METHODOLOGY: A cross-sectional study was conducted among the medical students who have been using **mobile phones** for the past 5 years. The effect of **mobile phones** on the PTA threshold in the exposed ear and the nonexposed ear was assessed.RESULTS: The study shows that there is a significant difference in average air conduction (AC) and bone conduction (BC) hearing threshold among the exposed and the nonexposed ears ($P < 0.05$). A significant rise of both AC and BC threshold at individual frequencies between the exposed and the nonexposed ear is also noted in this study.CONCLUSION: The study conducted shows changes in the hearing threshold of the exposed ear when compared with the nonexposed ear. There are however lot of unanswered questions which provide an interesting avenue for further research. Till concrete evidence is available the only feasible way to control its exposure is to limit the duration of usage of **mobile phones**.

**Dasdag, S, Ketani, MA, Akdag, Z, Ersay, AR, Sar,i I, Demirtas ,OC, Celik, MS, Whole-body microwave exposure emitted by cellular phones and testicular function of rats. Urol Res 27(3):219-223, 1999.**

This study investigated whether there are adverse effects due to microwave exposure emitted by cellular phones in male rats. Eighteen Wistar Albino rats were separated into three groups, a sham group and two experimental groups. The rats were confined in Plexiglas cages and cellular phones were placed 0.5 cm under the cages. In the first experimental group, cellular phones were in standby position for 2 h. In the second experimental group, phones were turned to the speech position three times each for 1 min duration over 2 h. Rats in the first and second experimental groups were exposed to microwaves emitted by phones for 2 h/day for a duration of 1 month. After the last exposure the rats were killed. Brain, eyes, ears, liver, heart, lungs, stomach, kidneys, testes, small and large intestines and skin of the rats were observed histologically. The decrease of epididymal sperm counts in the speech groups were not found to be significant ($P > 0.05$). Differences in terms of normal and abnormal sperm forms were not observed ($P > 0.05$). Histological changes were especially observed in the testes of rats of the speech groups. Seminiferous tubular diameter of rat testes in the standby and speech groups was found to be lower than the sham group ($P < 0.05$). Rectal temperatures of rats in the speech group were found to be higher than the sham and standby groups ($P < 0.05$). The rectal temperatures of rats before and after exposure were also found to be significantly higher in the speech group ($P < 0.05$). Specific absorption rate (SAR) was determined as 0.141 W/kg.

**Dasdag S, Zulkuf Akdag M, Aksen F, Yilmaz F, Bashan M, Mutlu Dasdag M, Salih Celik M. Whole body exposure of rats to microwaves emitted from a cell phone does not affect the testes. Bioelectromagnetics 24(3):182-188, 2003.**

The objective of this study was to investigate the effects of radiofrequency radiation emitted from cellular phones on the lipid composition, malondialdehyde concentration, p53 immune reactivity, sperm count, morphology, histological structure of testes, and on rectal temperature of rats exposed to microwave radiation emitted from cellular phones. Sixteen Spraque-Dawley rats were separated into two groups of eight, sham exposed (control) and experimental. The rats were confined in plexiglas cages specially designed for this study, and cellular phones were placed 0.5 cm under the cages. For the experimental group, cellular phones were activated 20 min per day (7 days a week) for 1 month. For the control group, the cellular phones were placed beneath the cages for 20 min a day, but the phones were turned off. Rectal temperatures were measured weekly. For 250 mW radiated power, the whole body average SAR (rms) is 0.52 W/kg and 1 g averaged peak SAR (rms) is 3.13 W/kg. The Mann-Whitney U-test was used for statistical comparisons of groups. No statistically significant alteration in any of the endpoints was noted. This study found no evidence suggesting an adverse effect of cell phone exposure on measures of testicular function or structure.

**Dasdag S; Akdag MZ; Ayy□ld□z O, Demirtas OC, Yayla M, Sert C. Do cellular phones alter blood parameters and birth weight of rats? Electromag Biol Med. 19:107-113, 2000.**

The present study aimed to investigate the effects of microwaves (MW) emitted by cellular phones (CPs) on peripheral blood parameters and birth weights of rats. Thirty-six albino rats were divided into four groups, male (n = 6) and female sham-exposed groups (n = 12) and male (n = 6) and female experimental groups (n = 12). No blood parameters differed following exposure ($p > 0.05$). The birth weight of offspring in the experimental group was significantly lower than in the sham-exposed group ($p < 0.001$). No significant differences were observed between rectal temperatures of rats in the sham and experimental groups ($p > 0.05$). The specific absorption rate (SAR) was found to be 0.155 W/kg for the experimental groups. All parameters investigated were normal in the next generation of rats ($p > 0.05$).

**Dasdag S, Akdag MZ, Ulukaya E, Uzunlar AK, Yegin D. Mobile phone exposure does not induce apoptosis on spermatogenesis in rats.Arch Med Res. 39(1):40-44, 2008.**

BACKGROUND: Some studies have reported that microwave radiation can have adverse effects on reproduction. Therefore, the purpose of this study was to investigate the apoptosis-inducing effect of mobile phone exposure on spermatogonia in seminiferous tubules. METHODS: The study was carried out on 31 Wistar albino adult male rats. The rats were separated into three groups in this study (cage control: 10, sham group: 7, and exposed group: 14). For the study group, rats were exposed to radiation 2 h/day (7 days/week) for 10 months. For the sham group, rats were placed into the carousel and the same procedure was applied except that the generator was turned off. For the cage control, nothing was applied to the rats in this group and they completed their life cycle in the cage during the study period. In this

study, rats were sacrificed after 10 months of exposure and their testes were taken. Testes tissue was immunohistochemically stained for the active (cleaved) caspase-3. Positively stained cells were counted in up to ten different areas, and the frequency of positive cells was determined in percentage. Scoring was done by taking into account both the intensity of staining and the distribution of positively stained cells. Therefore, protein expression was evaluated by a semiquantitative scoring system. RESULTS: The final score for apoptosis of testes in the exposed group was not statistically significant according to the sham and the cage control groups ($p > 0.05$). CONCLUSIONS: The results of this study showed that 2 h/day (7 days/week) exposure of 900 MHz radiation over a period of 10 months does not affect the active (cleaved) caspase-3 levels in testes, a well-known feature of typical apoptosis.

**Dasdag S, Akdag MZ, Ulukaya E, Uzunlar AK, Ocak AR. Effect of mobile phone exposure on apoptotic glial cells and status of oxidative stress in rat brain. Electromagn Biol Med. 28(4):342-354, 2009.**

The aim of this study was to investigate the effects of mobile phone exposure on glial cells in brain. The study carried out on 31 Wistar Albino adult male rats. The rat heads in a carousel exposed to 900 MHz microwave. For the study group (n:14), rats exposed to the radiation 2 h per day (7 days in a week) for 10 months. For the sham group (n:7), rats were placed into the carousel and the same procedure was applied except that the generator was turned off. For the cage control (n:10), nothing applied to rats in this group. In this study, rats were euthanized after 10 months of exposure periods and brains were removed. Brain tissues were immunohistochemically stained for the active (cleaved) caspase-3, which is a well-known apoptosis marker, and p53. The expression of the proteins was evaluated by a semi-quantitative scoring system. However, total antioxidative capacity (TAC), catalase, total oxidant status (TOS), and oxidative stress index were measured in rat brain. Final score for apoptosis in the exposed group was significantly lower than the sham ($p < 0.001$) and the cage control groups ($p < 0.01$). p53 was not significantly changed by the exposure ($p > 0.05$). The total antioxidant capacity and catalase in the experimental group was found higher than that in the sham group ($p < 0.001$, $p < 0.05$). In terms of the TOS and oxidative stress index, there was no statistically significant difference between exposure and sham groups ($p > 0.05$). In conclusion, the final score for apoptosis, total antioxidant capacity and catalase in rat brain might be altered by 900 MHz radiation produced by a generator to represent exposure of global systems for mobile communication (GSM) cellular phones.

**Dasdag S, Akdag MZ, Kizil G, Kizil M, Cakir DU, Yokus B. Effect of 900 MHz radio frequency radiation on beta amyloid protein, protein carbonyl, and malondialdehyde in the brain. Electromagn Biol Med. 31(1):67-74, 2012.**

Recently, many studies have been carried out in relation to 900 MHz radiofrequency radiation (RF) emitted from a mobile phone on the brain. However, there is little data concerning possible mechanisms between long-term exposure of RF radiation and biomolecules in brain. Therefore, we aimed to investigate long-term effects of 900 MHz radiofrequency radiation on beta amyloid protein, protein carbonyl, and malondialdehyde in the rat brain. The study was carried out on 17 Wistar Albino adult

male rats. The rat heads in a carousel were exposed to 900 MHz radiofrequency radiation emitted from a generator, simulating mobile phones. For the study group (n: 10), rats were exposed to the radiation 2 h per day (7 days a week) for 10 months. For the sham group (n: 7), rats were placed into the carousel and the same procedure was applied except that the generator was turned off. In this study, rats were euthanized after 10 months of exposure and their brains were removed. Beta amyloid protein, protein carbonyl, and malondialdehyde levels were found to be higher in the brain of rats exposed to 900 MHz radiofrequency radiation. However, only the increase of protein carbonyl in the brain of rats exposed to 900 MHz radiofrequency radiation was found to be statistically significant ($p<0.001$). In conclusion, 900 MHz radiation emitted from mobile/cellular phones can be an agent to alter some biomolecules such as protein. However, further studies are necessary.

**Dasdag S, Taş M, Akdag MZ, Yegin K. Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions. Electromagn Biol Med. 2014 Jan 24. [Epub ahead of print]**

The aim of this study was to investigate long-term effects of radiofrequency radiation (RFR) emitted from a Wireless Fidelity (Wi-Fi) system on testes. The study was carried out on 16 Wistar Albino adult male rats by dividing them into two groups such as sham (n: 8) and exposure (n: 8). Rats in the exposure group were exposed to 2.4 GHz RFR radiation for 24 h/d during 12 months (1 year). The same procedure was applied to the rats in the sham control group except the Wi-Fi system was turned off. Immediately after the last exposure, rats were sacrificed and reproductive organs were removed. Motility (%), concentration ($\times 10^6$/mL), tail defects (%), head defects (%) and total morphologic defects (%) of sperms and weight of testes (g), left epididymis (g), prostate (g), seminal vesicles (g) were determined. Seminiferous tubules diameter (μm) and tunica albuginea thickness (μm) were also measured. However, the results were evaluated by using Johnsen's score. Head defects increased in the exposure group ($p < 0.05$) while weight of the epididymis and seminal vesicles, seminiferous tubules diameter and tunica albuginea thickness were decreased in the exposure group ($p < 0.01$, $p < 0.001$, $p < 0.0001$). However, other alterations of other parameters were not found significant ($p > 0.05$). In conclusion, we observed that long-term exposure of 2.4 GHz RF emitted from Wi-Fi (2420 μW/kg, 1 g average) affects some of the reproductive parameters of male rats. We suggest Wi-Fi users to avoid long-term exposure of RF emissions from Wi-Fi equipment.

**Dasdag S, Yavuz I1, Bakkal M, Kargul B. Effect of long term 900 MHz radiofrequency radiation on enamel microhardness of rat's teeth. Oral Health Dent Manag. 13(3):749-752, 2014.**

PURPOSE:  Oral tissues are important parts of body that absorbs radiation emitted from mobile phones which is the most popular technological equipment in the world. Because of the limited studies in this field, we aimed to investigate the effect of Radio Frequency (RF) radiation emitted from 900 MHz mobile phones on the enamel micro hardness of rat teeth. MATERIALS AND METHODS:  The study was carried out on twenty one Wistar

Albino adult male rats which were divided into two groups such as control and experiment groups. For the study group (n: 14), rats exposed to the radiation 2 h per day (7 days in a week) for 10 months. For the control group (n: 7), rats were placed into the carousel and the same procedure was applied except that the generator was turned off. At the end of the study, enamel micro hardness of rat's teeth was measured. RESULTS: The results of this study showed that 900 MHz RF radiation did not alter the enamel micro hardness of rats' teeth (p>0.05). CONCLUSIONS: Exposure of 900 MHz RF radiation for 2 hours per day during ten months does not alter enamel micro hardness of rats' teeth. However, further studies are necessary to clarify this topic.

**Dasdag S, Akdag MZ, Erdal ME, Erdal N, Ay OI, Ay ME, Yilmaz SG, Tasdelen B, Yegin K. Long term and excessive use of 900 MHz radiofrequency radiation alter microrna expression in brain. Int J Radiat Biol. 2014 Dec 20:1-22. [Epub ahead of print].**

Purpose: We still do not have any information on the interaction between radiofrequency radiation (RF) and miRNAs, which play paramount role in growth, differentiation, proliferation and cell death by suppressing one or more target genes. The purpose of this study is to bridge this gap by investigating effects of long term 900 MHz mobile phone exposure on some of the miRNAs in brain tissue.
Materials and Methods: The study was carried out on fourteen Wistar Albino adult male rats by dividing them into two groups: sham (n: 7) and exposure (n: 7). Rats in the exposure group were exposed to 900 MHz RF radiation for 3 h per day (7 d a week) for twelve months (one year). The same procedure was applied to the rats in the sham group except the generator was turned off. Immediately after the last exposure, rats were sacrificed and their brains were removed. rno-miR-9-5p, rno-miR-29a-3p, rno-miR-106b-5p, rno-miR-107 and rno-miR-125a-3p in brain were investigated in detail. Results: Results revealed that long term exposure of 900 MHz RF radiation only decreased rno-miR107 (adjP*= 0,045) value where the whole body (rms) SAR value was 0.0369 W/kg. However, our results indicated that other micro RNAs evaluated in this study was not altered by 900 MHz RF radiation. Conclusion: 900 MHz RF radiation can alter some of the miRNAs, which, in turn, may lead to adverse effects. Therefore, further studies should be performed.

**Dasdag S, Akdag MZ, Erdal ME, Erdal N, Ay OI, Ay ME, Yilmaz SG, Tasdelen B, Yegin K. Long term and excessive use of 900 MHz radiofrequency radiation alter microRNA expression in brain. Int J Radiat Biol. 2015 Jan 27:1-6. [Epub ahead of print]**

Purpose: We still do not have any information on the interaction between radiofrequency radiation (RF) and miRNA, which play paramount role in growth, differentiation, proliferation and cell death by suppressing one or more target genes. The purpose of this study was to bridge this gap by investigating effects of long-term 900 MHz mobile phone exposure on some of the miRNA in brain tissue. Materials and methods: The study was carried out on 14 Wistar Albino adult male rats by dividing them into two groups: Sham (n = 7) and exposure (n = 7). Rats in the exposure group were exposed to 900 MHz RF radiation for 3 h per day (7 days a week) for 12 months (one year). The same procedure

was applied to the rats in the sham group except the generator was turned off. Immediately after the last exposure, rats were sacrificed and their brains were removed. rno-miR-9-5p, rno-miR-29a-3p, rno-miR-106b-5p, rno-miR-107 and rno-miR-125a-3p in brain were investigated in detail. Results: Results revealed that long-term exposure of 900 MHz RF radiation only decreased rno-miR107 (adjP* = 0.045) value where the whole body (rms) SAR value was 0.0369 W/kg. However, our results indicated that other microRNA evaluated in this study was not altered by 900 MHz RF radiation. Conclusion: 900 MHz RF radiation can alter some of the miRNA, which, in turn, may lead to adverse effects. Therefore, further studies should be performed.

**Davis RL, Mostofi FK, Cluster of testicular cancer in police officers exposed to hand-held radar. Am J Ind Med 24(2):231-233, 1993.**

Within a cohort of 340 police officers, six incident cases of testicular cancer occurred between 1979 and 1991 (O/E 6.9; $p < 0.001$, Poisson distribution). Occupational use of hand-held radar was the only shared risk factor among all six officers, and all routinely held the radar gun directly in close proximity to their testicles. Health effects of occupational radar use have not been widely studied, and further research into a possible association with testicular cancer is warranted.

**Davidson HC, Lutman ME. Survey of mobile phone use and their chronic effects on the hearing of a student population. Int J Audiol. 46(3):113-118, 2007.** [Article in English, French]

Mobile phone ownership and usage is now widespread and public concern has developed over possible harmful physiological effects of their use. This study aimed to investigate the prevalence of student mobile phone ownership and any possible chronic effects of usage on hearing, tinnitus and balance. Questionnaires for electronic self-completion were distributed to University of Southampton postgraduates, and 117 out of 160 returned met the criteria for analysis. A total of 94% were current mobile phone users, and only 2% had never used a mobile phone. Duration of ownership and daily usage ranged from 0-7 years and 0-45 minutes respectively. Text-messaging was more popular than talking. High or long-term users reported no worse hearing, tinnitus, or balance than low or short-term users. The results of this study confirm that the prevalence of mobile phone ownership amongst students is extremely high. However there appear to be no harmful effects of mobile phone usage on their audiovestibular systems within the range of exposure of the study, insofar as can be detected by the self-report method employed.

**Dawe AS, Smith B, Thomas DW, Greedy S, Vasic N, Gregory A, Loader B, de Pomerai DI. A small temperature rise may contribute towards the apparent induction by microwaves of heat-shock gene expression in the nematode Caenorhabditis Elegans. Bioelectromagnetics.27(2):88-97, 2006.**

We have previously reported that low intensity microwave exposure (0.75-1.0 GHz CW at 0.5 W; SAR 4-40 mW/kg) can induce an apparently non-thermal heat-shock response in Caenorhabditis elegans worms carrying hsp16-1::reporter genes. Using matched copper TEM cells for both sham and exposed groups, we can detect only modest reporter

induction in the latter exposed group (15-20% after 2.5 h at 26 degrees C, rising to approximately 50% after 20 h). Traceable calibration of our copper TEM cell by the National Physical Laboratory (NPL) reveals significant power loss within the cell (8.5% at 1.0 GHz), accompanied by slight heating of exposed samples ( approximately 0.3 degrees C at 1.0 W). Thus, exposed samples are in fact slightly warmer (by </=0.2 degrees C at 0.5 W) than sham controls. Following NPL recommendations, our TEM cell design was modified with the aim of reducing both power loss and consequent heating. In the modified silver-plated cell, power loss is only 1.5% at 1.0 GHz, and sample warming is reduced to approximately 0.15 degrees C at 1.0 W (i.e., </=0.1 degrees C at 0.5 W). Under sham:sham conditions, there is no difference in reporter expression between the modified silver-plated TEM cell and an unmodified copper cell. However, worms exposed to microwaves (1.0 GHz and 0.5 W) in the silver-plated cell also show no detectable induction of reporter expression relative to sham controls in the copper cell. Thus, the 20% "microwave induction" observed using two copper cells may be caused by a small temperature difference between sham and exposed conditions. In worms incubated for 2.5 h at 26.0, 26.2, and 27.0 degrees C with no microwave field, there is a consistent and significant increase in reporter expression between 26.0 and 26.2 degrees C (by approximately 20% in each of the six independent runs), but paradoxically expression levels at 27.0 degrees C are similar to those seen at 26.0 degrees C. This surprising result is in line with other evidence pointing towards complex regulation of hsp16-1 gene expression across the sub-heat-shock range of 25-27.5 degrees C in C. elegans. We conclude that our original interpretation of a non-thermal effect of microwaves cannot be sustained; at least part of the explanation appears to be thermal.

**Dawe AS, Nylund R, Leszczynski D, Kuster N, Reader T, De Pomerai DI. Continuous wave and simulated GSM exposure at 1.8 W/kg and 1.8 GHz do not induce hsp16-1 heat-shock gene expression in Caenorhabditis elegans. Bioelectromagnetics. 29(2):92-99, 2008.**

Recent data suggest that there might be a subtle thermal explanation for the apparent induction by radiofrequency (RF) radiation of transgene expression from a small heat-shock protein (hsp16-1) promoter in the nematode, Caenorhabditis elegans. The RF fields used in the C. elegans study were much weaker (SAR 5-40 mW kg(-1)) than those routinely tested in many other published studies (SAR approximately 2 W kg(-1)). To resolve this disparity, we have exposed the same transgenic hsp16-1::lacZ strain of C. elegans (PC72) to higher intensity RF fields (1.8 GHz; SAR approximately 1.8 W kg(-1)). For both continuous wave (CW) and Talk-pulsed RF exposures (2.5 h at 25 degrees C), there was no indication that RF exposure could induce reporter expression above sham control levels. Thus, at much higher induced RF field strength (close to the maximum permitted exposure from a mobile telephone handset), this particular nematode heat-shock gene is not up-regulated. However, under conditions where background reporter expression was moderately elevated in the sham controls (perhaps as a result of some unknown co-stressor), we found some evidence that reporter expression may be reduced by approximately 15% following exposure to either Talk-pulsed or CW RF fields.

**D'Costa H, Trueman G, Tang L, Abdel-rahman U, Abdel-rahman W, Ong K, Cosic I. Human brain wave activity during exposure to radiofrequency field emissions from mobile phones. Australas Phys Eng Sci Med. 26(4):162-167, 2003.**

The aim of this study was to determine whether there is an effect of mobile phone electromagnetic field emissions on the human electroencephalograph (EEG). EEG recordings from ten awake subjects were taken during exposure to radiofrequency (RF) emissions from a mobile phone positioned behind the head. Two experimental trials were conducted. In the first trial, RF exposures were generated by a GSM mobile phone with the speaker disabled and configured to transmit at full-radiated power. During the second trial, exposures were generated by a non-modified GSM mobile phone in active standby mode. For each trial, subjects were exposed in five minute intervals to a randomized, interrupted sequence of five active and five sham exposures. The experiment was conducted under single-blind conditions. The average EEG band power in active exposure recordings was compared to corresponding sham recordings. Statistical tests indicated significant difference in the full-power mode trial within the EEG alpha (8-13 Hz) and beta (13-32 Hz) bands. A subsequent statistical analysis of median spectral power in discrete EEG rhythms revealed significant differences in 7 of the 32 distinct frequencies overall. In conclusion, the results of this study lend support to EEG effects from mobile phones activated in talk-mode.

**de Gannes FP, Taxile M, Duleu S, Hurtier A, Haro E, Geffard M, Ruffié G, Billaudel B, Lévêque P, Dufour P, Lagroye I, Veyret B. A confirmation study of Russian and Ukrainian data on effects of 2450 MHz microwave exposure on immunological processes and teratology in rats. Radiat Res. 172(5):617-624, 2009.**

In a series of Russian and Ukrainian papers published from 1974-1986, it was reported that 30-day whole-body exposures to continuous-wave (CW) radiofrequency (RF) radiation at 2375 MHz and 5 W/m(2) disrupted the antigenic structure of rat brain tissue. The authors suggested that this action caused an autoimmune response in exposed animals. Moreover, these studies reported that blood serum from exposed rats injected into intact nonexposed female rats on the 10th day of pregnancy led to increased postimplantation embryo mortality and decreased fetus size and body weight. Because the results of these studies served in part as the basis for setting exposure limits in the former USSR, it was deemed necessary to perform confirmation studies, using modern dosimetric and biological methods. In our study, a new system was constructed to expose free-moving rats under far-field conditions. Whole-body and brain-averaged specific absorption rates (SARs) were calculated. All results, using ELISA and classic teratology end points, were negative in our laboratory. On the basis of this investigation, we conclude that, under these exposure conditions (2450 MHz, CW, 7 h/day, 30 days, 0.16 W/kg whole-body SAR), RF-radiation exposure had no influence on several immune and degenerative parameters or on prenatal development.

**de Gannes FP, Billaudel B, Taxile M, Haro E, Ruffié G, Lévêque P, Veyret B, Lagroye I. Effects of head-only exposure of rats to GSM-900 on blood-brain barrier permeability and neuronal degeneration. Radiat Res. 172(3):359-367, 2009.**

Salford et al. reported in 2003 that a single 2-h exposure to GSM-900 mobile telephony signals induced brain damage (increased permeability of the blood-brain barrier and presence of dark neurons) 50 days after exposure. In our study, 16 Fischer 344 rats (14

weeks old) were exposed head-only to the GSM-900 signal for 2 h at various brain-averaged SARs (0, 0.14 and 2.0 W/kg) or were used as cage or positive controls. Albumin leakage and neuron degeneration were evaluated 14 and 50 days after exposure. No apoptotic neurons were found 14 days after the last exposure using the TUNEL method. No statistically significant albumin leakage was observed. Neuronal degeneration, assessed using cresyl violet or the more specific marker Fluoro-Jade B, was not significantly different among the tested groups. No apoptotic neurons were detected. The findings of our study did not confirm the previous results of Salford et al.

**De Iuliis GN**, **Newey RJ**, **King BV**, **Aitken RJ**. **Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa in vitro. PLoS One. 4(7):e6446, 2009.**

BACKGROUND: In recent times there has been some controversy over the impact of electromagnetic radiation on human health. The significance of mobile phone radiation on male reproduction is a key element of this debate since several studies have suggested a relationship between mobile phone use and semen quality. The potential mechanisms involved have not been established, however, human spermatozoa are known to be particularly vulnerable to oxidative stress by virtue of the abundant availability of substrates for free radical attack and the lack of cytoplasmic space to accommodate antioxidant enzymes. Moreover, the induction of oxidative stress in these cells not only perturbs their capacity for fertilization but also contributes to sperm DNA damage. The latter has, in turn, been linked with poor fertility, an increased incidence of miscarriage and morbidity in the offspring, including childhood cancer. In light of these associations, we have analyzed the influence of RF-EMR on the cell biology of human spermatozoa in vitro. PRINCIPAL FINDINGS: Purified human spermatozoa were exposed to radio-frequency electromagnetic radiation (RF-EMR) tuned to 1.8 GHz and covering a range of specific absorption rates (SAR) from 0.4 W/kg to 27.5 W/kg. In step with increasing SAR, motility and vitality were significantly reduced after RF-EMR exposure, while the mitochondrial generation of reactive oxygen species and DNA fragmentation were significantly elevated ($P<0.001$). Furthermore, we also observed highly significant relationships between SAR, the oxidative DNA damage bio-marker, 8-OH-dG, and DNA fragmentation after RF-EMR exposure. CONCLUSIONS: RF-EMR in both the power density and frequency range of mobile phones enhances mitochondrial reactive oxygen species generation by human spermatozoa, decreasing the motility and vitality of these cells while stimulating DNA base adduct formation and, ultimately DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offspring.

**De Luca C, Chung Sheun Thai J, Raskovic D, Cesareo E, Caccamo D, Trukhanov A, Korkina L. Metabolic and genetic screening of electromagnetic hypersensitive subjects as a feasible tool for diagnostics and intervention. Mediators Inflamm. 2014;2014:924184. doi: 10.1155/2014/924184. Epub 2014 Apr 9.**

Growing numbers of "electromagnetic hypersensitive" (EHS) people worldwide self-report severely disabling, multiorgan, non-specific symptoms when exposed to low-dose

electromagnetic radiations, often associated with symptoms of multiple chemical sensitivity (MCS) and/or other environmental "sensitivity-related illnesses" (SRI). This cluster of chronic inflammatory disorders still lacks validated pathogenetic mechanism, diagnostic biomarkers, and management guidelines. We hypothesized that SRI, not being merely psychogenic, may share organic determinants of impaired detoxification of common physic-chemical stressors. Based on our previous MCS studies, we tested a panel of 12 metabolic blood redox-related parameters and of selected drug-metabolizing-enzyme gene polymorphisms, on 153 EHS, 147 MCS, and 132 control Italians, confirming MCS altered ($P < 0.05$-$0.0001$) glutathione-(GSH), GSH-peroxidase/S-transferase, and catalase erythrocyte activities. We first described comparable-though milder-metabolic pro-oxidant/proinflammatory alterations in EHS with distinctively increased plasma coenzyme-Q10 oxidation ratio. Severe depletion of erythrocyte membrane polyunsaturated fatty acids with increased ω 6/ ω 3 ratio was confirmed in MCS, but not in EHS. We also identified significantly ($P = 0.003$) altered distribution-versus-control of the CYP2C19∗1/∗2 SNP variants in EHS, and a 9.7-fold increased risk (OR: 95% C.I. = 1.3-74.5) of developing EHS for the haplotype (null)GSTT1 + (null)GSTM1 variants. Altogether, results on MCS and EHS strengthen our proposal to adopt this blood metabolic/genetic biomarkers' panel as suitable diagnostic tool for SRI.

**de Pomerai D, Daniells C, David H, Allan J, Duce I, Mutwakil M, Thomas D, Sewell P, Tattersall J, Jones D, Candido P, Non-thermal heat-shock response to microwaves, Nature 405:417-418, 2000.**

Nematode worms (C. elegans) exposed overnight to 750-MHz microwaves at a SAR of 0.001 W/kg showed an increased in heat shock proteins (HSPs). (Heat shock proteins are induced in most organisms by adverse conditions (such as heat or toxins) that cause damage to cellular proteins, acting as molecular chaperones to rescue damaged proteins). The authors give several arguments that the microwave-induced effect on HSPs is non-thermal and suggest that ‘current exposure limits for microwave equipment may need to be reconsidered.’

**de Pomerai DI, Dawe A, DjerbibL, Allan, Brunt G, Daniells C. Growth and maturation of the nematode Caenorhabditis elegans following exposure to weak microwave fields. Enzyme Microbial Tech 30:73-79, 2002.**

Prolonged exposure to weak microwave fields (750–1000 MHz, 0.5 W) at 25°C induces a heat-shock response in transgenic C. elegans strains carrying hsp16 reporter genes [1]. A comparable response to heat alone requires a substantially higher temperature of 28°C, suggesting that microwave heating of worms or of the system as a whole might provide a sufficient explanation, although this can be ruled out by indirect arguments [1]. Here we investigate two further biological consequences of prolonged microwave exposure at 25°C in synchronised cultures of wild-type worm larvae, namely alterations in (i) growth rate (GR) and (ii) the proportion of worms later maturing into egg-bearing adults (MP). Both of these parameters are significantly increased following microwave exposure (GR by 8–11%, and MP by 28–40%), whereas both are significantly decreased (GR by 10% and MP almost abolished) after mild heat treatment at 28°C for the same period. It follows that the biological consequences of microwave exposure are opposite to, and therefore

incompatible with, those attributable to mild heating. This evidence does not in itself necessitate a non-thermal mechanism, but does eliminate explanations that invoke the bulk heating of tissues by microwaves. This latter, however, remains the sole basis for current regulations governing microwave exposure.

**de Pomerai DI, Smith B, Dawe A, North K, Smith T, Archer DB, Duce IR, Jones D, Candido EP. Microwave radiation can alter protein conformation without bulk heating. FEBS Lett 543(1-3):93-97, 2003.**

Exposure to microwave radiation enhances the aggregation of bovine serum albumin in vitro in a time- and temperature-dependent manner. Microwave radiation also promotes amyloid fibril formation by bovine insulin at 60 degrees C. These alterations in protein conformation are not accompanied by measurable temperature changes, consistent with estimates from field modelling of the specific absorbed radiation (15-20 mW kg(-1)). Limited denaturation of cellular proteins could explain our previous observation that modest heat-shock responses are induced by microwave exposure in Caenorhabditis elegans. We also show that heat-shock responses both to heat and microwaves are suppressed after RNA interference ablating heat-shock factor function.

**De Roos AJ, Teschke K, Savitz DA, Poole C, Grufferman S, Pollock BH, Olshan AF. Parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring. Epidemiology 12(5):508-517, 2001.**

**W**e examined parental occupational exposures to electromagnetic fields and radiation and the incidence of neuroblastoma in offspring. Cases were 538 children diagnosed with neuroblastoma between 1992 and 1994 in the United States or Canada. Age-matched controls were selected by random-digit dialing. Occupational exposures to electrical equipment and radiation sources were classified by an industrial hygienist, and average exposures to extremely low frequency magnetic fields were estimated using a job exposure matrix. Maternal exposure to a broad grouping of sources that produce radiofrequency radiation was associated with an increased incidence of neuroblastoma (odds ratio = 2.8; 95% confidence interval = 0.9-8.7). Paternal exposure to battery-powered forklifts was positively associated with neuroblastoma (odds ratio = 1.6; 95% confidence interval = 0.8-3.2), as were some types of equipment that emit radiofrequency radiation (odds ratios congruent with2.0); however, the broad groupings of sources that produce ELF fields, radiofrequency radiation, or ionizing radiation were not associated with neuroblastoma. Paternal average extremely low frequency magnetic field exposure >0.4 microTesla was weakly associated with neuroblastoma (odds ratio = 1.6; 95% confidence interval = 0.9-2.8), whereas maternal exposure was not. Overall, there was scant supportive evidence of strong associations between parental exposures in electromagnetic spectrum and neuroblastoma in offspring.

**de Salles AA, Bulla G, Rodriguez CE. Electromagnetic absorption in the head of adults and children due to mobile phone operation close to the head. Electromagn Biol Med. 2006;25(4):349-360, 2006.**

The Specific Absorption Rate (SAR) produced by mobile phones in the head of adults and children is simulated using an algorithm based on the Finite Difference Time Domain (FDTD) method. Realistic models of the child and adult head are used. The

electromagnetic parameters are fitted to these models. Comparison also are made with the SAR calculated in the children model when using adult human electromagnetic parameters values. Microstrip (or patch) antennas and quarter wavelength monopole antennas are used in the simulations. The frequencies used to feed the antennas are 1850 MHz and 850 MHz. The SAR results are compared with the available international recommendations. It is shown that under similar conditions, the 1g-SAR calculated for children is higher than that for the adults. When using the 10-year old child model, SAR values higher than 60% than those for adults are obtained.

**de Seze R, Ayoub J, Peray P, Miro L, Touitou Y, Evaluation in humans of the effects of radiocellular telephones on the circadian patterns of melatonin secretion, a chronobiological rhythm marker. J Pineal Res 27(4):237-242, 1999.**

A decrease in melatonin secretion has been observed in small mammals under exposure to extremely low frequency electromagnetic fields. As there is some concern about possible health effects of the increasing use of radiocellular telephones emitting radiofrequency electromagnetic fields, we examined whether such fields would alter melatonin levels in the human. Volunteers were two groups totalling 38 men, 20-32 yr old. Exposures were to commercially available cellular telephones of the GSM 900 type (Global System for Mobile communication at 900 MHz) or DCS 1800 type (Digital Communication System at 1800 MHz), for 2 hr/day, 5 days/wk, for 4 wk, at their maximum power. Attention of the volunteers was sustained by TV projection of movies. Blood samples were collected hourly during the night and every 3 hr in the daytime. Four sampling sessions were performed at 15-day intervals: before the beginning of the exposure period, at the middle and the end of the exposure period, and 15 days later to evaluate the persistence or late appearance of potential effects. Evaluated parameters were the maximum serum concentration, the time of this maximum, and the area under the curve of the hormone profile. Melatonin circadian profile was not disrupted in 37 young male volunteers submitted to a typical pattern of exposure to the electromagnetic fields generated by two common types of cell phones.

**de Seze R, Fabbro-Peray P, Miro L, GSM radiocellular telephones do not disturb the secretion of antepituitary hormones in humans. Bioelectromagnetics 19(5):271-278, 1998.**

It is known that the endocrine system of experimental animals is susceptible to perturbation by radiofrequency (RF) radiation. Because of the recent interest in health and safety issues of cellular telephones, an experiment was designed to evaluate the effect of a 900 MHz RF radiation emitted by a Global System for Mobile radiotelephone (217 Hz impulses, one-eighth duty cycle, 2 W peak power) on human endocrine functions. Twenty healthy male volunteers aged from 19 to 40 were inducted in the present experiment. Each subject was exposed to RF radiation through the use of a cellular phone 2 h/day, 5 days/wk, for 1 month. Subjects were their own control. End points were serum adrenocorticotropin, thyrotropin, growth hormone, prolactin, luteinizing hormone, and follicle stimulating hormone concentrations. These end points were determined in nine weekly blood samples obtained starting 3 weeks before the

commencement of the exposure and ending 2 weeks after exposures. All but one blood sample was drawn 48 h after each weekly session. The seventh drawing was performed the morning after the last weekly exposure. Within each individual, the preexposure hormone concentration was used as a control. Results indicated that all hormone concentrations remained within normal physiologic ranges. A difference was not noted among the nine weekly samples in five of six hormones studied. There was a significant change only in thyrotropin concentration, showing a 21% decrease on the seventh sampling. Because this change recovered fully during the postexposure period, it is concluded that 1 month of intermittent exposures to RF radiation from a cellular telephone does not induce a long-lasting or cumulative effect on the hormone secretion rate of the anterior pituitary gland in humans.

**de Souza FT, Silva JF, Ferreira EF, Siqueira EC, Duarte AP, Gomez MV, Gomez RS, Gomes CC. Cell phone use and parotid salivary gland alterations: no molecular evidence. Cancer Epidemiol Biomarkers Prev. 2014 Apr 21. [Epub ahead of print]**

Background The association between cell phone use and the development of parotid tumors is controversial. Because there is unequivocal evidence that the microenvironment is important for tumor formation, we investigated in the parotid glands whether cell phone use alters the expression of gene products related to cellular stress. Methods We used the saliva produced by the parotid glands of 62 individuals to assess molecular alterations compatible with cellular stress, comparing the saliva from the gland exposed to cell phone radiation (ipsilateral) to the saliva from the opposite, unexposed parotid gland (contralateral) of each individual. We compared salivary flow, total protein concentration, p53, p21, reactive oxygen species (ROS), and salivary levels of glutathione (GSH), heat shock proteins 27 and 70 and IgA between the ipsilateral and contralateral parotids. Results No difference was found for any of these parameters, even when grouping individuals by period of cell phone use in years or by monthly average calls in minutes. Conclusions and Impact We provide molecular evidence that the exposure of parotid glands to cell phone use does not alter parotid salivary flow, protein concentration or levels of proteins of genes that are directly or indirectly affected by heat-induced cellular stress.

**de Tommaso M, Rossi P, Falsaperla R, Francesco VD, Santoro R, Federici A. Mobile Phones exposure induces changes of Contingent Negative Variation in humans. Neurosci Lett.464(2):79-83, 2009.**

Event related potentials have been largely employed to test effects of GSM emissions on human brain. The aim of the present study, was the evaluation of initial Contingent Negative Variation (iCNV) changes, induced by 900MHz GSM exposure, in a double blind design in healthy volunteers, subjected to a threefold experimental condition, EXPOSED (A), a real GSM phone emitting electromagnetic power, SHAM (B), a real phone where the electromagnetic power was dissipated on an internal load and OFF (C), a phone completely switched off. Ten healthy right-handed volunteers were evaluated. The CNV was recorded during a 10minutes time interval in each of the three experimental conditions A, B, and C, in order to assess the iCNV amplitude and habituation. The iCNV amplitude decreased and habituation increased during both A and B conditions,

compared with condition C. This effect was diffuse over the scalp, and there was no significant prevalence of iCNV amplitude reduction on the left side, were the phones were located. Mobile Phones exposures A and B seemed to act on brain electrical activity, reducing the arousal and expectation of warning stimulus. This evidence, limited by the low number of subjects investigated, could be explained in terms of an effect induced by both the GSM signal and the Extremely Low Frequency magnetic field produced by battery and internal circuits.

**de Vocht F, Hannam K, Buchan I. Environmental risk factors for cancers of the brain and nervous system: the use of ecological data to generate hypotheses. Occup Environ Med. 2013 Jan 23. [Epub ahead of print]**

BACKGROUND: There is a public health need to balance timely generation of hypotheses with cautious causal inference. For rare cancers this is particularly challenging because standard epidemiological study designs may not be able to elucidate causal factors in an early period of newly emerging risks. Alternative methodologies need to be considered for generating and shaping hypotheses prior to definitive investigation. OBJECTIVES: To evaluate whether open-access databases can be used to explore links between potential risk factors and cancers at an ecological level, using the case study of brain and nervous system cancers as an example. METHODS: National age-adjusted cancer incidence rates were obtained from the GLOBOCAN 2008 resource and combined with data from the United Nations Development Report and the World Bank list of development indicators. Data were analysed using multivariate regression models. RESULTS: Cancer rates, potential confounders and environmental risk factors were available for 165 of 208 countries. 2008 national incidences of brain and nervous system cancers were associated with continent, gross national income in 2008 and Human Development Index Score. The only exogenous risk factor consistently associated with higher incidence was the penetration rate of mobile/cellular telecommunications subscriptions, although other factors were highlighted. According to these ecological results the latency period is at least 11-12 years, but probably more than 20 years. Missing data on cancer incidence and for other potential risk factors prohibit more detailed investigation of exposure-response associations and/or explore other hypotheses. CONCLUSIONS: Readily available ecological data may be underused, particularly for the study of risk factors for rare diseases and those with long latencies. The results of ecological analyses in general should not be overinterpreted in causal inference, but equally they should not be ignored where alternative signals of aetiology are lacking.

**Degrave E, Autier P, Grivegnee AR, Zizi M. All-cause mortality among belgian military radar operators: a 40-year controlled longitudinal study. Eur J Epidemiol. 20(8):677-681, 2005.**

Background: It has been suggested that exposure to radiofrequency/microwaves radiations could be associated with greater health hazards and higher mortality. Methods: The all-cause mortality of 27,671 Belgian militaries who served from 1963 until 1994 in battalions equipped with radars for anti-aircraft defence was studied over the period 1968-2003. End of the seventies, technical modifications brought to the shielding of the micro-

wave generators resulted in a reduction in irradiations. A control group was formed by 16,128 militaries who served during the same period in the same military area but who were never exposed to radars. Administrative procedures for identifying militaries and their vital status were equivalent in the radar and the control groups. Results: The age-standardized mortality ratio (SMR) in the radar battalions was 1.05 (95% CI: 0.95-1.16) in professional militaries, and 0.80 (95% CI: 0.75-0.85) in conscripts. In professional militaries no difference in mortality was found according to duration (less than, or five years or more) or to period of service (before 1978 or after 1977). Conclusions: During a 40-year period of observation, we found no increase in all-cause mortality in Belgian militaries who were in close contact with radar equipments of anti-aircraft defence battalions.

**Del Signore A, Boscolo P, Kouri S, Di Martino G, Giuliano G, Combined effects of traffic and electromagnetic fields on the immune system of fertile atopic women. Ind Health 38(3):294-300, 2000**.

Object of this preliminary study was the immune response to high or low frequency electromagnetic fields (ELMF) of non-atopic and atopic fertile women with uniform exposure to toxic compounds produced by traffic. Women were divided in group A (non-atopic, non-exposed to ELMF); B (atopic, non-exposed to ELMF); C (non-atopic, exposed to ELMF); D (atopic, exposed to ELMF). "In vitro" cell proliferation of peripheral blood mononuclear cells (PBMC) of atopic women (groups B and D) stimulated by phytohaemoglutinin (PHA) was reduced. The ELMF exposed women (groups C and D) showed lower levels of blood NK CD16(+)-CD56+ lymphocyte subpopulations and of "in vitro" production of interferon-gamma (both spontaneously and in presence of PHA) by PBMC, suggesting that ELMF reduces blood cytotoxic activity. Serum IgE of the atopic women exposed to ELMF (group D) was higher than that of the other groups. Linear discriminant analysis including serum zinc and copper (essential enzymes for immune functions), blood lead and urinary transtrans muconic acid, a metabolite of benzene (markers of exposure to traffic) and key parameters of immune functions (CD16(+)-CD56+ lymphocyte subset, serum IgE, interferon-gamma produced by PBMC in presence of PHA, stimulation index of blastogenesis) showed absence of significant difference between groups A and C and a marked separation of groups B and D. This datum suggests that ELMF have a greater influence on atopic women exposed to traffic than on non-atopic ones.

**Del Vecchio G, Giuliani A, Fernandez M, Mesirca P, Bersani F, Pinto R, Ardoino L, Lovisolo GA, Giardino L, Calzaà L. Effect of radiofrequency electromagnetic field exposure on in vitro models of neurodegenerative disease. Bioelectromagnetics.30(7):564-72, 2009.**

In this work we tested viability, proliferation, and vulnerability of neural cells, after continuous radiofrequency (RF) electromagnetic fields exposure (global system for mobile telecommunications (GSM) modulated 900 MHz signal at a specific absorption rate (SAR) of 1 W/kg and maximum duration 144 h) generated by transverse electromagnetic cells. We used two cellular systems, SN56 cholinergic for example, SN56 cholinergic cell line and rat primary cortical neurons, and well-known neurotoxic

challenges, such as glutamate, 25-35AA beta-amyloid, and hydrogen peroxide. Exposure to RF did not change viability/proliferation rate of the SN56 cholinergic cells or viability of cortical neurons. Co-exposure to RF exacerbated neurotoxic effect of hydrogen peroxide in SN56, but not in primary cortical neurons, whereas no cooperative effects of RF with glutamate and 25-35AA beta-amyloid were found. These data suggest that only under particular circumstances exposure to GSM modulated, 900 MHz signal act as a co-stressor for oxidative damage of neural cells.

**Del Vecchio G, Giuliani A, Fernandez M, Mesirca P, Bersani F, Pinto R, Ardoino L, Lovisolo GA, Giardino L, Calzà L. Continuous exposure to 900MHz GSM-modulated EMF alters morphological maturation of neural cells. Neurosci Lett. 455(3):173-177, 2009.**

The effects of radiofrequency electromagnetic field (RF-EMF) exposure on neuronal phenotype maturation have been studied in two different in vitro models: murine SN56 cholinergic cell line and rat primary cortical neurons. The samples were exposed at a dose of 1W/kg at 900 MHz GSM modulated. The phenotype analysis was carried out at 48 and 72 h (24 and 48 h of SN56 cell line differentiation) or at 24, 72, 120 h (2, 4 and 6 days in vitro for cortical neurons) of exposure, on live and immunolabeled neurons, and included the morphological study of neurite emission, outgrowth and branching. Moreover, cortical neurons were studied to detect alterations in the expression pattern of cytoskeleton regulating factors, e.g. beta-thymosin, and of early genes, e.g. c-Fos and c-Jun through real-time PCR on mRNA extracted after 24h exposure to EMF. We found that RF-EMF exposure reduced the number of neurites generated by both cell systems, and this alteration correlates to increased expression of beta-thymosin mRNA.

**Deltour I, Auvinen A, Feychting M, Johansen C, Klaeboe L, Sankila R, Schüz J. Mobile phone use and incidence of glioma in the Nordic countries 1979-2008: consistency check.Epidemiology. 23(2):301-307, 2012.**

**BACKGROUND:** Some case-control studies have reported increased risks of glioma associated with mobile phone use. If true, this would ultimately affect the time trends for incidence rates (IRs). Correspondingly, lack of change in IRs would exclude certain magnitudes of risk. We investigated glioma IR trends in the Nordic countries, and compared the observed with expected incidence rates under various risk scenarios.**METHODS:** We analyzed annual age-standardized incidence rates in men and women aged 20 to 79 years during 1979-2008 using joinpoint regression (35,250 glioma cases). Probabilities of detecting various levels of relative risk were computed using simulations.**RESULTS:** For the period 1979 through 2008, the annual percent change in incidence rates was 0.4% (95% confidence interval = 0.1% to 0.6%) among men and 0.3% (0.1% to 0.5%) among women. Incidence rates have decreased in young men (20-39 years) since 1987, remained stable in middle-aged men (40-59 years) throughout the 30-year study period, and increased slightly in older men (60-79 years). In simulations, assumed relative risks for all users of 2.0 for an induction time of up to 15 years, 1.5 for up to 10 years, and 1.2 for up to 5 years were incompatible with observed incidence time trends. For heavy users of mobile phones, risks of 2.0 for up to 5 years' induction were also incompatible.**CONCLUSION:** No clear trend change in glioma incidence rates was

observed. Several of the risk increases seen in case-control studies appear to be incompatible with the observed lack of incidence rate increase in middle-aged men. This suggests longer induction periods than currently investigated, lower risks than reported from some case-control studies, or the absence of any association.

**Deltour I, Wiart J, Taki M, Wake K, Varsier N, Mann S, Schüz J, Cardis E. Analysis of three-dimensional SAR distributions emitted by mobile phones in an epidemiological perspective.Bioelectromagnetics. 32(8):634-643, 2011.**

The three-dimensional distribution of the specific absorption rate of energy (SAR) in phantom models was analysed to detect clusters of mobile phones producing similar spatial deposition of energy in the head. The clusters' characteristics were described from the phones external features, frequency band and communication protocol. Compliance measurements with phones in cheek and tilt positions, and on the left and right side of a physical phantom were used. Phones used the Personal Digital Cellular (PDC), Code division multiple access One (CdmaOne), Global System for Mobile Communications (GSM) and Nordic Mobile Telephony (NMT) communication systems, in the 800, 900, 1500 and 1800 MHz bands. Each phone's measurements were summarised by the half-ellipsoid in which the SAR values were above half the maximum value. Cluster analysis used the Partitioning Around Medoids algorithm. The dissimilarity measure was based on the overlap of the ellipsoids, and the Manhattan distance was used for robustness analysis. Within the 800 MHz frequency band, and in part within the 900 MHz and the 1800 MHz frequency bands, weak clustering was obtained for the handset shape (bar phone, flip with top and flip with central antennas), but only in specific positions (tilt or cheek). On measurements of 120 phones, the three-dimensional distribution of SAR in phantom models did not appear to be related to particular external phone characteristics or measurement characteristics, which could be used for refining the assessment of exposure to radiofrequency energy within the brain in epidemiological studies such as the Interphone.

**Demirel S, Doganay S, Turkoz Y, Dogan Z, Turan B, Firat PG. Effects of third generation mobile phone-emitted electromagnetic radiation on oxidative stress parameters in eye tissue and blood of rats. Cutan Ocul Toxicol.31(2):89-94, 2012.**

Purpose: To investigate the effects of electromagnetic radiation (EMR) emitted by a third generation (3G) mobile phone on the antioxidant and oxidative stress parameters in eye tissue and blood of rats. Methods: Eighteen Wistar albino rats were randomly assigned into two groups: Group I (n = 9) received a standardized a daily dose of 3G mobile phone EMR for 20 days, and Group II served as the control group (n = 9), receiving no exposure to EMR. Glutathione peroxidase (GSH-Px) and catalase (CAT) levels were measured in eye tissues; in addition, malondialdehyde (MDA) and reduced GSH levels were measured in blood. Results: There was no significant difference between groups in GSH-Px ($p = 0.99$) and CAT ($p = 0.18$) activity in eye tissue. There was no significant difference between groups in MDA ($p = 0.69$) and GSH levels ($p = 0.83$) in blood. Conclusions: The results of this study suggest that under a short period of exposure, 3G mobile phone radiation does not

lead to harmful effects on eye tissue and blood in rats.

**Demsia G, Vlastos D, Matthopoulos DP. Effect of 910-MHz electromagnetic field on rat bone marrow. ScientificWorldJournal. 4 Suppl 2:48-54, 2004.**

Aiming to investigate the possibility of electromagnetic fields (EMF) developed by nonionizing radiation to be a noxious agent capable of inducing genotoxicity to humans, in the current study we have investigated the effect of 910-MHz EMF in rat bone marrow. Rats were exposed daily for 2 h over a period of 30 consecutive days. Studying bone marrow smears from EMF-exposed and sham-exposed animals, we observed an almost threefold increase of micronuclei (MN) in polychromatic erythrocytes (PCEs) after EMF exposure. An induction of MN was also observed in polymorphonuclear cells. The induction of MN in female rats was less than that in male rats. The results indicate that 910-MHz EMF could be considered as a noxious agent capable of producing genotoxic effects.

**Denny-Bas V, Zmirou-Navier D, De Tychey C, Briançon S. The role of anxiety in the perception of technological hazards - A cross-sectional study on cell phones and masts. Rev Epidemiol Sante Publique. 2014 Mar 16. pii: S0398-7620(14)00160-6. doi: 10.1016/j.respe.2013.11.076. [Epub ahead of print]**

BACKGROUND: Risk perception is determined by parameters related to the nature of the risk, as well as inherent to the individual perceiving this risk. This study was designed to provide a better understanding of the role of personality, especially anxiety traits, on risk perception. It compared representations of two different risks, smoking (with known and generally accepted adverse health effects) and cell phones (whose hazardous potency is still controversial), each presented in two different forms of exposure, active (smokers and cell phone users) and passive (passive smoking and exposure to cell phone masts). METHODS: A self-administered questionnaire sent to volunteer subjects collected sociodemographic and exposure data. It measured the perceived risk as well as 11 psychometric properties of risk using visual analogue scales (values ranging from 0 to 10). An anxiety trait was evaluated by the Spielberger questionnaire. RESULTS: In all, 72% of the questionnaires sent were returned. Mean declared risk scores attributed to passive and active smoking were higher (8.75 and 8.31 respectively) than those attributed to cell phones and masts (4.44 and 4.73 respectively). However, scores for the 11 psychometric properties of the risk attributed to cell phones were higher than those associated with smoking, especially for dissatisfaction with information (6.71 and 7.36 respectively for cell phones and masts versus 1.75 and 2.18 for passive and active smoking) and the capacity of authorities to master the risk (6.45 and 6.65 for cell phones and masts versus 4.72 and 4.40 for passive and active smoking). Anxiety did not directly influence the risk scores attributed to these 4 forms of exposure but was predictive of the way in which subjects perceived the risk in terms of two essential properties: uncertainty concerning the effects on health and the potential to trigger health catastrophes. Indeed anxious subjects are more certain about the hazards of cell phones and masts than non-anxious subjects ($P=0.008$ et $P\leq0.001$) and attributed a higher catastrophic potential ($P=0.02$ and $P=0.004$). CONCLUSION: This study suggests that subjects with an anxious

profile are affected by the destabilizing nature of uncertain knowledge concerning the hazardous potency of new technologies and of the controversies concerning this hazard.

**de Oliveira FM, Carmona AM[2] Ladeira C. Is mobile phone radiation genotoxic? An analysis of micronucleus frequency in exfoliated buccal cells. Mutat Res. 2017 Oct;822:41-46. doi: 10.1016/j.mrgentox.2017.08.001. Epub 2017 Aug 5.**

Electromagnetic fields (EMF) are classified as "possibly carcinogenic" by the International Agency for Research on Cancer (IARC). Some publications have reported associations between EMF exposure and DNA damage, but many other studies contradict such findings. Cytomorphological changes, such as micronuclei (MN), indicative of genomic damage, are biomarkers of genotoxicity. To test whether mobile phone-associated EMF exposure affects the MN frequency in exfoliated buccal cells, we obtained cells smears from the left and right inner cheeks of healthy mobile phone users, aged 18-30 (n=86), who also completed a characterization survey. MN frequencies were tested for potential confounding factors and for duration of phone use and preferential side of mobile phone use. No relationship was observed between MN frequency and duration of mobile phone use in daily calls. Cells ipsilateral to mobile phone use did not present a statistically significantly higher MN frequency, compared to cells contralateral to exposure. A highly statistically significant ($p<0.0001$) increase in MN frequency was found in subjects reporting regular exposure to genotoxic agents. Therefore, our results suggest that mobile phone-associated EMF do not to induce MN formation in buccal cells at the observed exposure levels.

**Deshmukh PS, Banerjee BD, Abegaonkar MP, Megha K, Ahmed RS, Tripathi AK, Mediratta PK. Effect of low level microwave radiation exposure on cognitive function and oxidative stress in rats. Indian J Biochem Biophys. 50(2):114-119, 2013.**

Use of wireless communicating devices is increasing at an exponential rate in present time and is raising serious concerns about possible adverse effects of microwave (MW) radiation emitted from these devices on human health. The present study aimed to evaluate the effects of 900 MHz MW radiation exposure on cognitive function and oxidative stress in blood of Fischer rats. Animals were divided into two groups (6 animals/group): Group I (MW-exposed) and Group II (Sham-exposed). Animals were subjected to MW exposure (Frequency 900 MHz; specific absorption rate 8.4738 x 10(-5) W/kg) in Gigahertz transverse electromagnetic cell (GTEM) for 30 days (2 h/day, 5 days/week). Subsequently, cognitive function and oxidative stress parameters were examined for each group. Results showed significant impairment in cognitive function and increase in oxidative stress, as evidenced by the increase in levels of MDA (a marker of lipid peroxidation) and protein carbonyl (a marker of protein oxidation) and unaltered GSH content in blood. Thus, the study demonstrated that low level MW radiation had significant effect on cognitive function and was also capable of leading to oxidative stress.

**Deshmukh PS, Megha K, Banerjee BD, Ahmed RS, Chandna S, Abegaonkar MP, Tripathi AK. Detection of Low Level Microwave Radiation Induced Deoxyribonucleic Acid Damage Vis-à-vis Genotoxicity in Brain of Fischer Rats. Toxicol Int. 20(1):19-24, 2013.**

BACKGROUND: Non-ionizing radiofrequency radiation has been increasingly used in industry, commerce, medicine and especially in mobile phone technology and has become a matter of serious concern in present time. OBJECTIVE: The present study was designed to investigate the possible deoxyribonucleic acid (DNA) damaging effects of low-level microwave radiation in brain of Fischer rats. MATERIALS AND METHODS: Experiments were performed on male Fischer rats exposed to microwave radiation for 30 days at three different frequencies: 900, 1800 and 2450 MHz. Animals were divided into 4 groups: Group I (Sham exposed): Animals not exposed to microwave radiation but kept under same conditions as that of other groups, Group II: Animals exposed to microwave radiation at frequency 900 MHz at specific absorption rate (SAR) 5.953 × 10(-4) W/kg, Group III: Animals exposed to 1800 MHz at SAR 5.835 × 10(-4) W/kg and Group IV: Animals exposed to 2450 MHz at SAR 6.672 × 10(-4) W/kg. At the end of the exposure period animals were sacrificed immediately and DNA damage in brain tissue was assessed using alkaline comet assay. RESULTS: In the present study, we demonstrated DNA damaging effects of low level microwave radiation in brain. CONCLUSION: We concluded that low SAR microwave radiation exposure at these frequencies may induce DNA strand breaks in brain tissue.

**Deshmukh PS, Nasare N, Megha K, Banerjee BD, Ahmed RS, Singh D, Abegaonkar MP, Tripathi AK, Mediratta PK. Cognitive Impairment and Neurogenotoxic Effects in Rats Exposed to Low-Intensity Microwave Radiation. Int J Toxicol. 2015 Mar 5. pii: 1091581815574348. [Epub ahead of print]**

The health hazard of microwave radiation (MWR) has become a recent subject of interest as a result of the enormous increase in mobile phone usage. The present study aimed to investigate the effects of chronic low-intensity microwave exposure on cognitive function, heat shock protein 70 (HSP70), and DNA damage in rat brain. Experiments were performed on male Fischer rats exposed to MWR for 180 days at 3 different frequencies, namely, 900, 1800 MHz, and 2450 MHz. Animals were divided into 4 groups: group I: sham exposed; group II: exposed to MWR at 900 MHz, specific absorption rate (SAR) $5.953 \times 10^{-4}$ W/kg; group III: exposed to 1800 MHz, SAR $5.835 \times 10^{-4}$ W/kg; and group IV: exposed to 2450 MHz, SAR $6.672 \times 10^{-4}$ W/kg. All the rats were tested for cognitive function at the end of the exposure period and were subsequently sacrificed to collect brain. Level of HSP70 was estimated by enzyme-linked immunotarget assay and DNA damage was assessed using alkaline comet assay in all the groups. The results showed declined cognitive function, elevated HSP70 level, and DNA damage in the brain of microwave-exposed animals. The results indicated that, chronic low-intensity microwave exposure in the frequency range of 900 to 2450 MHz may cause hazardous effects on the brain.

**Deshmukh PS, Megha K, Nasare N, Banerjee BD, Ahmed RS, Abegaonkar MP, Tripathi AK, Mediratta PK. Effect of Low Level Subchronic Microwave Radiation on Rat Brain. Biomed Environ Sci. 29(12):858-867, 2016**

OBJECTIVE: The present study was designed to investigate the effects of subchronic low level microwave radiation (MWR) on cognitive function, heat shock protein 70 (HSP70) level and DNA damage in brain of Fischer rats. METHODS: Experiments were performed on male Fischer rats exposed to microwave radiation for 90 days at three different frequencies: 900, 1800, and 2450 MHz. Animals were divided into 4 groups: Group I: Sham exposed, Group II: animals exposed to microwave radiation at 900 MHz and specific absorption rate (SAR) 5.953 × 10-4 W/kg, Group III: animals exposed to 1800 MHz at SAR 5.835 × 10-4 W/kg and Group IV: animals exposed to 2450 MHz at SAR 6.672 × 10-4 W/kg. All the animals were tested for cognitive function using elevated plus maze and Morris water maze at the end of the exposure period and subsequently sacrificed to collect brain tissues. HSP70 levels were estimated by ELISA and DNA damage was assessed using alkaline comet assay. RESULTS: Microwave exposure at 900-2450 MHz with SAR values as mentioned above lead to decline in cognitive function, increase in HSP70 level and DNA damage in brain. CONCLUSION: The results of the present study suggest that low level microwave exposure at frequencies 900, 1800, and 2450 MHz may lead to hazardous effects on brain.

**Desta AB, Owen RD, Cress LW. Non-thermal exposure to radiofrequency energy from digital wireless phones does not affect ornithine decarboxylase activity in L929 Cells. Radiat Res 160:488–491, 2003.**

L929 murine fibroblast cells were exposed to radiofrequency (RF) radiation from a time division multiple access wireless phone operating at 835 MHz frequency to determine the effect of RF-radiation energy emitted by wireless phones on ornithine decarboxylase (ODC) activity in cultured cells. Exposure was for 8 h to an average specific absorption rate (SAR) from <1 W/kg up to 15 W/kg. After exposure, cells were harvested and ODC activity was measured. No statistically significant difference in ODC activity was found between RF-radiation-exposed and sham-exposed cells at non-thermal specific absorption rates. At SARs which resulted in measurable heating of the medium, a dose-dependent decrease in enzymatic activity was observed and was shown to be consistent with a comparable decrease caused by non-RF-radiation heating. Thus we observed only the well-known enzyme inhibition due to heating, rather than the previously reported enhancement attributed to RF-radiation exposure.

**Detlavs I, Dombrovska L, Turauska A, Shkirmante B, Slutskii L. Experimental study of the effects of radiofrequency electromagnetic fields on animals with soft tissue wounds. Sci Total Environ 180(1):35-42, 1996.**

The effect of radio frequency electromagnetic fields (RF EMF) was studied on Wistar rats with excised full-thickness dermal wounds in the interscapular region. The wounded regions of experimental animals were subjected to EMF for 30 min daily during the first 5 days after wound infliction. Control animals received no treatment. We used RF EMF with (1) frequency 53.53 GHz without modulation; (2) frequency 42.19 GHz without

modulation; (3) frequency 42.19 GHz, but with a frequency modulation band 200-MHz wide. On the 7th day the animals were terminated and the granulation-fibrous tissue (GFT) developed in the wounds was subjected to complex quantitative biochemical analysis. RF EMF without frequency modulation decreased the amounts of glycoprotein macromolecules, diminishing the inflammatory exudation. In striking contrast, under the influence of RF EMF with frequency modulation, hexoses and especially sialic acid concentrations were significantly elevated ($P < 0.001$). This indicated intensification of exudative phenomena. As a consequence of inflammation inhibition in the treatment without frequency modulation, the total collagen accumulation was lowered. However, when frequency was modulated, the inflammatory phenomena were intensified, and pronounced accumulation of collagenous proteins was noted. Thus, our experiments confirm the effects of non-thermal EMF on the reparative-proliferative processes of animals with soft tissue wounds

**Devrim E, Ergüder IB, Kılıçoğlu B, Yaykaşlı E, Cetin R, Durak I. Effects of electromagnetic radiation use on oxidant/antioxidant status and dna turn-over enzyme activities in erythrocytes and heart, kidney, liver, and ovary tissues from rats: possible protective role of Vitamin C. Toxicol Mech Methods.18(9):679-683, 2008.**

ABSTRACT In this study, the aim was to investigate possible effects of Electromagnetic Radiation (EMR) use on oxidant and antioxidant status in erythrocytes and kidney, heart, liver, and ovary tissues from rats, and possible protective role of vitamin C. For this aim, 40 Wistar albino female rats were used throughout the study. The treatment group was exposed to EMR in a frequency of 900 MHz, the EMR plus vitamin C group was exposed to the same EMR frequency and given vitamin C (250 mg/kg/day) orally for 4 weeks. There were 10 animals in each group including control and vitamin C groups. At the end of the study period, blood samples were obtained from the animals to get erythrocyte sediments. Then the animals were sacrificed and heart, kidney, liver, and ovary tissues were removed. Malondialdehyde (MDA) levels and superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px), xanthine oxidase (XO), and adenosine deaminase (ADA) enzyme activities were measured in the tissues and erythrocytes. It was observed that MDA level, XO, and GSH-Px activities significantly increased in the EMR group as compared with those of the control group in the erythrocytes. In the kidney tissues, it was found that MDA level and CAT activity significantly increased, whereas XO and ADA activities decreased in the cellular phone group as compared with those of the control group. However, in the heart tissues it was observed that MDA level, ADA, and XO activities significantly decreased in the cellular phone group as compared with those of the control group. The results suggest that EMR at the frequency generated by a cell phone causes oxidative stress and peroxidation in the erythrocytes and kidney tissues from rats. In the erythrocytes, vitamin C seems to make partial protection against the oxidant stress.

**Devyatkov ND, Pletnyov SD, Betskii OV, Faikin VV, Effect of low-energy and high-peak-power nanosecond pulses of microwave radiation on malignant tumors. Crit Rev Biomed Eng 29(1):98-110, 2001.**

This article presents the results of experimental investigations of the inhibitory effect of low-energy and high-peak-power nanosecond microwave pulses on the growth of malignant tumors. From the results obtained, it was concluded that these microwave pulses can serve as a promising means for treating malignant diseases.

**Dhami AK. Study of electromagnetic radiation pollution in an Indian city. Environ Monit Assess.184(11):6507-6512, 2012.**

Abstract. Electromagnetic radiation emitted by cell phone towers is a form of environmental pollution and is a new health hazard, especially to children and patients. The present studies were taken to estimate the microwave/RF pollution by measuring radiation power densities near schools and hospitals of Chandigarh city in India. The cell phone radiations were measured using a handheld portable power density meter TES 593 and specific absorption rates were estimated from the measured values. These values of electromagnetic radiation in the environment were compared with the levels at which biological system of humans and animals starts getting affected. The values were also compared with the international exposure limits set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The highest measured power density was 11.48 mW/m(2) which is 1,148% of the biological limit. The results indicated that the exposure levels in the city were below the ICNIRP limit, but much above the biological limit.

**Di Carlo A, White N, Guo F, Garrett P, Litovitz T. Chronic electromagnetic field exposure decreases HSP70 levels and lowers cytoprotection. J. Cell. Biochem. 84: 447-454, 2002.**

Electromagnetic field (EMF) exposures have been shown to induce heat shock proteins (HSPs), which help to maintain the conformation of cellular proteins during periods of stress. We have previously reported that short-term exposure of chick embryos to either 60 Hz (extremely low frequency: ELF), or radio-frequency (RF: 915 MHz) EMFs induce protection against hypoxia. Experiments presented in the current report are based on a study in which long-term (4 days), continuous exposure to ELF-EMFs decreased protection against ultraviolet radiation. Based on this result, it was hypothesized that de-protection against hypoxia should also occur following long-term, continuous, or daily, repeated exposures to EMFs. To test this hypothesis, chick embryos were exposed to ELF-EMFs (8 μT) continuously for 4 days, or to ELF or RF (3.5 mW incident power)-EMFs repeated daily (20, 30, or 60 min once or twice daily for 4 days). Several of the exposure protocols yielded embryos that had statistically significant decreases in protection against hypoxic stress (continuous and 30 or 60 min ELF twice daily; or 30 or 60 min once daily RF). This is consistent with our finding that following 4 days of ELF-EMF exposure, HSP70 levels decline by 27% as compared to controls. In addition, the superposition of ELF-EM noise, previously shown to minimize ELF-EMF induced hypoxia protection, inhibited hypoxia de-protection caused by long term, continuous ELF or daily, repeated RF exposures. This EMF-induced decrease in HSP70 levels and resulting decline in cytoprotection suggests a mechanism by which daily exposure (such as might be experienced by mobile phone users) could enhance the probability of cancer and other diseases.

**Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. Non-thermal DNA breakage by**

**mobile-phone radiation (1800MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutat Res. 583:178-183, 2005.**

Cultured human diploid fibroblasts and cultured rat granulosa cells were exposed to intermittent and continuous radiofrequency electromagnetic fields (RF-EMF) used in mobile phones, with different specific absorption rates (SAR) and different mobile-phone modulations. DNA strand breaks were determined by means of the alkaline and neutral comet assay. RF-EMF exposure (1800MHz; SAR 1.2 or 2W/kg; different modulations; during 4, 16 and 24h; intermittent 5min on/10min off or continuous wave) induced DNA single- and double-strand breaks. Effects occurred after 16h exposure in both cell types and after different mobile-phone modulations. The intermittent exposure showed a stronger effect in the comet assay than continuous exposure. Therefore we conclude that the induced DNA damage cannot be based on thermal effects.

**Dimbylow PJ. FDTD calculations of the SAR for a dipole closely coupled to the head at 900 MHz and 1.9 GHz. Phys Med Biol 38(3):361-368, 1993.**

This paper presents finite-different time-domain (FDTD) calculations of the specific absorption rate (SAR) averaged over the mass of the eye, and over 1 g and 100 g of tissue in a realistic model of the head from a closely coupled half-wavelength dipole source. The SAR is predicted as a function of the separation between the vertical dipole and the surface of the eye. The feed point of the dipole is on the axis defined by the centre of the eye. Phantoms representing an adult and a one-year-old child have been considered for irradiation at 900 MHz and 1.9 GHz.

**Dimbylow PJ, Mann SM. SAR calculations in an anatomically realistic model of the head for mobile communication transceivers at 900 MHz and 1.8 GHz. Phys. Med. Biol. 39:1537-1553, 1994.**

Abstract. A new mathematical model of the head has been constructed from a set of serial MRI slices from one subject. Finite-difference time-domain (FDTD) calculations of the specific energy absorption rate (SAR) have been performed on this model with a 2 mm resolution for a generic mobile communication transceiver represented by a quarter-wavelength monopole on a metal box. The antenna was mounted either at the centre or corner of the top face of the box. The frequencies considered were 900 MHz and 1.8 GHz. Three irradiation geometries were considered, a vertical handset in front of the eye and vertical and horizontal orientations at the side of the ear. The effect of a hand grasping the handset was considered. The head model was scaled to represent the head of an infant and a subset of calculations was performed to verify that the SAR deposited in the infant head did not exceed that in the adult. Results are also presented for a half-wavelength dipole. The maximum SAR values produced by the generic transceiver for the horizontal orientation at the side of the head which is the most typical position, averaged over 10 g of tissue at 900 MHz and 1.8 GHz, are 2.1 and 3.0 W $kg^{-1}$ per W of radiated power. The corresponding values over 1 g of tissue are 2.3 and 4.8 W $kg^{-1}$ per W at 900 MHz and 1.8 GHz. However, if one were to consider all possible operational conditions, the placement of the transceiver in front of the eye will give 3.1 and 4.6 W $kg^{-1}$ per W averaged over 10 g of tissue and 4.7 and 7.7 W $kg^{-1}$ per W over 1 g of tissue at 900 MHz and 1.8 GHz, respectively.

**Dimbylow P, Khalid M, Mann S. Assessment of specific energy absorption rate (SAR) in the head from a TETRA handset. Phys Med Biol. 48(23):3911-26, 2003.**

Finite-difference time-domain (FDTD) calculations of the specific energy absorption rate (SAR) from a representative TETRA handset have been performed in an anatomically realistic model of the head. TETRA (Terrestrial Trunked Radio) is a modern digital private mobile radio system designed to meet the requirements of professional users, such as the police and fire brigade. The current frequency allocations in the UK are 380-385 MHz and 390-395 MHz for the public sector network. A comprehensive set of calculations of SAR in the head was performed for positions of the handset in front of the face and at both sides of the head. The representative TETRA handset considered. operating at 1 W in normal use, will show compliance with both the ICNIRP occupational and public exposure restrictions. The handset with a monopole antenna operating at 3 W in normal use will show compliance with both the ICNIRP occupational and public exposure restrictions. The handset with a helical antenna operating at 3 W in normal use will show compliance with the ICNIRP occupational exposure restriction but will be over the public exposure restriction by up to approximately 50% if kept in the position of maximum SAR for 6 min continuously.

**Dimbylow P. SAR in the mother and foetus for RF plane wave irradiation. Phys Med Biol. 52(13):3791-3802, 2007.**

This paper describes the finite-difference time-domain calculation of SAR from 20 MHz to 3 GHz in hybrid voxel-mathematical models of the pregnant female. Mathematical models of the developing foetus at 8-, 13-, 26- and 38-week gestation were converted into voxels and combined with the reference adult female model, NAOMI at a resolution of 2 mm. Whole-body averaged SAR in the mother is presented as well as the average over the foetus, over the foetal brain and in 10 g of the foetus. The electric field values required to produce the ICNIRP public exposure restriction of 2 W kg(-1) when averaged over 10 g of the foetus were calculated. Comparison suggests that the ICNIRP public reference level is a conservative predictor of local SAR in the foetus.

**Dimbylow PJ, Hirata A, Nagaoka T. Intercomparison of whole-body averaged SAR in European and Japanese voxel phantoms.Phys Med Biol. 53(20):5883-5897, 2008.**

This paper provides an intercomparison of the HPA male and female models, NORMAN and NAOMI with the National Institute of Information and Communications Technology (NICT) male and female models, TARO and HANAKO. The calculations of the whole-body SAR in these four phantoms were performed at the HPA, at NICT and at the Nagoya Institute of Technology (NIT). These were for a plane wave with a vertically aligned electric field incident upon the front of the body from 30 MHz to 3 GHz for isolated conditions. As well as investigating the general differences through this frequency range, particular emphasis was placed on the assumptions of how dielectric properties are assigned to tissues (particularly skin and fat) and the consequence of using different algorithms for calculating SAR at the higher frequencies.

**Dimbylow PJ, Nagaoka T, Xu XG. A comparison of foetal SAR in three sets of pregnant female models. Phys Med Biol. 54(9):2755-2767, 2009.**

This paper compares the foetal SAR in the HPA hybrid mathematical phantoms with the 26-week foetal model developed at the National Institute of Information and Communications Technology, Tokyo, and the set of 13-, 26- and 38-week boundary representation models produced at Rensselaer Polytechnic Institute. FDTD calculations are performed at a resolution of 2 mm for a plane wave with a vertically aligned electric field incident upon the body from the front, back and two sides from 20 MHz to 3 GHz under isolated conditions. The external electric field values required to produce the ICNIRP public exposure localized restriction of 2 W kg(-1) when averaged over 10 g of the foetus are compared with the ICNIRP reference levels.

**Ding G, Xie X, Zhang L et al. Changes of nitric oxide synthase in hippocampus and cerebellum of the rat following exposure to electromagnetic pulse. Chin J Phys Med 20:81-83, 1998.**

Objective: In order to explore the role of nitric oxide in the obstruction of learning and memory of the rat caused by exposing to electromagnetic pulses (EMP), the distribution of nitric oxide synthase (NOS) expression was studied in hippocampus and cerebellum of the rat following exposure to EMP. Methods: SP immunohistochemical staining was employed to detect the distribution of NOS expression. Results: The number of NOS positive neurons and the intensity of positive staining in hippocampus were decreased at 1.5 and 24 h after exposure to EMP. At 48 h, the number of NOS positive neurons reversed to control level but the intensity of positive staining was still low. the expression of NOS in cerebellum had no obvious changes. Conclusion: Decrease of NOS expression in hippocampus relates to the obstruction of learning and memory of the rat after exposure to EMP.

**Ding S, Peng H, Fang HS, Zhou JL, Wang Z. Pulsed electromagnetic fields stimulation prevents steroid-induced osteonecrosis in rats.BMC Musculoskelet Disord. 12:215, 2011.**

**BACKGROUND:** Pulsed electromagnetic fields (PEMF) stimulation has been used successfully to treat nonunion fractures and femoral head osteonecrosis, but relatively little is known about its effects on preventing steroid-induced osteonecrosis. The purpose of the study was to investigate the effects of PEMF stimulation on the prevention of steroid-induced osteonecrosis in rats and explore the underlying mechanisms. **METHODS:** Seventy-two male adult Wistar rats were divided into three groups and treated as follows. (1) PEMF stimulation group (PEMF group, n = 24): intravenously injected with lipopolysaccharide (LPS, 10 μg/kg) on day 0 and intramuscularly injected with methylprednisolone acetate (MPSL, 20 mg/kg) on days 1, 2 and 3, then subjected to PEMF stimulation 4 h per day for 1 to 8 weeks. (2) Methylprednisolone-treated group (MPSL group, n = 24): injected the same dose of LPS and MPSL as the PEMF group but without exposure to PEMF. (3) Control group (PS group, n = 24): injected 0.9% saline in the same mode at the same time points. The incidence of osteonecrosis, serum lipid levels and the mRNA and protein expression of transforming growth factor β1 (TGF-β1) in the proximal femur were measured 1, 2, 4 and 8 weeks after the last MPSL (or saline) injection. **RESULTS:** The incidence of osteonecrosis in the PEMF group (29%) was significantly lower than that observed in the MPSL group (75%), while no osteonecrosis

was observed in the PS group. The serum lipid levels were significantly lower in the PEMF and PS groups than in the MPSL group. Compared with the MPSL and PS groups, the mRNA expression of TGF-β1 increased, reaching a peak 1 week after PEMF treatment, and remained high for 4 weeks, then declined at 8 weeks, whereas the protein expression of TGF-β1 increased, reaching a peak at 2 weeks after PEMF treatment, and remained high for 8 weeks. **CONCLUSIONS:** PEMF stimulation can prevent steroid-induced osteonecrosis in rats, and the underlying mechanisms involve decreased serum lipid levels and increased expression of TGF-β1.

**D'Silva MH, Swer RT, Anbalagan J, Rajesh B. Effect of Radiofrequency Radiation Emitted from 2G and 3G** Cell Phone **on Developing Liver of Chick Embryo - A Comparative Study. J Clin Diagn Res. 11(7):AC05-AC09,2017.**

INTRODUCTION: The increasing scientific evidence of various health hazards on exposure of Radiofrequency Radiation (RFR) emitted from both the **cell phones** and base stations have caused significant media attention and public discussion in recent years. The mechanism of interaction of RF fields with developing tissues of children and fetuses may be different from that of adults due to their smaller physical size and variation in tissue electromagnetic properties. The present study may provide an insight into the basic mechanisms by which RF fields interact with developing tissues in an embryo. AIM: To evaluate the possible tissue and DNA damage in developing liver of chick embryo following chronic exposure to Ultra-High Frequency/Radiofrequency Radiation (UHF/RFR) emitted from 2G and 3G **cell phone**.MATERIALS AND METHODS: Fertilized chick embryos were incubated in four groups. Group A-experimental group exposed to 2G radiation (60 eggs), Group B- experimental group exposed to 3G radiation (60 eggs), Group C- sham exposed control group (60 eggs) and Group D- control group (48 eggs). On completion of scheduled duration, the embryos were collected and processed for routine histological studies to check structural changes in liver. The nuclear diameter and karyorrhexis changes of hepatocytes were analysed using oculometer and square reticule respectively. The liver procured from one batch of eggs from all the four groups was subjected to alkaline comet assay technique to assess DNA damage. The results were compared using one-way ANOVA test. RESULTS: In our study, the exposure of developing chick embryos to 2G and 3G **cell phone** radiations caused structural changes in liver in the form of dilated sinusoidal spaces with haemorrhage, increased vacuolations in cytoplasm, increased nuclear diameter and karyorrhexis and significantly increased DNA damage. CONCLUSION: The chronic exposure of chick embryo liver to RFR emitted from 2G and 3G **cell phone** resulted in various structural changes and DNA damage. The changes were more pronounced in 3G experimental group. Based on these findings it is necessary to create awareness among public about the possible ill effects of RFR exposure from **cell phone**

**Divan HA, Kheifets L, Obel C, Olsen J. Prenatal and postnatal exposure to cell phone use and behavioral problems in children. Epidemiology.19(4):523-529, 2008.**

BACKGROUND: The World Health Organization has emphasized the need for research into the possible effects of radiofrequency fields in children. We examined the association

between prenatal and postnatal exposure to cell phones and behavioral problems in young children. METHODS:: Mothers were recruited to the Danish National Birth Cohort early in pregnancy. When the children of those pregnancies reached 7 years of age in 2005 and 2006, mothers were asked to complete a questionnaire regarding the current health and behavioral status of children, as well as past exposure to cell phone use. Mothers evaluated the child's behavior problems using the Strength and Difficulties Questionnaire. RESULTS:: Mothers of 13,159 children completed the follow-up questionnaire reporting their use of cell phones during pregnancy as well as current cell phone use by the child. Greater odds ratios for behavioral problems were observed for children who had possible prenatal or postnatal exposure to cell phone use. After adjustment for potential confounders, the odds ratio for a higher overall behavioral problems score was 1.80 (95% confidence interval = 1.45-2.23) in children with both prenatal and postnatal exposure to cell phones. CONCLUSIONS: Exposure to cell phones prenatally-and, to a lesser degree, postnatally-was associated with behavioral difficulties such as emotional and hyperactivity problems around the age of school entry. These associations may be noncausal and may be due to unmeasured confounding. If real, they would be of public health concern given the widespread use of this technology.

**Divan HA, Kheifets L, Olsen J.Prenatal cell phone use and developmental milestone delays among infants.Scand J Work Environ Health.37(4):341-348, 2011.**

**OBJECTIVE:** The aim of this study was to examine if prenatal use of cell phones by pregnant mothers is associated with developmental milestones delays among offspring up to 18 months of age.**METHODS:** Our work is based upon the Danish National Birth Cohort (DNBC), which recruited pregnant mothers from 1996-2002, and was initiated to collect a variety of detailed information regarding in utero exposures and various health outcomes. At the end of 2008, over 41,000 singleton, live births had been followed with the Age-7 questionnaire, which collected cell phone use exposure for mothers during pregnancy. Outcomes for developmental milestones were obtained from telephone interviews completed by mothers at age 6 and 18 months postpartum.**RESULTS:** A logistic regression model estimated the odds ratios (OR) for developmental milestone delays, adjusted for potential confounders. Less than 5% of children at age 6 and 18 months had cognitive/language or motor developmental delays. At 6 months, the adjusted OR was 0.8 [95% confidence interval (95% CI) 0.7-1.0] for cognitive/language delay and 0.9 (95% CI 0.8-1.1) for motor development delay. At 18 months, the adjusted OR were 1.1 (95% CI 0.9-1.3) and 0.9 (95% CI 0.8-1.0) for cognitive/language and motor development delay, respectively.**CONCLUSIONS:** No evidence of an association between prenatal cell phone use and motor or cognitive/language developmental delays among infants at 6 and 18 months of age was observed. Even when considering dose-response associations for cell phone, associations were null.

**Divan HA, Kheifets L, Obel C, Olsen J. Cell phone use and behavioural problems in young children. J Epidemiol Community Health.66(6):524-529, 2012.**

Background: Potential health effects of cell phone use in children have not been adequately examined. As children are using cell phones at earlier ages, research among

this group has been identified as the highest priority by both national and international organisations. The authors previously reported results from the Danish National Birth Cohort (DNBC), which looked at prenatal and postnatal exposure to cell phone use and behavioural problems at age 7years. Exposure to cell phones prenatally, and to a lesser degree postnatally, was associated with more behavioural difficulties. The original analysis included nearly 13 000 children who reached age 7 years by November 2006. Methods: To see if a larger, separate group of DNBC children would produce similar results after considering additional confounders, children of mothers who might better represent current users of cell phones were analysed. This 'new' dataset consisted of 28 745 children with completed Age-7 Questionnaires to December 2008. Results: The highest OR for behavioural problems were for children who had both prenatal and postnatal exposure to cell phones compared with children not exposed during either time period. The adjusted effect estimate was 1.5 (95% CI 1.4 to 1.7). Conclusions: The findings of the previous publication were replicated in this separate group of participants demonstrating that cell phone use was associated with behavioural problems at age 7years in children, and this association was not limited to early users of the technology. Although weaker in the new dataset, even with further control for an extended set of potential confounders, the associations remained.

**Djeridane Y, Touitou Y, de Seze R. Influence of Electromagnetic Fields Emitted by GSM-900 Cellular Telephones on the Circadian Patterns of Gonadal, Adrenal and Pituitary Hormones in Men. Radiat Res. 169(3):337-343, 2008.**

.The potential health risks of radiofrequency electromagnetic fields (RF EMFs) emitted by mobile phones are currently of considerable public interest. The present study investigated the effect of exposure to 900 MHz GSM radiofrequency radiation on steroid (cortisol and testosterone) and pituitary (thyroid-stimulating hormone, growth hormone, prolactin and adrenocorticotropin) hormone levels in 20 healthy male volunteers. Each subject was exposed to RF EMFs through the use of a cellular phone for 2 h/day, 5 days/ week, for 4 weeks. Blood samples were collected hourly during the night and every 3 h during the day. Four sampling sessions were performed at 15-day intervals: before the beginning of the exposure period, at the middle and the end of the exposure period, and 15 days later. Parameters evaluated included the maximum serum concentration, the time of this maximum, and the area under the curve for hormone circadian patterns. Each individual's pre-exposure hormone concentration was used as his control. All hormone concentrations remained within normal physiological ranges. The circadian profiles of prolactin, thyroid-stimulating hormone, adrenocorticotropin and testosterone were not disrupted by RF EMFs emitted by mobile phones. For growth hormone and cortisol, there were significant decreases of about 28% and 12%, respectively, in the maximum levels when comparing the 2-week (for growth hormone and cortisol) and 4-week (for growth hormone) exposure periods to the pre-exposure period, but no difference persisted in the postexposure period. Our data show that the 900 MHz EMF exposure, at least under our experimental conditions, does not appear to affect endocrine functions in men.

**Djordjevic B, Sokolovic D, Kocic G, Veljkovic A, Despotovic M, Basic J, Jevtovic-Stoimenov T, Sokolovic DM. The effect of melatonin on the liver of rats exposed to microwave radiation. Bratisl Lek Listy. 116(2):96-100, 2015.**

OBJECTIVES: We aimed to clarify if melatonin treatment (2 mg/kg i.p.) may favorably impact the liver tissue in rats exposed to microwave radiation. The experiment was performed on 84 six-weeks-old Wistar male rats exposed for 4h a day, for 20, 40 and 60 days, respectively, to microwaves (900 MHz, 100-300 microT, 54-160 V/m). Rats were divided in to four groups: I (control) - rats treated with saline, II (Mel) - rats treated with melatonin, III (MWs) - microwave exposed rats, IV (MWs + Mel) - MWs exposed rats treated with melatonin. We evaluated oxidative stress parameters (malondialdehyde and carbonyl group content), catalase, xanthine oxidase, deoxyribonuclease I and II activity. BACKGROUND: Oxidative stress is the key mechanism of the microwave induced tissue injury. Melatonin, a lipophilic indoleamine primarily synthesized and released from the pineal gland is a powerful antioxidant. RESULTS: Exposure to microwaves caused an increase in malondialdehyde after 40 ($p < 0.01$), protein carbonyl content after 20 ($p < 0.05$), catalase ($p < 0.05$) and xantine oxidase activity ($p < 0.05$) after 40 days. Increase in deoxyribonuclease I activity was observed after 60 days ($p < 0.05$), while deoxyribonuclease II activity was unaffected. Melatonin treatment led to malondialdehyde decrease after 40 days ($p< 0.05$), but surprisingly had no effect on other analyzed parameters. CONCLUSION: Melatonin exerts certain antioxidant effects in the liver of rats exposed to microwaves, by diminishing the intensity of lipid peroxidation(Fig. 6, Ref. 32).

**Dmoch A, Moszczynski P, [Levels of immunoglobulin and subpopulations of T lymphocytes and NK cells in men occupationally exposed to microwave radiation in frequencies of 6-12 GHz]. Med Pr 49(1):45-49, 1998.** [Article in Polish]

Immunoglobulin concentrations and T-lymphocyte subsets in workers of TV re-transmission and satellite communication centres were assessed. An increase in IgG and IgA concentrations, an increased count of lymphocytes and T8 lymphocytes, an decreased count of NK cells and a lower value of T-helper/T-suppressor ratio were found. Neither disorders in immunoglobulin concentrations nor in the count of T8 and NK cells had any clinical implications.

**Dode AC, Leão MM, Tejo Fde A, Gomes AC, Dode DC, Dode MC, Moreira CW, Condessa VA, Albinatti C, Caiaffa WT. Mortality by neoplasia and cellular telephone base stations in the Belo Horizonte municipality, Minas Gerais state, Brazil.Sci Total Environ. 409(19):3649-3665, 2011.**

Pollution caused by the electromagnetic fields (EMFs) of radio frequencies (RF) generated by the telecommunication system is one of the greatest environmental problems of the twentieth century. The purpose of this research was to verify the existence of a spatial correlation between base station (BS) clusters and cases of deaths by neoplasia in the Belo Horizonte municipality, Minas Gerais state, Brazil, from 1996 to 2006 and to measure the human exposure levels to EMF where there is a major concentration of cellular telephone transmitter antennas. A descriptive spatial analysis of the BSs and the cases of death by neoplasia identified in the municipality was performed

through an ecological-epidemiological approach, using georeferencing. The database employed in the survey was composed of three data banks: 1. death by neoplasia documented by the Health Municipal Department; 2. BSs documented in ANATEL (''Agência Nacional de Telecomunicações'': 'Telecommunications National Agency'); and 3. census and demographic city population data obtained from official archives provided by IBGE (''Instituto Brasileiro de Geografia e Estatística'': 'Brazilian Institute of Geography and Statistics'). The results show that approximately 856 BSs were installed through December 2006. Most (39.60%) of the BSs were located in the ''Centro-Sul'' ('Central-Southern') region of the municipality. Between 1996 and 2006, 7191 deaths by neoplasia occurred and within an area of 500 m from the BS, the mortality rate was 34.76 per 10,000 inhabitants. Outside of this area, a decrease in the number of deaths by neoplasia occurred. The greatest accumulated incidence was 5.83 per 1000 in the Central-Southern region and the lowest incidence was 2.05 per 1000 in the Barreiro region. During the environmental monitoring, the largest accumulated electric field measured was 12.4 V/m and the smallest was 0.4 V/m. The largest density power was 40.78 μW/cm(2), and the smallest was 0.04 μW/cm(2).

**Dogan M, Turtay MG, Oguzturk H, Samdanci E, Turkoz Y, Tasdemir S, Alkan A, Bakir S. Effects of electromagnetic radiation produced by 3G mobile phones on rat brains: magnetic resonance spectroscopy, biochemical, and histopathological evaluation.Hum Exp Toxicol. 31(6):557-564, 2012.**

Objective: The effects of electromagnetic radiation (EMR) produced by a third-generation (3G) mobile phone (MP) on rat brain tissues were investigated in terms of magnetic resonance spectroscopy (MRS), biochemistry, and histopathological evaluations. Methods: The rats were randomly assigned to two groups: Group 1 is composed of 3G-EMR-exposed rats (n = 9) and Group 2 is the control group (n = 9). The first group was subjected to EMR for 20 days. The control group was not exposed to EMR. Choline (Cho), creatinin (Cr), and N-acetylaspartate (NAA) levels were evaluated by MRS. Catalase (CAT) and glutathione peroxidase (GSH-Px) enzyme activities were measured by spectrophotometric method. Histopathological analyses were carried out to evaluate apoptosis in the brain tissues of both groups. Results: In MRS, NAA/Cr, Cho/Cr, and NAA/Cho ratios were not significantly different between Groups 1 and 2. Neither the oxidative stress parameters, CAT and GSH-Px, nor the number of apoptotic cells were significantly different between Groups 1 and 2. Conclusions:Usage of short-term 3G MP does not seem to have a harmful effect on rat brain tissue.

**Dolk H, Shaddick G, Walls P, Grundy C, Thakrar B, Kleinschmidt I, Elliott P, Cancer incidence near radio and television transmitters in Great Britain. I. Sutton Coldfield transmitter. Am J Epidemiol 145(1):1-9, 1997.**

A small area study of cancer incidence in 1974-1986 was carried out to investigate an unconfirmed report of a ''cluster'' of leukemias and lymphomas near the Sutton Coldfield television (TV) and frequency modulation (FM) radio transmitter in the West Midlands, England. The study used a national database of postcoded cancer registrations, and population and socioeconomic data from the 1981 census. Selected cancers were hematopoietic and lymphatic, brain, skin, eye, male breast, female breast, lung,

colorectal, stomach, prostate, and bladder. Expected numbers of cancers in small areas were calculated by indirect standardization, with stratification for a small area socioeconomic index. The study area was defined as a 10 km radius circle around the transmitter, within which 10 bands of increasing distance from the transmitter were defined as a basis for testing for a decline in risk with distance, and an inner area was arbitrarily defined for descriptive purposes as a 2 km radius circle. The risk of adult leukemia within 2 km was 1.83 (95% confidence interval 1.22-2.74), and there was a significant decline in risk with distance from the transmitter (p = 0.001). These findings appeared to be consistent over the periods 1974-1980, 1981-1986, and were probably largely independent of the initially reported cluster, which appeared to concern mainly a later period. In the context of variability of leukemia risk across census wards in the West Midlands as a whole, the Sutton Coldfield findings were unusual. A significant decline in risk with distance was also found for skin cancer, possibly related to residual socioeconomic confounding, and for bladder cancer. Study of other radio and TV transmitters in Great Britain is required to put the present results in wider context. No causal implications can be made from a single cluster investigation of this kind.

**Dolk H, Elliott P, Shaddick G, Walls P, Thakrar B, Cancer incidence near radio and television transmitters in Great Britain. II. All high power transmitters. Am J Epidemiol 145(1):10-17, 1997.**

A small area study of cancer incidence, 1974-1986, near 20 high power television (TV) and frequency modulation (FM) radio transmitters in Great Britain was carried out to place in context the findings of an earlier study around the Sutton Coldfield transmitter. The national database of postcoded cancer registrations was used with population and socioeconomic data from the 1981 census. Cancers examined were adult leukemias, skin melanoma, and bladder cancer, following the findings in the earlier study of significant declines in risk of these cancers with distance from the Sutton Coldfield transmitter. Childhood leukemia and brain cancer were also examined. Statistical analysis was performed for all transmitters combined, four overlapping groups of transmitters defined by their transmission characteristics, and for all transmitters separately. There were 3,305 adult leukemia cases from 0-10 km (observed/expected (O/E) ratio = 1.03, 95% confidence interval (CI) 1.00-1.07). A decline in risk of adult leukemia was found for all transmitters combined (p = 0.05), two of the transmitter groups, and three of the single transmitters; for all transmitters combined, observed excess risk was no more than 15% at any distance up to 10 km, and there was no observed excess within 2 km of transmitters (O/E ratio = 0.97, 95% CI 0.78-1.21). For childhood leukemia and brain cancer, and adult skin melanoma and bladder cancer, results were not indicative of a decline in risk with distance from transmitters. The magnitude and pattern of risk found in the Sutton Coldfield study did not appear to be replicated. The authors conclude that the results at most give no more than very weak support to the Sutton Coldfield findings.

**Donnellan M, McKenzie DR, French PW**, **Effects of exposure to electromagnetic radiation at 835 MHz on growth, morphology and secretory characteristics of a mast cell analogue, RBL-2H3.Cell Biol Int 21:427-439, 1997.**

A mast cell line, RBL-2H3, was exposed to 835 MHz for 20 minutes, three times per day for 7 days at a power density of 8.1 +/- 3 mW/cm2. From day 4 onwards, it was observed

that the rate of DNA synthesis and cell replication increased, that actin distribution and cell morphology became altered, and the amount of beta-hexosaminidase (a marker of granule secretion) released in response to a calcium ionophore was significantly enhanced, in comparison to unexposed cultures. There were no effects seen on levels of cytoskeletal protein synthesis or of beta-actin mRNA. Morphological changes persisted following subculture for at least 7 days in the absence of further exposure. It is hypothesized that effects of exposure to an electromagnetic field at 835 MHz may be mediated via a signal transduction pathway.

**Dovrat A, Berenson R, Bormusov E, Lahav A, Lustman T, Sharon N, Schachter L. Localized effects of microwave radiation on the intact eye lens in culture conditions. Bioelectromagnetics. 26(5):398-405, 2005.**

A novel experimental system was used to investigate the localized effects of microwave radiation on bovine eye lenses in culture for over 2 weeks. Using this setup, we found clear evidence that this radiation has a significant impact on the eye lens. At the macroscopic level, it is demonstrated that exposure to a few mW at 1 GHz for over 36 h affects the optical function of the lens. Most importantly, self-recovery occurs if the exposure is interrupted. At the microscopic level, close examination of the lens indicates that the interaction mechanism is completely different from the mechanism-causing cataract via temperature increase. Contrary to the latter's effect, that is particularly pronounced in the vicinity of the sutures and it is assumed to be a result of local friction between the edges of the fibers consisting the lens. Even if macroscopically the lens has recovered from the irradiation, microscopically the indicators of radiation impact remain.

**Dragicevic N, Bradshaw PC, Mamcarz M, Lin X, Wang L, Cao C, Arendash GW. Long-term electromagnetic field treatment enhances brain mitochondrial function of both Alzheimer's transgenic mice and normal mice: a mechanism for electromagnetic field-induced cognitive benefit? Neuroscience. 185:135-149, 2011.**

We have recently reported that long-term exposure to high frequency electromagnetic field (EMF) treatment not only prevents or reverses cognitive impairment in Alzheimer's transgenic (Tg) mice, but also improves memory in normal mice. To elucidate the possible mechanism(s) for these EMF-induced cognitive benefits, brain mitochondrial function was evaluated in aged Tg mice and non-transgenic (NT) littermates following 1 month of daily EMF exposure. In Tg mice, EMF treatment enhanced brain mitochondrial function by 50-150% across six established measures, being greatest in cognitively-important brain areas (e.g. cerebral cortex and hippocampus). EMF treatment also increased brain mitochondrial function in normal aged mice, although the enhancement was not as robust and less widespread compared to that of Tg mice. The EMF-induced enhancement of brain mitochondrial function in Tg mice was accompanied by 5-10 fold increases in soluble Aβ1-40 within the same mitochondrial preparations. These increases in mitochondrial soluble amyloid-β peptide (Aβ) were apparently due to the ability of EMF treatment to disaggregate Aβ oligomers, which are believed to be the form of Aβ causative to mitochondrial dysfunction in Alzheimer's disease (AD). Finally, the EMF-induced mitochondrial enhancement in both Tg and normal mice occurred through non-thermal effects because brain temperatures were either stable or decreased

during/after EMF treatment. These results collectively suggest that brain mitochondrial enhancement may be a primary mechanism through which EMF treatment provides cognitive benefit to both Tg and NT mice. Especially in the context that mitochondrial dysfunction is an early and prominent characteristic of Alzheimer's pathogenesis, EMF treatment could have profound value in the disease's prevention and treatment through intervention at the mitochondrial level.

**Dreyer NA, Loughlin JE, Rothman KJ, Cause-specific mortality in cellular telephone users. JAMA 282(19):1814-1816, 1999.**

A survey of standandized mortality rates (from cancer, circulatory diseases, and motor vehicle collisions) of 285,561 analog telephone users with known age, sex, and telephone type, showed that the only catelogy of cause of death for which there was an indication of increasing risk with increasing minutes of phone use was motor vehicle collisions. Similar results were found for number of telephone calls per day. collision were particularly hazardous (relative risk, 4.8 for calls placed within 5 minutes of the accident, as compared with 1.3 for calls placed more than 15 minutes before the accident; P<0.001); and units that allowed the hands to be free (relative risk, 5.9) offered no safety advantage over hand-held units (relative risk, 3.9; P not significant). Thirty-nine percent of the drivers called emergency services after the collision, suggesting that having a cellular telephone may have had advantages in the aftermath of an event. CONCLUSIONS: The use of cellular telephones in motor vehicles is associated with a quadrupling of the risk of a collision during the brief time interval involving a call. Decisions about regulation of such telephones, however, need to take into account the benefits of the technology and the role of individual responsibility.

**Duan L, Shan Y, Yu X, [Observations of changes in neurobehavioral functions in workers exposed to high-frequency radiation]. Chung Hua Yu Fang I Hsueh Tsa Chih 32(2):109-111, 1998.** [Article in Chinese]

OBJECTIVE: To study the effects of exposure to high-frequency radiation on neurobehavioral function of the exposed workers and its measurement in evaluating occupational hazards caused by it. METHODS: Four neurobehavioral functions were tested for the workers exposed to high-frequency radiation with Neurobehavioral Core Tests Battery recommended by WHO. RESULTS: Scores for various indicators in exposed workers were significantly lower than those in controls, and correlated to the detection of neurasthenia in the exposed workers, to certain extent. CONCLUSION: Changes in neurobehavioral function in workers exposed to high-frequency radiation can reflect its important adverse effects.

**Dubreuil D, Jay T, Edeline JM. Does head-only exposure to GSM-900 electromagnetic fields affect the performance of rats in spatial learning tasks? Behav Brain Res 129(1-2):203-210, 2002.**

The rapid expansion of mobile communication has generated intense interest, but has also fuelled ongoing concerns. In both humans and animals, radiofrequency radiations are suspected to affect cognitive functions. More specifically, several studies performed in rodents have suggested that spatial learning can be impaired by electromagnetic field exposure. However, none of these previous studies have simulated the common

conditions of GSM mobile phones use. This study is the first using a head-only exposure system emitting a 900-MHz GSM electromagnetic field (pulsed at 217 Hz). The two behavioural tasks that were evaluated here have been used previously to demonstrate performance deficits in spatial learning after electromagnetic field exposure: a classical radial maze elimination task and a spatial navigation task in an open-field arena (dry-land version of the Morris water maze). The performances of rats exposed for 45 min to a 900-MHz electromagnetic field (1 and 3.5 W/kg) were compared to those of sham-exposed and cage-control rats. There were no differences among exposed, sham, and cage-control rats in the two spatial learning tasks. The discussion focuses on the potential reasons that led previous studies to conclude that learning deficits do occur after electromagnetic field exposure.

**Dubreuil D, Jay T, Edeline JM.Head-only exposure to GSM 900-MHz electromagnetic fields does not alter rat's memory in spatial and non-spatial tasks. Behav Brain Res. 145(1-2):51-61, 2003.**

Over the last decade, exposure to high frequency (2450 MHz) electromagnetic fields (EMFs) has been found to induce performance deficit in rodents in spatial memory tasks. As concern was expressed about potential biological effects of mobile communication microwaves, studies testing the effects of signals such as GSM were required. In a previous study, using head-only exposure to 900 MHz GSM EMF, we could not demonstrate any behavioural deficit in two simple learning tasks. The present study aimed at extending these results with more complex spatial learning tasks and a non-spatial task. In a first experiment, rats were trained in a radial-arm maze with a 10-s confinement between each visited arm. In a second experiment, a 15-min intra-trial delay was introduced after four visited arms. In a third experiment, non-spatial memory was tested in an object recognition task. In all experiments, performance of the head-only exposed rats (1 and 3.5 W/kg) was compared with that of sham and control rats. In the first experiment, a slightly improved performance was found after 3.5 W/kg exposure, a result that was not observed in the delay-task. In the third experiment, although some effects on exploratory activity were found, recognition memory was unaffected in exposed rats. Altogether, this set of experiments provides no evidence indicating that spatial and non-spatial memory can be affected by a 45-min head-only exposure to 900 MHz GSM EMF.

**Durusoy R, Hassoy H, Özkurt A, Karababa AO.** Mobile phone **use, school electromagnetic field levels and related symptoms: a cross-sectional survey among 2150 high school students in Izmir. Environ Health. 16(1):51, 2017.**

BACKGROUND: Health outcomes of electromagnetic fields (EMF) from **mobile phones** and their base stations are of concern. Conducting multidisciplinary research, targeting children and exploring dose-response are recommended. Our objectives were to describe the **mobile phone** usage characteristics of high school students and to explore the association between **mobile phone** usage characteristics, high school EMF levels and self-reported symptoms.METHODS: This cross-sectional study's data were collected by a survey questionnaire and by measuring school EMF levels between November 2009 and April 2011. A sample size of 2530 was calculated from a total of 20,493 students in 26 high schools and 2150 (85.0%) were included in the analysis. The frequencies of 23

symptoms were questioned and analysed according to 16 different aspects of **mobile phone** use and school EMF levels, exploring also dose-response. School EMF levels were measured with Aaronia Spectran HF-4060 device. Chi square and trend tests were used for univariate and logistic regression was used for multivariate analyses.RESULTS: Among participants, 2021 (94.0%) were using **mobile phones** and 129 (6.0%) were not. Among users, 49.4% were speaking <10 min and 52.2% were sending/receiving 75 or more messages per day. Headache, fatigue and sleep disturbances were observed respectively 1.90 (95% CI 1.30-2.77), 1.78 (1.21-2.63) and 1.53 (1.05-2.21) times more among **mobile phone** users. Dose-response relationships were observed especially for the number of calls per day, total duration of calls per day, total number of text messages per day, position and status of **mobile phone** at night and making calls while charging as exposures and headache, concentration difficulties, fatigue and sleep disturbances as general symptoms and warming of the ear and flushing as local symptoms. CONCLUSIONS: We found an association between **mobile phone** use and especially headache, concentration difficulties, fatigue, sleep disturbances and warming of the ear showing also dose-response. We have found limited associations between vicinity to base stations and some general symptoms; however, we did not find any association with school EMF levels. Decreasing the numbers of calls and messages, decreasing the duration of calls, using earphones, keeping the **phone** away from the head and body and similar precautions might decrease the frequencies or prevalence of the symptoms.

**Dutta SK, Das K, Ghosh B, Blackman CF, Dose dependence of acetylcholinesterase activity in neuroblastoma cells exposed to modulated radio-frequency electromagnetic radiation. Bioelectromagnetics 13(4):317-322, 1992.**

Radio-frequency electromagnetic radiation (RFR) at 915 and 147 MHz, when sinusoidally amplitude modulated (AM) at 16 Hz, has been shown to enhance release of calcium ions from neuroblastoma cells in culture. The dose-response relation is unusual, consisting of two power-density "windows" in which enhanced efflux occurs, separated by power-density regions in which no effect is observed. To explore the physiological importance of these findings, we have examined the impact of RFR exposure on a membrane-bound enzyme, acetylcholinesterase (AChE), which is intimately involved with the acetylcholine (ACh) neurotransmitter system. Neuroblastoma cells (NG108), exposed for 30 min to 147-MHz radiation, AM at 16 Hz, demonstrated enhanced AChE activity, as assayed by a procedure using 14C-labeled ACh. Enhanced activity was observed within a time window between 7.0 and 7.5 h after the cells were plated and only when the exposure occurred at power densities identified in a previous report as being effective for altering the release of calcium ions. Thus RFR affects both calcium-ion release and AChE activity in nervous system-derived cells in culture in a common dose-dependent manner.

**Dutta SK, Verma M, Blackman CF, Frequency-dependent alterations in enolase activity in Escherichia coli caused by exposure to electric and magnetic fields. Bioelectromagnetics 15(5):377-383, 1994.**

Some neurochemical effects of low-intensity electric and magnetic fields have been

shown to be nonlinear functions of exposure parameters. These effects occurred within narrow ranges of frequency and intensity. Previous studies on membrane-associated endpoints in cell culture preparations demonstrated changes in calcium efflux and in acetylcholinesterase activity following exposure to radiofrequency radiation, amplitude modulated (AM) at 16 and at 60 Hz, at a specific absorption rate of 0.05 W/kg. In this study, these modulation frequencies were tested for their influence on the activity of a cytoplasmic enzyme, enolase, which is being tested clinically for detection of neoplasia. Escherichia coli cultures containing a plasmid with a mammalian gene for enolase were exposed for 30 min, and cell extracts were assayed for enolase activity by measuring absorbance at 240 nm. The enolase activity in exposed cultures was compared to the activity in paired control cultures. Exposure to 147 MHz carrier waves at 0.05 W/kg, AM at 16 Hz showed enolase activity enhanced by 62%, and AM at 60 Hz showed enolase activity reduced by 28%. Similarly, exposure to 16 Hz fields alone, at 21.2 V/mrms (electric) and 97 nTrms (magnetic), showed enhancement in enolase activity by 59%, whereas exposure to 60 Hz fields alone, at 14.1 V/mrms (electric) and 65 nTrms (magnetic), showed reduction in activity by 24%. Sham exposures as well as exposure to continuous-wave 147 MHz radiation at 0.05 W/kg showed no change in enolase activity.

**Eberhardt JL, Persson BR, Brun AE, Salford LG, Malmgren LO. Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones. Electromagn Biol Med. 27(3):215-229, 2008.**

We investigated the effects of global system for mobile communication (GSM) microwave exposure on the permeability of the blood-brain barrier and signs of neuronal damage in rats using a real GSM programmable mobile phone in the 900 MHz band. Ninety-six non-anaesthetized rats were either exposed to microwaves or sham exposed in TEM-cells for 2 h at specific absorption rates of average whole-body Specific Absorption Rates (SAR) of 0.12, 1.2, 12, or 120 mW/kg. The rats were sacrificed after a recovery time of either 14 or 28 d, following exposure and the extravazation of albumin, its uptake into neurons, and occurrence of damaged neurons was assessed. Albumin extravazation and also its uptake into neurons was seen to be enhanced after 14 d (Kruskal Wallis test: $p = 0.02$ and 0.002, respectively), but not after a 28 d recovery period. The occurrence of dark neurons in the rat brains, on the other hand, was enhanced later, after 28 d ($p = 0.02$). Furthermore, in the 28-d brain samples, neuronal albumin uptake was significantly correlated to occurrence of damaged neurons (Spearman $r = 0.41$; $p < 0.01$).

**Ebert S, Eom SJ, Schuderer J, Apostel U, Tillmann T, Dasenbrock C, Kuster N. Response, thermal regulatory threshold and thermal breakdown threshold of restrained RF-exposed mice at 905 MHz. Phys Med Biol. 50(21):5203-5215, 2005.**

The objective of this study was the determination of the thermal regulatory and the thermal breakdown thresholds for in-tube restrained B6C3F1 and NMRI mice exposed to radiofrequency electromagnetic fields at 905 MHz. Different levels of the whole-body averaged specific absorption rate (SAR = 0, 2, 5, 7.2, 10, 12.6 and 20 W kg(-1)) have been applied to the mice inside the 'Ferris Wheel' exposure setup at 22 +/- 2 degrees C and 30-70% humidity. The thermal responses were assessed by measurement of the rectal temperature prior, during and after the 2 h exposure session. For B6C3F1 mice, the

thermal response was examined for three different weight groups (20 g, 24 g, 29 g), both genders and for pregnant mice. Additionally, NMRI mice with a weight of 36 g were investigated for an interstrain comparison. The thermal regulatory threshold of in-tube restrained mice was found at SAR levels between 2 W kg(-1) and 5 W kg(-1), whereas the breakdown of regulation was determined at 10.1 +/- 4.0 W kg(-1)(K = 2) for B6C3F1 mice and 7.7 +/- 1.6 W kg(-1)(K = 2) for NMRI mice. Based on a simplified power balance equation, the thresholds show a clear dependence upon the metabolic rate and weight. NMRI mice were more sensitive to thermal stress and respond at lower SAR values with regulation and breakdown. The presented data suggest that the thermal breakdown for in-tube restrained mice, whole-body exposed to radiofrequency fields, may occur at SAR levels of 6 W kg(-1)(K = 2) at laboratory conditions.

**Edelstyn N, Oldershaw A. The acute effects of exposure to the electromagnetic field emitted by mobile phones on human attention. Neuroreport 13(1):119-121, 2002.**

The aim of our study was to investigate the effects of acute mobile phone exposure on a range of tasks which tapped capacity and processing speed within the attentional system. Thirty-eight healthy volunteers were randomly assigned to either an experimental group which was exposed to a connected mobile phone or a control group in which the mobile phone was switched off. Subjects remained blind to mobile phone status throughout duration of study. The experimental group were exposed to an electromagnetic field emitted by a 900 MHz mobile phone for 30 min. Cognitive performance was assessed at three points (prior to mobile phone exposure, at 15 and 30 min post-exposure) using six cognitive neuropsychological tests (digit span and spatial span forwards and backwards, serial subtraction and verbal fluency). Significant differences between the two groups were evident after 5 min on two tests of attentional capacity (digit span forwards and spatial span backwards) and one of processing speed (serial subtraction). In all three instances, performance was facilitated following mobile phone exposure. No deficits were evident. These findings are discussed in terms of possible functional and neuroanatomical bases.

**Eghlidospour M, Ghanbari A, Mortazavi SMJ, Azari H. Effects of radiofrequency exposure emitted from a GSM mobile phone on proliferation, differentiation, and apoptosis of neural stem cells. Anat Cell Biol. 50(2):115-123, 2017.**

Due to the importance of neural stem cells (NSCs) in plasticity of the nervous system and treating neurodegenerative diseases, the main goal of this study was to evaluate the effects of radiofrequency radiation emitted from a GSM 900-MHz mobile phone with different exposure duration on proliferation, differentiation and apoptosis of adult murine NSCs *in vitro*. We used neurosphere assay to evaluate NSCs proliferation, and immunofluorescence assay of neural cell markers to examine NSCs differentiation. We also employed alamarBlue and caspase 3 apoptosis assays to assess harmful effects of mobile phone on NSCs. Our results showed that the number and size of resulting neurospheres and also the percentage of cells differentiated into neurons decreased significantly with increasing exposure duration to GSM 900-MHz radiofrequency (RF)-electromagnetic field (EMF). In contrast, exposure to GSM 900-MHz RF-EMF at different durations did not influence cell viability and apoptosis of NSCs and also their astrocytic

differentiation. It is concluded that accumulating dose of GSM 900-MHz RF-EMF might have devastating effects on NSCs proliferation and neurogenesis requiring more causations in terms of using mobile devices.

**Ekici B, Tanındı A, Ekici G, Diker E. The effects of the duration of mobile phone use on heart rate variability parameters in healthy subjects. Anatol J Cardiol. 2016 Apr 7. doi: 10.14744/AnatolJCardiol.2016.6717. [Epub ahead of print]**

OBJECTIVE: This study aimed to estimate the influence of the duration of mobile phone use on heart rate variability (HRV) in healthy individuals. METHODS: One hundred forty-eight individuals without any established systemic disease and who had undergone 24-h ambulatory ECG monitoring were included in the case-control study. All the individuals had been using mobile phones for more than 10 years. Three-channel 24-h Holter monitoring was performed to derive the mean heart rate, standard deviation of normal NN intervals (SDNN), standard deviation of 5-min (m) mean NN intervals (SDANN), the proportion of NN50 divided by the total number of NNs (pNN50), the root mean square differences of successive NN intervals (RMSSD), high (HF)-, low (LF)-, very low (VLF)-frequency power, total power components, and the LF/HF ratio. Individuals were divided into four groups according to their duration of mobile phone use [no mobile phone use (Control group), <30 min/day (Group 1), 30-60 min/day (Group 2), and >60 min/day (Group 3)]. RESULTS: All the groups had similar features with regard to demographic and clinical characteristics. No significant arrhythmias were observed in any of the groups. The LF/HF ratio was higher, whereas the SDNN, SDANN, RMSSD, and pNN50 values were lower in the study groups than in the control group ($p<0.05$). No significant differences were identified among groups with respect to heart rate, VLF, and total power values ($p>0.05$). CONCLUSION: In this study, it was shown that the duration of mobile phone use may affect the autonomic balance in healthy subjects. The electromagnetic field created by mobile phone use may induce HRV changes in the long term.

**El-Bediwi AB, Saad M, El-Kott AF, Eid E. Influence of Electromagnetic Radiation Produced by Mobile Phone on Some Biophysical Blood Properties in Rats.Cell Biochem Biophys. 2012 Oct 10. [Epub ahead of print]**

Effects of electromagnetic radiation produced by mobile phone on blood viscosity, plasma viscosity, hemolysis, Osmotic fragility, and blood components of rats have been investigated. Experimental results show that there are significant change on blood components and its viscosity which affects on a blood circulation due to many body problems. Red blood cells, White blood cells, and Platelets are broken after exposure to electromagnetic radiation produced by mobile phone. Also blood viscosity and plasma viscosity values are increased but Osmotic fragility value decreased after exposure to electromagnetic radiation produced by mobile phone.

**El Kholy SE, El Husseiny EM. Effect of 60 minutes exposure to electromagnetic field on fecundity, learning and memory, speed of movement and whole body protein of the fruit fly Drosophila melanogaster. J Egypt Soc Parasitol. 42(3):639-648, 2012.**

This study investigated the effect of four different electrical devices as source of electromagnetic field on fecundity, learning and memory function, speed of movement, in addition to the whole body proteins of the fruit fly Drosophila melanogaster. The results showed that exposure to EMF has no significant effect on adult fecundity (ANOVA and Duncan's test) but alters learning and memory function in Drosophila larvae, especially those exposed to mobile phone. Highly significant differences occurred in the larval speed of movement after exposure to EMF, with maximal effect occurred for larvae exposed to mobile phone (their speed of movement increased 2.5 times of wild type). Some protein bands serve as characters for exposure to certain electrical devices which suggest that exposure to EMF may affect the whole body proteins.

**Elekes, E, Thuroczy, G, Szabo, LD, Effect on the immune system of mice exposed chronically to 50 Hz amplitude-modulated 2.45 GHz microwaves. Bioelectromagnetics 17(3):246-248, 1996.**

The effect of continuous (CW; 2.45 GHz carrier frequency) or amplitude-modulated (AM; 50 Hz square wave) microwave radiation on the immune response was tested. CW exposures (6 days, 3 h/day) induced elevations of the number of antibody-producing cells in the spleen of male Balb/c mice (+37%). AM microwave exposure induced elevation of the spleen index (+15%) and antibody-producing cell number (+55%) in the spleen of male mice. No changes were observed in female mice. It is concluded that both types of exposure conditions induced moderate elevation of antibody production only in male mice.

**El-Gohary OA, Said MA. Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D. Can J Physiol Pharmacol. 2016 Sep 5:1-6. [Epub ahead of print]**

There are considerable public concerns about the relationship between mobile phone radiation and human health. The present study assesses the effect of electromagnetic field (EMF) emitted from a mobile phone on the immune system in rats and the possible protective role of vitamin D. Rats were randomly divided into six groups: Group I: control group; Group II: received vitamin D (1000 IU/kg/day) orally; Group III: exposed to EMF 1 h/day; Group IV: exposed to EMF 2 h/day; Group V: exposed to EMF 1 h/day and received vitamin D (1000 IU/kg/day); Group VI: exposed to EMF 2 h/day and received vitamin D (1000 IU/kg/day). After 30 days of exposure time, 1 h/day EMF exposure resulted in significant decrease in immunoglobulin levels (IgA, IgE, IgM, and IgG); total leukocyte, lymphocyte, eosinophil and basophil counts; and a significant increase in neutrophil and monocyte counts. These changes were more increased in the group exposed to 2 h/day EMF. Vitamin D supplementation in EMF-exposed rats reversed these results when compared with EMF-exposed groups. In contrast, 7, 14, and 21 days of EMF exposure produced nonsignificant differences in these parameters among all experimental groups. We concluded that exposure to mobile phone radiation compromises the immune system of rats, and vitamin D appears to have a protective effect.

**Elhag MA, Nabil GM, Attia AM. Effects of electromagnetic field produced by mobile phones on the oxidant and antioxidant status of rats. Pak J Biol Sci. 10(23):4271-4274, 2007.**

This study was designed to investigate the effect of EMR produced by GSM Mobile Phones (MP) on the oxidant and antioxidant status in rats. Rats were divided into three groups: (1) controls, (2) rats exposed to a fractionated dose of EMR (15 min day(-1) for four days) (EMR-F) and (3) rats exposed to an acute dose of EMR (EMR-A). A net drop in the plasma concentration of vitamin C (-47 and -59.8%) was observed in EMR-F and EMR-A groups, respectively, when compared to controls. While, a significant decrease in the levels of lypophilic antioxidant vitamins: vitamin E (-33 and -65.8%), vitamin A (-44.4 and -46.8%) was observed in EMR-F and EMR-A groups, respectively, when compared to controls. A net drop in plasma level of reduced glutathione (GSH) (-19.8 and -35.3%) was observed in EMR-F and EMR-A groups, respectively. EMR exposure of rats produced a significant decrease in catalase (CAT) and superoxide dismutase (SOD) activities, with the values of these activities for EMR-A group is significantly lower than those of EMR-F. These results indicate that the effects of acute doses of EMR produced by mobile phones on the rat's antioxidant status is significantly higher than those of fractionated doses of the same type of radiation. On the basis of present results, it can be concluded that exposure to acute doses of EMR produced by mobile phones is more hazardous than that produced by fractionated doses of the same type of radiation.

**Eliyahu I, Luria R, Hareuveny R, Margaliot M, Meiran N, Shani G. Effects of radiofrequency radiation emitted by cellular telephones on the cognitive functions of humans. Bioelectromagnetics.27(2):119-126, 2006.**

The present study examined the effects of exposure to Electromagnetic Radiation emitted by a standard GSM phone at 890 MHz on human cognitive functions. This study attempted to establish a connection between the exposure of a specific area of the brain and the cognitive functions associated with that area. A total of 36 healthy right-handed male subjects performed four distinct cognitive tasks: spatial item recognition, verbal item recognition, and two spatial compatibility tasks. Tasks were chosen according to the brain side they are assumed to activate. All subjects performed the tasks under three exposure conditions: right side, left side, and sham exposure. The phones were controlled by a base station simulator and operated at their full power. We have recorded the reaction times (RTs) and accuracy of the responses. The experiments consisted of two sections, of 1 h each, with a 5 min break in between. The tasks and the exposure regimes were counterbalanced. The results indicated that the exposure of the left side of the brain slows down the left-hand response time, in the second-later-part of the experiment. This effect was apparent in three of the four tasks, and was highly significant in only one of the tests. The exposure intensity and its duration exceeded the common exposure of cellular phone users.

**Ellingsrud S, Johnsson A, Perturbations of plant leaflet rhythms caused by electromagnetic radio-frequency radiation. Bioelectromagnetics 14(3):257-271, 1993.**

The minute-range up and down rhythms of the lateral leaflets of Desmodium gyrans

has been studied when exposed to electromagnetic radiation in the radio-frequency (RF) range. The RF radiation was applied as homogeneous 27.12 MHz fields in specially-designed exposure cells (and in some cases as non-homogeneous radiation of 27 MHz, amplitude modulated by 50 Hz, in front of commercial diathermy equipment). All fields were applied as pulses. We report effects in the leaflet rhythms such as temporary changes in the amplitude, period, and phase. The radiation could also cause temporary or complete cessations of the rhythms. The lowest dose (8 W/cm2) used was still effective.

**Elliott P, Toledano MB, Bennett J, Beale L, de Hoogh K, Best N, Briggs DJ. Mobile phone base stations and early childhood cancers: case-control study.BMJ. 340:c3077, 2010.**

**OBJECTIVE:** To investigate the risk of early childhood cancers associated with the mother's exposure to radiofrequency from and proximity to macrocell mobile phone base stations(masts) during pregnancy. **DESIGN:** Case-control study. **SETTING:** Cancer registry and national birth register data in Great Britain. **PARTICIPANTS:** 1397 cases of cancer in children aged 0-4 from national cancer registry 1999-2001 and 5588 birth controls from national birth register, individually matched by sex and date of birth (four controls per case). **MAIN OUTCOME MEASURES:** Incidence of cancers of the brain and central nervous system, leukaemia, and non-Hodgkin's lymphomas, and all cancers combined, adjusted for small area measures of education level, socioeconomic deprivation, population density, and population mixing. **RESULTS:** Mean distance of registered address at birth from a macrocell base station, based on a national database of 76,890 base station antennas in 1996-2001, was similar for cases and controls (1107 (SD 1131) m v 1073 (SD 1130) m, P=0.31), as was total power output of base stations within 700 m of the address (2.89 (SD 5.9) kW v 3.00 (SD 6.0) kW, P=0.54) and modelled power density (-30.3 (SD 21.7) dBm v -29.7 (SD 21.5) dBm, P=0.41). For modelled power density at the address at birth, compared with the lowest exposure category the adjusted odds ratios were 1.01 (95% confidence interval 0.87 to 1.18) in the intermediate and 1.02 (0.88 to 1.20) in the highest exposure category for all cancers (P=0.79 for trend), 0.97 (0.69 to 1.37) and 0.76 (0.51 to 1.12), respectively, for brain and central nervous system cancers (P=0.33 for trend), and 1.16 (0.90 to 1.48) and 1.03 (0.79 to 1.34) for leukaemia and non-Hodgkin's lymphoma (P=0.51 for trend). **CONCLUSIONS:** There is no association between risk of early childhood cancers and estimates of the mother's exposure to mobile phone base stations during pregnancy.

**Eltiti S, Wallace D, Ridgewell A, Zougkou K, Russo R, Sepulveda F, Mirshekar-Syahkal D, Rasor P, Deeble R, Fox E. Does short-term exposure to mobile phone base station signals increase symptoms in individuals who report sensitivity to electromagnetic fields? A double-blind randomized provocation study. Environ Health Perspect. 115(11):1603-1608, 2007.**

BACKGROUND: Individuals with idiopathic environmental illness with attribution to electromagnetic fields (IEI-EMF) believe they suffer negative health effects when exposed to electromagnetic fields from everyday objects such as mobile phone base stations. OBJECTIVES: This study used both open provocation and double-blind tests to

determine if sensitive and control individuals experience more negative health effects when exposed to base station-like signals compared with sham. METHODS: Fifty-six self-reported sensitive and 120 control participants were tested in an open provocation test. Of these, 12 sensitive and 6 controls withdrew after the first session. The remainder completed a series of double-blind tests. Subjective measures of well-being and symptoms as well as physiological measures of blood volume pulse, heart rate, and skin conductance were obtained. RESULTS: During the open provocation, sensitive individuals reported lower levels of well-being in both the global system for mobile communication (GSM) and universal mobile telecommunications system (UMTS) compared with sham exposure, whereas controls reported more symptoms during the UMTS exposure. During double-blind tests the GSM signal did not have any effect on either group. Sensitive participants did report elevated levels of arousal during the UMTS condition, whereas the number or severity of symptoms experienced did not increase. Physiological measures did not differ across the three exposure conditions for either group. CONCLUSIONS: Short-term exposure to a typical GSM base station-like signal did not affect well-being or physiological functions in sensitive or control individuals. Sensitive individuals reported elevated levels of arousal when exposed to a UMTS signal. Further analysis, however, indicated that this difference was likely to be due to the effect of order of exposure rather than the exposure itself.

**Eltiti S, Wallace D, Ridgewell A, Zougkou K, Russo R, Sepulveda F, Fox E. Short-term exposure to mobile phone base station signals does not affect cognitive functioning or physiological measures in individuals who report sensitivity to electromagnetic fields and controls. Bioelectromagnetics.30(7):556-563, 2009.**

Individuals who report sensitivity to electromagnetic fields often report cognitive impairments that they believe are due to exposure to mobile phone technology. Previous research in this area has revealed mixed results, however, with the majority of research only testing control individuals. Two studies using control and self-reported sensitive participants found inconsistent effects of mobile phone base stations on cognitive functioning. The aim of the present study was to clarify whether short-term (50 min) exposure at 10 mW/m(2) to typical Global System for Mobile Communication (GSM) and Universal Mobile Telecommunications System (UMTS) base station signals affects attention, memory, and physiological endpoints in sensitive and control participants. Data from 44 sensitive and 44 matched-control participants who performed the digit symbol substitution task (DSST), digit span task (DS), and a mental arithmetic task (MA), while being exposed to GSM, UMTS, and sham signals under double-blind conditions were analyzed. Overall, cognitive functioning was not affected by short-term exposure to either GSM or UMTS signals in the current study. Nor did exposure affect the physiological measurements of blood volume pulse (BVP), heart rate (HR), and skin conductance (SC) that were taken while participants performed the cognitive tasks.

**Elwood JM. Microwaves in the cold war: the Moscow embassy study and its interpretation. Review of a retrospective cohort study.Environ Health. 11(1):85, 2012.**

BACKGROUND: From 1953 to 1976, beams of microwaves of 2.5 to 4.0 GHz were

aimed at the US embassy building in Moscow. An extensive study investigated the health of embassy staff and their families, comparing Moscow embassy staff with staff in other Eastern European US embassies. The resulting large report has never been published in peer reviewed literature.**METHODS:** The original report and other published comments or extracts from the report were reviewed.**RESULTS:** The extensive study reports on mortality and morbidity, recorded on medical records and by regular examinations, and on self-reported symptoms. Exposure levels were low, but similar or greater than present-day exposures to radiofrequencies sources such as cell phone base stations. The conclusions were that no adverse health effects of the radiation were shown. The study validity depends on the assumption that staff at the other embassies were not exposed to similar radiofrequencies. This has been questioned, and other interpretations of the data have been presented.**CONCLUSIONS:** The conclusions of the original report are supported. Contrary conclusions given in some other reports are due to misinterpretation of the results.

**Engelmann JC, Deeken R, Müller T, Nimtz G, Roelfsema MR, Hedrich R. Is gene activity in plant cells affected by UMTS-irradiation? A whole genome approach.Adv Appl Bioinform Chem. 1:71-83, 2008.**

Mobile phone technology makes use of radio frequency (RF) electromagnetic fields transmitted through a dense network of base stations in Europe. Possible harmful effects of RF fields on humans and animals are discussed, but their effect on plants has received little attention. In search for physiological processes of plant cells sensitive to RF fields, cell suspension cultures of Arabidopsis thaliana were exposed for 24 h to a RF field protocol representing typical microwave exposition in an urban environment. mRNA of exposed cultures and controls was used to hybridize Affymetrix-ATH1 whole genome microarrays. Differential expression analysis revealed significant changes in transcription of 10 genes, but they did not exceed a fold change of 2.5. Besides that 3 of them are dark-inducible, their functions do not point to any known responses of plants to environmental stimuli. The changes in transcription of these genes were compared with published microarray datasets and revealed a weak similarity of the microwave to light treatment experiments. Considering the large changes described in published experiments, it is questionable if the small alterations caused by a 24 h continuous microwave exposure would have any impact on the growth and reproduction of whole plants.

**English NJ, Mooney DA. Denaturation of hen egg white lysozyme in electromagnetic fields: A molecular dynamics study. J Chem Phys. 126(9):091105, 2007.**

Nonequilibrium molecular dynamics simulations of hen egg white lysozyme have been performed in the canonical ensemble at 298 K in the presence of external electromagnetic fields of varying intensity in the microwave to far-infrared frequency range. Significant nonthermal field effects were noted, such as marked changes in the protein's secondary structure which led to accelerated incipient local denaturation relative to zero-field conditions. This occurred primarily as a consequence of alignment of the protein's total dipole moment with the external field, although the

enhanced molecular mobility and dipolar alignment of water molecules is influential on sidechain motion in solvent-exposed regions. The applied field intensity was found to be highly influential on the extent of denaturation in the frequency range studied, and 0.25-0.5 V A(rms) (-1) fields were found to induce initial denaturation to a comparable extent to thermal denaturation in the 400 to 500 K range. In subsequent zero-field simulations following exposure to the e/m field, the extent of perturbation from the native fold and the degree of residual dipolar alignment were found to be influential on incipient folding.

**Enin LD, Akoev GN, Potekhina IL, Oleiner VD, [Effect of extremely high-frequency electromagnetic radiation on the function of skin sensory endings]. Patol Fiziol Eksp Ter Sep-Dec;(5-6):23-25, 1992.** [Article in Russian]

The specific features of skin receptor function on the sole of the hind limb of an albino rat were studied in an acute experiment. Impulse activity recorded from the solitary fibres of the tibial nerve showed that receptor units (RU) responded to mechanical stimulation of the skin. Irradiation of the skin surface by low-intensity millimeter band electromagnetic field (frequencies of 55.61 and 73 GHz) in the zone of the RU led to diminution of RU sensitivity to the mechanical stimulus. One half of the RU ceased to respond to the mechanical stimulation 25 minutes after irradiation. The other half continued responding to stimulation even after 35 minutes of irradiation, but the character of the RU response was significantly changed. A strict frequency-resonance dependence of the biological effects was revealed. It is concluded that electromagnetic radiation has a modulatory-inhibiting effect on the skin RU. The authors suggest a possible mechanism of realization of the effect of electromagnetic radiation of extremely high-frequencies and low power on the skin receptor function.

**Erdem Koç G, Kaplan S, Altun G, Gümüş H, Gülsüm Deniz Ö, Aydin I, Emin Onger M, Altunkaynak Z. Neuroprotective effects of melatonin and omega-3 on hippocampal cells prenatally exposed to 900 MHz electromagnetic fields. Int J Radiat Biol. 92(10):590-595, 2016.**

PURPOSE: Adverse effects on human health caused by electromagnetic fields (EMF) associated with the use of mobile phones, particularly among young people, are increasing all the time. The potential deleterious effects of EMF exposure resulting from mobile phones being used in close proximity to the brain require particular evaluation. However, only a limited number of studies have investigated the effects of prenatal exposure to EMF in the development of the pyramidal cells using melatonin (MEL) and omega-3 (ω-3). MATERIALS AND METHODS: We established seven groups of pregnant rats consisting of three animals each; control (CONT), SHAM, EMF, EMF + MEL, MEL, EMF + ω-3 and ω-3 alone. The rats in the EMF, EMF + MEL, EMF + ω-3 groups were exposed to 900 MHz EMF for 60 min/day in an exposure tube during the gestation period. The CONT, MEL and ω-3 group rats were not placed inside the exposure tube or exposed to EMF during the study period. After delivery, only spontaneously delivered male rat pups were selected for the establishment of further groups. Each group of offspring consisted of six animals. The optical fractionator technique was used to determine total pyramidal neuron numbers in the rat hippocampal region. RESULTS: The total number of pyramidal cells in the cornu ammonis (CA) in the

EMF group was significantly lower than in the CONT, SHAM, EMF + MEL, and EMF + ω-3 groups. No significant difference was observed between the EMF, MEL and ω-3 groups. No difference was also observed between any groups in terms of rats' body or brain weights. CONCLUSION: MEL and ω-3 can protect the cell against neuronal damage in the hippocampus induced by 900 MHz EMF. However, further studies are now needed to evaluate the chronic effects of 900 MHz EMF on the brain in the prenatal period.

**Erdreich LS, Van Kerkhove MD, Scrafford CG, Barraj L, McNeely M, Shum M, Sheppard AR, Kelsh M. Factors that influence the radiofrequency power output of GSM mobile phones. Radiat Res. 168(2):253-261, 2007.**

Epidemiological studies of mobile phone use and risk of brain cancer have relied on self-reported use, years as a subscriber, and billing records as exposure surrogates without addressing the level of radiofrequency (RF) power output. The objective of this study was to measure environmental, behavioral and engineering factors affecting the RF power output of GSM mobile phones during operation. We estimated the RF-field exposure of volunteer subjects who made mobile phone calls using software-modified phones (SMPs) that recorded output power settings. Subjects recruited from three geographic areas in the U.S. were instructed to log information (place, time, etc.) for each call made and received during a 5-day period. The largest factor affecting energy output was study area, followed by user movement and location (inside or outside), use of a hands-free device, and urbanicity, although the two latter factors accounted for trivial parts of overall variance. Although some highly statistically significant differences were identified, the effects on average energy output rate were usually less than 50% and were generally comparable to the standard deviation. These results provide information applicable to improving the precision of exposure metrics for epidemiological studies of GSM mobile phones and may have broader application for other mobile phone systems and geographic locations.

**Eris AH, Kiziltan HS, Meral I, Genc H, Trabzon M, Seyithanoglu H, Yagci B, Uysal O. Effect of Short-term 900 MHz low level electromagnetic radiation exposure on blood serotonin and glutamate levels. Bratisl Lek Listy. 116(2):101-103, 2015.**

BACKGROUND: Long term exposure to low level electromagnetic radiation (LLER) by using cellular phones causes serious health problems. METHODS: Ten male Wistar Albino rats were anesthetized 30 min before the LLER exposure, 0.5 ml blood was taken from the tail vein of rats in order to determine control values. Rats were grouped by three and placed on a plexi-glass flat. A fixed equivalent frequency emitter device was used. A sign to be an electromagnetic field 15.14 V/m (608 mW/m2) in strength in the head region with 100 kHz FM modulation at 900 MHz was applied to the animals. After calculating the ideal position for the device, electromagnetic LLER energy was applied for 45 minutes from a distance to be equal with energy transmitted by a mobile phone from a 0.5-1 cm distance to their head regions. After 1.5 hours and before the rats awoke, 0.5 ml of blood was taken from the tail veins in order to determine the treatment values. RESULTS: Plasma 5-HT and glutamate levels were measured by enzyme immunoassay (EIA) using commercial kits. It was found that a single 45 min of LLER exposure increased the blood

5-HT level significantly, but did not change the glutamate level of rats. CONCLUSION: It was concluded that even a single 45 min of LLER exposure may produce an increase in 5-HT level without changing the blood glutamate level. Increased 5-HT level may lead to a retarded learning and a deficit in spatial memory (Tab. 2, Fig. 2, Ref. 24).

**Erkut A, Tumkaya L, Balik MS, Kalkan Y, Guvercin Y, Yilmaz A, Yuce S, Cure E, Sehitoglu I. The effect of prenatal exposure to 1800 MHz electromagnetic field on calcineurin and bone development in rats. Acta Cir Bras. 2016 Feb;31(2):74-83.**

PURPOSE: To investigate the effects of exposure to an 1800 MHz electromagnetic field (EMF) on bone development during the prenatal period in rats. METHODS: Pregnant rats in the experimental group were exposed to radiation for six, 12, and 24 hours daily for 20 days. No radiation was given to the pregnant rats in the control group. We distributed the newborn rats into four groups according to prenatal EMF exposure as follows: Group 1 was not exposed to EMF; groups 2, 3, and 4 were exposed to EMF for six, 12, and 24 hours a day, respectively. The rats were evaluated at the end of the 60th day following birth. RESULTS: Increasing the duration of EMF exposure during the prenatal period resulted in a significant reduction of resting cartilage levels and a significant increase in the number of apoptotic chondrocytes and myocytes. There was also a reduction in calcineurin activities in both bone and muscle tissues. We observed that the development of the femur, tibia, and ulna were negatively affected, especially with a daily EMF exposure of 24 hours. CONCLUSION: Bone and muscle tissue development was negatively affected due to prenatal exposure to 1800 MHz radiofrequency electromagnetic field.

**Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, Irkilata HC, Irmak MK, Peker AF. Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study. Arch Med Res. 37(7):840-843, 2006.**

BACKGROUND: There has been growing public concern on the effects of electromagnetic radiation (EMR) emitted by cellular phones on human health. Many studies have recently been published on this topic. However, possible consequences of the cellular phone usage on human sperm parameters have not been investigated adequately. METHODS: A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. The concentration and motility of the specimens were compared to analyze the effects of EMR. Assessment of sperm movement in all specimens was performed using four criteria: (A) rapid progressive, (B) slow progressive, (C) nonprogressive, (D) no motility. RESULTS: Statistically significant changes were observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR exposure caused a subtle decrease in the rapid progressive and slow progressive sperm movement. It also caused an increase in the no-motility category of sperm movement. There was no statistically significant difference in the sperm concentration between two groups. CONCLUSIONS: These

data suggest that EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.

**Ersan Odacı, Ayşe İkinci, Mehmet Yıldırım, Haydar Kaya, Metehan Akça, Hatice Hancı, Osman Fikret Sönmez, Ali Aslan, Mukadder Okuyan, Orhan Baş The Effects of 900 Megahertz Electromagnetic Field Applied in the Prenatal Period on Spinal Cord Morphology and Motor Behavior in Female Rat Pups. NeuroQuantology 11:573-581, 2013.**

This study investigated the effect of a 900 megahertz (MHz) electromagnetic field (EMF) applied in the prenatal period on the spinal cord and motor behavior of female rat pups. Beginning of the study, female Sprague Dawley rats (180–250 g) were left to mate with male rats. Rats identified as pregnant were then divided into control (n=3) and EMF groups (n=3). The EMF group was exposed to 1-h 900 MHz EMF daily between days 13 and 21 of pregnancy. At 21 days old, rat pups were removed from their mothers and divided into two newborn rat groups, control (n=13) and EMF (n=10). The rotarod test was applied to the rat pups to assess motor functions and the open field test to evaluate locomotor activity. On day 32 of the study, the rat pups were decapitated, and the spinal cord in the upper thoracic region was removed. Following routine histological tests, they were stained with Cresyl fast violet. Rotarod test results revealed a significant increase in EMF group rat pups' motor functions ($p=0.037$). However, no difference was observed in the open field test results ($p>0.05$). In the EMF group' rat pups, we observed pathological changes in the spinal cord. On the basis of our results, 900 MHz EMF applied in the prenatal period affected spinal cord development. This effect was observed in the form of pathological changes in the spinal cord of rat pups, and it may be that these pathological changes led to an increase in rat pups' motor activities.

**Esen F, Esen HEffect of electromagnetic fields emitted by cellular phones on the latency of evoked electrodermal activity. Int J Neurosci. 116(3):321-329, 2006.**

The widespread use of cellular phones raises the question of their possible adverse biological effects, especially on the central nervous system (CNS). Therefore, the authors examined the effect of electromagnetic fields emitted by cellular phones (CPEMFs) on the evoked neuronal activity of CNS relating to generation and representation of electrodermal activity (EDA), an index of sympathetic nervous system activity. EDA (skin resistance response; SRR) latency was lengthened approximately 200 ms with CPEMFs exposure irrespective of the head site next to mobile phone used. Hemispheric asymmetry of EDA-2 pathway, which is represented by shorter SRR latency in the right hand of the right hand responders, was also distorted with CPEMFs. Because the CNS regions including EDA-2 are also involved in tasks of motor timing and time estimation, delayed response in this neuronal network due to CPEMFs exposure may increase the response time of mobile phone users. Therefore, the findings point to the potential risks of mobile phones on the function of CNS and consequently, possible increase in the risk of phone-related driving hazards.

**Eser O, Songur A, Aktas C, Karavelioglu E, Caglar V, Aylak F, Ozguner F, Kanter M. The effect of electromagnetic radiation on the rat brain: an experimental study. Turk Neurosurg. 23(6):707-715, 2013.**

AIM: The aim of this study is to determine the structural changes of electromagnetic waves in the frontal cortex, brain stem and cerebellum. MATERIAL and METHODS: 24 Wistar Albino adult male rats were randomly divided into four groups: group I consisted of control rats, and groups II-IV comprised electromagnetically irradiated (EMR) with 900, 1800 and 2450 MHz. The heads of the rats were exposed to 900, 1800 and 2450 MHz microwaves irradiation for 1h per day for 2 months. RESULTS: While the histopathological changes in the frontal cortex and brain stem were normal in the control group, there were severe degenerative changes, shrunken cytoplasm and extensively dark pyknotic nuclei in the EMR groups. Biochemical analysis demonstrated that the Total Antioxidative Capacity level was significantly decreased in the EMR groups and also Total Oxidative Capacity and Oxidative Stress Index levels were significantly increased in the frontal cortex, brain stem and cerebellum. IL-1β level was significantly increased in the EMR groups in the brain stem. CONCLUSION: EMR causes to structural changes in the frontal cortex, brain stem and cerebellum and impair the oxidative stress and inflammatory cytokine system. This deterioration can cause to disease including loss of these areas function and cancer development.

**Eskander EF, Estefan SF, Abd-Rabou AA. How does long term exposure to base stations and mobile phones affect human hormone profiles? Clin Biochem. 45(1-2):157-161, 2012**

**OBJECTIVES:** This study is concerned with assessing the role of exposure to radio frequency radiation (RFR) emitted either from mobiles or base stations and its relations with human's hormone profiles. **DESIGN AND METHODS:** All volunteers' samples were collected for hormonal analysis. **RESULTS:** This study showed significant decrease in volunteers' ACTH, cortisol, thyroid hormones, prolactin for young females, and testosterone levels. **CONCLUSION:** The present study revealed that high RFR effects on pituitary-adrenal axis.

**Eşmekaya MA, Seyhan N, Omeroğlu S. Pulse modulated 900 MHz radiation induces hypothyroidism and apoptosis in thyroid cells: A light, electron microscopy and immunohistochemical study. Int J Radiat Biol. 86(12):1106-1116, 2010.**

Purpose: In the present study we investigated the possible histopathological effects of pulse modulated Radiofrequency (RF) fields on the thyroid gland using light microscopy, electron microscopy and immunohistochemical methods. Materials and methods: Two months old male Wistar rats were exposed to a 900 MHz pulse-modulated RF radiation at a specific absorption rate (SAR) of 1.35 Watt/kg for 20 min/day for three weeks. The RF signals were pulse modulated by rectangular pulses with a repetition frequency of 217 Hz and a duty cycle of 1:8 (pulse width 0.576 ms). To assess thyroid endocrine disruption and estimate the degree of the pathology of

the gland, we analysed structural alterations in follicular and colloidal diameters and areas, colloid content of the follicles, and height of the follicular epithelium. Apoptosis was confirmed by Transmission Electron Microscopy and assessing the activites of an initiator (caspase-9) and an effector (caspase-3) caspases that are important markers of cells undergoing apoptosis. Results: Morphological analyses revealed hypothyrophy of the gland in the 900 MHz RF exposure group. The results indicated that thyroid hormone secretion was inhibited by the RF radiation. In addition, we also observed formation of apoptotic bodies and increased caspase-3 and caspase-9 activities in thyroid cells of the rats that were exposed to modulated RF fields. Conclusion: The overall findings indicated that whole body exposure to pulse-modulated RF radiation that is similar to that emitted by global system for mobile communications (GSM) mobile phones can cause pathological changes in the thyroid gland by altering the gland structure and enhancing caspase-dependent pathways of apoptosis.

**Esmekaya MA, Aytekin E, Ozgur E, Güler G, Ergun MA, Omeroğlu S, Seyhan N. Mutagenic and morphologic impacts of 1.8GHz radiofrequency radiation on human peripheral blood lymphocytes (hPBLs) and possible protective role of pre-treatment with Ginkgo biloba (EGb 761). Sci Total Environ. 410-411:59-64, 2011.**

The mutagenic and morphologic effects of 1.8GHz Global System for Mobile Communications (GSM) modulated RF (radiofrequency) radiation alone and in combination with Ginkgo biloba (EGb 761) pre-treatment in human peripheral blood lymphocytes (hPBLs) were investigated in this study using Sister Chromatid Exchange (SCE) and electron microscopy. Cell viability was assessed with 3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide (MTT) reduction assay. The lymphocyte cultures were exposed to GSM modulated RF radiation at 1.8GHz for 6, 8, 24 and 48h with and without EGb 761. We observed morphological changes in pulse-modulated RF radiated lymphocytes. Longer exposure periods led to destruction of organelle and nucleus structures. Chromatin change and the loss of mitochondrial crista occurred in cells exposed to RF for 8h and 24h and were more pronounced in cells exposed for 48h. Cytoplasmic lysis and destruction of membrane integrity of cells and nuclei were also seen in 48h RF exposed cells. There was a significant increase ($p<0.05$) in SCE frequency in RF exposed lymphocytes compared to sham controls. EGb 761 pre-treatment significantly decreased SCE from RF radiation. RF radiation also inhibited cell viability in a time dependent manner. The inhibitory effects of RF radiation on the growth of lymphoctes were marked in longer exposure periods. EGb 761 pre-treatment significantly increased cell viability in RF+EGb 761 treated groups at 8 and 24h when compared to RF exposed groups alone. The results of our study showed that RF radiation affects cell morphology, increases SCE and inhibits cell proliferation. However, EGb 761 has a protective role against RF induced mutagenity. We concluded that RF radiation induces chromosomal damage in hPBLs but this damage may be reduced by EGb 761 pre-treatment.

**Esmekaya MA, Ozer C, Seyhan N. 900 MHz pulse-modulated radiofrequency radiation induces oxidative stress on heart, lung, testis and liver tissues. Gen Physiol Biophys. 30(1):84-89, 2011.**

Oxidative stress may affect many cellular and physiological processes including gene expression, cell growth, and cell death. In the recent study, we aimed to investigate whether 900 MHz pulse-modulated radiofrequency (RF) fields induce oxidative damage on lung, heart and liver tissues. We assessed oxidative damage by investigating lipid peroxidation (malondialdehyde, MDA), nitric oxide (NOx) and glutathione (GSH) levels which are the indicators of tissue toxicity. A total of 30 male Wistar albino rats were used in this study. Rats were divided randomly into three groups; control group (n = 10), sham group (device off, n = 10) and 900 MHz pulsed-modulated RF radiation group (n = 10). The RF rats were exposed to 900 MHz pulsed modulated RF radiation at a specific absorption rate (SAR) level of 1.20 W/kg 20 min/day for three weeks. MDA and NOx levels were increased significantly in liver, lung, testis and heart tissues of the exposed group compared to sham and control groups ($p < 0.05$). Conversely GSH levels were significantly lower in exposed rat tissues ($p < 0.05$). No significantly difference was observed between sham and control groups. Results of our study showed that pulse-modulated RF radiation causes oxidative injury in liver, lung, testis and heart tissues mediated by lipid peroxidation, increased level of NOx and suppression of antioxidant defense mechanism.

**Espinosa JM, Liberti M, Lagroye I, Veyret B. Exposure to AC and DC magnetic fields induces changes in 5-HT1B receptor binding parameters in rat brain membranes. Bioelectromagnetics. 27(5):414-422, 2006.**

The binding properties of the G-protein coupled receptor (GPCR) serotonin 5-HT1B receptor were studied under exposure to AC (50 and 400 Hz) and DC magnetic fields (MF) in rat brain membranes. This was an attempt at replicating the positive findings of Massot et al. In saturation experiments using [3H]5-HT, 1-h exposures at 1.1 mT(rms) 50 Hz caused statistically significant increases in both the K(D) and B(max) binding parameters, from 1.74 +/- 0.3 to 4.51 +/- 0.86 nM and from 1428 +/- 205 to 2137 +/- 399 CPM, respectively, in good agreement with previous results. Exposure of the membranes at 400 Hz 0.675 mT(rms) did not elicit a larger increase in K(D) in spite of a much larger induced current density. DC fields (1.1 and 11 mT) had a lesser effect compared to AC fields at low values of K(Dsham), but decreased the affinity at higher values of K(Dsham). Modeling of the receptor-ligand-G protein interactions using the extended ternary complex model yielded good fits for all our data and that of Massot et al., showing that the AC field may act by decreasing the ability of the G-protein to alter the ligand-receptor affinity. The hypothesis is that the bipolar nature of the AC field explains the different nature of the effects observed with AC and DC exposures. These findings constitute one of the few documented pieces of evidence for cell-free effects of DC and extremely low frequency (ELF) AC MFs in the mT range.

**Estenberg J, Augustsson T. Extensive frequency selective measurements of radiofrequency fields in outdoor environments performed with a novel mobile monitoring system. Bioelectromagnetics. 2013 Dec 27. doi: 10.1002/bem.21830. [Epub ahead of print]**

A novel, car based, measuring system for estimation of general public outdoor exposure to radiofrequency fields (RF) has been developed. The system enables fast, large area, isotropic spectral measurements with a bandwidth covering the frequency range of 30 MHz to 3 GHz. Measurements have shown that complete mapping of a town with 15000 inhabitants and a path length of 115 km is possible to perform within 1 day. The measured areas were chosen to represent typical rural, urban and city areas of Sweden. The data sets consist of more than 70000 measurements. All measurements were performed during the daytime. The median power density was 16 μW/$m^2$ in rural areas, 270 μW/$m^2$ in urban areas, and 2400 μW/$m^2$ in city areas. In urban and city areas, base stations for mobile phones were clearly the dominating sources of exposure.

**Eulitz, C, Ullsperger, P, Freude, G, Elbert ,T, Mobile phones modulate response patterns of human brain activity. Neuroreport 9(14):3229-3232, 1998.**

Mobile phones emit a pulsed high-frequency electromagnetic field (PEMF) which may penetrate the scalp and the skull. Increasingly, there is an interest in the interaction of this pulsed microwave radiation with the human brain. Our investigations show that these electromagnetic fields alter distinct aspects of the brain's electrical response to acoustic stimuli. More precisely, our results demonstrate that aspects of the induced but not the evoked brain activity during PEMF exposure can be different from those not influenced by PEMF radiation. This effect appears in higher frequency bands when subjects process task-relevant target stimuli but was not present for irrelevant standard stimuli. As the induced brain activity in higher frequency bands has been proposed to be a correlate of coherent high-frequency neuronal activity, PEMF exposure may provide means to systematically alter the pattern fluctuations in neural mass activity.

**Exelmans L, Van den Bulck J. Bedtime mobile phone use and sleep in adults. Soc Sci Med. 148:93-101, 2015.**

BACKGROUND: The few studies that have investigated the relationship between mobile phone use and sleep have mainly been conducted among children and adolescents. In adults, very little is known about mobile phone usage in bed our after lights out. This cross-sectional study set out to examine the association between bedtime mobile phone use and sleep among adults. METHODS: A sample of 844 Flemish adults (18-94 years old) participated in a survey about electronic media use and sleep habits. Self-reported sleep quality, daytime fatigue and insomnia were measured using the Pittsburgh Sleep Quality Index (PSQI), the Fatigue Assessment Scale (FAS) and the Bergen Insomnia Scale (BIS), respectively. Data were analyzed using hierarchical and multinomial regression analyses. RESULTS: Half of the respondents owned a smartphone, and six out of ten took their mobile phone with them to the bedroom. Sending/receiving text messages and/or phone calls after lights out significantly predicted respondents' scores

on the PSQI, particularly longer sleep latency, worse sleep efficiency, more sleep disturbance and more daytime dysfunction. Bedtime mobile phone use predicted respondents' later self-reported rise time, higher insomnia score and increased fatigue. Age significantly moderated the relationship between bedtime mobile phone use and fatigue, rise time, and sleep duration. An increase in bedtime mobile phone use was associated with more fatigue and later rise times among younger respondents (≤ 41.5 years old and ≤ 40.8 years old respectively); but it was related to an earlier rise time and shorter sleep duration among older respondents (≥ 60.15 years old and ≥ 66.4 years old respectively). CONCLUSION: Findings suggest that bedtime mobile phone use is negatively related to sleep outcomes in adults, too. It warrants continued scholarly attention as the functionalities of mobile phones evolve rapidly and exponentially.

**Fabbro-Peray P, Daures JP, Rossi JF. Environmental risk factors for non-Hodgkin's lymphoma: a population-based case-control study in Languedoc-Roussillon, France. Cancer Causes Control 12(3):201-212, 2001.**

OBJECTIVE: To investigate the occupational and environmental risk factors related to non-Hodgkin's lymphoma (NHL). METHODS: A case-control study was performed during the 1992-1996 period in Languedoc-Roussillon, southern France. Four hundred and forty-five cases of histologically diagnosed NHL were declared. One thousand and twenty-five randomly selected population controls were interviewed about their medical histories; occupational exposures, such as chemicals, pesticides, and electromagnetic radiation; and toxic habits. RESULTS: The following factors were independently and significantly related to NHL as a result of the multivariate analysis: a previous hematopoietic malignancy (ORa = 11.5, 95% CI 2.4-55.4), a history of hives (ORa = 1.7, 95% CI 1.2-2.2), benzene exposure > 810 days (ORa = 4.6, 95% CI 1.1-19.2), daily welding (ORa = 2.5, 95% CI 1.2-5.0), and activity of radio operator (ORa = 3.1, 95% CI 1.4-6.6). To be an agricultural professional seemed slightly related to NHL in reference to non-professionals (ORa = 1.5, 95% CI 1.0-2.1). All of these results have also been adjusted for age, gender, education level, and urban setting. CONCLUSIONS: As some of the reported associations were based on a very small proportion of exposed subjects, further investigations are necessary to confirm our results. However, the findings suggest that factors related to altered immune functions such as a history of hematopoietic malignancy, history of hives, occupational exposure to benzene, or being an agricultural professional might increase the risk of NHL. Currently, underlying mechanisms for these associations are still unclear, and further investigations focused on interactions between immunity alterations and different chemicals would be of great interest.

**Falzone N, Huyser C, Fourie F, Toivo T, Leszczynski D, Franken D. In vitro effect of pulsed 900 MHz GSM radiation on mitochondrial membrane potential and motility of human spermatozoa. Bioelectromagnetics.29(4):268-276, 2008.**

Ejaculated, density purified, human spermatozoa were exposed to pulsed 900 MHz GSM mobile phone radiation at two specific absorption rate levels (SAR 2.0 and 5.7 W/kg) and compared with controls over time. Change in sperm mitochondrial membrane potential was analysed using flow cytometry. Sperm motility was determined by computer assisted sperm analysis (CASA). There was no effect of

pulsed 900 MHz GSM radiation on mitochondrial membrane potential. This was also the case for all kinematic parameters assessed at a SAR of 2.0 W/kg. However, over time, the two kinematic parameters straight line velocity (VSL) and beat-cross frequency (BCF) were significantly impaired ($P < 0.05$) after the exposure at SAR 5.7 W/kg and no exposure by time interaction was present. This result should not be ascribed to thermal effects, due to the cooling methods employed in the RF chamber and temperature control within the incubator.

**Falzone N, Huyser C, Becker P, Leszczynski D, Franken DR. The effect of pulsed 900-MHz GSM mobile phone radiation on the acrosome reaction, head morphometry and zona binding of human spermatozoa. Int J Androl. 34(1):20-26, 2011.**

Summary Several recent studies have indicated that radiofrequency electromagnetic fields (RF-EMF) have an adverse effect on human sperm quality, which could translate into an effect on fertilization potential. This study evaluated the effect of RF-EMF on sperm-specific characteristics to assess the fertilizing competence of sperm. Highly motile human spermatozoa were exposed for 1 h to 900-MHz mobile phone radiation at a specific absorption rate of 2.0 W/kg and examined at various times after exposure. The acrosome reaction was evaluated using flow cytometry. The radiation did not affect sperm propensity for the acrosome reaction. Morphometric parameters were assessed using computer-assisted sperm analysis. Significant reduction in sperm head area (9.2 +/- 0.7 mum(2) vs. 18.8 +/- 1.4 mum(2)) and acrosome percentage of the head area (21.5 +/- 4% vs. 35.5 +/- 11.4%) was reported among exposed sperm compared with unexposed controls. Sperm-zona binding was assessed directly after exposure using the hemizona assay. The mean number of zona-bound sperm of the test hemizona and controls was 22.8 +/- 12.4 and 31.8 +/- 12.8 ($p < 0.05$), respectively. This study concludes that although RF-EMF exposure did not adversely affect the acrosome reaction, it had a significant effect on sperm morphometry. In addition, a significant decrease in sperm binding to the hemizona was observed. These results could indicate a significant effect of RF-EMF on sperm fertilization potential.

**Falzone N, Huyser C, Franken DR, Leszczynski D. Mobile phone radiation does not induce pro-apoptosis effects in human spermatozoa. Radiat Res. 174(2):169-176, 2010.**

Abstract Recent reports suggest that mobile phone radiation may diminish male fertility. However, the effects of this radiation on human spermatozoa are largely unknown. The present study examined effects of the radiation on induction of apoptosis-related properties in human spermatozoa. Ejaculated, density-purified, highly motile human spermatozoa were exposed to mobile phone radiation at specific absorption rates (SARs) of 2.0 and 5.7 W/kg. At various times after exposure, flow cytometry was used to examine caspase 3 activity, externalization of phosphatidylserine (PS), induction of DNA strand breaks, and generation of reactive oxygen species. Mobile phone radiation had no statistically significant effect on any of the parameters studied. This suggests that the impairment of fertility reported in some studies was not caused by the induction of apoptosis in spermatozoa.

**Faraone, A., Luengas, W., Chebrolu, S., Ballen, M., Bit-Babik, G., Gessner, A. V., Kanda, M. Y., Babij, T., Swicord, M. L. and Chou, C-K. Radiofrequency dosimetry for the ferris-wheel mouse exposure system. Radiat. Res. 165, 105-112, 2006.**

Numerical and experimental methods were employed to assess the individual and collective dosimetry of mice used in a bioassay on the exposure to pulsed radiofrequency energy at 900 MHz in the Ferris-wheel exposure system (Utteridge et al., Radiat. Res. 158, 357-364, 2002). Twin-well calorimetry was employed to measure the whole-body specific absorption rate (SAR) of mice for three body masses (23 g, 32 g and 36 g) to determine the lifetime exposure history of the mice used in the bioassay. Calorimetric measurements showed about 95% exposure efficiency and lifetime average whole-body SARs of 0.21, 0.86, 1.7 and 3.4 W kg(-1) for the four exposure groups. A larger statistical variation in SAR was observed in the smallest mice because they had the largest variation in posture inside the plastic restrainers. Infrared thermography provided SAR distributions over the sagittal plane of mouse cadavers. Thermograms typically showed SAR peaks in the abdomen, neck and head. The peak local SAR at these locations, determined by thermometric measurements, showed peak-to-average SAR ratios below 6:1, with typical values around 3:1. Results indicate that the Ferris wheel fulfills the requirement of providing a robust exposure setup, allowing uniform collective lifetime exposure of mice.

**Fasseas MK, Fragopoulou AF, Manta AK, Skouroliakou A, Vekrellis K, Margaritis LH, Syntichaki P. Response of Caenorhabditis elegans to wireless devices radiation exposure. Int J Radiat Biol. 91(3):286-293, 2015.**

Purpose: The aim of this study was to examine the impact of electromagnetic radiation, produced by GSM (Global System for Mobile communications) mobile phones, Wi-Fi (Wireless-Fidelity) routers and wireless DECT (Digital Enhanced Cordless Telecommunications) phones, on the nematode C. elegans. Materials and methods: We exposed synchronized populations, of different developmental stages, to these wireless devices at E-field levels below ICNIRP's (International Commission on Non-Ionizing Radiation Protection) guidelines for various lengths of time. WT (wild-type) and aging- or stress-sensitive mutant worms were examined for changes in growth, fertility, lifespan, chemotaxis, short-term memory, increased ROS (Reactive Oxygen Species) production and apoptosis by using fluorescent marker genes or qRT-PCR (quantitative Reverse Transcription-Polymerase Chain Reaction). Results: No statistically significant differences were found between the exposed and the sham/control animals in any of the experiments concerning lifespan, fertility, growth, memory, ROS, apoptosis or gene expression. Conclusions: The worm appears to be robust to this form of (pulsed) radiation, at least under the exposure conditions used.

**Fatma M. Ghoneim, Eetmad A. Arafat. Histological and histochemical study of the protective role of rosemary extract against harmful effect of cell phone electromagnetic radiation on the parotid glands. Acta Histochemica, Available online 4 May 2016.**

Electromagnetic fields (EMFs) are a class of non-ionizing radiation (NIR) that is emitted

from mobile phone. It may have hazardous effects on parotid glands. So, we aimed to investigate the histological and histochemical changes of the parotid glands of rats exposed to mobile phone and study the possible protective role of rosemary against its harmful effect. Forty adult male albino rats were used in this study. They were classified into 4 equal groups. Group I (control), group II (control receiving rosemary), group III (mobile phone exposed group) and group IV (mobile exposed, rosemary treated group). Parotid glands were dissected out for histological and histochemical study. Moreover, measurement of oxidative stress markers; malondialdehyde (MDA) and total antioxidant capacity (TAC) was done. The results of this study revealed that rosemary has protective effect through improving the histological and histochemical picture of the parotid gland in addition of its antioxidant effect. It could be concluded from the current study, that exposure of parotid gland of rat models to electromagnetic radiation of mobile phone resulted in structural changes at the level of light and electron microscopic examination which could be explained by oxidative stress effect of mobile phone. Rosemary could play a protective role against this harmful effect through its antioxidant activity.

**Fattahi-Asl J, Baradaran-Ghahfarokhi M, Karbalae M, Baradaran-Ghahfarokhi M, Baradaran-Ghahfarokhi HR. Effects of radiofrequency radiation on human ferritin: an in vitro enzymun assay. J Med Signals Sens. 2(4):235-340, 2012.**

Ferritin is a macromolecule and is responsible for the long term iron storage function in human serum and plasma. Recent studies have highlighted the role of cell phone exposure on central nervous system, immune function and reproduction. The aim of this study was to investigate whether the human serum ferritin level could be interfered by the exposure to the 900 MHz GSM cell phones. Fifty human serum wells from 25 normal healthy donors were labeled with ruthenium to form a sandwich complex based on an immunoassay technique. All of them were placed into two batches, and the well heads in the first batch were exposed to 900 MHz exposure emitted from a speech mode cell phone (Nokia, Model 1202, India) for 30 min. Unexposed batch was served as the control sample under identical conditions and was compared with the exposed one in quantitative determination of ferritin using the Wilcoxon test with criterion level of P = 0.050. Human serum wells in the exposed batch showed a significant decrease in serum ferritin relative to the control batch (P = 0.029). The average ± SD ferritin level in the exposed batch was 84.94 ± 1.04 μg/L while it was 87.25 ± 0.83 μg/L for the unexposed batch. Radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress and rapid diffusion of the human ferritin level in an in vitro enzymun assay. Also, the enzyme activity can be affected. Effects of exposure from mobile phones must be considered further.

**Faucon G, Le Bouquin Jeannes R, Maby E. Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram. Conf Proc IEEE Eng Med Biol Soc. 1(1):3751-3754, 2006.**

The aim of the study was to investigate whether the GSM (global system for mobile) signals affect the electrical activity of the human brain. Nine healthy subjects and six temporal epileptic patients were exposed to radiofrequencies emitted by a GSM

mobile phone signals. Electroencephalographic (EEG) signals were recorded using surface electrodes with and without radiofrequency. In order to obtain a reference, a control session was also carried out. The spectral attributes of the EEG signals recorded by surface electrodes were analyzed. The significant decrease of spectral correlation coefficients under radiofrequency influence showed that the GSM signal altered the spectral arrangement of the EEG activity for healthy subjects as well as epileptic patients. For the healthy subjects, the EEG spectral energy decreased on the studied frequency band [0-40 Hz] and more precisely on occipital electrodes for the alpha-band. For the epileptic patients, these modifications were demonstrated by an increase of the power spectral density of the EEG signal. Nevertheless, these biological effects on the EEG are not sufficient to put forward some electrophysiological hypothesis.

**Favre D. Mobile phone-induced honeybee worker piping Apidologie 42:270–279, 2011.**

The worldwide maintenance of the honeybee has major ecological, economic, and political implications. In the present study, electromagnetic waves originating from mobile phones were tested for potential effects on honeybee behavior. Mobile phone handsets were placed in the close vicinity of honeybees. The sound made by the bees was recorded and analyzed. The audiograms and spectrograms revealed that active mobile phone handsets have a dramatic impact on the behavior of the bees, namely by inducing the worker piping signal. In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony.

**Fayos-Fernandez J, Arranz-Faz C, Martinez-Gonzalez AM, Sanchez-Hernandez D. Effect of pierced metallic objects on sar distributions at 900 MHz. Bioelectromagnetics. 27(5):337-353, 2006.**

. A study of the interaction between mobile phone antennas and a human head in the presence of different types of metallic objects, attached and pierced to the compressed ear, is presented in this article. Computed and measured results have been performed by considering a quasi-half-wavelength dipole as the radiating source and measurements with the DASY4 dosimetric assessment system. Two different human head models have been implemented: a homogeneously shaped sphere and a three-level head model with four different kinds of tissue. Antenna input impedance, reflection coefficient, radiation patterns, SAR distribution, absorbed power, and peak SAR values have been computed and measured for diverse scenarios, electromagnetic simulators, and organs. Despite the measuring accuracy limitations of the study, both simulated and measured results suggest that special attention has to be paid to peak SAR averaged values when wearing metallic objects close to the radiation source, since some increment of peak SAR averaged values is expected.

**Fejes I, Za Vaczki Z, Szollosi J, Kolosza R S, Daru J, Kova Cs L, Pa L AIs there a relationship between cell phone use and semen quality? Arch Androl. 51(5):385-393, 2005.**

This study was conducted to determine a possible relationship between regular cell

phone use and different human semen attributes. The history-taking of men in our university clinic was supplemented with questions concerning cell phone use habits, including possession, daily standby position and daily transmission times. Semen analyses were performed by conventional methods. Statistics were calculated with SPSS statistical software. A total of 371 were included in the study. The duration of possession and the daily transmission time correlated negatively with the proportion of rapid progressive motile sperm (r = - 0.12 and r = - 0.19, respectively), and positively with the proportion of slow progressive motile sperm (r = 0.12 and r = 0.28, respectively). The low and high transmitter groups also differed in the proportion of rapid progressive motile sperm (48.7% vs. 40.6%). The prolonged use of cell phones may have negative effects on the sperm motility characteristics.

**Ferreira AR, Knakievicz T, de Bittencourt Pasquali MA, Gelain DP, Dal-Pizzol F, Fernandez CE, de Almeida de Salles AA, Ferreira HB, Moreira JC. Ultra high frequency-electromagnetic field irradiation during pregnancy leads to an increase in erythrocytes micronuclei incidence in rat offspring. Life Sci. 80(1)43-50, 2006.**

Mobile telephones and their base stations are an important ultra high frequency-electromagnetic field (UHF-EMF) source and their utilization is increasing all over the world. Epidemiological studies suggested that low energy UHF-EMF emitted from a cellular telephone may cause biological effects, such as DNA damage and changes on oxidative metabolism. An in vivo mammalian cytogenetic test, the micronucleus (MN) assay, was used to investigate the occurrence of chromosomal damage in erythrocytes from rat offspring exposed to a non-thermal UHF-EMF from a cellular phone during their embryogenesis; the irradiated group showed a significant increase in MN occurrence. In order to investigate if UHF-EMF could also alter oxidative parameters in the peripheral blood and in the liver - an important hematopoietic tissue in rat embryos and newborns - we also measured the activity of antioxidant enzymes, quantified total sulfhydryl content, protein carbonyl groups, thiobarbituric acid-reactive species and total non-enzymatic antioxidant defense. No significant differences were found in any oxidative parameter of offspring blood and liver. The average number of pups in each litter has also not been significantly altered. Our results suggest that, under our experimental conditions, UHF-EMF is able to induce a genotoxic response in hematopoietic tissue during the embryogenesis through an unknown mechanism.

**Ferreri F, Curcio G, Pasqualetti P, De Gennaro L, Fini R, Rossini PM. Mobile phone emissions and human brain excitability. Ann Neurol.60(2):188-196, 2006.**

OBJECTIVE: To test-via Transcranial Magnetic Stimulation (TMS)-the excitability of each brain hemisphere after 'real' or 'sham' exposure to the electromagnetic field (EMF) generated by a mobile phone operating in the Global System for Mobile Communication (GSM). METHODS: Fifteen male volunteers attended two experimental sessions, one week apart, in a cross-over, double-blind paradigm. In one session the signal was turned ON (EMF-on, real exposure), in the other it was turned OFF (EMF-off, sham exposure), for 45 minutes. Motor Evoked Potentials (MEPs) were recorded using a paired-pulse paradigm (testing intracortical excitability with 1 to 17 ms interstimulus intervals), both before and at different times after exposure to the EMF. Short Intracortical Inhibition (SICI) and Facilitation (ICF) curves were evaluated both on the exposed and non-

exposed hemispheres. Tympanic temperature was collected during each session. RESULTS: The intracortical excitability curve becomes significantly modified during real exposure, with SICI being reduced and ICF enhanced in the acutely exposed brain hemisphere as compared to the contralateral, non-exposed hemisphere or to sham exposure. Tympanic temperature showed no significant main effect or interactions. INTERPRETATION: These results demonstrate that GSM-EMFs modify brain excitability. Possible implications and applications are discussed.

**Fesenko EE, Geletyuk VI, Kazachenko VN, Chemeris NK Preliminary microwave irradiation of water solutions changes their channel-modifying activity. FEBS Lett 366(1):49-52, 1995.**

Earlier we have shown that millimetre microwaves (42.25 GHz) of non-thermal power, upon direct admittance into an experiment bath, greatly influence activation characteristics of single Ca(2+)-dependent K+ channels (in particular, the channel open state probability, Po). Here we present new data showing that similar changes in Po arise due to the substitution of a control bath solution for a preliminary microwave irradiated one of the same composition (100 mmol/l KCl with Ca2+ added), with irradiation time being 20-30 min. Therefore, due to the exposure to the field the solution acquires some new properties that are important for the channel activity. The irradiation terminated, the solution retains a new state for at least 10-20 min (solution memory). The data suggest that the effects of the field on the channels are mediated, at least partially, by changes in the solution properties.

**Fesenko EE, Novoselova EG, Semiletova NV, Agafonova TA, Sadovnikov VB, [Stimulation of murine natural killer cells by weak electromagnetic waves in the centimeter range]. Biofizika 44(4):737-741, 1999.** [Article in Russian]

Irradiation with electromagnetic waves (8.15-18 GHz, 1 Hz within, 1 microW/cm2) in vivo increases the cytotoxic activity of natural killer cells of rat spleen. In mice exposed for 24-72 h, the activity of natural killer cells increased by 130-150%, the increased level of activity persisting within 24 h after the cessation of treatment. Microwave irradiation of animals in vivo for 3.5 and 5 h, and a short exposure of splenic cells in vitro did not affect the activity of natural killer cells.

**Fesenko, EE, Makar, VR, Novoselova, EG, Sadovnikov, VB, Microwaves and cellular immunity. I. Effect of whole body microwave irradiation on tumor necrosis factor production in mouse cells. Bioelectrochem Bioenerg 49(1):29-35, 1999**.

Whole body microwave sinusoidal irradiation of male NMRI mice with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm2 caused a significant enhancement of TNF production in peritoneal macrophages and splenic T lymphocytes. Microwave radiation affected T cells, facilitating their capacity to proliferate in response to mitogenic stimulation. The exposure duration necessary for the stimulation of cellular immunity ranged from 5 h to 3 days. Chronic irradiation of mice for 7 days produced the decreasing of TNF production in peritoneal macrophages. The exposure of mice for 24 h increased the TNF production and immune proliferative response, and these stimulatory effects persisted over 3 days after the termination of exposure. Microwave treatment increased the endogenously produced TNF more effectively than did lipopolysaccharide, one of the

most potential stimuli of synthesis of this cytokine. The role of microwaves as a factor interfering with the process of cell immunity is discussed.

**Fetter JG, Ivans V, Benditt DG, Collins J, Digital cellular telephone interaction with implantable cardioverter-defibrillators. J Am Coll Cardiol 31(3):623-628, 1998.**

OBJECTIVES: This study sought to determine, in vivo, whether electromagnetic interference (EMI), generated by North American Digital Communications (NADC)/Time Division Multiple Access-50-Hz (TDMA-50) mobile cellular digital telephone model AT&T 6650, disturbs normal implantable cardioverter-defibrillator (ICD) operation and to verify these observations in vitro by testing a selection of telephones representing worldwide systems. METHODS: The effects of cellular phone interference on the operation of various models of market-released ICDs from a single manufacturer, Medtronic, Inc., were tested. The in vivo clinical test was undertaken in 41 patients using the AT&T 6650 digital telephone with the NADC/TDMA-50 technology. The in vitro component of the study was examined twofold: 1) antenna generated far field; and 2) analog/digital cellular telephone near field. RESULTS: None of the ICDs tested in 41 patients were affected by oversensing of the EMI field of the cellular telephones during the in vivo study. Therefore, the binomial upper 95% confidence limit for the failure rate of 0% is 7%. The in vitro antenna-generated field testing showed that telephone modulation frequencies used in the international Global System Mobile and TDMA-50 cellular telephone technologies did not result in ICD sensing interference at the predicted electric field intensity. The in vitro near field tests were performed using both analog and digital cellular telephones in service, or in the test mode, and indicated no interaction with normal operation. However, the static magnetic field generated by the cellular telephone placed over the ICD at a distance < or = 0.5 cm will activate the internal reed switch, resulting in temporary suspension of ventricular tachycardia and fibrillation detection. CONCLUSIONS: We conclude that TDMA-50 cellular telephones did not interfere with these types of ICDs. However, we recommend that the patient not carry or place the digital cellular telephone within 15 cm (6 in.) of the ICD.

**Field AS, Ginsburg K, Lin JC The effect of pulsed microwaves on passive electrical properties and interspike intervals of snail neurons. Bioelectromagnetics 14(6):503-520, 1993.**

The effects of pulsed microwaves (2.45 GHz, 10 microseconds, 100 pps, SAR: 81.5 kW/kg peak, 81.5 W/kg average) on membrane input resistance and action potential (AP) interval statistics were studied in spontaneously active ganglion neurons of land snails (Helix aspersa), at strictly constant temperature (20.8 +/- .07 degrees C worst case). Statistical comparison with sham-irradiated neurons revealed a significant increase in the mean input resistance of neurons exposed to pulsed microwaves (P < or = .05). Pulsed microwaves had no visible effect on mean AP firing rate; this observation was confirmed by analysis of interspike intervals (ISIs). Using an integrator model for spontaneously active neurons, we found the net input current to be more variable in neurons exposed to pulsed microwaves. The mean input current was not affected. The standard deviation of ISIs and the autocorrelation of the input current were marginally affected, but these changes were not consistent across neurons. Although the observed effects were less obvious than those reported in other studies, they represent evidence of a direct interaction between neurons and pulsed microwaves, in the absence of macroscopic temperature changes. The data do not suggest a single, specific mechanism for such interaction.

**Findlay RP, Dimbylow PJ. SAR in a child voxel phantom from exposure to wireless computer networks (Wi-Fi). Phys Med Biol. 55(15):N405-411, 2010.**

Specific energy absorption rate (SAR) values have been calculated in a 10 year old sitting voxel model from exposure to electromagnetic fields at 2.4 and 5 GHz,

frequencies commonly used by Wi-Fi devices. Both plane-wave exposure of the model and irradiation from antennas in the near field were investigated for a variety of exposure conditions. In all situations studied, the SAR values calculated were considerably below basic restrictions. For a typical Wi-Fi exposure scenario using an inverted F antenna operating at 100 mW, a duty factor of 0.1 and an antenna-body separation of 34 cm, the maximum peak localized SAR was found to be 3.99 mW kg(-1) in the torso region. At 2.4 GHz, using a power of 100 mW and a duty factor of 1, the highest localized SAR value in the head was calculated as 5.7 mW kg(-1). This represents less than 1% of the SAR previously calculated in the head for a typical mobile phone exposure condition.

**Fink JM, Wagner JP, Congleton JJ, Rock JC, Microwave emission from police radar. Am Ind Hyg Assoc J 60(6):770-76, 1999.**

This study evaluated police officers' exposures to microwaves emitted by traffic radar units. Exposure measurements were taken at approximated ocular and testicular levels of officers seated in patrol vehicles. Comparisons were made of the radar manufacturers' published maximum power density specifications and actual measured power densities taken at the antenna faces of those units. Four speed-enforcement agencies and one transportation research institute provided 54 radar units for evaluation; 17 different models, encompassing 4 frequency bands and 3 antenna configurations, were included. Four of the 986 measurements taken exceeded the 5 mW/cm2 limit accepted by the International Radiation Protection Association and the National Council on Radiation Protection and Measurement, though none exceeded the American Conference of Governmental Industrial Hygienists, American National Standards Institute, Institute of Electrical and Electronic Engineers, or Occupational Safety and Health Administration standard of 10 mW/cm2. The four high measurements were maximum power density readings taken directly in front of the radar. Of the 812 measurements taken at the officers' seated ocular and testicular positions, none exceeded 0.04 mW/cm2; the highest of these (0.034 mW/cm2) was less than 1% of the most conservative current safety standards. High exposures in the limited region directly in front of the radar aperture are easily avoided with proper training. Results of this study indicate that police officer exposure to microwave radiation is apparently minimal. However, because of uncertainty in the medical and scientific communities concerning nonionizing radiation, it is recommended that law enforcement agencies implement a policy of prudent avoidance, including purchasing units with the lowest published maximum power densities, purchasing dash/rear deck-mounted units with antennae mounted outside the patrol vehicle, and training police officers to use the "stand-by" mode when not actually using radar.

**Finnie JW, Blumbergs PC, Manavis J, Utteridge TD, Gebski V, Swift JG, Vernon-Roberts B, Kuchel TR. Effect of global system for mobile communication (gsm)-like radiofrequency fields on vascular permeability in mouse brain. Pathology 33(3):338-340, 2001.**

The effect of global system for mobile communication (GSM) radiofrequency fields on vascular permeability in the brain was studied using a purpose-designed exposure system at 898.4 MHz. Mice (n= 30) were given a single far field, whole body exposure for

60 minutes at a specific absorption rate of 4 W/kg. Control mice were also sham-exposed (n = 10) or permitted free movement in a cage (n = 10) to exclude any stress-related effects. Vascular permeability changes were detected using albumin immunohistochemistry and the efficacy of this vascular tracer was confirmed with a positive control group exposed to a clostridial toxin known to increase vascular permeability in the brain. No significant difference in albumin extravasation was detected between any of the groups at the light microscope level using the albumin marker.

**Finnie JW, Blumbergs PC, Manavis J, Utteridge TD, Gebski V, Davies RA, Vernon-Roberts B, Kuchel TR. Effect of long-term mobile communication microwave exposure on vascular permeability in mouse brain. Pathology 34(4):344-347, 2002.**

AIMS: To study the effect of long-term exposure to global system for mobile communication (GSM) radiofrequency fields on vascular permeability in murine brains. METHODS: Using a purpose-designed exposure system at 900 MHz, mice were given a 60-minute far-field, whole body exposure on each of 5 days perweekfor 104 weeks at specific absorption rates (SAR) of 0.25, 1.0,2.0 and 4.0 W/kg. Control mice were sham-exposed or permitted free movement in a cage to evaluate any stress-related effects. Albumin immunohistochemistry was used to detect increased vascular permeability and the efficacy of the vascular tracer was confirmed with a positive control group exposed to a clostridial toxin known to increase vascular permeability in the brain. RESULTS: In all exposed and control groups, albumin extravasation was minimal, often leptomeningeal, and was deemed insignificant as a maximum of three capillaries or venules in a given brain showed leakage from the very many blood vessels present in the three coronal brain sections. CONCLUSIONS: These results suggest that prolonged exposure to mobile telephone-type radiation produces negligible disruption to blood-brain barrier integrity at the light microscope level using endogenous albumin as a vascular tracer.

**Finnie JW. Expression of the immediate early gene, c-fos, in mouse brain after acute global system for mobile communication microwave exposure. Pathology. 37(3):231-233, 2005.**

AIMS: To study the effect of acute exposure to global system for mobile communication radiofrequency fields on immediate early gene, c-fos, expression in the brain. METHODS: Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field, whole body exposure for 60 minutes at a specific absorption rate of 4 W/kg. Control mice were sham-exposed or freely mobile in a cage without further restraint. c-fos protein expression was detected immunohistochemically in perfusion-fixed brains. RESULTS: Activation of c-fos in exposed and sham-exposed brains was comparable, but was greatly increased compared with freely moving controls. CONCLUSION: These results suggest that the majority of the acute genomic response detected by c-fos expression was due to immobilisation rather than irradiation.

**Finnie JW, Blumbergs PC, Cai Z, Manavis J, Kuchel TR. Effect of mobile telephony on blood-brain barrier permeability in the fetal mouse brain. Pathology. 38(1):63-65, 2006.**

AIMS: To study the effect of mobile telephone exposure on blood-brain barrier (BBB) permeability in the immature brain. METHODS: Using a purpose-designed exposure

system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint and a positive control group with cadmium-induced BBB damage was also included. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in Bouin's fixative and paraffin embedded. Disruption of BBB integrity was detected immunohistochemically using endogenous albumin as a vascular tracer in cerebral cortex, thalamus, basal ganglia, hippocampus, cerebellum, midbrain and medulla. RESULTS: No albumin extravasation was found in exposed or control brains. CONCLUSION: In this animal model, whole of gestation exposure to global system for mobile communication-like radiofrequency fields did not produce any increase in vascular permeability in the fetal brain regions studied using endogenous albumin as a light microscopic immunohistochemical marker.

**Finnie JW, Cai Z, Blumbergs PC, Manavis J, Kuchel TR. Expression of the immediate early gene, c-fos, in fetal brain after whole of gestation exposure of pregnant mice to global system for mobile communication microwaves. Pathology. 38(4):333-335, 2006.**

Aims: To study immediate early gene, c-fos, expression as a marker of neural stress after whole of gestation exposure of the fetal mouse brain to mobile telephone-type radiofrequency fields.Methods: Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Pregnant control mice were sham-exposed or freely mobile in a cage without further restraint. Immediately prior to parturition on gestational day 19, fetal heads were collected, fixed in 4% paraformaldehyde and paraffin embedded. Any stress response in the brain was detected by c-fos immunohistochemistry in the cerebral cortex, basal ganglia, thalamus, hippocampus, midbrain, cerebellum and medulla.Results: c-fos expression was of limited, but consistent, neuroanatomical distribution and there was no difference in immunoreactivity between exposed and control brains. Conclusion: In this animal model, no stress response was detected in the fetal brain using c-fos immunohistochemistry after whole of gestation exposure to mobile telephony.

**Finnie JW, Chidlow G, Blumbergs PC, Manavis J, Cai Z.. Heat shock protein induction in fetal mouse brain as a measure of stress after whole of gestation exposure to mobile telephony radiofrequency fields.Pathology. 41(3):276-279, 2009.**

Aim: To determine whether whole of gestation exposure of fetal mouse brain to mobile telephone radiofrequency fields produces a stress response detectable by induction of heat shock proteins (HSPs). Methods: Using a purpose-designed exposure system at 900 MHz, pregnant mice were given a single, far-field, whole body exposure at a specific absorption rate of 4 W/kg for 60 min/day from day 1 to day 19 of gestation. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. Immediately prior to parturition on day 19, fetal brains were collected, fixed in 4% paraformaldehyde and paraffin-embedded. Three coronal sections encompassing a wide range of anatomical regions were cut from each brain and

any stress response detected by immunostaining for HSP25, 32 and 70. Results: There was no induction of HSP32 or 70 in any brains, while HSP25 expression was limited to two brainstem nuclei and occurred consistently in exposed and non-exposed brains. Conclusion: Whole of gestation exposure of fetal mouse brains to mobile phone radiofrequency fields did not produce any stress response using HSPs as an immunohistochemical marker.

**Finnie JW, Blumbergs PC, Cai Z, Manavis J. Expression of the water channel protein, aquaporin-4, in mouse brains exposed to mobile telephone radiofrequency fields. Pathology. 41(5):473-475, 2009.**

Aim: To determine whether exposure to mobile telephone radiofrequency (RF) fields, either acutely or long-term, produces up-regulation of the water channel protein, aquaporin-4 (AQP-4). Methods: Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate of 4 W/kg for 60 minutes or a similar exposure on 5 successive days/week for 104 weeks. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. A positive control group was given a clostridial toxin known to cause microvascular endothelial injury, severe vasogenic oedema and upregulation of AQP-4. Brains were perfusion fixed with 4% paraformaldehyde, coronal sections cut from six levels, and immunostained for the principal water channel protein in brain, AQP-4. Results: There was no increase in AQP-4 expression in brains exposed to mobile phone microwaves compared to control (sham exposed and freely moving caged mice) brains after short or protracted exposure, while AQP-4 was substantially upregulated in the brains of mice given the clostridial toxin. Conclusion: Brains exposed to mobile telephone RF fields for a short (60 minutes) or long (2 years) duration did not show any immunohistochemically detectable up-regulation of the water channel protein, AQP-4, suggesting that there was no significant increase in blood-brain barrier permeability.

**Finnie JW, Blumbergs PC, Cai Z, Manavis J. Expression of the water channel protein, aquaporin-4, in mouse brains exposed to mobile telephone radiofrequency fields. Pathology. 41(5):473-475, 2009**

AIM: To determine whether exposure to mobile telephone radiofrequency (RF) fields, either acutely or long-term, produces up-regulation of the water channel protein, aquaporin-4 (AQP-4). METHODS: Using a purpose-designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate of 4 W/kg for 60 minutes or a similar exposure on 5 successive days/week for 104 weeks. Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by restraint in the exposure module. A positive control group was given a clostridial toxin known to cause microvascular endothelial injury, severe vasogenic oedema and upregulation of AQP-4. Brains were perfusion fixed with 4% paraformaldehyde, coronal sections cut from six levels, and immunostained for the principal water channel protein in brain, AQP-4. RESULTS: There was no increase in AQP-4 expression in brains exposed to mobile phone microwaves compared to control (sham exposed and freely moving caged mice) brains after short or protracted exposure, while AQP-4 was substantially upregulated

in the brains of mice given the clostridial toxin. CONCLUSION: Brains exposed to mobile telephone RF fields for a short (60 minutes) or long (2 years) duration did not show any immunohistochemically detectable up-regulation of the water channel protein, AQP-4, suggesting that there was no significant increase in blood-brain barrier permeability

**Finnie JW, Cai Z, Manavis J, Helps S, Blumbergs PC. Microglial activation as a measure of stress in mouse brains exposed acutely (60 minutes) and long-term (2 years) to mobile telephone radiofrequency fields. Pathology. 42(2):151-154, 2010.**

AIM: To determine whether acute or long-term exposure of the brain to mobile telephone radiofrequency (RF) fields produces activation of microglia, which normally respond rapidly to any change in their microenvironment. METHODS: Using a purpose designed exposure system at 900 MHz, mice were given a single, far-field whole body exposure at a specific absorption rate (SAR) of 4 W/kg for 60 min (acute) or on five successive days per week for 104 weeks (long-term). Control mice were sham-exposed or freely mobile in a cage to control for any stress caused by immobilisation in the exposure module. Positive control brains subjected to a stab wound were also included to confirm the ability of microglia to react to any neural stress. Brains were perfusion-fixed with 4% paraformaldehyde and representative regions of the cerebral cortex and hippocampus immunostained for ionised calcium binding adaptor molecule (Iba1), a specific microglial marker. RESULTS: There was no increase in microglial Iba1 expression in brains short or long-term exposed to mobile telephony microwaves compared to control (sham-exposed or freely moving caged mice) brains, while substantial microglial activation occurred in damaged positive control neural tissue. CONCLUSION: Acute (60 minutes) or longer duration (2 years) exposure of murine brains to mobile telephone RF fields did not produce any microglial activation detectable by Iba1 immunostaining.

**Fisun OI,  2D plasmon excitation and nonthermal effects of microwaves on biological membranes. Bioelectromagnetics 14(1):57-66, 1993.**

There are several experimental reports that have demonstrated a remarkable increase in conduction of ions along the interface between water and a polar-lipid monolayer as contrasted with that in a bulk-water phase. A simple model was developed for the collective ionic modes of a charged spherical membrane that takes the increase into account. Starting from the hydrodynamic equations for surface ions inside and outside a cell, the dispersion relation for intrinsic cellular electrical oscillations was obtained. Properties were calculated for surface-plasmon modes as well as for a resonant response of a charged membrane bilayer to microwave pumping.

**Forgacs Z, Somosy Z, Kubinyi G, Bakos J, Hudak A, Surjan A, Thuroczy G. Effect of whole-body 1800MHz GSM-like microwave exposure on testicular steroidogenesis and histology in mice. Reprod Toxicol.22(1):111-117, 2006.**

The aim of our study was to evaluate the possible effects of whole-body 1800MHz GSM-like microwave exposure on male reproduction. After repeated exposure of mice to microwaves at 0.018-0.023W/kg whole-body specific energy absorption rate (SAR) an

elevated serum testosterone level was measured, but no microwave exposure related histopathological alteration could be detected in the reproductive organs. The in vitro steroidogenic response of 48h Leydig cell cultures obtained from exposed animals did not differ from the controls, suggesting that Leydig cells were not the primary targets of the applied microwave exposure or direct action of microwaves on Leydig cells was temporary only. In exposed animals the red blood cell count and volume of packed red cells were also increased. Further investigations are required to clarify the mechanism of action of the applied microwave exposure on male mice, as well as to establish the biological significance of the observed phenomena.

**Fornes-Leal A, Garcia-Pardo C, Frasson M, Pons Beltrán V, Cardona N. Dielectric characterization of healthy and malignant colon tissues in the 0.5-18 GHz frequency band. Phys Med Biol.61(20):7334-7346, 2016.**

Several reports over the last few decades have shown that the dielectric properties of healthy and malignant tissues of the same body organ usually show different values. However, no intensive dielectric studies of human colon tissue have been performed, despite colon cancer's being one of the most common types of cancer in the world. In order to provide information regarding this matter, a dielectric characterization of healthy and malignant colon tissues is presented. Measurements are performed on ex vivo surgery samples obtained from 20 patients, using an open-ended coaxial probe in the 0.5-18 GHz frequency band. Results show that the dielectric constant of colon cancerous tissue is 8.8% higher than that of healthy tissues ($p = 0.002$). Besides, conductivity is about 10.6% higher, but in this case measurements do not have statistical significance ($p = 0.038$). Performing an analysis per patient, the differences in dielectric constant between healthy and malignant tissues appear systematically. Particularized results for specific frequencies (500 MHz, 900 MHz, 2.45 GHz, 5 GHz, 8.5 GHz and 15 GHz) are also reported. The findings have potential application in early-stage cancer detection and diagnosis, and can be useful in developing new tools for hyperthermia treatments as well as creating electromagnetic models of healthy and cancerous tissues.

**Fragopoulou AF**, **Koussoulakos SL**, **Margaritis LH**. **Cranial and postcranial skeletal variations induced in mouse embryos by mobile phone radiation. Pathophysiology. 17(3):169-177, 2010.**

This study focuses on foetal development following mild daily exposure of pregnant mice to near field electromagnetic radiation emitted by a mobile phone. The investigation was motivated by the fact that the potentially hazardous electromagnetic radiation emitted by mobile phones is currently of tremendous public interest. Physically comparable pregnant mice were exposed to radiofrequency radiation GSM 900MHz emitted by a mobile phone. Within 5h after birth most cubs were fixed followed by double staining in toto, and conventional paraffin histology. Other cubs remained with their mothers until teeth eruption. Structural development was assessed by examining newborns for the presence of anomalies and/or variations in soft tissues and skeletal anatomy. Electromagnetic radiofrequency exposed newborns, externally examined, displayed a normal phenotype. Histochemical and histological studies, however, revealed variations in the exposed foetuses with respect to control ones concerning the ossification of cranial bones and

thoracic cage ribs, as well as displacement of Meckelian cartilage. Littermates examined after teeth eruption displayed normal phenotypes. It is concluded that mild exposure to mobile phone radiation may affect, although transiently, mouse foetal development at the ossification level. The developmental variations observed could be explained by considering the different embryonic origin and mode of ossification of the affected skeletal elements.

**Fragopoulou AF, Miltiadous P, Stamatakis A, Stylianopoulou F, Koussoulakos SL, Margaritis LH. Whole body exposure with GSM 900MHz affects spatial memory in mice. Pathophysiology. 17(3):179-187,2010.**

Extended work has been performed worldwide on the effects of mobile phone radiation upon rats' cognitive functions, however there is great controversy to the existence or not of deficits. The present work has been designed in order to test the effects of mobile phone radiation on spatial learning and memory in mice Mus musculus Balb/c using the Morris water maze (a hippocampal-dependent spatial memory task), since there is just one other study on mice with very low SAR level (0.05W/kg) showing no effects. We have applied a 2h daily dose of pulsed GSM 900MHz radiation from commercially available mobile phone for 4 days at SAR values ranging from 0.41 to 0.98W/kg. Statistical analysis revealed that during learning, exposed animals showed a deficit in transferring the acquired spatial information across training days (increased escape latency and distance swam, compared to the sham-exposed animals, on the first trial of training days 2-4). Moreover, during the memory probe-trial sham-exposed animals showed the expected preference for the target quadrant, while the exposed animals showed no preference, indicating that the exposed mice had deficits in consolidation and/or retrieval of the learned spatial information. Our results provide a basis for more thorough investigations considering reports on non-thermal effects of electromagnetic fields (EMFs).

**Fragopoulou AF, Samara A, Antonelou MH, Xanthopoulou A, Papadopoulou A, Vougas K, Koutsogiannopoulou E, Anastasiadou E, Stravopodis DJ, Tsangaris GT, Margaritis LH. Brain proteome response following whole body exposure of mice to mobile phone or wireless DECT base radiation. Electromagn Biol Med.31(4):250-274, 2012.**

The objective of this study was to investigate the effects of two sources of electromagnetic fields (EMFs) on the proteome of cerebellum, hippocampus, and frontal lobe in Balb/c mice following long-term whole body irradiation. Three equally divided groups of animals (6 animals/group) were used; the first group was exposed to a typical mobile phone, at a SAR level range of 0.17-0.37 W/kg for 3 h daily for 8 months, the second group was exposed to a wireless DECT base (Digital Enhanced Cordless Telecommunications/Telephone) at a SAR level range of 0.012-0.028 W/kg for 8 h/day also for 8 months and the third group comprised the sham-exposed animals. Comparative proteomics analysis revealed that long-term irradiation from both EMF sources altered significantly ($p < 0.05$) the expression of 143 proteins in total (as low as 0.003 fold downregulation up to 114 fold overexpression). Several neural function related proteins (i.e., Glial Fibrillary Acidic Protein (GFAP), Alpha-

synuclein, Glia Maturation Factor beta (GMF), and apolipoprotein E (apoE)), heat shock proteins, and cytoskeletal proteins (i.e., Neurofilaments and tropomodulin) are included in this list as well as proteins of the brain metabolism (i.e., Aspartate aminotransferase, Glutamate dehydrogenase) to nearly all brain regions studied. Western blot analysis on selected proteins confirmed the proteomics data. The observed protein expression changes may be related to brain plasticity alterations, indicative of oxidative stress in the nervous system or involved in apoptosis and might potentially explain human health hazards reported so far, such as headaches, sleep disturbance, fatigue, memory deficits, and brain tumor long-term induction under similar exposure conditions.

**Franke H, Streckert J, Bitz A, Goeke J, Hansen V, Ringelstein EB, Nattkamper H, Galla HJ, Stogbauer FEffects of universal mobile telecommunications system (UMTS) electromagnetic fields on the blood-brain barrier In Vitro. Radiat Res. 164(3):258-269, 2005.**

The extensive use of mobile phone communication has raised public concerns about adverse health effects of radiofrequency (RF) electromagnetic fields (EMFs) in recent years. A central issue in this discussion is the question whether EMFs enhance the permeability of the blood-brain barrier (BBB). Here we report an investigation on the influence of a generic UMTS (Universal Mobile Telecommunications System) signal on barrier tightness, transport processes and the morphology of porcine brain microvascular endothelial cell cultures (PBEC) serving as an in vitro model of the BBB. An exposure device with integrated online monitoring system was developed for simultaneous exposure and measuring of transendothelial electrical resistance (TEER) to determine the tightness of the BBB. PBEC were exposed continuously for up to 84 h at an average electric-field strength of 3.4-34 V/m (maximum 1.8 W/kg) ensuring athermal conditions. We did not find any evidence of RF-field-induced disturbance of the function of the BBB. After and during exposure, the tightness of the BBB quantified by (14)C-sucrose and serum albumin permeation as well as by TEER remained unchanged compared to sham-exposed cultures. Permeation of transporter substrates at the BBB as well as the localization and integrity of the tight-junction proteins occludin and ZO1 were not affected either.

**Franzellitti S, Valbonesi P, Contin A, Biondi C, Fabbri E. HSP70 expression in human trophoblast cells exposed to different 1.8 Ghz mobile phone signals. Radiat Res. 170(4):488-497, 2008.**

The heat-shock proteins (HSPs) are important cellular stress markers and have been proposed as candidates to infer biological effects of high-frequency electromagnetic fields (EMFs). In the current study, HSP70 gene and protein expression were evaluated in cells of the human trophoblast cell line HTR-8/SVneo after prolonged exposure (4 to 24 h) to 1.8 GHz continuous-wave (CW) and different GSM signals (GSM-217Hz and GSM-Talk) to assess the possible effects of time and modulation schemes on cell responses. Inducible HSP70 protein expression was not modified by high-frequency EMFs under any condition tested. The inducible HSP70A, HSP70B and the constitutive HSC70 transcripts did not change in cells exposed to high-frequency EMFs with the different modulation schemes. Instead, levels of the

inducible HSP70C transcript were significantly enhanced after 24 h exposure to GSM-217Hz signals and reduced after 4 and 16 h exposure to GSM-Talk signals. As in other cell systems, in HTR-8/SVneo cells the response to high-frequency EMFs was detected at the mRNA level after exposure to amplitude-modulated GSM signals. The present results suggest that the expression analysis for multiple transcripts, though encoding the same or similar protein products, can be highly informative and may account for subtle changes not detected at the protein level.

**Franzellitti S, Valbonesi P, Ciancaglini N, Biondi C, Contin A, Bersani F, Fabbri E. Transient DNA damage induced by high-frequency electromagnetic fields (GSM 1.8 GHz) in the human trophoblast HTR-8/SVneo cell line evaluated with the alkaline comet assay. Mutat Res. 683(1-2):35-42, 2010.**

One of the most controversial issue regarding high-frequency electromagnetic fields (HF-EMF) is their putative capacity to affect DNA integrity. This is of particular concern due to the increasing use of HF-EMF in communication technologies, including mobile phones. Although epidemiological studies report no detrimental effects on human health, the possible disturbance generated by HF-EMF on cell physiology remains controversial. In addition, the question remains as to whether cells are able to compensate their potential effects. We have previously reported that a 1-h exposure to amplitude-modulated 1.8 GHz sinusoidal waves (GSM-217 Hz, SAR=2 W/kg) largely used in mobile telephony did not cause increased levels of primary DNA damage in human trophoblast HTR-8/SVneo cells. Nevertheless, further investigations on trophoblast cell responses after exposure to GSM signals of different types and durations were considered of interest. In the present work, HTR-8/SVneo cells were exposed for 4, 16 or 24h to 1.8 GHz continuous wave (CW) and different GSM signals, namely GSM-217 Hz and GSM-Talk (intermittent exposure: 5 min field on, 10 min field off). The alkaline comet assay was used to evaluate primary DNA damages and/or strand breaks due to uncompleted repair processes in HF-EMF exposed samples. The amplitude-modulated signals GSM-217 Hz and GSM-Talk induced a significant increase in comet parameters in trophoblast cells after 16 and 24h of exposure, while the un-modulated CW was ineffective. However, alterations were rapidly recovered and the DNA integrity of HF-EMF exposed cells was similar to that of sham-exposed cells within 2h of recovery in the absence irradiation. Our data suggest that HF-EMF with a carrier frequency and modulation scheme typical of the GSM signal may affect the DNA integrity.

**Frei, MR, Jauchem, JR, Dusch, SJ, Merritt ,JH, Berger, RE, Stedham, MA, Chronic, low-level (1.0 W/kg) exposure of mice prone to mammary cancer to 2450 MHz microwaves. Radiat Res 150(5):568-576, 1998.**

In a previous study (Frei et al., Bioelectromagnetics 19, 20-31, 1998), we showed that low-level (0.3 W/kg), long-term exposure of mice prone to mammary tumors to 2450 MHz radiofrequency (RF) radiation did not affect the incidence of mammary tumors, latency to tumor onset, tumor growth rate or animal survival when compared to sham-irradiated animals. In the current study, the specific absorption rate (SAR) was increased from 0.3 W/kg to 1.0 W/kg. The same biological end points were used. One hundred C3H/HeJ mice were exposed in circularly polarized waveguides for 78 weeks (20 h/day, 7

days/week) to continuous-wave, 2450 MHz RF radiation; 100 mice were sham-exposed. There was no significant difference between exposed and sham-exposed groups with respect to the incidence of palpated mammary tumors (sham-exposed = 30%; irradiated = 38%), latency to tumor onset (sham-exposed = 62.0 +/- 2.3 weeks; irradiated = 62.5 +/- 2.2 weeks) and rate of tumor growth. Histopathological evaluations revealed no significant difference in numbers of malignant, metastatic or benign neoplasms between the two groups. Thus long-term exposures of mice prone to mammary tumors to 2450 MHz RF radiation at SARs of 0.3 and 1.0 W/kg had no significant effects when compared to sham-irradiated animals.

**Frei P, Mohler E, Neubauer G, Theis G, Bürgi A, Fröhlich J, Braun-Fahrländer C, Bolte J, Egger M, Röösli M. Temporal and spatial variability of personal exposure to radio frequency electromagnetic fields.Environ Res. 109:779-785, 2009.**

BACKGROUND: Little is known about the population's exposure to radio frequency electromagnetic fields (RF-EMF) in industrialized countries. OBJECTIVES: To examine levels of exposure and the importance of different RF-EMF sources and settings in a sample of volunteers living in a Swiss city. METHODS: RF-EMF exposure of 166 volunteers from Basel, Switzerland, was measured with personal exposure meters (exposimeters). Participants carried an exposimeter for 1 week (two separate weeks in 32 participants) and completed an activity diary. Mean values were calculated using the robust regression on order statistics (ROS) method. RESULTS: Mean weekly exposure to all RF-EMF sources was 0.13mW/m(2) (0.22V/m) (range of individual means 0.014-0.881mW/m(2)). Exposure was mainly due to mobile phone base stations (32.0%), mobile phone handsets (29.1%) and digital enhanced cordless telecommunications (DECT) phones (22.7%). Persons owning a DECT phone (total mean 0.15mW/m(2)) or mobile phone (0.14mW/m(2)) were exposed more than those not owning a DECT or mobile phone (0.10mW/m(2)). Mean values were highest in trains (1.16mW/m(2)), airports (0.74mW/m(2)) and tramways or buses (0.36mW/m(2)), and higher during daytime (0.16mW/m(2)) than nighttime (0.08mW/m(2)). The Spearman correlation coefficient between mean exposure in the first and second week was 0.61. CONCLUSIONS: Exposure to RF-EMF varied considerably between persons and locations but was fairly consistent within persons. Mobile phone handsets, mobile phone base stations and cordless phones were important sources of exposure in urban Switzerland.

**Frei P, Mohler E, Bürgi A, Fröhlich J, Neubauer G, Braun-Fahrländer C, Röösli M; The QUALIFEX Team. Classification of personal exposure to radio frequency electromagnetic fields (RF-EMF) for epidemiological research: Evaluation of different exposure assessment methods. Environ Int.36(7):714-20, 2010.**

The use of personal exposure meters (exposimeters) has been recommended for measuring personal exposure to radio frequency electromagnetic fields (RF-EMF) from environmental far-field sources in everyday life. However, it is unclear to what extent exposimeter readings are affected by measurements taken when personal mobile and cordless phones are used. In addition, the use of exposimeters in large epidemiological studies is limited due to high costs and large effort for study

participants. In the current analysis we aimed to investigate the impact of personal phone use on exposimeter readings and to evaluate different exposure assessment methods potentially useful in epidemiological studies. We collected personal exposimeter measurements during one week and diary data from 166 study participants. Moreover, we collected spot measurements in the participants' bedrooms and data on self-estimated exposure, assessed residential exposure to fixed site transmitters by calculating the geo-coded distance and mean RF-EMF from a geospatial propagation model, and developed an exposure prediction model based on the propagation model and exposure relevant behavior. The mean personal exposure was 0.13mW/m(2), when measurements during personal phone calls were excluded and 0.15mW/m(2), when such measurements were included. The Spearman correlation with personal exposure (without personal phone calls) was 0.42 (95%-CI: 0.29 to 0.55) for the spot measurements, -0.03 (95%-CI: -0.18 to 0.12) for the geo-coded distance, 0.28 (95%-CI: 0.14 to 0.42) for the geospatial propagation model, 0.50 (95%-CI: 0.37 to 0.61) for the full exposure prediction model and 0.06 (95%-CI: -0.10 to 0.21) for self-estimated exposure. In conclusion, personal exposure measured with exposimeters correlated best with the full exposure prediction model and spot measurements. Self-estimated exposure and geo-coded distance turned out to be poor surrogates for personal exposure.

**Frei P, Poulsen AH, Johansen C, Olsen JH, Steding-Jessen M, Schüz J. Use of mobile phones and risk of brain tumours: update of Danish cohort study. BMJ. 2011 Oct 19;343:d6387. doi: 10.1136/bmj.d6387.**

OBJECTIVE: To investigate the risk of tumours in the central nervous system among Danish mobile phone subscribers.DESIGN: Nationwide cohort study.SETTING: Denmark.PARTICIPANTS: All Danes aged ≥ 30 and born in Denmark after 1925, subdivided into subscribers and non-subscribers of mobile phones before 1995.MAIN OUTCOME MEASURES: Risk of tumours of the central nervous system, identified from the complete Danish Cancer Register. Sex specific incidence rate ratios estimated with log linear Poisson regression models adjusted for age, calendar period, education, and disposable income.RESULTS: 358,403 subscription holders accrued 3.8 million person years. In the follow-up period 1990-2007, there were 10,729 cases of tumours of the central nervous system. The risk of such tumours was close to unity for both men and women. When restricted to individuals with the longest mobile phone use--that is, ≥ 13 years of subscription--the incidence rate ratio was 1.03 (95% confidence interval 0.83 to 1.27) in men and 0.91 (0.41 to 2.04) in women. Among those with subscriptions of ≥ 10 years, ratios were 1.04 (0.85 to 1.26) in men and 1.04 (0.56 to 1.95) in women for glioma and 0.90 (0.57 to 1.42) in men and 0.93 (0.46 to 1.87) in women for meningioma. There was no indication of dose-response relation either by years since first subscription for a mobile phone or by anatomical location of the tumour--that is, in regions of the brain closest to where the handset is usually held to the head.CONCLUSIONS: In this update of a large nationwide cohort study of mobile phone use, there were no increased risks of tumours of the central nervous system, providing little evidence for a causal association.

**Frei P, Mohler E, Braun-Fahrländer C, Fröhlich J, Neubauer G, Röösli M; QUALIFEX-team. Cohort study on the effects of everyday life radio frequency**

**electromagnetic field exposure on non-specific symptoms and tinnitus.Environ Int. 38(1):29-36, 2012.**

**BACKGROUND:** There is public concern regarding potential health effects of radio frequency electromagnetic fields (RF-EMF) exposure, as produced by mobile phones or broadcast transmitters. The objective of this study was to investigate the association between RF-EMF exposure and non-specific symptoms and tinnitus in a prospective cohort study.**METHODS:** In 2008, 1375 randomly selected participants from Basel, Switzerland, were enrolled in a questionnaire survey with follow-up after one year (participation rate 82%). A score for somatic complaints (von Zerssen list) and headache (HIT-6) was assessed. Far-field environmental RF-EMF exposure was predicted using a validated prediction model. Regarding near-field exposure, self-reported mobile and cordless phone use as well as mobile phone operator data were collected. In multivariate regression models, we investigated whether exposure at baseline (cohort analysis) or changes in exposure between baseline and follow-up (change analysis) were related to changes in health scores.**RESULTS:** For participants in the top decile of environmental far-field RF-EMF exposure at baseline, in comparison to participants exposed below the median value, the change in the von Zerssen- and HIT-6-scores between baseline and follow-up was -0.12 (95%-CI: -1.79 to 1.56) and -0.37 (95%-CI: -1.80 to 1.07) units, respectively. Exposure to near-field sources and a change in exposure between baseline and follow-up were not related to non-specific symptoms. Similarly, no association between RF-EMF exposure and tinnitus was observed.**CONCLUSIONS:** In this first cohort study using objective and well-validated RF-EMF exposure measures, we did not observe an association between RF-EMF exposure and non-specific symptoms or tinnitus.

**French PW, Donnellan M, McKenzie DR, Electromagnetic radiation at 835 MHz changes the morphology and inhibits proliferation of a human astrocytoma cell line. Bioelectrochem Bioenerg 43:13-18, 1997.**

A human astrocytoma cell line, U-87 MG, was exposed to 835 MHz electromagnetic radiation for 20 min, 3 times per day for 7 days, at a power density of either 40+15 $mWcm^{-2}$ or 8.1 + 3 $mWcm^{-2}$. At the low power density, it was observed that the rate of DNA synthesis decreased, and that the cells flattened and spread out in comparison to unexposed culture. At 40 $mWcm^{-2}$, there were no effects seen on cell proliferation, but alteration in cell morphology included increased cell spreading and also the appearance of actin-containing blebs at localized sites on the membrane. It is hypothesised that 835 MHz radiation at low power density may be affecting a signal transduction pathway involved in cell proliferation.

**Freude, G, Ullsperger, P, Eggert ,S, Ruppe, I, Effects of microwaves emitted by cellular phones on human slow brain potentials. Bioelectromagnetics 19(6):384-387, 1998.**

The influence of electromagnetic fields (EMF) emitted by cellular phones on preparatory slow brain potentials (SP) was studied in two different experimental tasks: In the first, healthy male human subjects had to perform simple self-paced finger movements to elicit a Bereitschaftspotential; in the second, they performed a complex and cognitive

demanding visual monitoring task (VMT). Both tasks were performed with and without EMF exposure in counterbalanced order. Whereas subjects' performance did not differ between the EMF exposure conditions, SP parameters were influenced by EMF in the VMT: EMF exposure effected a significant decrease of SPs at central and temporo-parieto-occipital brain regions, but not at the frontal one. In the simple finger movement task, EMF did not affect the Bereitschaftspotential.

**Freude, G, Ullsperger, P, Eggert, S, Ruppe, I, Microwaves emitted by cellular telephones affect human slow brain potentials. Eur J Appl Physiol 81(1-2):18-27, 2000.**

The influence of electromagnetic fields (EMF) emitted by cellular telephones on preparatory slow brain potentials (SP) was studied in two experiments, about 6 months apart. In the first experiment, a significant decrease of SP was found during exposure to EMF in a complex visual monitoring task (VMT). This effect was replicated in the second experiment. In addition to the VMT, EMF effects on SP were analysed in two further, less demanding tasks: in a simple finger movement task to elicit a Bereitschaftspotential (BP) and in a two-stimulus task to elicit a contingent negative variation (CNV). In comparison to the VMT, no significant main EMF effects were found in BP and CNV tasks. The results accounted for a selective EMF effect on particular aspects of human information processing, but did not indicate any influence on human performance, well-being and health.

**Frey AH, Headaches from cellular telephones: are they real and what are the implications? Environ Health Perspect 106(3):101-103, 1998.**

There have been numerous recent reports of headaches occurring in association with the use of hand-held cellular telephones. Are these reported headaches real? Are they due to emissions from telephones? There is reason to believe that the answer is "yes" to both questions. There are several lines of evidence to support this conclusion. First, headaches as a consequence of exposure to low intensity icrowaves were reported in the literature 30 years ago. These were observed during the course of microwave hearing research before there were cellular telephones. Second, the blood-brain barrier appears to be involved in headaches, and low intensity microwave energy exposure affects the barrier. Third, the dopamine-opiate systems of the brain appear to be involved in headaches, and low intensity electromagnetic energy exposure affects those systems. In all three lines of research, the microwave energy used was approximately the same--in frequencies, modulations, and incident energies—as those emitted by present day cellular telephones. Could the current reports of headaches be the canary in the coal mine, warning of biologically significant effects?

**Frick U, Rehm J, Eichhammer P. Risk perception, somatization, and self report of complaints related to electromagnetic fields--a randomized survey study.Int J Hyg Environ Health. 205(5):353-360, 2002.**

Exposure to electromagnetic fields (EMF) as well as EMF-related complaints has increased over the past decades. However, it is unclear whether these complaints are related to the electromagnetic or other physical properties of these fields per se, to salience of EMF in media, or to both. What is the prevalence of EMF-related

complaints in the general population? What are the influencing factors on this prevalence? Does reporting of EMF-related symptoms depend on cognitive factors? To answer these questions, a survey with random variation of three cognitive factors was performed. As expected, EMF-related complaints were reported more by females and people with higher somatization tendency. Age had no significant linear effect on EMF-related complaints. The cognitive condition of threat produced a significant contrast effect among people with high somatization tendency on EMF-related complaints. Cognition can influence reporting of EMF-related effects. Thus, in future research of such effects, psychologically influencing factors should be included. Also risk communication should incorporate knowledge about social cognition.

**Friedman J, Kraus S, Hauptman Y, Schiff Y, Seger R. Mechanism of a short-term ERK activation by electromagnetic fields at mobile phone frequency. Biochem J. 405:559-568, 2007.**

The exposure to non-thermal microwave electromagnetic field generated by mobile phones affects the expression of many proteins. This effect on transcription and protein stability can be mediated by the mitogen-activated protein kinase (MAPK) cascades, which serve as central signaling pathways, and govern essentially all stimulated cellular processes. Indeed, a long-term exposure of cells to mobile phone irradiation results in the activation of p38MAPKs as well as the ERK/MAPKs. Here we studied the immediate effect of irradiation on the MAPK cascades, and found that ERKs, but not stress related MAPKs are rapidly activated in response to various frequencies and intensities. Using signaling inhibitors we delineated the mechanism that is involved in this activation. We found that the first step is mediated in the plasma membrane by NADH oxidase, which rapidly generates reactive oxygen species (ROS). These ROS then directly stimulate matrix metalloproteinases and allow them to cleave and release heparin binding-EGF. This secreted factor, activates EGF receptor, which in turn further activates the ERK cascade. Thus, this study demonstrates for the first time a detailed molecular mechanism by which electromagnetic irradiation by mobile phones induces the activation of the ERK cascade and thereby induces transcription and other cellular processes.

**Fritze K, Wiessner C, Kuster N, Sommer C, Gass P, Hermann DM, Kiessling M,Hossmann KA, Effect of global system for mobile communication microwave exposure on the genomic response of the rat brain. Neuroscience 81(3):627-639, 1997.**

The acute effect of global system for mobile communication (GSM) microwave exposure on the genomic response of the central nervous system was studied in rats by measuring changes in the messenger RNAs of hsp70, the transcription factor genes c-fos and c-jun and the glial structural gene GFAP using in situ hybridization histochemistry. Protein products of transcription factors, stress proteins and marker proteins of astroglial and microglial activation were assessed by immunocytochemistry. Cell proliferation was evaluated by bromodeoxyuridine incorporation. A special GSM radiofrequency test set, connected to a commercial cellular phone operating in the discontinuous transmission mode, was used to simulate GSM exposure. The study was conducted at time averaged

and brain averaged specific absorption rates of 0.3 W/kg (GSM exposure), 1.5 W/kg (GSM exposure) and 7.5 W/kg (continuous wave exposure), respectively. Immediately after exposure, in situ hybridization revealed slight induction of hsp70 messenger RNA in the cerebellum and hippocampus after 7.5 W/kg exposure, but not at lower intensities. A slightly increased expression of c-fos messenger RNA was observed in the cerebellum, neocortex and piriform cortex of all groups subjected to immobilization, but no differences were found amongst different exposure conditions. C-jun and GFAP messenger RNAs did not increase in any of the experimental groups. 24 h after exposure, immunocytochemical analysis of FOS and JUN proteins (c-FOS, FOS B, c-JUN JUN B, JUN D), of HSP70 or of KROX-20 and -24 did not reveal any alterations. Seven days after exposure, neither increased cell proliferation nor altered expression of astroglial and microglial marker proteins were observed. In conclusion, acute high intensity microwave exposure of immobilized rats may induce some minor stress response but does not result in lasting adaptive or reactive changes of the brain.

**Fritze K, Sommer C, Schmitz B, Mies G, Hossmann KA, Kiessling M, Wiessner C, Effect of global system for mobile communication (GSM) microwave exposure on blood-brain barrier permeability in rat. Acta Neuropathol (Berl) 94(5):465-470, 1997.**

We investigated the effects of global system for mobile communication (GSM) microwave exposure on the permeability of the blood-brain barrier using a calibrated microwave exposure system in the 900 MHz band. Rats were restrained in a carousel of circularly arranged plastic tubes and sham-exposed or microwave irradiated for a duration of 4 h at specific brain absorption rates (SAR) ranging from 0.3 to 7.5 W/kg. The extravasation of proteins was assessed either at the end of exposure or 7 days later in three to five coronal brain slices by immunohistochemical staining of serum albumin. As a positive control two rats were subjected to cold injury. In the brains of freely moving control rats (n = 20) only one spot of extravasated serum albumin could be detected in one animal. In the sham-exposed control group (n = 20) three animals exhibited a total of 4 extravasations. In animals irradiated for 4 h at SAR of 0.3, 1.5 and 7.5 W/kg (n = 20 in each group) five out of the ten animals of each group killed at the end of the exposure showed 7, 6 and 14 extravasations, respectively. In the ten animals of each group killed 7 days after exposure, the total number of extravasations was 2, 0 and 1, respectively. The increase in serum albumin extravasations after microwave exposure reached significance only in the group exposed to the highest SAR of 7.5 W/kg but not at the lower intensities. Histological injury was not observed in any of the examined brains. Compared to other pathological conditions with increased blood-brain barrier permeability such as cold injury, the here observed serum albumin extravasations are very modest and, moreover, reversible. Microwave exposure in the frequency and intensity range of mobile telephony is unlikely to produce pathologically significant changes of the blood-brain barrier permeability.

**Fritzer G, Göder R, Friege L, Wachter J, Hansen V, Hinze-Selch D, Aldenhoff JB. Effects of short- and long-term pulsed radiofrequency electromagnetic fields on night sleep and cognitive functions in healthy subjects.Bioelectromagnetics. 28(4):316-325, 2007.**

There has been wide public discussion on whether the electromagnetic fields of mobiletelephones and their base stations affect human sleep or cognitive functioning. As there is evidence for learning and memory-consolidating effects of sleep and particularly of REM sleep, disturbance of sleep by radiofrequency electromagnetic fields might also impair cognitive functions. Previously realized sleep studies yielded inconsistent results regarding short-term exposure. Moreover, data are lacking on the effect that short- and long-term exposure might have on sleep as well as on cognitive functions. Therefore, 10 healthy young male subjects were included and nocturnal sleep was recorded during eight consecutive nights. In the second, third, and last night, we investigated polysomnographic night sleep and cognitive functions. After the adaptation and baseline nights, the participants were exposed to a defined radiofrequency electromagnetic field during the following six nights. We analyzed polysomnographic night sleep according to Rechtschaffen and Kales [1968, Manual of Standardized Terminology, Techniques and Scoring System for Sleep of Human Subjects] as well as by power spectra and correlation dimension. Cognitive functions were investigated by an array of neuropsychological tests. Data analysis was done by comparing the baseline night with the first and last exposure night and the first two sleep cycles of the respective nights. We did not find significant effects, either on conventional sleep parameters or on power spectra and correlation dimension, nor were there any significant effects on cognitive functions. With our results, we are unable to reveal either short-term or cumulative long-term effects of radiofrequency electromagnetic fields on night sleep and cognitive functions in healthy young male subjects.

**Fry TL, Schlegel RE, Grant H, Impact of CDMA wireless phone power output and puncture rate on hearing aid interference levels. Biomed Instrum Technol 34(1):29-38, 2000.**

Interference between digital wireless phones and hearing aids occurs when the radiofrequency bursts from the phone transmission are demodulated by the hearing aid amplifier. The amplified interference signal is heard as a "buzz" or "static" by the hearing aid wearer. Most research and standards development activity has focused on worst-case scenarios with the phone operating at its maximum power. Since this power level is often not typical in urban and suburban settings, it is of value to determine the impact of lower power levels on the overall level of audible interference. Using a frequency analyzer, and several hearings aids and code division multiple access (CDMA) phones, the audio frequency spectrum of interference was recorded for each phone-aid combination and for a range of power levels producing from no interference to maximum interference. As phone power is increased, the interference signal becomes distinguishable from the ambient noise level and a linear response region is observed in which a specified increase in power output results in a proportional increase in the overall input referenced interference level (OIRIL). As power is increased beyond the linear region, the hearing aid enters a saturation region where an additional power increase results in a reduction or no increase in the OIRIL. The numeric differences in interference documented in this study were used in conjunction with the results of a previous study by the authors to determine the impact of reduced power on speech intelligibility and annoyance. The amount of improvement for a given power reduction depends on the

radiofrequency immunity of the hearing aid and is substantial for hearing aids with poor immunity. For high-immunity aids, the level of audible interference remains low even at high phone power levels.

**Fucic A, Garaj-Vrhovac V, Skara M, Dimitrovic B, X-rays, microwaves and vinyl chloride monomer: their clastogenic and aneugenic activity, using the micronucleus assay on human lymphocytes. Mutat Res 282(4):265-271, 1992.**

Chromosome aberration assays, sister-chromatid exchange techniques and micronucleus assays are commonly used methods for biomonitoring genetic material damaged by chemical or physical agents. On the other hand, their aneugenic activity, which can lead to hypoploidy and may also be associated with carcinogenesis, has not been thoroughly investigated. In our study we chose the micronucleus assay with a new mathematical approach to separate clastogenic from aneugenic activity of three well-known mutagens (vinyl chloride monomer, X-rays and microwaves) on the genome of human somatic cells. The comparison of frequencies of size distribution of micronuclei in the lymphocytes of humans exposed to each of these three mutagens showed that X-rays and microwaves were preferentially clastogens while vinyl chloride monomer showed aneugenic activity as well. Microwaves possess some mutagenic characteristics typical of chemical mutagens.

**Fukui Y, Hoshino K, Inouye M, Kameyama Y, Effects of hyperthermia induced by microwave irradiation on brain development in mice. J Radiat Res (Tokyo) 33(1):1-10, 1992.**

Pregnant mice were exposed to 2.45 GHz of microwave radiation for 15 or 20 min on day 13 of gestation. The highest maternal core temperature during the exposure did not exceed 42.5 degrees C. Pregnant females also were immersed in hot water at 42 degrees C for 15 min to compare thermal effects on brain development. Animals were killed 9 hours after treatment, and the pyknotic cells in the ventricular zone of telencephalon were counted. The respective incidences of these cells in the groups exposed to microwaves for 15 and 20 min were 1.83% and 3.06%. Microwave radiation for 20 min had an effect that was comparable to that of immersion in 42 degrees C hot water for 15 min. In addition, some animals were examined on day 18 of gestation, and some of their offspring were examined at 6 weeks of age in an examination of long-term effects. Brain weight for the group exposed to microwaves for 20 min was significantly lower than for the control group, and the numerical density of the neurons in the cerebrum was higher. We concluded that microwave radiation at the dose tested mainly has a thermal effect.

**Funch DP, Rothman KJ, Loughlin JE, Dreyer NA, Utility of telephone company records for epidemiologic studies of cellular telephones. Epidemiology 7(3):299-302, 1996.**

We conducted a survey of over 5,000 telephone users who were customers of one large cellular telephone company covering four major geographical areas. Our primary goal was to assess the utility of ascertaining information on telephone use and type from telephone company records. We compared information from 3,949 respondents with corresponding data from company billing records. We found that 48% of the account

holders were sole users, and 69% were the primary user, meaning that they accounted for at least 75% of the use. Respondent reports of amount of telephone use were highly correlated with data on the billing record (r = 0.74). Respondent reports of telephone type were similarly correlated with data from the manufacturer (r = 0.92). We also inquired about telephone holding patterns, since these have implications for exposure. Most users reported favoring one side of the head when using the telephone, but the side of the head used was not strongly associated with handedness.

**Furtado-Filho OV, Borba JB, Dallegrave A, Pizzolato TM, Henriques JA, Moreira JC, Saffi J. Effect of 950 MHz UHF electromagnetic radiation on biomarkers of oxidative damage, metabolism of UFA and antioxidants in the livers of young rats of different ages. Int J Radiat Biol. 2013 Jul 25. [Epub ahead of print]**

Purpose: To assess the effect of 950 MHz ultra-high-frequency electromagnetic radiation (UHF EMR) on biomarkers of oxidative damage, as well as to verify the concentration of unsaturated fatty acids (UFA) and the expression of the catalase in the livers of rats of different ages. Materials and methods: Twelve rats were equally divided into two groups as controls (CR) and exposed (ER), for each age (0, 6, 15 and 30 days). Radiation exposure lasted half an hour per day for up to 51 days (21 days of gestation and 6, 15 or 30 days of life outside the womb). The specific absorption rate (SAR) ranged from 1.3-1.0 W/kg. The damage to lipids, proteins and DNA was verified by thiobarbituric acid reactive substances (TBARS), protein carbonyls and comets, respectively. UFA were determined by gas chromatography with a flame ionization detector. The expression of catalase was by Western blotting. Results: The neonates had low levels of TBARS and concentrations of UFA after exposure. There was no age difference in the accumulation of protein carbonyls for any age. The DNA damage of ER 15 or 30 days was different. The exposed neonates exhibited lower expression of catalase. Conclusions: 950 MHz UHF EMR does not cause oxidative stress (OS), and it is not genotoxic to the livers of neonates or those of 6 and 15 day old rats, but it changes the concentrations of polyunsaturated fatty acid (PUFA) in neonates. For rats of 30 days, no OS, but it is genotoxic to the livers of ER to total body irradiation.

**Furtado-Filho OV, Borba JB, Maraschin T, Souza LM, Jose JA, Moreira CF, Saffi J. Effects of chronic exposure to 950 MHz ultra-high-frequency electromagnetic radiation on reactive oxygen species metabolism in the right and left cerebral cortex of young rats of different ages. Int J Radiat Biol. 2015 Aug 14:1-17. [Epub ahead of print]**

PURPOSE: To assess the effect of 950 MHz ultra-high-frequency electromagnetic radiation (UHF-EMR) on biomarkers of oxidative damage to DNA, proteins and lipids in the left cerebral cortex (LCC) and right cerebral cortex (RCC) of neonate and 6-day-old rats. MATERIALS AND METHODS: Twelve rats were equally divided into two groups as controls (CR) and exposed (ER), for each age (0 and 6 days). The LCC and RCC were examined in ER and CR after exposure. Radiation exposure lasted half an hour per day for up to 27 days (throughout pregnancy and 6 days postnatal). The specific absorption rate ranged from 1.32 - 1.14 W/kg. The damage to lipids,

proteins and DNA was verified by thiobarbituric acid reactive substances, carbonylated proteins (CP) and comets, respectively. The concentration of glucose in the peripheral blood of the rats was measured by the Accu-Chek Active Kit due to increased CP in RCC. RESULTS: In neonates, no modification of the biomarkers tested was detected. On the other hand, there was an increase in the levels of CP in the RCC of the 6-day-old ER. Interestingly, the concentration of blood glucose was decreased in this group. CONCLUSIONS: Our results indicate that there is no genotoxicity and oxidative stress in neonates and 6 days rats. However, the RCC had the highest concentration of CP that do not seem to be a consequence of oxidative stress. This study is the first to demonstrate the use of UHF-EMR causes different damage responses to proteins in the LCC and RCC.

**Furubayashi T, Ushiyama A, Terao Y, Mizuno Y, Shirasawa K, Pongpaibool P, Simba AY, Wake K, Nishikawa M, Miyawaki K, Yasuda A, Uchiyama M, Yamashita HK, Masuda H, Hirota S, Takahashi M, Okano T, Inomata-Terada S, Sokejima S, Maruyama E, Watanabe S, Taki M, Ohkubo C, Ugawa Y. Effects of short-term W-CDMA mobile phone base station exposure on women with or without mobile phone related symptoms. Bioelectromagnetics. 30(2):100-113, 2009.**

To investigate possible health effects of mobile phone use, we conducted a double-blind, cross-over provocation study to confirm whether subjects with mobile phone related symptoms (MPRS) are more susceptible than control subjects to the effect of electromagnetic fields (EMF) emitted from base stations. We sent questionnaires to 5,000 women and obtained 2,472 valid responses from possible candidates; from these, we recruited 11 subjects with MPRS and 43 controls. There were four EMF exposure conditions, each of which lasted 30 min: continuous, intermittent, and sham exposure with and without noise. Subjects were exposed to EMF of 2.14 GHz, 10 V/m (W-CDMA), in a shielded room to simulate whole-body exposure to EMF from base stations, although the exposure strength we used was higher than that commonly received from base stations. We measured several psychological and cognitive parameters pre- and post-exposure, and monitored autonomic functions. Subjects were asked to report on their perception of EMF and level of discomfort during the experiment. The MPRS group did not differ from the controls in their ability to detect exposure to EMF; nevertheless they consistently experienced more discomfort, regardless of whether or not they were actually exposed to EMF, and despite the lack of significant changes in their autonomic functions. Thus, the two groups did not differ in their responses to real or sham EMF exposure according to any psychological, cognitive or autonomic assessment. In conclusion, we found no evidence of any causal link between hypersensitivity symptoms and exposure to EMF from base stations.

**Gadhia PK, Shah T, Mistry A, Pithawala M, Tamakuwala D. A preliminary study to assess possible chromosomal damage among users of digital mobile phones. Electromag Biol Med 22:149-159, 2003.**

In a preliminary study to examine possible lymphocyte chromosomal damage, we have tested two cytogenetic endpoints, namely, chromosomal aberrations (CA) and sister chromatid exchange frequencies (SCE), in 24 mobile phone users (12 nonsmoker–nonalcoholic subjects and 12 smoker–alcoholics), who used digital

mobile phones for at least 2 years, employing Gaussian Minimum Shift Keying modulations with uplink frequencies at 935–960 MHz. and downlinks at 890–915 MHz. For comparison, the control study group included another 24 individuals, matched according to their age, sex, drinking and smoking habits, as well as similar health status, working habits, and professional careers; but did not use mobile phones. Blood samples of 12 mobile users (6 smoker–alcoholic and 6 nonsmoker–nonalcoholic) and 12 controls (identical to mobile users in every respect) were further treated with a known mutagen Mitomycin-C (MMC) to find out comutagenic/synergistic effect. A complete blood picture for each individual was assessed with an automatic particle cell counter. There was a significant increase ($P < 0.05$) in dicentric chromosomes among mobile users who were smoker–alcoholic as compared to nonsmoker–nonalcoholic; the same held true for controls of both types. After MMC treatment, there was a significant increase in dicentrics ($P < 0.05$) and ring chromosomes ($P < 0.001$) in both smoker–alcoholic and nonsmoker–nonalcoholic mobile users when compared with the controls. Although SCEs showed a significant increase among mobile users, no change in cell cycle progression was noted. The hematological picture showed only minor variations between mobile users and controls.

**Gadzicka E, Bortkiewicz A, Zmyslony M, Palczynski C, [Evaluation of selected functional circulation parameters of workers from various occupational groups exposed to electromagnetic fields of high frequency. III. 24-h monitoring of arterial blood pressure]. Med Pr 48(1):15-24, 1997.** [Article in Polish]

The problem of blood pressure regulation in persons occupationally exposed to electromagnetic fields (EMF) has not as yet been elucidated, and most data come from studies carried out long time ago (1960-70) in the former Soviet Union. Our study was aimed at verifying the Soviet data by means of modern methods. Together with traditional methods, a 24-h monitoring of arterial blood pressure (ABP) using a Medilog ABP kit (Oxford) were employed. Measurements were taken automatically every 0.5 h during daily activities and every 1 h during the night rest (about 41 measurements/day). The mean systolic and diastolic blood pressure and heart rate were calculated over day (BPSDOver, BPDOver, HROver), during daily activities (HPDD, BPSD, HRD) and during the night rest (BPSN, BPDN, HRN). The subjective and objective examinations were carried out as well as resting ECG and a 24-h Holter were performed (the results have been published earlier). The study covered male workers of middlewave broadcast stations (71), radioservice (40) and radio line stations (42). The subjects were aged 21-60 years and the duration of their work with devices generating high frequency EMF ranged between 1 and 42 years. The first group of workers was exposed to EFM at the frequency of 1 Mhz, the second at about 150 Mhz and the third group, not exposed, served as the control group. The study revealed that the mean arterial blood pressure and the day/night blood pressure variability indicator showed no significant differences between the groups, whereas the daily heart rate was significantly lower in the workers of middlewave broadcast stations in comparison with the controls despite similar type of work as far as physical effort and psychic burden are concerned, and similar non-occupational activities. The day/night heart rate variability indicator was significantly lower in the groups exposed. The decreased value of this indicator may suggest the occurrence of disorders in the

neurovegetative regulation. In persons employed at radioservice stations a higher incidence of the increased arterial blood pressure, in comparison with the control group, was observed.

**Gajski G, Garaj-Vrhovac V. Radioprotective effects of honeybee venom (Apis mellifera) against 915-MHz microwave radiation-induced DNA damage in wistar rat lymphocytes: in vitro study. Int J Toxicol. 28(2):88-98, 2009.**

The aim of this study is to investigate the radioprotective effect of bee venom against DNA damage induced by 915-MHz microwave radiation (specific absorption rate of 0.6 W/kg) in Wistar rats. Whole blood lymphocytes of Wistar rats are treated with 1 microg/mL bee venom 4 hours prior to and immediately before irradiation. Standard and formamidopyrimidine-DNA glycosylase (Fpg)-modified comet assays are used to assess basal and oxidative DNA damage produced by reactive oxygen species. Bee venom shows a decrease in DNA damage compared with irradiated samples. Parameters of Fpg-modified comet assay are statistically different from controls, making this assay more sensitive and suggesting that oxidative stress is a possible mechanism of DNA damage induction. Bee venom is demonstrated to have a radioprotective effect against basal and oxidative DNA damage. Furthermore, bee venom is not genotoxic and does not produce oxidative damage in the low concentrations used in this study.

**Galat VV, Mezhevikina LM, Zubin MN, Lepikhov KA, Khramov RN, Chailakhian LM, [Effect of millimeter waves on the early development of the mouse and sea urchin embryo]. Biofizika 44(1):137-140, 1999.** [Article in Russian]

The action of nonthermal electromagnetic radiation (EMR) of the millimeter range on the early development of murine and sea urchin embryos was investigated. An MRTA-01E-03 generator with a frequency of 54-78 GHz and radiation intensity of 0.06 mWt/cm2 was used. The embryos were irradiated during 30 min at the stage of two blastomeres. The number of murine embryos that reached the blastocyst stage increased (up to 97.3% in comparison with 87.5% in control). The total time of cultivation up to the blastocyst stage was also shorter (72 h) than in control (96 h). The irradiation had effect on the development of sea urchin embryos only if embryos with a weakened viability were tested. The results indicate that millimeter electromagnetic radiation has a stimulating effect on the early development of embryos, increasing the resistance of embryos to unfavorable environmental conditions.

**Galloni P, Lovisolo GA, Mancini S, Parazzini M, Pinto R, Piscitelli M, Ravazzani P, Marino C. Effects of 900 MHz electromagnetic fields exposure on cochlear cells' functionality in rats: Evaluation of distortion product otoacoustic emissions. Bioelectromagnetics. 26(7):536-547, 2005.**

In recent years, the widespread use of mobile phones has been accompanied by public debate about possible adverse consequences on human health. The auditory system is a major target of exposure to electromagnetic fields (EMF) emitted by cellular telephones; the aim of this study was the evaluation of possible effects of cellular phone-like emissions on the functionality of rat's cochlea. Distortion Products OtoAcoustic Emission (DPOAE) amplitude was selected as cochlea's outer hair cells (OHC) status indicator. A

number of protocols, including different frequencies (the lower ones in rat's cochlea sensitivity spectrum), intensities and periods of exposure, were used; tests were carried out before, during and after the period of treatment. No significant variation due to exposure to microwaves has been evidenced.

**Galloni P, Parazzini M, Piscitelli M, Pinto R, Lovisolo GA, Tognola G, Marino C, Ravazzani P. Electromagnetic Fields from mobile phones do not affect the inner auditory system of Sprague-Dawley Rats. Radiat Res. 164(6):798-804, 2005.**

The auditory system is the first biological structure facing the electromagnetic fields emitted by mobile phones. The aim of this study was to evaluate the cochlear functionality of Sprague-Dawley rats exposed to electromagnetic fields at the typical frequencies of GSM mobile phones (900 and 1800 MHz) by distortion product otoacoustic emissions, which are a well-known indicator of the status of the cochlea's outer hair cells. A population of 48 rats was divided into exposed and sham-exposed groups. Three sets of four loop antennas, one for sham-exposed animals and two for exposed animals, were used for the local exposures. Rats were exposed 2 h/day, 5 days/week for 4 weeks at a local SAR of 2 W/kg in the ear. Distortion product otoacoustic emissions tests were carried out before, during and after the exposure. The analysis of the data shows no statistically significant differences between the audiological signals recorded for the different groups

**Gandhi G, Anita Genetic damage in mobile phone users: some preliminary findings. Ind J Hum Genet 11(2): 99-104, 2005.**

**BACKGROUND:** The impact of microwave (MW)/radio frequency radiation (RFR) on important biological parameters is probably more than a simply thermal one. Exposure to radio frequency (RF) signals generated by the use of cellular telephones have increased dramatically and reported to affect physiological, neurological, cognitive and behavioural changes and to induce, initiate and promote carcinogenesis. Genotoxicity of RFR has also been reported in various test systems after in vitro and/or in vivo exposure but none in mobile phone users. **AIMS:** In the present study, DNA and chromosomal damage investigations were carried out on the peripheral blood lymphocytes of individuals using mobile phones, being exposed to MW frequency ranging from 800 to 2000 MHz. **METHODS:** DNA damage was assessed using the single cell gel electrophoresis assay and aneugenic and clastogenic damage by the in vivo capillary blood micronucleus test (MNT) in a total of 24 mobile phone users. **RESULTS:** Mean comet tail length (26.76 ± 0.054 mm; 39.75% of cells damaged) in mobile phone users was highly significant from that in the control group. The in vivo capillary blood MNT also revealed highly significant (0.25) frequency of micronucleated (MNd) cells. **CONCLUSIONS:** These results highlight a correlation between mobile phone use (exposure to RFR) and genetic damage and require interim public health actions in the wake of widespread use of mobile telephony.

**Gandhi G, Singh P. Cytogenetic damage in mobile phone users: preliminary data. Int J Hum Genet 5(4):259-265, 2005.**

Mobile telephones, sometimes called cellular (cell) phones or handies, are now an integral part of modern life. The mobile phone handsets are low-powered radiofrequency transmitters, emitting maximum powers in the range of 0.2 to 0.6 watts. Scientific

concenrns have increased sufficiently over the possible hazard to health from using cell phones. The reported adverse health effects include physiological, behavioural and cognitive changes as well as tumour formation and genetic damage. However findings are controversial and no consensus exists. Genotoxicity has been observed either in lower organisms or in vitro studies. The aim of the present study hence was to detect any cytogenertic damage in mobile phone users by analysing short term peripheral lymphocyte cultures for chromosomal aberrations and the buccal mucosal cells for micronuclei (aneugenicity and clastogenicity). The results revealed increased number of micronucleated buccal cells and cytological abnormalities in cultured lymphocytes indicating the genotoxic response from mobile phone use.

**Gandhi G, Kaur G, Nisar U. A cross-sectional case control study on genetic damage in individuals residing in the vicinity of a mobile phone base station. Electromagn Biol Med. 34(4):344-354, 2015.**

Mobile phone base stations facilitate good communication, but the continuously emitting radiations from these stations have raised health concerns. Hence in this study, genetic damage using the single cell gel electrophoresis (comet) assay was assessed in peripheral blood leukocytes of individuals residing in the vicinity of a mobile phone base station and comparing it to that in healthy controls. The power density in the area within 300 m from the base station exceeded the permissive limits and was significantly ($p = 0.000$) higher compared to the area from where control samples were collected. The study participants comprised 63 persons with residences near a mobile phone tower, and 28 healthy controls matched for gender, age, alcohol drinking and occupational sub-groups. Genetic damage parameters of DNA migration length, damage frequency (DF) and damage index were significantly ($p = 0.000$) elevated in the sample group compared to respective values in healthy controls. The female residents ($n = 25$) of the sample group had significantly ($p = 0.004$) elevated DF than the male residents ($n = 38$). The linear regression analysis further revealed daily mobile phone usage, location of residence and power density as significant predictors of genetic damage. The genetic damage evident in the participants of this study needs to be addressed against future disease-risk, which in addition to neurodegenerative disorders, may lead to cancer.

**Gandhi OP. ELECTROMAGNETIC FIELDS: Human Safety Issues. Annu Rev Biomed Eng 4:211-234, 2002.**

Most of the recently revised safety standards worldwide are set in terms of internal rates of electromagnetic energy deposition (specific absorption rates or SAR) at radio frequencies (RF) and microwave frequencies, and of induced electric fields or current densities at lower frequencies up to 10 MHz. Numerical methods have been developed that use millimeter resolution anatomically based models of the human body to determine SAR or the induced electric fields and current densities for real-life EM exposure conditions. A popular method for use at RF and microwave frequencies is the finite-difference time-domain method. This method is described and illustrated for SAR distributions due to cellular telephones for head models based on human anatomy. A method often used for calculations of induced electric fields and current densities at low frequencies is the impedance method. Use of this method is illustrated by an example of

an electronic article surveillance (EAS) system for anatomic models of an adult and 10- and 5-year-old children. Experimental phantoms using a fluid to simulate the dielectric properties of the brain may be used for determination of peak 1- or 10-g SAR needed for compliance with the various safety standards.

**Gandhi OP, Lazzi G, Tinniswood A, Yu QS, Comparison of numerical and experimental methods for determination of SAR and radiation patterns of handheld wireless telephones. Bioelectromagnetics Suppl 4:93-101, 1999.**

Some recent developments in both the numerical and experimental methods for determination of SARs and radiation patterns of handheld wireless telephones are described, with emphasis on comparison of results using the two methods. For numerical calculations, it was possible to use the Pro-Engineer CAD Files of cellular telephones for a realistic description of the device. Also, we used the expanding grid formulation of the finite-difference time-domain (FDTD) method for finer-resolution representation of the coupled region, including the antenna, and an increasingly coarser representation of the more-distant, less-coupled region. Together with the truncation of the model of the head, this procedure led to a saving of computer memory needed for SAR calculations by a factor of over 20. Automated SAR and radiation pattern measurement systems were used to validate both the calculated 1-g SARs and radiation patterns for several telephones, including some research test samples, using a variety of antennas. Even though widely different peak 1-g SARs were obtained, ranging from 0.13 to 5.41 W/kg, agreement between the calculated and the measured data for these telephones, five each at 835 and 1900 MHz, was excellent and generally within +/-20% (+/-1 dB). An important observation was that for a maximum radiated power of 600 mW at 800/900 MHz, which may be used for telephones using AMPS technology, the peak 1-g SARs can be higher than 1.6 W/kg unless antennas are carefully designed and placed further away from the head.

**Gao X, Luo R, Ma B, Wang H, Liu T, Zhang J, Lian Z, Cui X. [Interference of vitamin E on the brain tissue damage by electromagnetic radiation of cell phone in pregnant and fetal rats]. Wei Sheng Yan Jiu. 2013 Jul;42(4):642-6.**
[Article in Chinese]

OBJECTIVE: To investigate the interlerence ot vitamin E on brain tissue damage by electromagnetic radiation of cell phone in pregnant and fetal rats. METHODS: 40 pregnant rats were randomly divided into five groups (positive control, negative control, low, middle and high dosage of vitamin E groups). The low, middle and high dosage of vitamin E groups were supplemented with 5, 15 and 30 mg/ml vitamin E respectively since the first day of pregnancy. And the negative control group and the positive control group were given peanut oil without vitamin E. All groups except for the negative control group were exposed to 900MHz intensity of cell phone radiation for one hour each time, three times per day for 21 days. After accouchement, the right hippocampus tissue of fetal rats in each group was taken and observed under electron microscope. The vitality of superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), and the content of malondialdehyde (MDA) in pregnant and fetal rats' brain tissue were tested. RESULTS: Compared with the negative control group, the chondriosomes in neuron and neuroglia of brain tissues was swelling, mild edema was found around the capillary, chromatin was

concentrated and collected, and bubbles were formed in vascular endothelial cells (VEC) in the positive fetal rat control group, whereas the above phenomenon was un-conspicuous in the middle and high dosage of vitamin E groups. We can see uniform chromatin, abundant mitochondrion, rough endoplasmic reticulum and free ribosomes in the high dosage group. The apoptosis has not fond in all groups'sections. In the antioxidase activity analysis, compared with the negative control group, the vitality of SOD and GSH-Px significantly decreased and the content of MDA significantly increased both in the pregnant and fetal rats positive control group ($P < 0.05$). In fetal rats, the vitality of SOD and GSH-Px significantly increased in the brain tissues of all three different vitamin E dosages groups when compared with the positive control group, and the content of MDA was found significantly decreased in both middle and high dosage of vitamin E groups($P < 0.05$). The same results have also been found in high dosage pregnant rat group, but in middle dosage group only SOD activity was found increased with significance ($P < 0.05$). With the dosage increase of vitamin E, the vitality of SOD and GSH-Px was increasing and the content of MDA was decreasing. CONCLUSION: Under the experimental dosage, vitamin E has certain interference on damage of antioxidant capacity and energy metabolization induced by electromagnetic radiation of cell phone in pregnant rats and fetal rats.

**Gao XF,Pei LP, Chen CH, Yang XS, Zhang GB, Deng ZH, Yu ZP. [Effects of occupational microwave irradiation on heat shock protein 70 expressions in rat hippocampus.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):553-556, 2009.** [Article in Chinese]

OBJECTIVE: To study the change of heat shock protein (HSP)70 expression after exposure to occupational microwave in rats hippocampus, and explore the role of HSP70 in the mechanism of bio-effect of microwave irradiation. METHODS: The animal model was established by whole body exposures in 90, 5 W/cm(2) microwave irradiation field for 20 min in rats. Changes of the mRNA of hsp70 expressions in rat hippocampus at different time were studied by RT-PCR, and the protein change by Western blot. RESULTS: The mRNA and protein expression of hsp70 in rat hippocampus increased after 90 W/cm(2) and 5 W/cm(2) microwave irradiation for 20 min. The anal temperature and the value of SAR increased significantly. These changes were positively correlated with power and irradiation time of microwave. The results indicated that microwave irradiation led to HSP70 syntheses effectively. CONCLUSION: Microwave irradiation can obviously induce the thermal effect and activate HSP70, and initiate the endogens protective mechanism of central nervous system.

**Gao XF, Wang SM, Peng RY, Wang LF, Zuo HY, Gao YB, Dong Q, Dong B. [Effect of microwave radiation on primary cultured Sertoli cells.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):530-533, 2009.** [Article in Chinese]

OBJECTIVE: To explore whether microwave radiation may cause injury of primary cultured Sertoli cells. METHODS: The model of primary cultured Sertoli cells in vitro was established, which was radiated by microwave with average power density 0, 30 and 100 mW/cm(2) for five minutes. The changes of cell cycle, apoptosis and death, and intracellular Ca2+ concentration in the Sertoli cells were measured at sixth hours

through Annexin V-PI double labeling and Fluo-3-AM labeling, flow cytometry combined with laser scanning confocal microscopy after microwave exposure. RESULTS: The numbers of Sertoli cells were obviously reduced in G0-G1 and G2-M phase (62.57% +/- 3.22% and 8.25% +/- 1.75%) and increased in S phase (29.17% +/- 4.87%) compared with the control groups (79.18% +/- 0.24%, 11.17% +/- 0.50% and 9.64% +/- 0.62%) (P < 0.05 or P < 0.01), but the changes of rate of apoptosis and death and intracellular Ca2+ concentration showed no difference at 6 h after exposure to 30 mW/cm(2) microwave. There was a significant increase in the Sertoli cell counts of G0-G1 phase (87.69% +/- 1.32%), and decrese in the Sertoli cell counts of G2-M and S phase (7.41% +/- 0.60% and 4.87% +/- 0.91%) (P < 0.01). There was also a significant increase in intracellular Ca2+ concentration and rate of apoptosis and death (P < 0.05 or P < 0.01) at 6 h after exposure to 100 mW/cm(2) microwave. CONCLUSION: 100 mW/cm(2) microwave radiation may cause growth inhibition and increase of apoptosis and death in the primary cultured Sertoli cells. The increase of intracellular Ca2+ concentration is one of the injury mechanisms.

**Gapeev AB, Lakushina VS, Chemeris NK, Fesenko EE [Modulated extremely high frequency electromagnetic radiation of low intensity activates or inhibits respiratory burst in neutrophils depending on modulation frequency]. Biofizika 42(5):1125-1134, 1997.** [Article in Russian]

The influence of low-intensity modulated electromagnetic radiation of extremely high frequencies (EHF EMR) on synergistic reaction of calcium ionophore A23187 and phorbol ester PMA in activation of the respiratory burst of the peritoneal neutrophils of mice line NMRI was investigated. The production of reactive oxygen species by the neutrophils was estimated by luminol-dependent chemiluminescence technique. The cells were irradiated in the far field zone of the channel radiator for 20 min in the presence of A23187 and then were activated by PMA after switching off the irradiation. It was shown, that continuous EHF EMR (50 microW/cm2) inhibited quasi-resonantly the synergistic reaction. The maximum effect was about 25% at carrier frequency of 41.95 GHz. Modulated radiation with carrier frequency of 41.95 GHz and modulation frequency of 1 Hz activated the synergistic reaction, but at modulation frequencies of 0.1, 16 and 50 Hz inhibited one. At fixed modulation frequency of 1 Hz the nonlinear dependence of the effect on the carrier frequency was found. The synergistic reaction was activated in the frequency range of 41.95-42.05 GHz and was inhibited at the frequencies of 41.8-41.9 GHz. The effect was observed only at raised intracellular free calcium concentration and at calcium fluxes through plasma membrane. The obtained results prove the possibility of control over cell functioning by low-intensity modulated EHF EMR, presumably, manipulating by connected systems of enzyme reactions.

**Gapeev AB, Safronova VG, Chemeris NK, Fesenko EE [Modification of the activity of murine peritoneal neutrophils upon exposure to millimeter waves at close and far distances from the emitter]. Biofizika 41(1): 205-219, 1996.** [Article in Russian]

The comparison of horn, dielectric and channel antennae on their matching with various types of loads, including a biological object, is carried out. The channel antenna in contrast to dielectric and horn ones provides the uniform spatial distribution of specific absorbed rating in the frequency range used and wide-band matching with the object

both in near field and far field zones of the radiator. It is shown, that low-intensity electromagnetic radiation of extremely high frequency in near field zone of the channel radiator modifies the activity of mouse peritoneal neutrophils on a quasi-resonance manner. The interaction of electromagnetic radiation with the biological object has been revealed in the narrow-band frequencies of 41.8-42.05 GHz and consists in inhibition of luminol-dependent chemiluminescence of neutrophils activated by opsonized zymosan. It is not found any frequency dependence of the electromagnetic radiation effects in the far field zone of the radiator. The results obtained suggest, that the quasi-resonance dependence of the biological effect on the frequency of the electromagnetic radiation in the near field zone is conditioned by structure and nature of the electromagnetic radiation in this zone.

**Gapeev AB, Chemeris NK, [Modeling of the effect of modulated electromagnetic radiation on animal cells]. Biofizika 45(2):299-312, 2000.**

Frequency-dependent modifications of intracellular free calcium concentration ([Ca2+]i) in neutrophils exposures to modulated extremely high frequency electromagnetic radiation were analyzed using a special mathematical model for [Ca2+]i oscillations. The model took into account the activation of Ca2+ influx into the cell by cytosolic Ca2+ and Ca(2+)-induced Ca2+ release from intracellular stores. The calcium channels of plasma membrane were chosen as a target for the influence of harmonic signal and additive noise in the model. The model simulation showed that in response to modulating signal, the rise in [Ca2+]i, has frequency dependence and phase dependence in relation to the moment of chemical stimulation. The phase-frequency dependence of the effect was observed at a certain sequence of delivery of chemical stimulus and modulating signal to the cell. At intensities of modulating signals exceeding the threshold, a rise in [Ca2+]i, reaching a level of more than 50% of the initial level, was observed at a frequency of about 1 Hz and in the phase range of 0.3-2.5 radians. The effect was found only at high intensities of chemical stimulus. The additive noise introduced into the system modified qualitatively and quantitatively the phase-frequency characteristics of the cell response to the modulating signal. An increase in noise intensity resulted in a displacement of the average frequency of the band of rise in [Ca2+]i, and then the emergence of a set of bands with a greater Q-factors. The analysis of dynamics of the nonlinear system in terms of the stability theory showed that, as the intensity of chemical stimulus increases, the system transits by means of a series of bifurcations from regular driving to chaotic, and then to oscillations, induced by a modulating harmonic signal. The boundary of the transition of oscillations from chaotic to induced ones corresponds to a specific "threshold" of the intensity of chemical stimulus for the significant rise in [Ca2+]i in response to the modulating signal. The results of the model analysis are in good correspondence with the experimental data obtained earlier, namely, with the effects of modulated extremely high-frequency electromagnetic radiation on neutrophils, which were observed only in the presence of Ca2+ in extracellular medium and at high concentrations of calcium ionophore A23187. Thus, as the characteristic frequency of the quasi-periodic process of calcium signalling in the cell coincides with the frequency of external field, a narrow-band rise in [Ca2+]i is observed, which can result in a modification of the functional activity of the cell.

**Gapeev AB, Lushnikov KV, Shumilina IuV, Sirota NP, Sadovnikov VB, Chemeris**

**NK. [Effects of low-intensity extremely high frequency electromagnetic radiation on chromatin structure of lymphoid cells in vivo and in vitro] Radiats Biol Radioecol 43(1):87-92, 2003.** [Article in Russian]

Using a comet assay technique, it was shown for the first time that low-intensity extremely high-frequency electromagnetic radiation (EHF EMR) in vivo causes oppositely directed effects on spatial organization of chromatin in cells of lymphoid organs. In 3 hrs after single whole-body exposure of NMRI mice for 20 min at 42.0 GHz and 0.15 mW/cm2, an increase by 16% ($p < 0.03$ as compared with control) and a decrease by 16% ($p < 0.001$) in fluorescence intensity of nucleoids stained with ethidium bromide were found in thymocytes and splenocytes, respectively. The fluorescence intensity of stained nucleoids in peripheral blood leukocytes was not changed after the exposure. The exposure of cells of Raji hunan lymphoid line and peripheral blood leukocytes to the EHF EMR in vitro induced a decrease in fluorescence intensity by 23% ($p < 0.001$) and 18% ($p < 0.05$), respectively. These effects can be determined by changes in a number of physiological alkali-labile sites in DNA of exposed cells. We suggested that the effects of low-intensity EHF EMR on the immune system cells are realized with the participation of neuroendocrine and central nervous systems.

**Gapeyev AB, Kulagina TP, Aripovsky AV. Exposure of tumor-bearing mice to extremely high-frequency electromagnetic radiation modifies the composition of fatty acids in thymocytes and tumor tissue. Int J Radiat Biol. 89(8):602-610, 2013.**

Purpose: To test the participation of fatty acids (FA) in antitumor effects of extremely high-frequency electromagnetic radiation (EHF EMR), the changes in the FA composition in the thymus, liver, blood plasma, muscle tissue, and tumor tissue in mice with Ehrlich solid carcinoma exposed to EHF EMR were studied. Materials and methods: Normal and tumor-bearing mice were exposed to EHF EMR with effective parameters (42.2 GHz, 0.1 mW/cm$^2$, 20 min daily during five consecutive days beginning the first day after the inoculation of tumor cells). Fatty acid composition of various organs and tissues of mice were determined using a gas chromatography. Results: It was shown that the exposure of normal mice to EHF EMR or tumor growth significantly increased the content of monounsaturated FA (MUFA) and decreased the content of polyunsaturated FA (PUFA) in all tissues examined. Exposure of tumor-bearing mice to EHF EMR led to the recovery of FA composition in thymocytes to the state that is typical for normal animals. In other tissues of tumor-bearing mice, the exposure to EHF EMR did not induce considerable changes that would be significantly distinguished between disturbances caused by EHF EMR exposure or tumor growth separately. In tumor tissue which is characterized by elevated level of MUFA, the exposure to EHF EMR significantly decreased the summary content of MUFA and increased the summary content of PUFA. Conclusions: The recovery of the FA composition in thymocytes and the modification of the FA composition in the tumor under the influence of EHF EMR on tumor-bearing animals may have crucial importance for elucidating the mechanisms of antitumor effects of the electromagnetic radiation.

**Gapeyev AB, Aripovsky AV, Kulagina TP. Modifying Effects of Low-Intensity Extremely High-Frequency Electromagnetic Radiation on Content and Composition of Fatty Acids in Thymus of Mice Exposed to X-Rays. Int J Radiat Biol. 2014 Oct 27:1-26. [Epub ahead of print]**

Purpose: To test the involvement of fatty acids (FA) in possible protective effects of extremely high-frequency electromagnetic radiation (EHF EMR) against ionizing radiation, the effects of EHF EMR on thymus weight and its FA content and FA composition in X-irradiated mice were studied. Materials and methods: Mice were exposed to low-intensity pulse-modulated EHF EMR (42.2 GHz, 0.1 mW/cm$^2$, 20 min exposure, 1 Hz modulation) and/or X-rays at a dose of 4 Gy with different sequences of the treatments. In four-five hours, 10, 30, and 40 days after the last exposure, the thymuses were weighed; total FA content and FA composition of the thymuses were determined on days 1, 10, and 30 using a gas chromatography. Results: It was shown that after X-irradiation of mice the total FA content per mg of thymic tissue was significantly increased in 4-5 h and decreased in 10 and 30 days after the treatment. On days 30 and 40 after X-irradiation, the thymus weight remained significantly reduced. First and tenth days after X-rays injury independently of the presence and sequence of EHF EMR exposure were characterized by an increased content of polyunsaturated FA (PUFA) and a decreased content of monounsaturated FA (MUFA) with unchanged content of saturated FA (SFA). Exposure of mice to EHF EMR before or after X-irradiation prevented changes in the total FA content in thymic tissue, returned the summary content of PUFA and MUFA to the control level and decreased the summary content of SFA on the 30$^{th}$ day after the treatments, and promoted the restoration of the thymus weight of X-irradiated mice to 40$^{th}$ day of the observations. Conclusions: Changes in the content and composition of PUFA in the early period after treatments as well as at the restoration of the thymus weight under the combined action of EHF EMR and X-rays indicate to an active participation of FA in the acceleration of post-radiation recovery of the thymus by EHF EMR exposure.

**Garaj-Vrhovac V, Horvat D, Koren Z, The effect of microwave radiation on the cell genome. Mutat Res 243(2):87-93, 1990.**

Cultured V79 Chinese hamster cells were exposed to continuous radiation, frequency 7.7 GHz, power density 30 mW/cm2 for 15, 30, and 60 min. The parameters investigated were the incorporation of [3H]thymidine and the frequency of chromosome aberrations. Data obtained by 2 methods (the incorporation of [3H]thymidine into DNA and autoradiography) showed that the inhibition of [3H]thymidine incorporation took place by complete prevention of DNA from entering into the S phase. The normal rate of incorporation of [3H]thymidine was recovered within 1 generation cycle of V79 cells. Mutagenic tests performed concurrently showed that even DNA macromolecules were involved in the process. In comparison with the control samples there was a higher frequency of specific chromosome lesions in cells that had been irradiated. Results discussed in this study suggest that microwave radiation causes changes in the synthesis as well as in the structure of DNA molecules.

**Garaj-Vrhovac V, Horvat D, Koren Z, The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese**

**hamster cells exposed to microwave radiation. Mutat Res 263(3):143-149, 1991.**

Cultured V79 Chinese hamster fibroblast cells were exposed to continuous radiation, frequency 7.7 GHz, power density 0.5 mW/cm2 for 15, 30 and 60 min. The effect of microwave radiation on cell survival and on the incidence and frequency of micronuclei and structural chromosome aberrations was investigated. The decrease in the number of irradiated V79 cell colonies was related to the power density applied and to the time of exposure. In comparison with the control samples there was a significantly higher frequency of specific chromosome aberrations such as dicentric and ring chromosomes in irradiated cells. The presence of micronuclei in irradiated cells confirmed the changes that had occurred in chromosome structure. These results suggest that microwave radiation can induce damage in the structure of chromosomal DNA.

**Garaj-Vrhovac V, Fucic A, Horvat D, The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwave radiation in vitro. Mutat Res 281(3):181-186, 1992.**

Human whole-blood samples were exposed to continuous microwave radiation, frequency 7.7 GHz, power density 0.5, 10 and 30 mW/cm2 for 10, 30 and 60 min. A correlation between specific chromosomal aberrations and the incidence of micronuclei after in vitro exposure was observed. In all experimental conditions, the frequency of all types of chromosomal aberrations was significantly higher than in the control samples. In the irradiated samples the presence of dicentric and ring chromosomes was established. The incidence of micronuclei was also higher in the exposed samples. The results of the structural chromosome aberration test and of the micronucleus test were comparatively analyzed. The values obtained showed a positive correlation between micronuclei and specific chromosomal aberrations (acentric fragments and dicentric chromosomes). The results of the study indicate that microwave radiation causes changes in the genome of somatic human cells and that the applied tests are equally sensitive for the detection of the genotoxicity of microwaves.

**Garaj-Vrhovac, V, Micronucleus assay and lymphocyte mitotic activity in risk assessment of occupational exposure to microwave radiation. Chemosphere;39(13):2301-2312, 1999.**

The effects of radiofrequency electromagnetic radiation (RFR) on the cell kinetics and genome damages in peripheral blood lymphocytes were determined in lymphocytes of 12 subjects occupationally exposed to microwave radiation. Results showed an increase in frequency of micronuclei (MN) as well as disturbances in the distribution of cells over the first, second and third mitotic division in exposed subjects compared to controls. According to previous reports micronucleus assay can serve as a suitable indicator for the assessment of exposure to genotoxic agents (such as RFR) and the analysis of mitotic activity as an additional parameter for the efficient biomonitoring.

**Garaj-Vrhovac V, Gajski G, Pažanin S, Sarolić A, Domijan AM, Flajs D, Peraica M. Assessment of cytogenetic damage and oxidative stress in personnel occupationally exposed to the pulsed microwave radiation of marine radar equipment. Int J Hyg Environ Health. 4(1):59-65, 2011.**

Due to increased usage of microwave radiation, there are concerns of its adverse effect in today's society. Keeping this in view, study was aimed at workers occupationally exposed to pulsed microwave radiation, originating from marine radars. Electromagnetic field strength was measured at assigned marine radar frequencies (3 GHz, 5.5 GHz and 9.4 GHz) and corresponding specific absorption rate values were determined. Parameters of the comet assay and micronucleus test were studied both in the exposed workers and in corresponding unexposed subjects. Differences between mean tail intensity (0.67 vs. 1.22) and moment (0.08 vs. 0.16) as comet assay parameters and micronucleus test parameters (micronuclei, nucleoplasmic bridges and nuclear buds) were statistically significant between the two examined groups, suggesting that cytogenetic alterations occurred after microwave exposure. Concentrations of glutathione and malondialdehyde were measured spectrophotometrically and using high performance liquid chromatography. The glutathione concentration in exposed group was significantly lower than in controls (1.24 vs. 0.53) whereas the concentration of malondialdehyde was significantly higher (1.74 vs. 3.17), indicating oxidative stress. Results suggests that pulsed microwaves from working environment can be the cause of genetic and cell alterations and that oxidative stress can be one of the possible mechanisms of DNA and cell damage.

**Garcia Callejo FJ, Garcia Callejo F, Pena Santamaria J, Alonso Castaneira I, Sebastian Gil E, Marco Algarra J. [Hearing level and intensive use of mobile phones] Acta Otorrinolaringol Esp. 56(5):187-191, 2005.** [Article in Spanish]

INTRODUCTION: Wide studies and substantial controversies build on utilization of actual mobile phones and appearance of systemic disorders or even tumours, but there is no knowledge about an eventual involvement on early hearing loss. PATIENTS AND METHODS: In a group of three hundred and twenty-three healthy and normoacoustic volunteers who were usual costumers of mobile phones an audiometric evaluation was made at the beginnig of its use and three years later, inquiring about the periods of time per day and year employed on direct contacts with phone. A healthy and normoacoustic control group of non users was studied too. RESULTS: Cases carried out 24.3 +/- 8.2 active contacts, reaching 50.4 +/- 27.8 days of mobile phone employment in three years. Audiometric curve was similar in cases and controls at the beginning of the study. After this follow-up, cases showed an increase on hearing threshold between 1 and 5 dB HL more than controls in speech tones ($p<0.001$). Moreover, there was a trend to correlate time of phone use to hearing impairment, but this finding did not result statistically significative. CONCLUSIONS: Frequent management of mobile phones in a middle period of time allows to detect a mild hearing loss, but the cause of this disorder keeps unclear.

**Garson OM, McRobert TL, Campbell LJ, Hocking BA, Gordon I. A chromosomal study of workers with long-term exposure to radio-frequency radiation. Med J Aust 155(5):289-292, 1991.**

OBJECTIVE: To examine whether an increased level of chromosome damage occurs in the stimulated lymphocytes of radio-linemen after long-term but intermittent exposure to radio-frequency radiation (RFR) during the course of their work. DESIGN AND

PARTICIPANTS: Chromosome studies were performed on blood samples from 38 radio-linemen matched by age with 38 controls, all of whom were employed by Telecom Australia. The radio-linemen had all worked with RFR in the range 400 kHz-20 GHz with exposures at or below the Australian occupational limits, and the controls were members of the clerical staff who had no exposure to RFR. Two hundred metaphases from each subject were studied and chromosome damage was scored by an observer who was blind to the status of the subjects. RESULTS: The ratio of the rate of aberrant cells in the radio-linemen group to that in the control group was 1.0 (95% confidence interval, 0.8-1.3). There were no statistically significant differences in the types of aberrations that were scored. CONCLUSION: Exposure to RFR at or below the described limits did not appear to cause any increase in chromosomal damage in circulating lymphocytes.

**Gasmelseed A. Electromagnetic energy absorption patterns in subjects with common visual disorders. Electromagn Biol Med. 30(3):136-145, 2011.**

This article describes the analysis of electromagnetic energy absorption properties of models of the human eye with common visual disorders. The investigation addresses two types of visual disorders, namely hyperopia (or farsightedness) and myopia (or nearsightedness). Calculations were carried out using plane multilayered method with common wireless communication frequencies of 900, 1800, and 2450 MHz. The effect of wireless radiation on the eye is studied by calculation of the specific absorption rate (SAR) in three different eye models. The results of the simulations confirmed the anticipated and more complex relationship between absorption and structural variations of the eye at these frequencies.

**Gasmelseed A, Yunus J. The effects of metamaterial on electromagnetic fields absorption characteristics of human eye tissues. Prog Biophys Mol Biol. 2013 Nov 13. pii: S0079-6107(13)00113-2. doi: 10.1016/j. pbiomolbio.2013.10.004. [Epub ahead of print]**

The interaction of a dipole antenna with a human eye model in the presence of a metamaterial is investigated in this paper. The finite difference time domain (FDTD) method with convolutional perfectly matched layer (CPML) formulation have been used. A three-dimensional anatomical model of the human eye with resolution of 1.25 mm × 1.25 mm × 1.25 mm was used in this study. The dipole antenna was driven by modulated Gaussian pulse and the numerical study is performed with dipole operating at 900 MHz. The analysis has been done by varying the size and value of electric permittivity of the metamaterial. By normalizing the peak SAR (1 g and 10 g) to 1 W for all examined cases, we observed how the SAR values are not affected by the different permittivity values with the size of the metamaterial kept fixed.

**Gatta L, Pinto R, Ubaldi V, Pace L, Galloni P, Lovisolo GA, Marino C, Pioli C. Effects of In Vivo Exposure to GSM-Modulated 900 MHz Radiation on Mouse Peripheral Lymphocytes. Radiat Res. 160(5):600-605, 2003.**

The aim of this study was to evaluate whether daily whole-body exposure to 900 MHz

GSM-modulated radiation could affect spleen lymphocytes. C57BL/6 mice were exposed 2 h/day for 1, 2 or 4 weeks in a TEM cell to an SAR of 1 or 2 W/kg. Untreated and sham-exposed groups were also examined. At the end of the exposure, mice were killed humanely and spleen cells were collected. The number of spleen cells, the percentages of B and T cells, and the distribution of T-cell subpopulations (CD4 and CD8) were not altered by the exposure. T and B cells were also stimulated ex vivo using specific monoclonal antibodies or LPS to induce cell proliferation, cytokine production and expression of activation markers. The results did not show relevant differences in either T or B lymphocytes from mice exposed to an SAR of 1 or 2 W/kg and sham-exposed mice with few exceptions. After 1 week of exposure to 1 or 2 W/kg, an increase in IFN-gamma (Ifng) production was observed that was not evident when the exposure was prolonged to 2 or 4 weeks. This suggests that the immune system might have adapted to RF radiation as it does with other stressing agents. All together, our in vivo data indicate that the T- and B-cell compartments were not substantially affected by exposure to RF radiation and that a clinically relevant effect of RF radiation on the immune system is unlikely to occur.

**Geletyuk VI, Kazachenko VN, Chemeris NK, Fesenko EE, Dual effects of microwaves on single Ca(2+)-activated K+ channels in cultured kidney cells Vero. FEBS Lett 359(1):85-88, 1995.**

Using the patch voltage-clamp method, possible effects of millimetre microwaves (42.25 GHz) on single Ca(2+)-activated K+ channels in cultured kidney cells (Vero) were investigated. It was found that exposure to the field of non-thermal power (about 100 microW/cm2) for 20-30 min greatly modifies both the Hill coefficient and an apparent affinity of the channels for Ca2+(i). The data suggest that the field alters both cooperativity and binding characteristics of the channel activation by internal Ca2+. The effects depend on initial sensitivity of the channels to Ca2+ and the Ca2+ concentration applied.

**Geller L, Thuroczy G, Merkely B. Orv Hetil 142(36):1963-1970, 2001.** [Article in Hungarian]

Electromagnetic compatibility (EMC) of cellular phones and pacemakers (PM) was examined in four different cellular phone system (NMT, GSM, RLL, DCS 1800 MHz) and in fifteen different PM type in-vitro and in-vivo in humans. After more than 1100 in-vitro and 130 in-vivo tests we concluded, that the electromagnetic immunity of the PMs which are implanted in Hungary is suitable with only few exceptions. The highest rate of EMC problems was observed with NMT 450 MHz cellular phones (10.5%-63%). There was no EMC disturbance observed with GSM and DCS 1800 MHz cellular phones. There was only one case when clinically significant symptom was noticed with only one PM type and with NMT system cellular phone when the distance of cellular phone was 3-4 cms, and the power was maximal. There was not any EMC disturbance observed with none of the cellular phone systems during normal talking and when the distance of the PM and cellular phone was more than 20 cms. Our study supports guidelines which suggest that PM patients should contact their physicians when using cellular phones and cellular phones and PMs should not get closer than 20 cms.

**George DF, Bilek MM, McKenzie DR.Non-thermal effects in the microwave induced unfolding of proteins observed by chaperone binding. Bioelectromagnetics 29(4):324-330, 2008.**

We study the effect of microwaves at 2,450 MHz on protein unfolding using surface plasmon resonance sensing. Our experimental method makes use of the fact that unfolding proteins tend to bind to chaperones on their unfolding pathway and this attachment is readily monitored by surface plasmon resonance. We use the protein citrate synthase (CS) for this study as it shows strong binding to the chaperone alpha crystallin when stressed by exposure to excess temperature. The results of microwave heating are compared with the effect of ambient heating and a combination of ambient and microwave heating to the same final temperature. We study the temperature distributions during the heating process. We show that microwaves cause a significantly higher degree of unfolding than conventional thermal stress for protein solutions heated to the same maximum temperature.

**Gerner C, Haudek V, Schandl U, Bayer E, Gundacker N, Hutter HP, Mosgoeller W. Increased protein synthesis by cells exposed to a 1,800-MHz radio-frequency mobile phone electromagnetic field, detected by proteome profiling. Int Arch Occup Environ Health.83(6):691-702, 2010.**

PURPOSE: To investigate whether or not low intensity radio frequency electromagnetic field exposure (RF-EME) associated with mobile phone use can affect human cells, we used a sensitive proteome analysis method to study changes in protein synthesis in cultured human cells. METHODS: Four different cell kinds were exposed to 2 W/kg specific absorption rate in medium containing (35)S-methionine/cysteine, and autoradiography of 2D gel spots was used to measure the increased synthesis of individual proteins. RESULTS: While short-term RF-EME did not significantly alter the proteome, an 8-h exposure caused a significant increase in protein synthesis in Jurkat T-cells and human fibroblasts, and to a lesser extent in activated primary human mononuclear cells. Quiescent (metabolically inactive) mononuclear cells, did not detectably respond to RF-EME. Since RF exposure induced a temperature increase of less than 0.15 degrees C, we suggest that the observed cellular response is a so called "athermal" effect of RF-EME. CONCLUSION: Our finding of an association between metabolic activity and the observed cellular reaction to low intensity RF-EME may reconcile conflicting results of previous studies. We further postulate that the observed increased protein synthesis reflects an increased rate of protein turnover stemming from protein folding problems caused by the interference of radio-frequency electromagnetic fields with hydrogen bonds. Our observations do not directly imply a health risk. However, vis-a-vis a synopsis of reports on cells stress and DNA breaks, after short and longer exposure, on active and inactive cells, our findings may contribute to the re-evaluation of previous reports.

**Geronikolou S, Zimeras S, Davos CH, Michalopoulos I, Tsitomeneas S. Diverse Radiofrequency Sensitivity and Radiofrequency Effects of Mobile or Cordless Phone near Fields Exposure in Drosophila melanogaster. PLoS One. 2014 Nov 17;9(11):e112139. doi: 10.1371/journal.pone.0112139. eCollection 2014.**

**INTRODUCTION:** The impact of electromagnetic fields on health is of increasing scientific interest. The aim of this study was to examine how the Drosophila melanogaster animal model is affected when exposed to portable or mobile phone fields.

**METHODS/RESULTS:** Two experiments have been designed and performed in the same laboratory conditions. Insect cultures were exposed to the near field of a 2G mobile phone (the GSM 2G networks support and complement in parallel the 3G wide band or in other words the transmission of information via voice signals is served by the 2G technology in both mobile phones generations) and a 1880 MHz cordless phone both digitally modulated by human voice. Comparison with advanced statistics of the egg laying of the second generation exposed and non-exposed cultures showed limited statistical significance for the cordless phone exposed culture and statistical significance for the 900 MHz exposed insects. We calculated by physics, simulated and illustrated in three dimensional figures the calculated near fields of radiation inside the experimenting vials and their difference. Comparison of the power of the two fields showed that the difference between them becomes null when the experimental cylinder radius and the height of the antenna increase. **CONCLUSIONS/SIGNIFICANCE:** Our results suggest a possible radiofrequency sensitivity difference in insects which may be due to the distance from the antenna or to unexplored intimate factors. Comparing the near fields of the two frequencies bands, we see similar not identical geometry in length and height from the antenna and that lower frequencies tend to drive to increased radiofrequency effects.

**Geronikolou SA, Chamakou A, Mantzou A, Chrousos G, KanakaGantenbein C. Frequent cellular phone use modifies hypothalamic-pituitary-adrenal axis response to a cellular phone call after mental stress in healthy children and adolescents: A pilot study. Sci Total Environ. 536:182-188, 2015.**

OBJECTIVE: The hypothalamic-pituitary-adrenal (HPA) axis is the main "gate-keeper" of the organism's response to every somatic or mental stress. This prospective study aims to investigate the HPA-axis response to a cellular phone call exposure after mental stress in healthy children and adolescents and to assess the possible predictive role of baseline endocrine markers to this response. SUBJECTS AND METHODS: Two groups of healthy school-age children aged 11-14 (12.5±1.5) years were included in the study, the one comprising those who are occasional users of a cellular phone (Group A; n=16)) while the second those who do regularly use one (Group B; n=12). Blood samples were obtained from all participants at 8.00am after a 12-hour overnight fasting for thyroid hormone, glucose, insulin, and cortisol levels determination. The participants performed the Trier Social Stress Test for Children (TSST-C) (5 min oral task followed by 5min arithmetic task). Salivary cortisol samples were obtained at baseline, 10 and 20 min after the TSST-C and 10 and 20 min after a 5-minute cellular phone call. RESULTS: Significant changes in the salivary cortisol levels were noted between 10 and 20 mins after the cellular phone call with different responses between the two groups. Baseline thyroid hormone levels seem to predict the cortisol response to mental stress mainly in group A, while HOMA (homostasis model assessment) had no impact on salivary cortisol response at any phase of the test, in either group.
CONCLUSIONS: HPA axis response to cellular phone after mental stress in children and adolescents follow a different pattern in frequent users than in occasional users that seems to be influenced by the baseline thyroid hormone levels.

**Gevrek F. Histopathological, immunohistochemical, and stereological analysis of the effect of Gingko biloba (Egb761) on the hippocampus of rats exposed to long-term cellphone radiation. Histol Histopathol. 2017 Nov 9:11943.**

Cellular phones are major sources of electromagnetic radiation (EMR) that can penetrate the human body and pose serious health hazards. The increasingly widespread use of mobile communication systems has raised concerns about the effects of cellphone radiofrequency (RF) on the hippocampus because of its close proximity to radiation during cellphone use. The effects of cellphone EMR exposure on the hippocampus of rats and the possible counteractive effects of ginkgo biloba (Egb761) were aimed to investigate. Rats were divided into three groups: Control, EMR, and EMR+Egb761. The EMR and EMR+Egb761 groups were exposed to cellphone EMR for one month. Egb761 was also administered to the EMR+Egb761 group. Specifically, we evaluated the effect of RF exposure on rat hippocampi at harmful EMR levels (0.96 W/kg specific absorption rate [SAR]) for one month and also investigated the possible impact of ginkgo biloba (Egb761) using stereological, TUNEL-staining, and immunohistochemical methods. An increase in apoptotic proteins (Bax, Acas-3) and a decrease in anti-apoptotic protein (Bcl-2) immunoreactivity along with a decrease in the total granule and pyramidal cell count were noted in the EMR group. A decrease in Bax and Acas-3 and an increase in Bcl-2 immunoreactivity were observed in rats treated with Egb761 in addition to a decrease in TUNEL-stained apoptotic cells and a higher total viable cell number. In conclusion, chronic cellphone EMR exposure may affect hippocampal cell viability, and Egb761 may be used to mitigate some of the deleterious effects.

**Ghanbari M, Mortazavi SB, Khavanin A, Khazaei M. The Effects of Cell Phone Waves (900 MHz-GSM Band) on Sperm Parameters and Total Antioxidant Capacity in Rats. Int J Fertil Steril. 7(1):21-28, 2013.**

BACKGROUND: There is tremendous concern regarding the possible adverse effects of cell phone microwaves. Contradictory results, however, have been reported for the effects of these waves on the body. In the present study, the effect of cell phone microwaves on sperm parameters and total antioxidant capacity was investigated with regard to the duration of exposure and the frequency of these waves. MATERIALS AND METHODS: This experimental study was performed on 28 adult male Wistar rats (200-250 g). The animals were randomly assigned to four groups (n=7): i. control; ii. two-week exposure to cell phone-simulated waves; iii. three-week exposure to cell phonesimulated waves; and iv. two-week exposure to cell phone antenna waves. In all groups, sperm analysis was performed based on standard methods and we determined the mean sperm total antioxidant capacity according to the ferric reducing ability of plasma (FRAP) method. Data were analyzed by one-way ANOVA followed by Tukey's test using SPSS version 16 software. RESULTS: The results indicated that sperm viability, motility, and total antioxidant capacity in all exposure groups decreased significantly compared to the control group ($p<0.05$). Increasing the duration of exposure from 2 to 3 weeks caused a statistically significant decrease in sperm viability and motility ($p<0.05$). CONCLUSION: Exposure to cell phone waves can decrease sperm viability and motility in rats. These waves can also decrease sperm total antioxidant capacity in rats and result in oxidative stress.

**Ghanmi A, Varsier N, Hadjem A, Conil E, Picon O, Wiart J. Analysis of the influence of handset phone position on RF exposure of brain tissue. Bioelectromagnetics. 34(8):568-579, 2014.**

Exposure to mobile phone radio frequency (RF) electromagnetic fields depends on many different parameters. For epidemiological studies investigating the risk of brain cancer linked to RF exposure from mobile phones, it is of great interest to characterize brain tissue exposure and to know which parameters this exposure is sensitive to. One such parameter is the position of the phone during communication. In this article, we analyze the influence of the phone position on the brain exposure by comparing the specific absorption rate (SAR) induced in the head by two different mobile phone models operating in Global System for Mobile Communications (GSM) frequency bands. To achieve this objective, 80 different phone positions were chosen using an experiment based on the Latin hypercube sampling (LHS) to select a representative set of positions. The averaged SAR over 10 g ($SAR_{10g}$) in the head, the averaged SAR over 1 g ($SAR_{1g}$) in the brain, and the averaged SAR in different anatomical brain structures were estimated at 900 and 1800 MHz for the 80 positions. The results illustrate that SAR distributions inside the brain area are sensitive to the position of the mobile phone relative to the head. The results also show that for 5-10% of the studied positions the $SAR_{10g}$ in the head and the $SAR_{1g}$ in the brain can be 20% higher than the SAR estimated for the standard cheek position and that the Specific Anthropomorphic Mannequin (SAM) model is conservative for 95% of all the studied positions.

**Ghatei N, Nabavi AS, Toosi MHB, Azimian H, Homayoun M, Targhi RG, Haghir H. Evaluation of bax, bcl-2, p21 and p53 genes expression variations on cerebellum of BALB/c mice before and after birth under** mobile phone **radiation exposure. Iran J Basic Med Sci. 20(9):1037-1043, 2017.**

OBJECTIVES: The increasing rate of over using **cell phones** has been considerable in youths and pregnant women. We examined the effect of **mobile phones** radiation on genes expression variation on cerebellum of BALB/c mice before and after of the birth. MATERIALS AND METHODS: In this study, a **mobile phone** jammer, which is an instrument to prevent receiving signals between cellular **phones** and base transceiver stations (two frequencies 900 and 1800 MHz) for exposure was used and twelve pregnant mice (BALB/c) divided into two groups (n=6), first group irradiated in pregnancy period (19th day), the second group did not irradiate in pregnancy period. After childbirth, offspring were classified into four groups (n=4): Group1: control, Group 2: B1 (Irradiated after birth), Group 3: B2 (Irradiated in pregnancy period and after birth), Group 4: B3 (Irradiated in pregnancy period). When maturity was completed (8-10 weeks old), mice were dissected and cerebellum was isolated. The expression level of *bax*, bcl-2, p21 and *p53* genes examined by real-time reverse transcription polymerase chain reaction (Real-Time RT- PCR). RESULTS: The data showed that **mobile phone** radio waves were ineffective on the expression level of bcl-2 and p53 genes) $P>0.05$(. Also gene expression level of *bax* decreased and gene expression level of *p21* increased comparing to the control group ($P<0.05$). CONCLUSION: From the obtained data it could be concluded that the **mobile phone**

radiations did not induce apoptosis in cells of the cerebellum and the injured cells can be repaired by **cell** cycle arrest.

**Ghazizadeh V, Nazıroğlu M. Electromagnetic radiation (Wi-Fi) and epilepsy induce calcium entry and apoptosis through activation of TRPV1 channel in hippocampus and dorsal root ganglion of rats. Metab Brain Dis. 29(3):787-799, 2014.**

Incidence rates of epilepsy and use of Wi-Fi worldwide have been increasing. TRPV1 is a $Ca^{2+}$ permeable and non-selective channel, gated by noxious heat, oxidative stress and capsaicin (CAP). The hyperthermia and oxidant effects of Wi-Fi may induce apoptosis and $Ca^{2+}$ entry through activation of TRPV1 channel in epilepsy. Therefore, we tested the effects of Wi-Fi (2.45 GHz) exposure on $Ca^{2+}$ influx, oxidative stress and apoptosis through TRPV1 channel in the murine dorsal root ganglion (DRG) and hippocampus of pentylentetrazol (PTZ)-induced epileptic rats. Rats in the present study were divided into two groups as controls and PTZ. The PTZ groups were divided into two subgroups namely PTZ + Wi-Fi and PTZ + Wi-Fi + capsazepine (CPZ). The hippocampal and DRG neurons were freshly isolated from the rats. The DRG and hippocampus in PTZ + Wi-Fi and PTZ + Wi-Fi + CPZ groups were exposed to Wi-Fi for 1 hour before CAP stimulation. The cytosolic free $Ca^{2+}$, reactive oxygen species production, apoptosis, mitochondrial membrane depolarization, caspase-3 and -9 values in hippocampus were higher in the PTZ group than in the control although cell viability values decreased. The Wi-Fi exposure induced additional effects on the cytosolic $Ca^{2+}$ increase. However, pretreatment of the neurons with CPZ, results in a protection against epilepsy-induced $Ca^{2+}$ influx, apoptosis and oxidative damages. In results of whole cell patch-clamp experiments, treatment of DRG with $Ca^{2+}$ channel antagonists [thapsigargin, verapamil + diltiazem, 2-APB, MK-801] indicated that Wi-Fi exposure induced $Ca^{2+}$ influx via the TRPV1 channels. In conclusion, epilepsy and Wi-Fi in our experimental model is involved in $Ca^{2+}$ influx and oxidative stress-induced hippocampal and DRG death through activation of TRPV1 channels, and negative modulation of this channel activity by CPZ pretreatment may account for the neuroprotective activity against oxidative stress.

**Ghosn R, Thuróczy G, Loos N, Brenet-Dufour V, Liabeuf S, de Seze R, Selmaoui B. Effects of GSM 900 MHz on Middle Cerebral Artery Blood Flow Assessed by Transcranial Doppler Sonography.Radiat Res. 178(6):543-550, 2012.**

Mobile phone use has increased worldwide but its possible effects on the brain remain unclear. The aim of the present study was to investigate the effect of acute exposure to a radio frequency electromagnetic field (RF EMF) generated by a mobile phone operating in the Global System for Mobile Communication (GSM) 900 MHz on cerebral blood flow. Twenty-nine volunteers attended two experimental sessions: a sham exposure session and a real exposure session in a cross-over double-blind study in which a mobile phone was positioned on the left side of the head. In one session, the mobile phone was operated without RF radiation (sham phone) and in the other study it was operated with RF radiation (real phone) for 20 min. Thus, each subject served as its own control. Middle cerebral artery blood flow was monitored noninvasively by transcranial Doppler sonography to measure middle cerebral artery blood flow velocity. Pulsatility index and

resistance index were also evaluated. A voluntary breath holding physiological test was carried out as a positive control for testing cerebral vasoreactivity. Hemodynamic variables were recorded and analyzed before, during and after mobile phone exposure. No significant changes were detected in studied variables in middle cerebral arteries during sham or real exposure. In the exposed side the cerebral blood flow velocity, the pulsatility index and the resistance index during sham and real exposure were respectively: [61.9 ± 1.3, 61.7 ± 1.3 cm/s (P = 0.89)]; [0.93 ± 0.03, 0.90 ± 0.02 (P = 0.84)] and [0.58 ± 0.01, 0.58 ± 0.01 (P = 0.96)] at baseline; and [60.6 ± 1.3, 62 ± 1.6 cm/s (P = 0.40)]; [0.91 ± 0.03, 0.87 ± 0.03 (P = 0.97)]; [0.57 ± 0.01, 0.56 ± 0.01 (P = 0.82)] after 20 min of exposure. Twenty minutes of RF exposure to a mobile phone does not seem to affect the cerebral circulation.

**Ghosn R, Yahia-Cherif L, Hugueville L, Ducorps A, Lemarechal JD, Thuroczy G, de Seze R, Selmaoui B. Radiofrequency signal affects alpha band in resting electroencephalogram. J Neurophysiol. 2015 Feb 18:jn.00765.2014. doi: 10.1152/jn.00765.2014. [Epub ahead of print]**

Objective: The aim of the present work was to investigate the effects of the radiofrequency (RF) electromagnetic fields (EMFs) on human resting EEG with a control of some parameters that are known to affect alpha band such as electrode impedance, salivary cortisol and caffeine. Methods: Eyes open and eyes-closed resting EEG data were recorded in 26 healthy young subjects under two conditions: sham exposure and real exposure in double-blind, counterbalanced, crossover design. Spectral power of EEG rhythms was calculated for the alpha band (8-12Hz). Saliva samples were collected before and after the study. Salivary cortisol and caffeine were assessed respectively by Enzyme linked immunosorbent assay (ELISA) and high performance liquid chromatography (HPLC). The electrode impedance was recorded at the beginning of each run. Results: Compared with sham session, the exposure session showed a statistically significant ($p < 0.0001$) decrease of the alpha band spectral power during closed eyes condition. This effect persisted in the post-exposure session ($p < 0.0001$). No significant changes were detected in electrode impedance, salivary cortisol and caffeine in the sham session when compared to the exposure one. Conclusions: These results suggest that GSM-EMFs of a mobile phone affect alpha band within spectral power of resting human EEG.

**Gkonis F, Boursianis A, Samaras T. Electromagnetic Field Exposure Changes Due to the Digital Television Switchover in Thessaloniki, Greece. Health Phys. 2017 Nov;113(5):382-386.**

In the present work, the changes in the exposure to electromagnetic fields due to television signals incurred by the digital switchover in Thessaloniki, Greece, are investigated. It is shown that the measured electric fields comply with ICNIRP guidelines but are higher than those in the reported literature for other countries. However, this may be attributed to the selection of measurement points. Moreover, it is shown that the median value of the power density dropped from 60 μW m during analog broadcasting to

13.3 µW m for digital television. This finding indicates that the digital switchover has resulted in reduced exposure for the population to radiofrequency fields in the UHF range.

**Gläser K, Rohland M, Kleine-Ostmann T, Schrader T, Stopper H, Hintzsche H. Effect of Radiofrequency Radiation on Human Hematopoietic Stem Cells. Radiat Res. 186(5):455-465, 2016.**

Exposure to electromagnetic fields in the radiofrequency range is ubiquitous, mainly due to the worldwide use of mobile communication devices. With improving technologies and affordability, the number of cell phone subscriptions continues to increase. Therefore, the potential effect on biological systems at low-intensity radiation levels is of great interest. While a number of studies have been performed to investigate this issue, there has been no consensus reached based on the results. The goal of this study was to elucidate the extent to which cells of the hematopoietic system, particularly human hematopoietic stem cells (HSC), were affected by mobile phone radiation. We irradiated HSC and HL-60 cells at frequencies used in the major technologies, GSM (900 MHz), UMTS (1,950 MHz) and LTE (2,535 MHz) for a short period (4 h) and a long period (20 h/66 h), and with five different intensities ranging from 0 to 4 W/kg specific absorption rate (SAR). Studied end points included apoptosis, oxidative stress, cell cycle, DNA damage and DNA repair. In all but one of these end points, we detected no clear effect of mobile phone radiation; the only alteration was found when quantifying DNA damage. Exposure of HSC to the GSM modulation for 4 h caused a small but statistically significant decrease in DNA damage compared to sham exposure. To our knowledge, this is the first published study in which putative effects (e.g., genotoxicity or influence on apoptosis rate) of radiofrequency radiation were investigated in HSC. Radiofrequency electromagnetic fields did not affect cells of the hematopoietic system, in particular HSC, under the given experimental conditions.

**Glenister H, How do mobile phones affect electromedical devices? Nurs Times 94(15):44-45, 1998.**

Mobile telephones and other electronic communication devices can interfere with medical equipment when used in close proximity. A study of different devices by the Medical Devices Agency showed that emergency services' radio handsets were the most likely to cause interference. It recommends that cell telephones be switched off in theatres and treatment areas and at a patients' bedsides where sensitive medical devices are in use.

**Gobba F. [Subjective non-specific symptoms related with electromagnetic fields: description of 2 cases].Epidemiol Prev. 26(4):171-175, 2002.** [Article in Italian]

In Italy, as in other countries, an apparently increasing number of subjects is reporting a variety of subjective symptoms that the subjects themselves refer to the exposure to electric, magnetic or electromagnetic fields (EMF) from nearby electric appliances, cellular phones, antennas, etc. Terms like electricity hypersensitivity (EHS), EMF hypersensitivity, or other similar, are frequently adopted to describe such symptoms;

nevertheless, up to now, these terms are not entered the medical terminology. No accepted diagnostic criteria or procedures for the diagnosis of EHS are currently available. Furthermore, apart from the subject's self-attribution of the symptoms to EMFs, no direct cause-effect relationship between EHS symptoms and electromagnetic fields has been proved; additionally, evidence of a possible pathogenetic mechanism is lacking. In this paper, two cases developing symptoms of EHS ascribed to overhead power line in the proximity of their house are discussed. Nervous system (asthenia, depression, paraesthesias etc.), cardiovascular system (cardiac palpitations) and the skin (tingling, itching, etc.), are mostly (but not exclusively) involved. Based on available scientific knowledge, the rationale for an approach to subjects claiming for EHS is discussed. The establishment of a National archive for the collection of cases is needed.

**Golden C, Golden CJ, Schneider B. Cell phone use and visual attention. Percept Mot Skills. 97(2):385-389, 2003.**

The purpose of the present study was to evaluate how much cell phones and just speaking (similar to speaking to someone in the car vs a hands-free cell phone task) interfere with visual attention skills as might be required in a driving situation. Influence of cell phones on attention has been noted but little research has been completed. Licensed adult drivers were divided into three groups (ns = 15) with all subjects taking the Connors Continuous Performance Test II. Group 1 performed without any distractions: those in Group 2 performed with someone in the same room talking to them: Group 3 engaged in a cell phone conversation during the task. Overall, there were substantial differences among groups on all variables, but primarily between the control group and the two experimental groups. While the cell phone group had lower mean scores than the talking group overall, the differences were not significant. Thus, while cell phones were distracting to visual attention functions on the Connors task, they were not more distracting than a similarly active conversation without a cell phone.

**Goldoni J, Hematological changes in peripheral blood of workers occupationally exposed to microwave radiation. Health Physics 58:205-207, 1990.**

In a group of 14 men occupationally exposed to microwaves, hematological examinations were performed at an interval of 2 years. The exposed group consisted of male radar technicians working in air traffic control. They were exposed to pulsed microwaves of various frequencies within the whole range used in radar operations for 7-14 years. Controls were 10 male electronic technicians working at the airport, but far from any sources of microwave radiation. The results of hematological examinations at a 2-year interval in the exposed group show a significant decrease in thrombocyte and leukocyte counts. The number of leukocytes and erythrocytes in the peripheral blood was significantly lower in the exposed than in the control group. There was no significant difference in reticulocyte and lymphocyte counts.

**Goldoni J, Durek M, Koren Z, Health status of personnel occupationally exposed to radiowaves. Arh Hig Rada Toksikol 44(3):223-228, 1993.**

The findings of medical examinations performed in two groups of persons occupationally exposed to microwaves and radiofrequency radiation are presented in comparison with control findings. A group of 49 radar operators from the Zagreb Air Traffic Control was

examined twice within a period of 18 months. The other group comprised 46 workers employed in radio relay stations. The control group were 46 workers from the Zagreb Airport. A follow-up study showed significant changes in haematological and biochemical parameters, in electrical brain activity and in capillaroscopic and ophthalmological findings in the group of radar operators within the followed period. For that group a cross-sectional study of the differences in general health status also showed the highest rate of changes. The results indicate that long-term occupational exposure to microwaves and radiofrequencies may damage sensitive organic systems.

**Goldwein O, Aframian DJ. The influence of handheld mobile phones on human parotid gland secretion. Oral Dis.16(2):146-150, 2010.**

Abstract. BACKGROUND: Handheld mobile phones (MPHs) have become a 'cultural' accessory device, no less so than a wrist watch. Nevertheless, the use of MPHs has given rise to great concern because of possible adverse health effects from exposure to the radiofrequency radiation (RFR) emitted by the device. Previous studies suggested correlation between MPH and salivary gland tumors. OBJECTIVE: To evaluate whether MPH induces physiologic changes in the adjacent parotid gland, located on the dominant side, in terms of secretion rates and protein levels in the secreted saliva. MATERIALS AND METHOD: Stimulated parotid saliva was collected simultaneously from both glands in 50 healthy volunteers whose MPH use was on a dominant side of the head. RESULTS: A significantly higher saliva secretion rate was noticed in the dominant MPH side compared with that in the non-dominant side. Lower total protein concentration was obtained in the dominant compared with the non-dominant MPH side among the right dominant MPH users. CONCLUSIONS: Parotid glands adjacent to handheld MPH in use respond by elevated salivary rates and decreased protein secretion reflecting the continuous insult to the glands. This phenomenon should be revealed to the worldwide population and further exploration by means of large-scale longitudinal studies is warranted.

**Gökçek-Saraç Ç, Er H, Kencebay Manas C, Kantar Gok D, Özen Ş, Derin N. Effects of acute and chronic exposure to both** 900 **MHz and 2100 MHz electromagnetic radiation on glutamate receptor signaling pathway. Int J Radiat Biol. 93(9):980-989, 2017.**

PURPOSE: To demonstrate the molecular effects of acute and chronic exposure to both **900** and 2100 MHz radiofrequency electromagnetic radiation (RF-EMR) on the hippocampal level/activity of some of the enzymes - including PKA, CaMKIIα, CREB, and p44/42 MAPK - from N-methyl-D-aspartate receptor (NMDAR)-related signaling pathways.MATERIALS AND METHODS: Rats were divided into the following groups: sham rats, and rats exposed to **900** and 2100 MHz RF-EMR for 2 h/day for acute (1 week) or chronic (10 weeks), respectively. Western blotting and activity measurement assays were used to assess the level/activity of the selected enzymes.RESULTS: The obtained results revealed that the hippocampal level/activity of selected enzymes was significantly higher in the chronic groups as compared to the acute groups at both **900** and 2100 MHz RF-EMR exposure. In addition, hippocampal level/activity of selected enzymes was significantly higher at 2100 MHz RF-EMR than **900** MHz RF-EMR in both

acute and chronic groups.CONCLUSIONS: The present study provides experimental evidence that both exposure duration (1 week versus 10 weeks) and different carrier frequencies (**900** vs. 2100 MHz) had different effects on the protein expression of hippocampus in Wistar rats, which might encourage further research on protection against RF-EMR exposure.

## Gómez-Perretta C, Navarro EA, Segura J, Portolés M. Subjective symptoms related to GSM radiation from mobile phone base stations: a cross-sectional study. BMJ Open. 3(12):e003836, 2013. doi: 10.1136/bmjopen-2013-003836.

OBJECTIVES: We performed a re-analysis of the data from Navarro et al (2003) in which health symptoms related to microwave exposure from mobile phone base stations (BSs) were explored, including data obtained in a retrospective inquiry about fear of exposure from BSs. DESIGN: Cross-sectional study. SETTING: La Ñora (Murcia), Spain. PARTICIPANTS: Participants with known illness in 2003 were subsequently disregarded: 88 participants instead of 101 (in 2003) were analysed. Since weather circumstances can influence exposure, we restricted data to measurements made under similar weather conditions. OUTCOMES AND METHODS: A statistical method indifferent to the assumption of normality was employed: namely, binary logistic regression for modelling a binary response (eg, suffering fatigue (1) or not (0)), and so exposure was introduced as a predictor variable. This analysis was carried out on a regular basis and bootstrapping (95% percentile method) was used to provide more accurate CIs. RESULTS: The symptoms most related to exposure were lack of appetite (OR=1.58, 95% CI 1.23 to 2.03); lack of concentration (OR=1.54, 95% CI 1.25 to 1.89); irritability (OR=1.51, 95% CI 1.23 to 1.85); and trouble sleeping (OR=1.49, 95% CI 1.20 to 1.84). Changes in -2 log likelihood showed similar results. Concerns about the BSs were strongly related with trouble sleeping (OR =3.12, 95% CI 1.10 to 8.86). The exposure variable remained statistically significant in the multivariate analysis. The bootstrapped values were similar to asymptotic CIs. CONCLUSIONS: This study confirms our preliminary results. We observed that the incidence of most of the symptoms was related to exposure levels-independently of the demographic variables and some possible risk factors. Concerns about adverse effects from exposure, despite being strongly related with sleep disturbances, do not influence the direct association between exposure and sleep.

### Gorlitz BD, Muller M, Ebert S, Hecker H, Kuster N, Dasenbrock C. Effects of 1-week and 6-week exposure to GSM/DCS radiofrequency radiation on micronucleus formation in B6C3F1 Mice. Radiat Res. 164(4):431-439, 2005.

The aim of this study was to examine the possible induction of micronuclei in erythrocytes of the peripheral blood and bone marrow and in keratinocytes and spleen lymphocytes of mice exposed to radiofrequency (RF) radiation for 2 h per day over periods of 1 and 6 weeks, respectively. The applied signal simulated the exposure from GSM900 and DCS1800 handsets, including the low-frequency amplitude-modulation components as they occur during speaking (GSM Basic), listening (DTX) and moving within the environment (handovers, power control). The carrier frequency was set to the center of

the system's uplink band, i.e., 902 MHz for GSM and 1747 MHz for DCS. Uniform whole-body exposure was achieved by restraining the mice in tubes at fixed positions in the exposure setup. Mice were exposed to slot-averaged whole-body SARs of 33.2, 11.0, 3.7 and 0 mW/g during the 1-week study and 24.9, 8.3, 2.8 and 0 mW/g during the 6-week study. Exposure levels for the 1- and 6-week studies were determined in a pretest to confirm that no thermal effect was present that could influence the genotoxic end points. During both experiments and for both frequencies, no clinical abnormalities were detected in the animals. Cells of the bone marrow from the femur (1-week study), erythrocytes of the peripheral blood (6-week study), keratinocytes from the tail root, and lymphocytes from the spleen (both studies) were isolated on slides and stained for micronucleus analysis. Two thousand cells per animal were scored in erythrocyte and keratinocyte samples. In spleen lymphocytes, 1000 binucleated lymphocytes were scored for each animal. The RF-field exposure had no influence on the formation of red blood cells. After 1 week of exposure, the ratio of polychromatic to normochromatic erythrocytes was unchanged in the treated groups compared to the sham-exposed groups. Furthermore, the RF-field exposure of mice did not induce an increase in the number of micronuclei in erythrocytes of the bone marrow or peripheral blood, in keratinocytes, or in spleen lymphocytes compared to the sham-treated control.

**Gorpinchenko I, Nikitin O, Banyra O, Shulyak A. The influence of direct mobile phone radiation on sperm quality. Cent European J Urol. 67(1):65-71, 2014.**

**INTRODUCTION:** It is impossible to imagine a modern socially-active man who does not use mobile devices and/or computers with Wi-Fi function. The effect of mobile phone radiation on male fertility is the subject of recent interest and investigations. The aim of this study was to investigate the direct in vitro influence of mobile phone radiation on sperm DNA fragmentation and motility parameters in healthy subjects with normozoospermia. **MATERIAL AND METHODS:** 32 healthy men with normal semen parameters were selected for the study. Each sperm sample was divided into two equal portions (A and B). Portions A of all involved men were placed for 5 hours in a thermostat, and portions B were placed into a second thermostat for the same period of time, where a mobile phone in standby/talk mode was placed. After 5 hours of incubation the sperm samples from both thermostats were re-evaluated regarding basic motility parameters. The presence of DNA fragmentation in both A and B portions of each sample was determined each hour using a standard sperm chromatin dispersion test. **RESULTS:** The number of spermatozoa with progressive movement in the group, influenced by electromagnetic radiation, is statistically lower than the number of spermatozoa with progressive movement in the group under no effect of the mobile phone. The number of non-progressive movement spermatozoa was significantly higher in the group, which was influenced by cell phone radiation. The DNA fragmentation was also significantly higher in this group. **CONCLUSIONS:** A correlation exists between mobile phone radiation exposure, DNA-fragmentation level and decreased sperm motility.

**Gos, P, Eicher, B, Kohli, J, Heyer, WD, Extremely high frequency electromagnetic fields at low power density do not affect the division of exponential phase Saccharomyces cerevisiae cells. Bioelectromagnetics 18(2):142-155, 1997.**

Exponentially growing cells of the yeast Saccharomyces cerevisiae were exposed to

electromagnetic fields in the frequency range from 41.682 GHz to 41.710 GHz in 2 MHz increments at low power densities (0.5 microW/cm2 and 50 microW/cm2) to observe possible nonthermal effects on the division of this microorganism. The electronic setup was carefully designed and tested to allow precise determination and stability of the electromagnetic field parameters as well as to minimize possible effects of external sources. Two identical test chambers were constructed in one exposure system to perform concurrent control and test experiments at every frequency step under well-controlled exposure conditions. Division of cells was assessed via time-lapse photography. Control experiments showed that the cells were dividing at submaximal rates, ensuring the possibility of observing either an increase or a decrease of the division rate. The data from several independent series of exposure experiments and from control experiments show no consistently significant differences (between) exposed and unexposed cells. This is in contrast to previous studies claiming nonthermal effects of electromagnetic fields in this frequency range on the division of S. cerevisiae cells. Possible reasons for this difference are discussed.

**Gos P, Eicher B, Kohli J, Heyer WD, No mutagenic or recombinogenic effects of mobile phone fields at 900 MHz detected in the yeast saccharomyces cerevisiae. Bioelectromagnetics 21(7):515-523, 2000.**

Both actively growing and resting cells of the yeast Saccharomyces cerevisiae were exposed to 900-MHz fields that closely matched the Global System for Mobile Communication (GSM) pulsed modulation format signals for mobile phones at specific absorption rates (SAR) of 0.13 and 1.3 W/kg. Two identical anechoic test chambers were constructed to perform concurrent control and test experiments under well-controlled exposure conditions. Using specific test strains, we examined the genotoxic potential of mobile phone fields, alone and in combination, with a known genotoxic compound, the alkylating agent methyl methansulfonate. Mutation rates were monitored by two test systems, a widely used gene-specific forward mutation assay at CAN1 and a wide-range assay measuring the induction of respiration-deficient (petite) clones that have lost their mitochondrial function. In addition, two further assays measured the recombinogenic effect of mobile phone fields to detect possible effects on genomic stability: First, an intrachromosomal, deletion-formation assay previously developed for genotoxic screening; and second, an intragenic recombination assay in the ADE2 gene. Fluctuation tests failed to detect any significant effect of mobile phone fields on forward mutation rates at CAN1, on the frequency of petite formation, on rates of intrachromosomal deletion formation, or on rates of intragenic recombination in the absence or presence of the genotoxic agent methyl methansulfonate.

**Goswami PC, Albee LD, Parsian AJ, Baty JD, Moros EG, Pickard WF, Roti Roti JL, Hunt CR, Proto-oncogene mRNA levels and activities of multiple transcription factors in C3H 10T 1/2 murine embryonic fibroblasts exposed to 835.62 and 847.74 MHz cellular phone communication frequency radiation. Radiat Res 151(3):300-309, 1999.**

This study was designed to determine whether two differently modulated radiofrequencies of the type generally used in cellular phone communications could elicit a general stress response in a biological system. The two modulations and frequencies

studied were a frequency-modulated continuous wave (FMCW) with a carrier frequency of 835.62 MHz and a code division multiple-access (CDMA) modulation centered on 847.74 MHz. Changes in proto-oncogene expression, determined by measuring Fos, Jun, and Myc mRNA levels as well as by the DNA-binding activity of the AP1, AP2 and NF-kappaB transcription factors, were used as indicators of a general stress response. The effect of radiofrequency exposure on proto-oncogene expression was assessed (1) in exponentially growing C3H 10T 1/2 mouse embryo fibroblasts during their transition to plateau phase and (2) during transition of serum-deprived cells to the proliferation cycle after serum stimulation. Exposure of serum-deprived cells to 835.62 MHz FMCW or 847.74 MHz CDMA microwaves (at an average specific absorption rate, SAR, of 0.6 W/kg) did not significantly change the kinetics of proto-oncogene expression after serum stimulation. Similarly, these exposures did not affect either the Jun and Myc mRNA levels or the DNA-binding activity of AP1, AP2 and NF-kappaB in exponential cells during transit to plateau-phase growth. Therefore, these results suggest that the radiofrequency exposure is unlikely to elicit a general stress response in cells of this cell line under these conditions. However, statistically significant increases (approximately 2-fold, P = 0.001) in Fos mRNA levels were detected in exponential cells in transit to the plateau phase and in plateau-phase cells exposed to 835.62MHz FMCW microwaves. For 847.74 MHz CDMA exposure, the increase was 1.4-fold (P = 0.04). This increase in Fos expression suggests that expression of specificgenes could be affected by radiofrequency exposure.

**Grafström G, Nittby H, Brun A, Malmgren L, Persson BR, Salford LG, Eberhardt J. Histopathological examinations of rat brains after long-term exposure to GSM-900 mobile phone radiation. Brain Res Bull.77(5):257-263, 2008.**

In order to mimic the real life situation, with often life-long exposure to the electromagnetic fields emitted by mobile phones, we have investigated in a rat model the effects of repeated exposures under a long period to Global System for Mobile Communication-900MHz (GSM-900) radiation. Out of a total of 56 rats, 32 were exposed once weekly in a 2-h period, for totally 55 weeks, at different average whole-body specific absorption rates (SAR) (of in average 0.6 and 60mW/kg at the initiation of the experimental period). The animals were exposed in a transverse electromagnetic transmission line chamber (TEM-cell) to radiation emitted by a GSM-900 test phone. Sixteen animals were sham exposed and eight animals were cage controls, which never left the animal house. After behavioural tests, 5-7 weeks after the last exposure, the brains were evaluated for histopathological alterations such as albumin extravasation, dark neurons, lipofuscin aggregation and signs of cytoskeletal and neuritic neuronal changes of the type seen in human ageing. In this study, no significant alteration of any these histopathological parameters was found, when comparing the GSM exposed animals to the sham exposed controls.

**Graham JM Jr, Jones KL, Brent RL, Contribution of clinical teratologists and geneticists to the evaluation of the etiology of congenital malformations alleged to be caused by environmental agents: ionizing radiation, electromagnetic fields, microwaves, radionuclides, and ultrasound. Teratology 59(4):307-313, 1999.**

Analysis of these six clinical problems demonstrates the value of a complete clinical

evaluation of a child with congenital malformations by an experienced and well-trained physician who is familiar with the fields of developmental biology, teratology , epidemiology, and genetics. Too often, the entire emphasis is placed on epidemiological data that may be meager or insufficient for a rational conclusion when clinical findings that are readily available can provide definitive answers with regard to the etiology of a child's malformations or the merits of an environmental etiology.

**Grajewski B, Cox C, Schrader SM, Murray WE, Edwards RM, Turner TW, Smith JM, Shekar SS, Evenson DP, Simon SD, Conover DL, Semen quality and hormone levels among radiofrequency heater operators. J Occup Environ Med42(10):993-1005, 2000.**

Approximately 9,000,000 US workers are occupationally exposed to radiogrequency (RF) radiation; over 250,000 operate RF dielectric heaters. Our purpose was to determine whether male RF heater operators experience increased adverse reproductive effects reflected in reduced semen quality or altered hormone levels. We measured incident RF heater radiation exposures and RF-induced foot currents at four companies. For 12 male heater operators and a comparison group of 34 RF-unexposed men, we measured 33 parameters of semen quality and four serum hormones. Despite wide variation in individual exposure levels, near field strengths and induced foot currents did not exceed current standard levels and guidelines. We observed minor semen quality and hormonal differences between the groups, including a slightly higher mean follicle-stimulating hormone level for exposed operators (7.6 vs 5.8 mIU/mL). Further occupational studies of RF-exposed men may be warranted.

**Gramowski-Voß A, Schwertle HJ, Pielka AM, Schultz L, Steder A, Jügelt K, Axmann J, Pries W5. Enhancement of Cortical Network Activity in vitro and Promotion of GABAergic Neurogenesis by Stimulation with an Electromagnetic Field with a 150 MHz Carrier Wave Pulsed with an Alternating 10 and 16 Hz Modulation. Front Neurol. 2015 Jul 14;6:158. doi: 10.3389/fneur.2015.00158. eCollection 2015.**

In recent years, various stimuli were identified capable of enhancing neurogenesis, a process which is dysfunctional in the senescent brain and in neurodegenerative and certain neuropsychiatric diseases. Applications of electromagnetic fields to brain tissue have been shown to affect cellular properties and their importance for therapies in medicine is recognized. In this study, differentiating murine cortical networks on multiwell microelectrode arrays were repeatedly exposed to an extremely low-electromagnetic field (ELEMF) with alternating 10 and 16 Hz frequencies piggy backed onto a 150 MHz carrier frequency. The ELEMF exposure stimulated the electrical network activity and intensified the structure of bursts. Further, the exposure to electromagnetic fields within the first 28 days in vitro of the differentiation of the network activity induced also reorganization within the burst structure. This effect was already most pronounced at 14 days in vitro after 10 days of exposure. Overall, the development of cortical activity under these conditions was accelerated. These functional electrophysiological changes were accompanied by morphological ones. The percentage of neurons in the neuron glia co-culture was increased without affecting the total number of cells, indicating an

enhancement of neurogenesis. The ELEMF exposure selectively promoted the proliferation of a particular population of neurons, evidenced by the increased proportion of GABAergic neurons. The results support the initial hypothesis that this kind of ELEMF stimulation could be a treatment option for specific indications with promising potential for CNS applications, especially for degenerative diseases, such as Alzheimer's disease and other dementias.

**Grant FH, Schlegel RE, Effects of an increased air gap on the in vitro interaction of wireless phones with cardiac pacemakers. Bioelectromagnetics 21(7):485-490, 2000.**

Several clinical and laboratory studies have demonstrated electromagnetic interaction between implantable cardiac pacemakers and hand-held wireless phones operated in close proximity. Current FDA and HIMA labeling guidelines indicate that a minimum separation of 6 in (15 cm) should be maintained between a hand-held wireless phone and an implanted pacemaker. This separation requirement does not distinguish between lateral locations on the chest and a perpendicular air gap. Evidence is provided here for a substantially reduced separation threshold when measured across an air gap rather than near the saline conductive media of a simulated torso. Twenty pacemaker-phone combinations involving 6 pacemakers and 9 phones were evaluated in vitro under worst-case conditions with respect to phone output power and pacemaker sensitivity. The phones represented CDMA, TDMA-11 Hz, TDMA-22 Hz, TDMA-50 Hz, and TDMA-217 Hz digital wireless technologies. Small increases in the perpendicular air gap between the phone and the saline surface resulted in a dramatic reduction in interaction. Approximately half of the 208 test runs exhibiting interaction at an air gap of 1 cm no longer resulted in interaction when the gap was increased to 2 cm. At a gap of 7.4 cm, the percentage of runs with interaction decreased to 1.4%. The overall interaction rate, considering a total of 8296 test runs from an earlier study, was less than 0.07% at a total perpendicular distance of 8.6 cm from the saline surface to the phone antenna axis. The perpendicular distance threshold of 8.6 cm was significantly less than the horizontal plane projection threshold of 19 cm previously reported. This difference is a function of the electromagnetic field coupling to the saline bath rather than field strength changes along the axis of the phone antenna. The results have implications for those making recommendations to pacemaker patients who may be unaware of this distinction.

**Grant H, Heirman D, Kuriger G, Ravindran MM. In vitro study of the electromagnetic interaction between wireless phones and an implantable neural stimulator. Bioelectromagnetics. 25(5):356-361, 2004.**

Several clinical and laboratory studies have demonstrated electromagnetic interaction between implantable medical devices like pacemakers and cell phones being operated in close proximity. Those devices are largely now immune to phone interaction or procedures have been established to limit their interaction. The use of cell phones near people with implanted neural stimulators has not been studied. This research was initiated to investigate electromagnetic interaction between current cell phone technology and specific models of Cyberonics neural stimulators. Out of 1080 test runs conducted for this study, no interactions were observed, and it was concluded that the phone

technologies examined in this study did not adversely affect the Cyberonics NeuroStar (Model 102) NeuroCybernetic Prosthesis (NCP) System. This article provides details on the experimental procedure that was used, which can also be used to test other neural stimulators and test technologies, and the results obtained.

**Grayson JK, Radiation exposure, socioeconomic status, and brain tumor risk in the US Air Force: a nested case-control study. Am J Epidemiol 143(5):480-486, 1996.**

A nested case-control study was used to investigate the relation between a range of electromagnetic field exposures and brain tumor risk in the US Air Force. Cumulative extremely low frequency and radiofrequency/microwave electromagnetic field potential exposures were estimated from a job-exposure matrix developed for this study. Ionizing radiation exposures were obtained from personal dosimetry records. Men who were exposed to nonionizing electromagnetic fields had a small excess risk for developing brain tumors, with the extremely low frequency and radiofrequency/microwave age-race-senior military rank-adjusted odds ratios being 1.28 (95% confidence interval (Cl) 0.95-1.74) and 1.39 (95% Cl 1.01-1.90), respectively. By contrast, men who were exposed to ionizing radiation had an age-race-senior military rank-adjusted odds ratio of 0.58 (95% Cl 0.22-1.52). These results support a small association between extremely low frequency and radiofrequency/microwave electromagnetic field exposure and no association between ionizing radiation exposure and brain tumors in the US Air Force population. Military rank was consistently associated with brain tumor risk. Officers were more likely than enlisted men to develop brain tumors (age-race-adjusted odds ratio (OR) = 2.11, 95% Cl 1.48-3.01), and senior officers were at increased risk compared with all other US Air Force members (age-race-adjusted OR = 3.30, 95% Cl 1.99-5.45).

**Green AC, Scott IR, Gwyther RJ, Peyman A, Chadwick P, Chen X, Alfadhl Y, Tattersall JE. An investigation of the effects of TETRA RF fields on intracellular calcium in neurones and cardiac myocytes. Int J Radiat Biol. 81(12):869-885, 2005.**

Purpose: This study aimed to determine whether Terrestrial Trunked Radio (TETRA) fields can affect intracellular calcium signalling in excitable cells.Materials and methods: Intracellular calcium concentration ([Ca(2 +) ](i)) was measured in cultured rat cerebellar granule cells and cardiac myocytes during exposure to TETRA fields (380.8875 MHz pulse modulated at 17.6 Hz, 25% duty cycle). [Ca(2 +) ](i) was measured as fura-PE3, fluo-3 or fluo-4 fluorescence by digital image analysis.Results: Granule cells exposed at specific absorption rates (SARs) of 5, 10, 20, 50 or 400 mW . kg(-1) showed no significant changes in resting [Ca(2 +) ](i). Increases in [Ca(2 +) ](i) in response to potassium-induced depolarization were significantly different from sham controls in TETRA-exposed cells, but the majority of the difference was attributable to initial biological variation between cell cultures. No difference was found between fura-PE3 (UV excitation) and fluo-3 (visible light excitation) measurements in these cells. Exposure to TETRA (50 or 400 mW . kg(-1)) had no significant effect on either the rate or amplitude of spontaneous Ca(2 +) transients in cardiac myocytes. The cells showed normal responses to salbutamol (50 microM) and acetylcholine (10 microM).Conclusions: Overall, these results showed no evidence of any consistent or biologically relevant effect of TETRA fields on [Ca(2 + )](i) in granule cells and cardiac myocytes at any of the SAR tested.

**Grell K, Frederiksen K, Schüz J, Cardis E, Armstrong B, Siemiatycki J, Krewski DR, McBride ML, Johansen C, Auvinen A, Hours M, Blettner M, Sadetzki S, Lagorio S, Yamaguchi N, Woodward A, Tynes T, Feychting M, Fleming SJ, Swerdlow AJ, Andersen PK. The Intracranial Distribution of Gliomas in Relation to Exposure From Mobile Phones: Analyses From the INTERPHONE Study. Am J Epidemiol. 184(11):818-828, 2016.**

When investigating the association between brain tumors and use of mobile telephones, accurate data on tumor position are essential, due to the highly localized absorption of energy in the human brain from the radio-frequency fields emitted. We used a point process model to investigate this association using information that included tumor localization data from the INTERPHONE Study (Australia, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, New Zealand, Norway, Sweden, and the United Kingdom). Our main analysis included 792 regular mobile phone users diagnosed with a glioma between 2000 and 2004. Similar to earlier results, we found a statistically significant association between the intracranial distribution of gliomas and the self-reported location of the phone. When we accounted for the preferred side of the head not being exclusively used for all mobile phone calls, the results were similar. The association was independent of the cumulative call time and cumulative number of calls. However, our model used reported side of mobile phone use, which is potentially influenced by recall bias. The point process method provides an alternative to previously used epidemiologic research designs when one is including localization in the investigation of brain tumors and mobile phone use.

**Grémiaux A, Girard S, Guérin V, Lothier J, Baluška F, Davies E, Bonnet P, Vian A. Low-amplitude, high-frequency electromagnetic field exposure causes delayed and reduced growth in Rosa hybrida. J Plant Physiol. 190:44-53, 2015.**

It is now accepted that plants perceive high-frequency electromagnetic field (HF-EMF). We wondered if the HF-EMF signal is integrated further in planta as a chain of reactions leading to a modification of plant growth. We exposed whole small ligneous plants (rose bush) whose growth could be studied for several weeks. We performed exposures at two different development stages (rooted cuttings bearing an axillary bud and 5-leaf stage plants), using two high frequency (900MHz) field amplitudes (5 and 200$Vm^{-1}$). We achieved a tight control on the experimental conditions using a state-of-the-art stimulation device (Mode Stirred Reverberation Chamber) and specialized culture-chambers. After the exposure, we followed the shoot growth for over a one-month period. We observed no growth modification whatsoever exposure was performed on the 5-leaf stage plants. When the exposure was performed on the rooted cuttings, no growth modification was observed on Axis I (produced from the elongation of the axillary bud). Likewise, no significant modification was noted on Axis II produced at the base of Axis I, that came from pre-formed secondary axillary buds. In contrast, Axis II produced at the top of Axis I, that came from post-formed secondary buds consistently displayed a delayed and significant reduced growth (45%). The measurements of plant energy uptake from HF-EMF in this exposure condition (SAR of 7.2 $10^{-4}Wkg^{-1}$) indicated that this biological

response is likely not due to thermal effect. These results suggest that exposure to electromagnetic field only affected development of post-formed organs.

**Grigor'ev IuG, Stepanov VS, [Forming of memory (imprinting) in chicks after prior low-level exposure to electromagnetic fields]. Radiats Biol Radioecol 38(2):223-231, 1998.** [Article in Russian]

EMF of power density from 0.4 to 10 mW/cm2 can influence forming the memory (imprinting). Showed the possibility to fix EMF modulated in embryonic brain during the natal period and conservation of this information after birth.

**Grigor'ev IuG, [Role of modulation in biological effects of electromagnetic radiation]. Radiats Biol Radioecol 36(5):659-670, 1996.** [Article in Russian]

Data, describing a role of modulation of electromagnetic fields in development of biological effect, are considered. Outcomes of researches, indicating the dependence of a response of nervous and immune systems on a kind of modulation at low levels of effect, are represented. The necessity of the account of a role of modulation in an evaluation of electromagnetic danger is formulated.

**Grigor'ev IuG, Luk'ianova SN, Makarov VP, Rynskov VV, [Total bioelectric activity of various structures of the brain in low-intensity microwave irradiation]. Radiats Biol Radioecol 35(1):57-65, 1995.** [Article in Russian]

In experiments with thirty rabbits the influence of thirty-minute microwave irradiation (1.5 GHz, pulse intensity 0.3 mW/cm2; pulsed modes: 0.12 Hz, 16 ms or 1000 Hz, 0.4 ms; pack-pulsed mode: pulse frequency 1000 Hz, pack frequency 0.12 Hz) on the total bioelectrical activity of brain structures was studied. The reliable effect was detected only in hippocampus. The total bioelectrical activity of cortex, caudate nucleus, hypothalamus, amygdala and septum was not changed reliably in animal group studied. The reaction of hippocampus was displayed as amplification of theta-range in spectrum within of normal functioning.

**Grigor'ev IuG, Luk'ianova SN, Makarov VP, Rynskov VV, Moiseeva NV, [Motor activity of rabbits in conditions of chronic low-intensity pulse microwave irradiation]. Radiats Biol Radioecol 35(1):29-35, 1995.** [Article in Russian]

Motor activity of rabbits under daily thirty-minute irradiation (1.5 GHz, pulse duration 16 ms, pulse recurrence frequency 0.12 Hz, pulse intensity 0.3 mw/cm2) for one month was studied. From 14th day the reliable disadaptation changes such as an anxiety and alarm reaction were found. The importance of prolonged irradiation is noted.

**Grigor'ev IuG. [Biological effects of mobile phone electromagnetic field on chick embryo (risk assessment using the mortality rate)] Radiats Biol Radioecol. 43(5):541-543, 2003.** [Article in Russian]

Chicken embryos were exposed to EMF from GSM mobile phone during the embryonic development (21 days). As a result the embryo mortality rate in the incubation period increased to 75% (versus 16% in control group).

**Grigoriev YG, Grigoriev OA, Ivanov AA, Lyaginskaya AM, Merkulov AV, Shagina**

**NB, Maltsev VN, Lévêque P, Ulanova AM, Osipov VA, Shafirkin AV. Confirmation studies of Soviet research on immunological effects of microwaves: Russian immunology results. Bioelectromagnetics. 31(8):589-602, 2010.**

This paper presents the results of a replication study performed to investigate earlier Soviet studies conducted between 1974 and 1991 that showed immunological and reproductive effects of long-term low-level exposure of rats to radiofrequency (RF) electromagnetic fields. The early studies were used, in part, for developing exposure standards for the USSR population and thus it was necessary to confirm the Russian findings. In the present study, the conditions of RF exposure were made as similar as possible to those in the earlier experiments: Wistar rats were exposed in the far field to 2450 MHz continuous wave RF fields with an incident power density in the cages of 5 W/m² for 7 h/day, 5 days/week for a total of 30 days, resulting in a whole-body SAR of 0.16 W/kg. Effects of the exposure on immunological parameters in the brain and liver of rats were evaluated using the complement fixation test (CFT), as in the original studies, and an additional test, the more modern ELISA test. Our results, using CFT and ELISA, partly confirmed the findings of the early studies and indicated possible effects from non-thermal RF exposure on autoimmune processes. The RF exposure resulted in minor increases in formation of antibodies in brain tissue extract and the exposure did not appear to be pathological. In addition, a study was conducted to replicate a previous Soviet study on effects from the injection of blood serum from RF-exposed rats on pregnancy and foetal and offspring development of rats, using a similar animal model and protocol. Our results showed the same general trends as the earlier study, suggesting possible adverse effects of the blood serum from exposed rats on pregnancy and foetal development of intact rats, however, application of these results in developing exposure standards is limited.

**Grisanti G, Parlapiano C, Tamburello CC, Tine G, Zanforlin L. Cellular phone effects on otoacoustic emissions. IEEE MTT-S Digest 2: 771-774, 1998.**

A study on bioelectromagnetic effects induced by the use of TACS phones, evidencing a variation of the natural response of the auditory system is presented. This study was performed applying a method based on the registration of the evoked otoacosutic emissions (transient and distortion products). The experimental results show that modulated electromagnetic fields modify the distortion products in about all the examined subjects.

**Gryz K, Karpowicz J, Leszko W, Zradziński P. Evaluation of exposure to electromagnetic radiofrequency radiation in the indoor workplace accessible to the public by the use of frequency-selective exposimeters. Int J Occup Med Environ Health. 2014 Dec 18. [Epub ahead of print]**

OBJECTIVES: The aim of the study was to identify and assess electromagnetic radiofrequency radiation (EMRR) exposure in a workplace located in a publicly accessible environment, and represented by offices (where exposure is caused by various transmitters of local fixed indoor and outdoor wireless communication systems).

MATERIAL AND METHODS: The investigations were performed in 45 buildings (in urban and rural areas in various regions of Poland), using frequency-selective electric field strength (E-field) exposimeters sensitive to the EMRR with a frequency range of 88-2500 MHz, split into 12 sub-bands corresponding to the operating frequencies of typical EMRR sources. The variability of the E-field was analyzed for each frequency range and the total level of exposure by statistical parameters of recorded exposimetric profiles: minimum, maximum, median values and 25-75th - percentiles. RESULTS: The main sources of exposure to EMRR are mobile phone base transceiver stations (BTS) and radio-television transmitters (RTV). The frequency composition in a particular office depends on the building's location. The E-field recorded in buildings in urban and rural areas from the outdoor BTS did not exceed respectively: medians - 0.19 and 0.05 V/m, 75th percentiles - 0.25 and 0.09 V/m. In buildings equipped with the indoor BTS antennas the E-field did not exceed: medians - 1 V/m, 75th percentiles - 1.8 V/m. Whereas in urban and rural areas, the median and 75th percentile values of the E-field recorded in buildings located near the RTV (within 1 km) did not exceed: 1.5 and 3.8 V/m or 0.4 and 0.8 V/m, for radio FM band or for TV bands, respectively. CONCLUSIONS: Investigations confirmed the practical applicability of the exposimetric measurements technique for evaluating parameters of worker's exposure in both frequency- and time-domain. The presented results show EMRR exposure of workers or general public in locations comparable to offices to be well below international limits.

**Guberan E, Campana A, Faval P, Guberan M, Sweetnam PM, Tuyn JW, Usel M, Gender ratio of offspring and exposure to shortwave radiation among female physiotherapists. Scand J Work Environ Health 20(5):345-348, 1994.**

OBJECTIVES--The goal of this study was to investigate whether the deficit of male births found among the offspring of Danish physiotherapists exposed to shortwave radiation during the first month of their pregnancy could be confirmed among the offspring of physiotherapists from Switzerland. METHODS--A self-administrated questionnaire was mailed (two mailings) to all of the 2846 female members of the Swiss Federation of Physiotherapists. It included questions on the gender and birth-weight of all children of the physiotherapists, as well as on the use of shortwave or microwave equipment during the first month of each pregnancy. The response rate was 79.5%, and the analysis was based on 1781 pregnancies. RESULTS--The gender ratio (the number of males per number of females x 100) was 107 with a 95% confidence interval (95% CI) of 89-127 for the 508 pregnancies exposed to shortwave radiation and 101 (95% CI 90-113) for the 1273 unexposed pregnancies. There was no trend in the gender ratio with increasing intensity or duration of exposure. The prevalence of low birthweight (< or = 2500 g) was not related to exposure to shortwave radiation for either the boys or the girls. CONCLUSIONS--No atypical gender ratio was found for the children of female physiotherapists from Switzerland who had been exposed to shortwave radiation at the beginning of pregnancy. The findings of the Danish study (Larsen et al., 1991) could not be confirmed.

**Gul A, Celebi H, Uğraş S. The effects of microwave emitted by cellular phones on ovarian follicles in rats. Arch Gynecol Obstet. 280(5):729-733, 2009.**

OBJECTIVE: The aim of this study was to investigate whether there were any toxic effects of microwaves of cellular phones on ovaries in rats. METHODS: In this study, 82 female pups of rats, aged 21 days (43 in the study group and 39 in the control group) were used. Pregnant rats in the study group were exposed to mobile phones that were placed beneath the polypropylene cages during the whole period of pregnancy. The cage was free from all kinds of materials, which could affect electromagnetic fields. A mobile phone in a standby position for 11 h and 45 min was turned on to speech position for 15 min every 12 h and the battery was charged continuously. On the 21st day after the delivery, the female rat pups were killed and the right ovaries were removed. The volumes of the ovaries were measured and the number of follicles in every tenth section was counted. RESULTS: The analysis revealed that in the study group, the number of follicles was lower than that in the control group. The decreased number of follicles in pups exposed to mobile phone microwaves suggest that intrauterine exposure has toxic effects on ovaries. CONCLUSION: We suggest that the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms.

**Gulati S, Yadav A, Kumar N, Kanupriya, Aggarwal NK, Kumar R, Gupta R. Effect of GSTM1 and GSTT1 Polymorphisms on Genetic Damage in Humans Populations Exposed to Radiation From Mobile Towers. Arch Environ Contam Toxicol. 70(3):615-625, 2016.**

All over the world, people have been debating about associated health risks due to radiation from mobile phones and mobile towers. The carcinogenicity of this nonionizing radiation has been the greatest health concern associated with mobile towers exposure until recently. The objective of our study was to evaluate the genetic damage caused by radiation from mobile towers and to find an association between genetic polymorphism of GSTM1 and GSTT1 genes and DNA damage. In our study, 116 persons exposed to radiation from mobile towers and 106 control subjects were genotyped for polymorphisms in the GSTM1 and GSTT1 genes by multiplex polymerase chain reaction method. DNA damage in peripheral blood lymphocytes was determined using alkaline comet assay in terms of tail moment (TM) value and micronucleus assay in buccal cells (BMN). There was a significant increase in BMN frequency and TM value in exposed subjects (3.65 ± 2.44 and 6.63 ± 2.32) compared with control subjects (1.23 ± 0.97 and 0.26 ± 0.27). However, there was no association of GSTM1 and GSTT1 polymorphisms with the level of DNA damage in both exposed and control groups.

**Gulati S, Yadav A, Kumar N, Priya K, Aggarwal NK, Gupta R. Phenotypic and genotypic characterization of antioxidant enzyme system in human population exposed to radiation from mobile towers. Mol Cell Biochem. 2017 Aug 17. doi: 10.1007/s11010-017-3150-6. [Epub ahead of print]**

In the present era, cellular phones have changed the life style of human beings completely and have become an essential part of their lives. The number of cell phones and cell towers are increasing in spite of their disadvantages. These cell towers transmit radiation continuously without any interruption, so people living within 100s of meters from

the tower receive 10,000 to 10,000,000 times stronger signal than required for mobile communication. In the present study, we have examined superoxide dismutase (SOD) enzyme activity, catalase (CAT) enzyme activity, lipid peroxidation assay, and effect of functional polymorphism of SOD and CAT antioxidant genes against mobile tower-induced oxidative stress in human population. From our results, we have found a significantly lower mean value of manganese superoxide dismutase (MnSOD) enzyme activity, catalase (CAT) enzyme activity, and a high value of lipid peroxidation assay in exposed as compared to control subjects. Polymorphisms in antioxidant MnSOD and CAT genes significantly contributed to its phenotype. In the current study, a significant association of genetic polymorphism of antioxidant genes with genetic damage has been observed in human population exposed to radiations emitted from mobile towers.

**Guler G, Tomruk A, Ozgur E, Seyhan N. The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen Physiol Biophys. 29(1):59-66, 2010.**

The concerns of people on possible adverse health effects of radiofrequency radiation (RFR) generated from mobile phones as well as their supporting transmitters (base stations) have increased markedly. RFR effect on oversensitive people, such as pregnant women and their developing fetuses, and older people is another source of concern that should be considered. In this study, oxidative DNA damage and lipid peroxidation levels in the brain tissue of pregnant and non-pregnant New Zealand White rabbits and their newborns exposed to RFR were investigated. Thirteen-month-old rabbits were studied in four groups as non-pregnant-control, non-pregnant-RFR exposed, pregnant-control and pregnant-RFR exposed. They were exposed to RFR (1800 MHz GSM; 14 V/m as reference level) for 15 min/day during 7 days. Malondialdehyde (MDA) and 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels were analyzed. MDA and 8-OHdG levels of non-pregnant and pregnant-RFR exposed animals significantly increased with respect to controls ($p < 0.001$, Mann-Whitney test). No difference was found in the newborns ($p > 0.05$, Mann-Whitney). There exist very few experimental studies on the effects of RFR during pregnancy. It would be beneficial to increase the number of these studies in order to establish international standards for the protection of pregnant women from RFR.

**Guler G, Tomruk A, Ozgur E, Seyhan N. The effect of radiofrequency radiation on DNA and lipid damage in non-pregnant and pregnant rabbits and their newborns. Gen Physiol Biophys. 29(1):59-66, 2010.**

The concerns of people on possible adverse health effects of radiofrequency radiation (RFR) generated from mobile phones as well as their supporting transmitters (base stations) have increased markedly. RFR effect on oversensitive people, such as pregnant women and their developing fetuses, and older people is another source of concern that should be considered. In this study, oxidative DNA damage and lipid peroxidation levels in the brain tissue of pregnant and non-pregnant New Zealand White rabbits and their newborns exposed to RFR were investigated. Thirteen-month-old rabbits were studied in four groups as non-pregnant-control, non-pregnant-RFR exposed, pregnant-control and pregnant-RFR exposed. They were exposed to RFR (1800 MHz GSM; 14 V/m as

reference level) for 15 min/day during 7 days. Malondialdehyde (MDA) and 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels were analyzed. MDA and 8-OHdG levels of non-pregnant and pregnant-RFR exposed animals significantly increased with respect to controls ($p < 0.001$, Mann-Whitney test). No difference was found in the newborns ($p > 0.05$, Mann-Whitney). There exist very few experimental studies on the effects of RFR during pregnancy. It would be beneficial to increase the number of these studies in order to establish international standards for the protection of pregnant women from RFR.

**Güler G, Tomruk A, Ozgur E, Sahin D, Sepici A, Altan N, Seyhan N.**
**The effect of radiofrequency radiation on DNA and lipid damage in female and male infant rabbits. Int J Radiat Biol. 88(4):367-373, 2012.**

**PURPOSE:** We aimed to design a prolonged radiofrequency (RF) radiation exposure and investigate in an animal model, possible bio-effects of RF radiation on the ongoing developmental stages of children from conception to childhood. **MATERIALS AND METHODS:** A total of 72 New Zealand female and male white rabbits aged one month were used. Females were exposed to RF radiation for 15 min/day during 7 days, whereas males were exposed to the same level of radiation for 15 min/day during 14 days. Thirty-six female and 36 male infant rabbits were randomly divided into four groups: Group I [Intrauterine (IU) exposure (-); Extrauterine (EU) exposure (-)]: Sham exposure which means rabbits were exposed to 1800 MHz Global System for Mobile Telecommunication (GSM)-like RF signals neither in the IU nor in the EU periods. Group II [IU exposure (-); EU exposure (+)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals when they reached one month of age. Group III [IU exposure (+); EU exposure (-)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals in the IU period (between 15th and 22nd days of the gestational period). Group IV [IU exposure (+); EU exposure (+)]: Infant rabbits were exposed to 1800 MHz GSM-like RF signals both in the IU period (between 15th and 22nd days of the gestational period) and in the EU period when they reached one month of age. Biochemical analysis for lipid peroxidation and DNA damage were carried out in the livers of all rabbits. **RESULTS:** Lipid peroxidation levels in the liver tissues of female and male infant rabbits increased under RF radiation exposure. Liver 8-hydroxy-2'-deoxyguanosine (8-OHdG) levels of female rabbits exposed to RF radiation were also found to increase when compared with the levels of non-exposed infants. However, there were no changes in liver 8-OHdG levels of male rabbits under RF exposure. **CONCLUSION:** Consequently, it can be concluded that GSM-like RF radiation may induce biochemical changes by increasing free radical attacks to structural biomolecules in the rabbit as an experimental animal model.

**Gultekin DH, Moeller L. NMR imaging of cell phone radiation absorption in brain tissue. Proc Natl Acad Sci U S A. 2012 Dec 17. [Epub ahead of print]**

A method is described for measuring absorbed electromagnetic energy radiated from cell phone antennae into ex vivo brain tissue. NMR images the 3D thermal dynamics inside ex vivo bovine brain tissue and equivalent gel under exposure to power and irradiation time-varying radio frequency (RF) fields. The absorbed RF energy in brain tissue converts into Joule heat and affects the nuclear magnetic shielding and the Larmor precession.

The resultant temperature increase is measured by the resonance frequency shift of hydrogen protons in brain tissue. This proposed application of NMR thermometry offers sufficient spatial and temporal resolution to characterize the hot spots from absorbed cell phone radiation in aqueous media and biological tissues. Specific absorption rate measurements averaged over 1 mg and 10 s in the brain tissue cover the total absorption volume. Reference measurements with fiber optic temperature sensors confirm the accuracy of the NMR thermometry.

**Guney M, Ozguner F, Oral B, Karahan N, Mungan T. 900 MHz radiofrequency-induced histopathologic changes and oxidative stress in rat endometrium: protection by vitamins E and C. Toxicol Ind Health. 23(7):411-420, 2007.**

There are numerous reports on the effects of electromagnetic radiation (EMR) in various cellular systems. Mechanisms of adverse effects of EMR indicate that reactive oxygen species (ROS) may play a role in the biological effects of this radiation. The aims of this study were to examine 900 MHz mobile phone-induced oxidative stress that promotes production of ROS and to investigate the role of vitamins E and C, which have antioxidant properties, on endometrial tissue against possible 900 MHz mobile phone-induced endometrial impairment in rats. The animals were randomly grouped (eight each) as follows: 1) Control group (without stress and EMR, Group I), 2) sham-operated rats stayed without exposure to EMR (exposure device off, Group II), 3) rats exposed to 900 MHz EMR (EMR group, Group III) and 4) a 900 MHz EMR exposed + vitamin-treated group (EMR + Vit group, Group IV). A 900 MHz EMR was applied to EMR and EMR + Vit group 30 min/day, for 30 days using an experimental exposure device. Endometrial levels of nitric oxide (NO, an oxidant product) and malondialdehyde (MDA, an index of lipid peroxidation), increased in EMR exposed rats while the combined vitamins E and C caused a significant reduction in the levels of NO and MDA. Likewise, endometrial superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GSH-Px) activities decreased in EMR exposed animals while vitamins E and C caused a significant increase in the activities of these antioxidant enzymes. In the EMR group histopathologic changes in endometrium, diffuse and severe apoptosis was present in the endometrial surface epithelial and glandular cells and the stromal cells. Diffuse eosinophilic leucocyte and lymphocyte infiltration were observed in the endometrial stroma whereas the combination of vitamins E and C caused a significant decrease in these effects of EMR. It is concluded that oxidative endometrial damage plays an important role in the 900 MHz mobile phone-induced endometrial impairment and the modulation of oxidative stress with vitamins E and C reduces the 900 MHz mobile phone-induced endometrial damage both at biochemical and histological levels.

**Gupta N, Goyal D, Sharma R, Arora KS. Effect of Prolonged Use of** Mobile Phone **on Brainstem Auditory Evoked Potentials. J Clin Diagn Res. 2015 May;9(5):CC07-9.**
OBJECTIVES: Mobile phones are being widely used throughout the world. Electromagnetic waves generated from mobile phones have raised concerns as these may have adverse effects on human auditory system owing to the daily use of mobile phones. The purpose of current study was to evaluate the effects of long term mobile phone usage on auditory brainstem evoked responses (ABR). MATERIALS AND

METHODS: A retrospective, cross-sectional, case control study was carried out in a tertiary care hospital. Total 100 healthy subjects aged 18 to 30 years of both the genders were selected, out of which 67 subjects were long-term GSM mobile phone users (using mobile phone for more than 1 year) and 33 were controls who were mobile phone non users. Both the groups were investigated for ABR and changes were studied in both the ears of cases and controls to ascertain the effects of electromagnetic exposure. RESULTS: No significant difference ($p>0.05$) was found in latencies, interpeak latencies and amplitudes of ABR waves between cases and controls. CONCLUSION: Our study shows that long term usage of mobile phones does not affect propagation of electrical stimuli along the auditory nerve to auditory brainstem centres.

**Gurbuz N, Sirav B, Yuvaci HU, Turhan N, Coskun ZK, Seyhan N. Is there any possible genotoxic effect in exfoliated bladder cells of rat under the exposure of 1800 MHz GSM-like modulated radio frequency radiation (RFR)? Electromagn Biol Med. 29(3):98-104, 2010.**

People are exposed to many carcinogenic and mutagenic chemicals in their everyday lives. These include antineoplastic drugs, Polycyclic aromatic hydrocarbons (PAH)s, aromatic amines, nitrosamines, metals, and electromagnetic radiation. Based on the state of knowledge acquired during the last 50 years of research on possible biological effects of electromagnetic fields (EMF), the majority of the scientific community is convinced that exposure to EMF below the existing security limits does not cause a risk to the health of the general public. However, this position is questioned by others, who are of the opinion that the available research data are contradictory or inconsistent and, therefore, unreliable. In this study, we aimed to investigate if there is any effect of 1800 MHz GSM modulated radio frequency radiation (RFR) on the number of micronucleus in exfoliated bladder cells of rat which will be informative about the genotoxic damage. Exposure period was 20 min/day, 5 days/week during a month. Six female Wistar rats were used for two groups: Group I (n=6): controls; Group II (n=6): 1.8 GHz exposed animals. 1800 MHz RFR did not showed a significant MN frequencies in rat bladder cells when compared with the control group ($p>0.05$). 1800 MHz RFR-exposed animals did not produce any genotoxic effect when compared with the control group ( $p>0.05$). Kinetic studies are important for any biomarker, especially those in which tissue differentiation and maturation processes will heavily influence the time between induction of damage and collection of damaged cells for micronucleus analysis.

**Gurbuz N, Sirav B, Colbay M, Yetkin I, Seyhan N. No genotoxic effect in exfoliated bladder cells of rat under the exposure of 1800 and 2100-MHz radio frequency radiation. Electromagn Biol Med. 2013 Nov 27. [Epub ahead of print]**

Abstract In this study, we aimed to investigate the effects of 1800 and 2100 MHz Radio Frequency (RF) radiation on the number of micronucleus (MN) in exfoliated bladder cells of rat which shows the genotoxic damage. Exposure period was 30 min/day, 6 days/week for a month and two months exposure periods. Thirty male wistar albino rats were used for five groups: Group I (n = 6): 1800 MHz RF exposed animals for one month, Group II (n = 6): 2100 MHz RF exposed animals for one

month, Group III (n = 6): 2100 MHz RF exposed for two months, Group IV (n = 6): control group for one month, Group V (n = 6): control group for two months. Rats of the control groups were housed in their home cages during the entire experimental period without subjecting to any experimental manipulation. 1800 and 2100 MHz RF exposures did not result in any significant MN frequencies in rat bladder cells with respect to the control groups ($p > 0.05$). There was no statistically significant difference between 2100 MHz RF exposed groups, either. Further studies are needed to demonstrate if there is any genotoxic effect, micronucleus formation in other tissues of rats.

**Gurbuz N, Sirav B, Kuzay D, Ozer C, Seyhan N. Does radio frequency radiation induce micronuclei frequency in exfoliated bladder cells of diabetic rats? Endocr Regul. 49(3):126-130, 2015.**

OBJECTIVE: For many years there has been a discussion among both experts and the general public regarding the effects of radio frequency (RF) radiation on the human organism. The purpose of the present study was to evaluate the relationship of micronucleui (MN) frequency and RF radiation in exfoliated bladder cells of non-diabetic and diabetic rats. METHODS: Three groups were used in the experiment: Group I (n=6): diabetic group without RF exposure; Group II (n=6): diabetic group exposed 2100 MHz RF radiation and Group III (n=6): control animals (non-diabetic group, no RF exposure). RF exposure in the experiment resulted in a whole body average SAR of 0.24 W/kg with an ERMS field of 17.5 V/m in non-thermal levels. RESULT: Results showed that there was no statistically important differences between non-RF exposed diabetes group and control group; Group I and Group III ($p>0.05$). There was no statistically important differences between diabetes group and diabetes+RF exposed group (Group I and Group II) ($p>0.05$). RF exposure did not result in increased MN frequencies in exfoliated bladder cells of diabetic rats with respect to control animals (Group II and Group III), either and this result found no statistically important ($p>0.05$). CONCLUSIONS: This study suggested no possible genotoxic effects of RF radiation among human beings especially with chronic disorders, such as diabetes.

**Gürler HS, Bilgici B, Akar AK, Tomak L, Bedir A. Increased DNA oxidation (8-OHdG) and protein oxidation (AOPP) by Low level electromagnetic field (2.45 GHz) in rat brain and protective effect of garlic. Int J Radiat Biol. 2014 May 21:1-15. [Epub ahead of print]**

Purpose: To investigate the oxidative damage and protective effect of garlic on rats exposed to low level of electromagnetic fields (EMF) at 2.45 GHz Microwave radiation (MWR). Methods: Thirty six Wistar rats were divided into three groups. Group I was the control group and not exposed to EMF. Group II and III were exposed to low level EMF (3.68±0.36 V/m) at 2.45 GHz MWR for 1 hour/day for 30 consecutive days. Daily 500 mg/kg garlic was given to Group III during the study period. At the end of the study, thiobarbituric acid reactive substances (TBARS), advanced oxidation protein products

(AOPP) and 8-hydroxydeoxyguanosine (8-OHdG) levels were investigated in brain tissue and blood samples. Results: Exposure to low level of EMF increased 8-OHdG level in both plasma and brain tissue whereas it increased AOPP level only in plasma. Garlic prevented the increase of 8-OHdG level in brain tissue and plasma AOPP levels. Conclusions: It may be concluded that low level EMF at 2.45 GHz MWR increases the DNA damage in both brain tissues and plasma of the rats whereas it increases protein oxidation only in plasma. It may also be argued that the use of garlic decreases these effects.

**Gutschi T, Mohamad Al-Ali B, Shamloul R, Pummer K, Trummer H. Impact of cell phone use on men's semen parameters.Andrologia. 43(5):312-316, 2011.**

The objective of the present retrospective study was to report our experience concerning the effects of cell phone usage on semen parameters. We examined 2110 men attending our infertility clinic from 1993 to October 2007. Semen analysis was performed in all patients. Serum free testosterone (T), follicle stimulating hormone (FSH), luteinising hormone (LH) and prolactin (PRL) were collected from all patients. The information on cell phone use of the patients was recorded and the subjects were divided into two groups according to their cell phone use: group A: cell phone use (n = 991); group B: no use (n = 1119). Significant difference was observed in sperm morphology between the two groups. In the patients of group A, 68.0% of the spermatozoa featured a pathological morphology compared to only 58.1% in the subjects of group B. Patients with cell phone usage showed significantly higher T and lower LH levels than those who did not use cell phone. No significant difference between the two groups was observed regarding FSH and PRL values. Our results showed that cell phone use negatively affects sperm quality in men. Further studies with a careful design are needed to determine the effect of cell phone use on male fertility.

**Guxens M, van Eijsden M, Vermeulen R, Loomans E, Vrijkotte TG, Komhout H, van Strien RT, Huss A. Maternal cell phone and cordless phone use during pregnancy and behaviour problems in 5-year-old children. J Epidemiol Community Health. 2013 Feb 5. [Epub ahead of print]**

**BACKGROUND:** A previous study found an association between maternal cell phone use during pregnancy and maternal-reported child behaviour problems at age 7. Together with cell phones, cordless phones represent the main exposure source of radiofrequency-electromagnetic fields to the head. Therefore, we assessed the association between maternal cell phone and cordless phone use during pregnancy and teacher-reported and maternal-reported child behaviour problems at age 5. **METHODS:** The study was embedded in the Amsterdam Born Children and their Development study, a population-based birth cohort study in Amsterdam, the Netherlands (2003-2004). Teachers and mothers reported child behaviour problems using the Strength and Difficulties Questionnaire at age 5. Maternal cell phone and cordless phone use during pregnancy was asked when children were 7 years old. **RESULTS:** A total of 2618 children were included. As compared to non-users, those exposed to prenatal cell phone use showed an increased but non-significant association of having teacher-reported overall behaviour

problems, although without dose-response relationship with the number of calls (OR=2.12 (95% CI 0.95 to 4.74) for <1 call/day, OR=1.58 (95% CI 0.69 to 3.60) for 1-4 calls/day and OR=2.04 (95% CI 0.86 to 4.80) for ≥5 calls/day). ORs for having teacher-reported overall behaviour problems across categories of cordless phone use were below 1 or close to unity. Associations of maternal cell phone and cordless phone use with maternal-reported overall behaviour problems remained non-significant. Non-significant associations were found for the specific behaviour problem subscales. **CONCLUSION:** Our results do not suggest that maternal cell phone or cordless phone use during pregnancy increases the odds of behaviour problems in their children.

**Ha M, Lim HJ, Cho SH, Choi HD, Cho KY. Incidence of cancer in the vicinity of Korean AM radio transmitters. Arch Environ Health. 58(12):756-762, 2003.**

Results of various studies have indicated a potential association between exposures to electrical and/or magnetic fields and risks of various cancers. The authors used a cross-sectional ecological study design to investigate such a potential association. In areas proximate to 42 amplitude modulated (AM) radio transmitters, 11 high-power study sites (i.e., areas exposed to 100-1500-kW transmission power) and 31 low-power study sites (i.e., areas exposed to 50-kW transmission power) were identified. The incidence of cancer within a 2-km radius of each transmitter was obtained from (a) Korean medical-insurance data for the years 1993 through 1996, (b) population census data for the year 1995, and (c) resident registration data for the year 1995. The authors calculated age-standardized rate ratios for total cancer, leukemia, malignant lymphoma, brain cancer, and breast cancer, and compared the incidence of cancer within 2 km of the high-power transmitters vs. the incidence within 2 km of the low-power transmitters. Four control areas for each high-power transmitter were also selected. The control areas were located in the same, or nearest adjacent, province as the high-power sites, but were at least 2 km from any of the transmitters. Indirect standardized observed/expected ratios for the high-power sites vs. control areas were calculated for each transmitter separately, and for 4 transmitter groupings defined by power level (i.e., 100 kW, 250 kW, 500 kW, and 1500 kW). The authors found no significant increase in age-standardized rate ratios of cancers for high-power vs. low-power sites, with the exceptions of total cancer and of brain cancer in women. Among the 11 high-power sites, there were significantly increased incidences of leukemia in 2 areas and of brain cancer in 1 area. Future studies should incorporate additional detailed exposure assessments and a strong analytical study design to explore the possible association between radiofrequency radiation from AM radio transmitters and cancer.

**Ha M, Im H, Lee M, Kim HJ, Kim BC, Gimm YM, Pack JK. Radio-frequency radiation exposure from AM radio transmitters and childhood leukemia and brain cancer. Am J Epidemiol. 166(3):270-279, 2007.**

Leukemia and brain cancer patients under age 15 years, along with controls with respiratory illnesses who were matched to cases on age, sex, and year of diagnosis (1993-1999), were selected from 14 South Korean hospitals using the South Korean Medical Insurance Data System. Diagnoses were confirmed through the South Korean National Cancer Registry. Residential addresses were obtained from medical records. A newly developed prediction program incorporating a geographic information system that

was modified by the results of actual measurements was used to estimate radio-frequency radiation (RFR) exposure from 31 amplitude modulation (AM) radio transmitters with a power of 20 kW or more. A total of 1,928 leukemia patients, 956 brain cancer patients, and 3,082 controls were analyzed. Cancer risks were estimated using conditional logistic regression adjusted for residential area, socioeconomic status, and community population density. The odds ratio for all types of leukemia was 2.15 (95% confidence interval (CI): 1.00, 4.67) among children who resided within 2 km of the nearest AM radio transmitter as compared with those resided more than 20 km from it. For total RFR exposure from all transmitters, odds ratios for lymphocytic leukemia were 1.39 (95% CI: 1.04, 1.86) and 1.59 (95% CI: 1.19, 2.11) for children in the second and third quartiles, respectively, versus the lowest quartile. Brain cancer and infantile cancer were not associated with AM RFR.

**Haarala C, Bjornberg L, Ek M, Laine M, Revonsuo A, Koivisto M, Hamalainen H. Effect of a 902 MHz electromagnetic field emitted by mobile phones on human cognitive function: A replication study. Bioelectromagnetics 24(4):283-288, 2003.**

Our study was a replication and extension with methodological improvements to a previous study on effects of the electromagnetic field (EMF) emitted by a 902 MHz mobile phone on human cognitive functioning. Improvements on the previous study included multicentre testing and a double blind design. A total of 64 subjects (32 men and 32 women) in two independent laboratories performed a battery of 9 cognitive tasks twice: while the EMF was on and while it was off. Reaction times (RTs) and accuracy were recorded. The order of exposure and tasks was counterbalanced across subjects and gender. There were no statistically significant differences in performance between genders or laboratories. Although the RTs and the accuracy of answers were very similar to those of our previous study, our previous results were not replicated. We concluded that EMF had no effect on RTs or on the accuracy of the subjects' answers. Further, our results indicate that our EMF had no immediate effect on human cognitive functioning or that such effects are so small that they are observed on behavior only occasionally.

**Haarala C, Aalto S, Hautzel H, Julkunen L, Rinne JO, Laine M, Krause B, Hamalainen H. Effects of a 902 MHz mobile phone on cerebral blood flow in humans: a PET study. Neuroreport. 14(16):2019-2023, 2003.**

SUMMARY: Fourteen healthy right-handed subjects were scanned using PET with a [15O]water tracer during exposure to electromagnetic field (EMF) emitted by a mobile phone and a sham-exposure under double-blind conditions. During scanning, the subjects performed a visual working memory task. Exposure to an active mobile phone produced a relative decrease in regional cerebral blood flow (rCBF) bilaterally in the auditory cortex but no rCBF changes were observed in the area of maximum EMF. It is possible that these remote findings were caused by the EMF emitted by the active mobile phone. A more likely interpretation of the present findings were a result of an auditory signal from the active mobile phone. Therefore, it is not reasoned to attribute this finding to the EMF emitted by the phone. Further study on human rCBF during exposure to EMF of a mobile phone is needed.

**Haarala C, Ek M, Bjornberg L, Laine M, Revonsuo A, Koivisto M, Hamalainen H. 902 MHz mobile phone does not affect short term memory in humans.**

**Bioelectromagnetics. 25(6):452-456, 2004.**

We studied the effects of an electromagnetic field (EMF) as emitted by a 902 MHz mobile phone on human short term memory. This study was a replication with methodological improvements to our previous study. The improvements included multi-centre testing and a double blind design. A total of 64 subjects (32 men) in two independent laboratories performed a short term memory task (n-back) which poses a varying memory load (0-3 items) on the subjects' memory. They performed the task twice, once each under EMF and sham exposure. Reaction times (RTs) and accuracy of the responses were recorded. The order of exposure and memory load conditions were counterbalanced across subjects and gender. There were no statistically significant differences in performance between the two laboratories. We could not replicate our previous results: the EMF had no effect on RTs or on the accuracy of the subjects' answers. The inability to replicate previous findings could have been caused by lack of actual EMF effects or the magnitude of effects being at the sensitivity threshold of the test used.

**Haarala C, Bergman M, Laine M, Revonsuo A, Koivisto M, Hamalainen H. Electromagnetic field emitted by 902 MHz mobile phones shows no effects on children's cognitive function. Bioelectromagnetics. Suppl 7:S144-150,2005.**

The present study investigated the potential effects of a standard 902 MHz global system for mobile communication (GSM) mobile phone on 10-14 years old children's cognitive function. A total of 32 children (16 boys, 16 girls) participated with their own and parental consent. The subjects were 10-14 years old (mean 12.1 years, SD 1.1). They performed a battery of cognitive tests twice in a counter-balanced order: once while exposed to an active mobile phone and once during exposure to an inactive phone. The tests were selected from those we used earlier with adults. The statistical analyses showed no significant differences between the mobile phone off and on conditions in reaction times and accuracy over all tests or in any single test. It was concluded that a standard mobile phone has no effect on children's cognitive function as measured by response speed and accuracy. The present results challenge some earlier findings suggesting that the electromagnetic field (EMF) created by an active mobile phone would facilitate cognitive functioning.

**Haarala C, Takio F, Rintee T, Laine M, Koivisto M, Revonsuo A, Hamalainen H. Pulsed and continuous wave mobile phone exposure over left versus right hemisphere: Effects on human cognitive function. Bioelectromagnetics.28(4):289-295. 2007.**

The possible effects of continuous wave (CW) and pulse modulated (PM) electromagnetic field (EMF) on human cognition was studied in 36 healthy male subjects. They performed cognitive tasks while exposed to CW, PM, and sham EMF. The subjects performed the same tasks twice during each session; once with left-sided and once with right-sided exposure. The EMF conditions were spread across three testing sessions, each session separated by 1 week. The exposed hemisphere, EMF condition, and test order were counterbalanced over all subjects. We employed a double-blind design: both the subject and the experimenter were unaware of the EMF condition. The EMF was created with a signal generator connected via amplifier to a dummy phone antenna, creating a power output distribution similar to the original

commercial mobile phone. The EMF had either a continuous power output of 0.25 W (CW) or pulsed power output with a mean of 0.25 W. An additional control group of 16 healthy male volunteers performed the same tasks without any exposure equipment to see if mere presence of the equipment could have affected the subjects' performance. No effects were found between the different EMF conditions, separate hemisphere exposures, or between the control and experimental group. In conclusion, the current results indicate that normal mobile phones have no discernible effect on human cognitive function as measured by behavioral tests.

**Haas AJ, Le Page Y, Zhadobov M, Sauleau R, Dréan YL, Saligaut C. Effect of acute millimeter wave exposure on dopamine metabolism of NGF-treated PC12 cells. J Radiat Res. 2017 Feb 24:1-7. doi: 10.1093/jrr/rrx004.**

Several forthcoming wireless telecommunication systems will use electromagnetic frequencies at millimeter waves (MMWs), and technologies developed around the 60-GHz band will soon know a widespread distribution. Free nerve endings within the skin have been suggested to be the targets of MMW therapy which has been used in the former Soviet Union. So far, no studies have assessed the impact of MMW exposure on neuronal metabolism. Here, we investigated the effects of a 24-h MMW exposure at 60.4 GHz, with an incident power density (IPD) of 5 mW/cm², on the dopaminergic turnover of NGF-treated PC12 cells. After MMW exposure, both intracellular and extracellular contents of dopamine (DA) and 3,4-dihydroxyphenylacetic acid (DOPAC) were studied using high performance liquid chromatography. Impact of exposure on the dopamine transporter (DAT) expression was also assessed by immunocytochemistry. We analyzed the dopamine turnover by assessing the ratio of DOPAC to DA, and measuring DOPAC accumulation in the medium. Neither dopamine turnover nor DAT protein expression level were impacted by MMW exposure. However, extracellular accumulation of DOPAC was found to be slightly increased, but not significantly. This result was related to the thermal effect, and overall, no evidence of non-thermal effects of MMW exposure were observed on dopamine metabolism.

**Habauzit D, Le Quément C, Zhadobov M, Martin C, Aubry M, Sauleau R, Le Dréan Y. Transcriptome Analysis Reveals the Contribution of Thermal and the Specific Effects in Cellular Response to Millimeter Wave Exposure. PLoS One. 2014 Oct 10;9(10):e109435. doi:10.1371/journal.pone.0109435. eCollection 2014.**

Radiofrequency radiations constitute a new form of environmental pollution. Among them, millimeter waves (MMW) will be widely used in the near future for high speed communication systems. This study aimed therefore to evaluate the biocompatibility of MMW at 60 GHz. For this purpose, we used a whole gene expression approach to assess the effect of acute 60 GHz exposure on primary cultures of human keratinocytes. Controls were performed to dissociate the electromagnetic from the thermal effect of MMW. Microarray data were validated by RT-PCR, in order to ensure the reproducibility of the results. MMW exposure at 20 mW/cm2, corresponding to the maximum incident power density authorized for public use (local exposure averaged over 1 cm2), led to an increase of temperature and to a strong modification of keratinocyte gene expression

(665 genes differentially expressed). Nevertheless, when temperature is artificially maintained constant, no modification in gene expression was observed after MMW exposure. However, a heat shock control did not mimic exactly the MMW effect, suggesting a slight but specific electromagnetic effect under hyperthermia conditions (34 genes differentially expressed). By RT-PCR, we analyzed the time course of the transcriptomic response and 7 genes have been validated as differentially expressed: ADAMTS6, NOG, IL7R, FADD, JUNB, SNAI2 and HIST1H1A. Our data evidenced a specific electromagnetic effect of MMW, which is associated to the cellular response to hyperthermia. This study raises the question of co-exposures associating radiofrequencies and other environmental sources of cellular stress.

**Haghani M, Shabani M, Moazzami K. Maternal mobile phone exposure adversely affects the electrophysiological properties of Purkinje neurons in rat offspring. Neuroscience. 2013 Jul 29. pii: S0306-4522(13)00643-X. doi: 10.1016/j.neuroscience.2013.07.049. [Epub ahead of print]**

Electromagnetic field (EMF) radiations emitted from mobile phones may cause structural damage to neurons. With the increased usage of mobile phones worldwide, concerns about their possible effects on the nervous system are rising. In the present study, we aimed to elucidate the possible effects of prenatal EMF exposure on the cerebellum of offspring Wistar rats. Rats in EMF group were exposed to 900 MHz Pulse-EMF irradiation for six hours per day during all gestation period. Ten offspring's per each group were evaluated for behavioral and electrophysiological evaluations. Cerebellum - related behavioral dysfunctions were analyzed using motor learning and cerebellum-dependent functional tasks (Accelerated Rotarod, Hanging and Open field tests). Whole cell- patch clamp recordings were used for electrophysiological evaluations. The results of the present study failed to show any behavioral abnormalities in rats exposed to chronic EMF radiation. However, whole cell patch clamp recordings revealed decreased neuronal excitability of Purkinje cells in rats exposed to EMF. The most prominent changes included afterhyperpolarization amplitude, spike frequency, half width and first spike latency. In conclusion, the results of the present study show that prenatal EMF exposure results in altered electrophysiological properties of Purkinje neurons. However, these changes may not be severe enough to alter the cerebellum-dependent functional tasks.

**Hagiwara S, Iwasaka H, Takeshima N, Noguchi T. Mechanisms of analgesic action of pulsed radiofrequency on adjuvant-induced pain in the rat: roles of descending adrenergic and serotonergic systems. Eur J Pain. 13(3):249-252, 2009.**

Pulsed radiofrequency (PRF) has been reported to be effective in the treatment of several types of pain. The mechanism of action, however, is not well known. In a recent study, the antinociceptive effects of acute thermal pain were shown to be mediated via descending pain inhibitory pathways. In this study we observed an analgesic effect of PRF treatment in an adjuvant induced inflammatory pain model in rats. In this model, sciatic nerves were treated with PRF at 37 degrees and 42 degrees , which inhibited hyperalgesia in the inflammatory groups when compared to

RF and sham treatment. This effect was attenuated after intrathecal administration of the alpha2-adrenoceptor antagonist yohimbine, the selective 5-HT3 serotonin receptor antagonist MDL72222, and the non-selective serotonin receptor antagonist methysergide. All three drugs were found to significantly inhibit the analgesic effect of PRF. The results suggest that the analgesic action of PRF involves the enhancement of noradrenergic and serotonergic descending pain inhibitory pathways.

**Hagström M, Auranen J, Ekman R. Electromagnetic hypersensitive Finns: Symptoms, perceived sources and treatments, a questionnaire study. Pathophysiology. 2013 Apr 1. pii: S0928-4680(13)00002-3.**

The aim was to analyze the subjective experiences of Finns who describe themselves as suffering from electromagnetic hypersensitivity (EHS), their symptoms, self-perceived sources of the health complaints and the effectiveness of medical and complementary alternative therapies. A total of 395 questionnaires were mailed to self-diagnosed EHS persons. Of the participants 345 belonged to a Finnish self-help group and 50 came from outside of the group. The return rate of the study was 52.1% (206) and 80.9% of the respondents were women. Before the onset of EHS the most common health complaints were different types of allergies (35.1%, 68). During the acute phase of EHS the most common symptoms were nervous system related: "stress" (60.3%, 117), "sleeping disorders" (59.3%, 115) and "fatigue" (57.2%, 111). The sources that were most often reported to have triggered EHS were: "personal computers" (50.8%, 94) and "mobile phones" (47.0%, 87). The same devices were also claimed to cause the most symptoms during the acute phase. After the acute phase of EHS had passed, the respondents still claimed to react to these same digital and wireless devices while their reactions to basic electrical appliances were reduced. According to 76% of 157 respondents the reduction or avoidance of electromagnetic fields (EMF) helped in their full or partial recovery. The best treatments for EHS were given as: "dietary change" (69.4%), "nutritional supplements" (67.8%) and "increased physical exercise" (61.6%). The official treatment recommendations of psychotherapy (2.6%) and medication (-4.2%) were not significantly helpful. According to the present results the official treatment protocols should take better account the EHS person's own experiences. The avoidance of electromagnetic radiation and fields effectively removed or lessened the symptoms in EHS persons.

**Haider T, Knasmueller S, Kundi M, Haider M, Clastogenic effects of radiofrequency radiations on chromosomes of Tradescantia. Mutat Res 324(1-2):65-68, 1994.**

The clastogenicity of electromagnetic fields (EMF) has so far been studied only under laboratory conditions. We used the Tradescantia-micronucleus (Trad-MCN) bioassay in an in situ experiment to find out whether short-wave electromagnetic fields used for broadcasting (10-21 MHz) may show genotoxic effects. Plant cuttings bearing young flower buds were exposed (30 h) on both sides of a slewable curtain antenna (300/500 kW, 40-170 V/m) and 15 m (90 V/m) and 30 m (70 V/m) distant from a vertical cage antenna (100 kW) as well as at the neighbors living near the broadcasting station (200 m, 1-3 V/m). The exposure at both sides of the slewable curtain antenna was performed simultaneously within cages, one of the Faraday type shielding the field and one non-shielding mesh cage. Laboratory controls were maintained for comparison. Higher MCN

frequencies than in laboratory controls were found for all exposure sites in the immediate vicinity of the antennae, where the exposure standards of the electric field strength of the International Radiation Protection Association (IRPA) were exceeded. The results at all exposure sites except one were statistically significant. Since the parallel exposure in a non-shielding and a shielding cage also revealed significant differences in MCN frequencies (the latter showing no significant differences from laboratory controls), the clastogenic effects are clearly attributable to the short-wave radiation from the antennae.

**Halgamuge MN. Radio Hazard Safety Assessment for Marine Ship Transmitters: Measurements Using a New Data Collection Method and Comparison with ICNIRP and ARPANSA Limits. Int J Environ Res Public Health. 12(5):5338-5354, 2015.**

We investigated the levels of radio frequency electromagnetic fields (RF EMFs) emitted from marine ship transmitters. In this study, we recorded the radio frequency (RF) electric field (EF) levels emitted from transmitters from a marine vessel focusing on the areas normally occupied by crew members and passengers. Previous studies considered radiation hazard safety assessment for marine vessels with a limited number of transmitters, such as very high-frequency (VHF) transceivers, radar and communication transmitters. In our investigation, EF levels from seven radio transmitters were measured, including: VHF, medium frequency/high frequency (MF/HF), satellite communication (Sat-Com C), AISnavigation, radar X-band and radar S-band. Measurements were carried out in a 40 m-long, three-level ship (upper deck, bridge deck and bridge roof) at 12 different locations. We developed a new data-collection protocol and performed it under 11 different scenarios to observe and measure the radiation emissions from all of the transmitters. In total, 528 EF field measurements were collected and averaged over all three levels of the marine ship with RF transmitters: the measured electric fields were the lowest on the upper deck (0.82-0.86 V/m), the highest on the bridge roof (2.15-3.70 V/m) and in between on the bridge deck (0.47-1.15 V/m). The measured EF levels were then assessed for compliance with the occupational and general public reference levels of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines and the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) standards. The ICNIRP and the ARPANSA limits for the general public were exceeded on the bridge roof; nevertheless, the occupational limits were respected everywhere. The measured EF levels, hence, complied with the ICNIRP guidelines and the ARPANSA standards. In this paper, we provide a new data collection model for future surveys, which could be conducted with larger samples to verify our observations. Furthermore, this new method could be useful as a reference for researchers and industry professionals without direct access to the necessary equipment.

**Halgamuge MN. Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants. Electromagn Biol Med. 36(2):213-235, 2017.**

AIM: The aim of this article was to explore the hypothesis that non-thermal, weak, radiofrequency electromagnetic fields (RF-EMF) have an effect on living plants. SUBJECT AND METHODS: In this study, we performed an analysis of the data extracted from the 45 peer-reviewed scientific publications (1996-2016) describing 169 experimental observations to detect the physiological and morphological changes in

plants due to the non-thermal RF-EMF effects from mobile phone radiation. Twenty-nine different species of plants were considered in this work. RESULTS: Our analysis demonstrates that the data from a substantial amount of the studies on RF-EMFs from mobile phones show physiological and/or morphological effects (89.9%, $p < 0.001$). Additionally, our analysis of the results from these reported studies demonstrates that the maize, roselle, pea, fenugreek, duckweeds, tomato, onions and mungbean plants seem to be very sensitive to RF-EMFs. Our findings also suggest that plants seem to be more responsive to certain frequencies, especially the frequencies between (i) 800 and 1500 MHz ($p < 0.0001$), (ii) 1500 and 2400 MHz ($p < 0.0001$) and (iii) 3500 and 8000 MHz ($p = 0.0161$). CONCLUSION: The available literature on the effect of RF-EMFs on plants to date observed the significant trend of radiofrequency radiation influence on plants. Hence, this study provides new evidence supporting our hypothesis. Nonetheless, this endorses the need for more experiments to observe the effects of RF-EMFs, especially for the longer exposure durations, using the whole organisms. The above observation agrees with our earlier study, in that it supported that it is not a well-grounded method to characterize biological effects without considering the exposure duration. Nevertheless, none of these findings can be directly associated with human; however, on the other hand, this cannot be excluded, as it can impact the human welfare and health, either directly or indirectly, due to their complexity and varied effects (calcium metabolism, stress proteins, etc.). This study should be useful as a reference for researchers conducting epidemiological studies and the long-term experiments, using whole organisms, to observe the effects of RF-EMFs.

**Hallberg O, Johansson O. Melanoma incidence and frequency modulation (FM) broadcasting. Arch Environ Health. 57(1):32-40, 2002.**

The incidence of melanoma has been increasing steadily in many countries since 1960, but the underlying mechanism causing this increase remains elusive. The incidence of melanoma has been linked to the distance to frequency modulation (FM) broadcasting towers. In the current study, the authors sought to determine if there was also a related link on a larger scale for entire countries. Exposure-time-specific incidence was extracted from exposure and incidence data from 4 different countries, and this was compared with reported age-specific incidence of melanoma. Geographic differences in melanoma incidence were compared with the magnitude of this environmental stress. The exposure-time-specific incidence from all 4 countries became almost identical, and they were approximately equal to the reported age-specific incidence of melanoma. A correlation between melanoma incidence and the number of locally receivable FM transmitters was found. The authors concluded that melanoma is associated with exposure to FM broadcasting.

**Hallberg O, Johansson O. Long-term sickness and mobile phone use. J Aust Coll Nutr & Env med 23:11-12, 2004.**

The number of people unable to work due to long-term sickness is drastically increasing in Sweden. In this paper we take a close look at the development of mobile phone communication to see how it possibly relates to the health impairment of the Swedish population. Official data was collected regarding mobile phone use and long-term

absence from work. The co-variation between those data sets was used to estimate future development of long-term absence rates under the hypothesis that there is a connection between the two sets of data. It was concluded that future long-term absence rates will continue to increase as long as the annual number of ear-heating minute per year is increasing.

**Hallberg O. Adverse health indicators correlating with sparsely populated areas in Sweden. Eur J Cancer Prev. 16(1):71-76, 2007.**

Earlier studies on health characteristics in Sweden have pointed at a sudden trend change in general health indicators around 1997. The decline was worse in areas with less estimated coverage by the mobile phone system; that is, areas where the average output power from mobile phone handsets is expected to be higher. In this study, health parameters were related to the population density, which is a well defined, rather than an estimated variable. Statistics were obtained from different authorities in Sweden. Data were correlated to the population densities in the 21 different counties of Sweden as well as to estimates of average mobile phone output power. Several health quality measures showed that people in sparsely populated counties in Sweden (as well as in Denmark and Norway) have suffered more illness, and lengthier recovery than people in more densely populated areas since 1997. This is in strong contrast to the situation 20 years ago, when the countryside was the healthiest place in which to live. The indicators strongly correlated with estimated mobile phone area coverage and estimated power output. The indicator statistics suggest that the decline in health in Sweden is not a primary consequence of low population density by itself, but that other factors related to population density are causative. The two factors having the strongest correlation with decreased health quality were the estimated average power output from mobile phones (positive correlation) and the reported coverage from the global system for mobile communication base stations (negative correlation) in each county.

**Hamann W, Abou-Sherif S, Thompson S, Hall S. Pulsed radiofrequency applied to dorsal root ganglia causes a selective increase in ATF3 in small neurons. Eur J Pain. 10(2):171-176, 2006.**

BACKGROUND: This is a "proof of concept study" to test the hypothesis that pulsed radiofrequency, PRF, produces cell stress at the primary afferent level without signs of overt thermal damage. We assumed that cell stress would result in impairment of normal function, and used the expression of activating transcription factor 3, ATF3, as an indicator of cellular "stress". METHODS: PRF (20ms of 500-kHz RF pulses, delivered at a rate of 2Hz; maximum temperature 42 degrees C) was delivered either to the sciatic nerve of adult rats in mid thigh, or to the L4 anterior primary ramus just distal to the intervertebral foramen. Controls were sham-operated or L4 axotomised. All tissues were examined 14 days after surgery. The percentage of CGRP- or ATF3-positive DRG neuronal somata was calculated using image analysis software (SigmaScan Pro 4). RESULTS: ATF3 expression was upregulated in L4 DRG neuronal cell bodies, irrespective of their size, after axotomy. It was also upregulated significantly ($p<0.002$) and selectively, in small and medium calibre L4 DRG neurons, when PRF was applied close to the DRG just distal to the intervertebral foramen. PRF did not produce any

obvious cellular changes in the nerve or L4 DRG neurons when applied to the sciatic nerve in mid-thigh. CONCLUSION: PRF has a biological effect, unlikely to be related to overt thermal damage. It appears to be selective in that it targets the group of neurons whose axons are the small diameter C and Adelta nociceptive fibres.

**Hamblin DL, Wood AW, Croft RJ, Stough C. Examining the effects of electromagnetic fields emitted by GSM mobile phones on human event-related potentials and performance during an auditory task. Clin Neurophysiol. 115(1):171-178, 2004.**

OBJECTIVE: Due to the widespread use of mobile phones (MP), it is important to determine whether they affect human physiology. The aim of this study was to explore the sensitivity of auditory event-related potentials to electromagnetic emissions. METHODS: Twelve participants attended two sessions, 1 week apart. Participants performed an auditory oddball task while they were exposed to an active MP during one session and sham exposure during the other. Each condition lasted 1 h and order was counterbalanced. N100 and P200 latencies and amplitudes were analysed for non-target waveforms, and N200 and P300 latencies and amplitudes were analysed for target waveforms. RESULTS: In real relative to sham exposure N100 amplitude and latency to non-targets were reduced, with the reduction larger over midline and right hemisphere sites. P300 latency to targets was delayed in the real exposure condition, however as this difference was greatest at left frontal and left central sites the interpretation of this result is unclear. Reaction time increased in the real relative to sham condition. No difference in accuracy was found. CONCLUSIONS: The results suggest that MP exposure may affect neural activity, particularly in proximity to the phone, however caution should be applied due to the small sample size.

**Hamblin DL, Croft RJ, Wood AW, Stough C, Spong J. The sensitivity of human event-related potentials and reaction time to mobile phone emitted electromagnetic fields. Bioelectromagnetics.27(4):265-273, 2006.**

There is some evidence to suggest that exposure to mobile phones (MPs) can affect neural activity, particularly in response to auditory stimuli. The current investigation (n = 120) aimed to test recent findings in this area, namely that N100 amplitude and latency would decrease, and that P300 latency and reaction time (RT) would increase under active relative to sham exposure during an auditory task. Visual measures were also explored. A double blind, counterbalanced, crossover design was employed where subjects attended two sessions 1 week apart. In both sessions participants (1) performed auditory and visual oddball tasks while electroencephalogram (EEG) was recorded with a MP set to sham exposure mounted over the temporal region, and (2) performed the same tasks while the handset was set to active/sham. When active, the MP transmitted for 30 min at 895 MHz (average power 250 mW, pulse modulated at 217 Hz, average SAR 0.11 W/kg). Paired t-tests compared difference scores from the sham/sham session to those from the sham/active condition. The study was designed to detect differences of ${1\over4}$ of a standard deviation with a power of 0.80. There was no significant difference between exposure conditions for any auditory or visual event related potential (ERP) component or RT. As previous positive findings were not replicated, it was concluded that there is currently no evidence that acute MP exposure affects these

indices of brain activity.

**Hamzany Y, Feinmesser R, Shpitzer T, Mizrachi A, Hilly O, Hod R, Bahar G, Otradnov I, Gavish M, Nagler RM. Is human saliva an indicator of the adverse health effects of using mobile phones? Antioxid Redox Signal. 18(6):622-627, 2013.**

Increasing use of mobile phones creates growing concern regarding harmful effects of radiofrequency non-ionizing electromagnetic radiation (NIER) on human tissues located close to the ear where phones are commonly held for long periods of time. We studied 20 subjects in the 'mobile phone group' who had a mean duration of mobile phone use of 12.5 years (range 8-15) and a mean time use of 29.6 hours per month (range 8-100). Deaf individuals served as controls. We compared salivary outcomes (secretion, oxidative damage indices, flow rate and composition) between mobile phone users and non-users. We report significant increase in all salivary oxidative stress indices studied in mobile phone users. Salivary flow, total protein, albumin and amylase activity were decreased in mobile phone users. These observations lead to the hypothesis that the use of mobile phones may cause oxidative stress and modify salivary function.

**Han YY, Kano H, Davis DL, Niranjan A, Lunsford LD. Cell phone use and acoustic neuroma: the need for standardized questionnaires and access to industry data. Surg Neurol. 72(3):216-22; discussion 222, 2009.**

BACKGROUND: The capacity of radiofrequency from cell phones to be absorbed into the brain has prompted concerns that regular cell phone use may increase the risk of acoustic neuroma (AN) and other brain tumors. This article critically evaluates current literature on cell phone use and AN risks and proposes additional studies to clarify any possible linkage. METHODS: Through a PubMed search, we identified and reviewed 10 case-control studies and 1 cohort study of AN risks associated with cell phone use and a meta-analysis of long-term mobile phone use and its association with AN and other brain tumors. RESULTS: Most studies did not find association between the development of AN and cell phone use, but some studies that followed cases for 10 years or more did show an association. Among 10 case-control studies, odds ratios for AN associated with regular cell phone use ranged from 0.5 (95% confidence interval [CI], 0.2-1.0) to 4.2 (95% CI, 1.8-10). Cell phone use was not associated with increased risk for AN in the Danish cohort study, which excluded business users from their study. The meta-analysis, which included 3 case-control studies, found that subjects who used cell phones for at least 10 years had a 2.4-fold greater risk of developing ipsilateral AN. In general, retrospective studies are limited in the ability to assess cell phone exposure because of recall bias and misclassification. CONCLUSIONS: The evaluation of AN risk factors is challenging due to its long latency. Some studies of longer term cell phone use have found an increased risk of ipsilateral AN. Adopting a prospective approach to acquire data on cell phone use, obtaining retrospective billing records that provide independent evaluations of exposures, and incorporating information on other key potential risk factors from questionnaires could markedly advance the capacity of studies to evaluate the impact of cell phones on AN.

**Han YY, Berkowitz O, Talbott E, Kondziolka D, Donovan M, Lunsford LD. Are frequent dental x-ray examinations associated with increased risk of vestibular schwannoma? J Neurosurg. 117 Suppl:78-83, 2012.**

Object The authors evaluated the potential role of environmental risk factors, including exposure to diagnostic or therapeutic radiation and to wireless phones that emit nonionizing radiation, in the etiology of vestibular schwannoma (VS). Methods A total of 343 patients with VSs who underwent Gamma Knife surgery performed between 1997 and 2007 were age and sex matched to 343 control patients from the outpatient degenerative spinal disorders service at the University of Pittsburgh Medical Center. The authors obtained information on previous exposure to medical radiation, use of wireless phone technologies, and other environmental factors thought to be associated with the development of a VS. Conditional multivariate logistic regression was used to estimate adjusted odds ratios (aORs) and 95% confidence intervals (CIs). Results After adjusting for race, education, cigarette smoking, alcohol consumption, occupational exposure to noise, use of cell phones, and family history of cancer, the authors identified only a single factor that was associated with a higher risk of VS: individuals exposed to dental x-rays once a year (aOR = 2.27, 95% CI = 1.01-5.09) or once every 2-5 years (aOR = 2.65, 95% CI = 1.20-5.85), compared with those exposed less than once every 5 years. Of interest, a history of exposure to radiation related to head or head-and-neck computed tomography was associated with a reduced risk of VS (aOR = 0.52, 95% CI = 0.30-0.90). No relationship was found between the use of cell phones or cordless phones and VS. Conclusions Patients with acoustic neuromas reported significantly more exposure to dental x-rays than a matched cohort control group. Reducing the frequency of dental x-ray examinations may decrease the potential risk of VS.

**Hanada E, Kodama K, Takano K, Watanabe Y, Nose Y. Possible electromagnetic interference with electronic medical equipment by radio waves coming from outside the hospital. J Med Syst 25(4):257-267, 2001.**

Electromagnetic interference (EMI) with electronic medical equipment by radio waves from mobile telephone handsets has been reported and is currently receiving wide attention. The possibility of EMI with electronic medical equipment by radio waves coming into the hospital has also been pointed out. But so far, there are no reports measuring the frequency distribution of electric field intensity induced by incoming radio waves. Therefore, we measured electric field intensity induced by radio waves coming into our 11-floor hospital, which was under construction. The maximum intensity observed was about 200 V/m at 2.79 GHz, from airport surveillance radar waves. The maximum intensity induced by radio waves from cellular phone base stations was 1.78 V/m. These data show that various frequencies of radio waves are common in this urban area, and that they induce strong electricfield intensity. This strong electric field intensity might cause EMI with electronic medical equipment. Measurement of the electromagnetic environment should be done by each hospital in urban areas to prevent EMI with electronic medical equipment.

**Hanada E, Takano K, Antoku Y, Matsumura K, Watanabe Y, Nose Y.A practical procedure to prevent electromagnetic interference with electronic medical**

**equipment. J Med Syst 26(1):61-65, 2002.**

Problems involving electromagnetic interference (EMI) with electronic medical equipment are well-documented. However, no systematic investigation of EMI has been done. We have systematically investigated the causes of EMI. The factors involved in EMI were determined as follows: 1) Electric-field intensity induced by invasive radio waves from outside a hospital. 2) Residual magnetic-flux density at welding points in a building. 3) Electric-field intensity induced by conveyance systems with a linear motor. 4) The shielding capacity of hospital walls. 5) The shielding capacity of commercial shields against a wide range frequency radio waves. 6) The immunity of electronic medical equipment. 7) EMI by cellular telephone and personal handy-phone system handsets. From the results of our investigation, we developed a following practical procedure to prevent EMI. 1) Measurement of electric-field intensity induced by invasive radio waves from outside the hospital and industrial systems in the hospital. 2) Measurement of residual magnetic-flux density at electric welding points of hospital buildings with steel frame structures. 3) Control of the electromagnetic environment by utilizing the shielding capacity of walls. 4) Measurement of the immunity of electronic medical equipment. And 5) Installation of electronic gate equipment at the building entrance to screen for handsets.

**Hanada E, Hoshino Y, Oyama H, Watanabe Y, Nose Y. Negligible electromagnetic interaction between medical electronic equipment and 2.4 GHz band wireless LAN. J Med Syst 26(4):301-308, 2002.**

Wireless LANs using radio waves have recently gained popularity for installation in hospitals. Because electromagnetic waves transmitted from mobile telephones have been shown to cause interference with medical electronic equipment, prudence would seem necessary when introducing radio wave communication devices into hospitals. Therefore, we tested the effect of wireless LAN communication on medical electronic equipment and the effect of electronic equipment on wireless LAN communication. We observed nine pieces of electronic equipment in the operating mode while transmitting radio waves from a wireless LAN. Even when the access point was put very close to the medical electronic equipment surface and data was transmitted, no malfunction of the equipment was observed. The medical electronic equipment caused little change in the effectiveness of the communication device, although radio waves emitted from electric knives and a remote patient monitor reduced the reception rate to about 60%. The communication speed of the wireless LAN was temporarily reduced only when a microwave oven was located close to and facing the access point. Because output in Japan is limited to a maximum of 10 mW wireless LAN following the IEEE802.11b standard should be able to be installed safely in Japanese hospitals. However, wireless LAN access points should not be installed near microwave ovens.

**Hancı H, Odacı E, Kaya H, Aliyazıcıoğlu Y, Turan I, Demir S, Colakoğlu S. The effect of prenatal exposure to 900-MHz electromagnetic field on the 21-old-day rat testicle. Reprod Toxicol. 42:203-209, 2013.**

The aim of this study was to investigate the effect of exposure to a 900-MHz electromagnetic field (EMF) in the prenatal term on the 21-old-day rat testicle. Pregnant

rats were divided into control (CG) and EMF (EMFG) groups. EMFG was exposed to 900-MHz EMF during days 13-21 of pregnancy. Newborn CG rats were obtained from the CG and newborn EMFG (NEMFG) rats from the EMFG. Testicles were extracted at postnatal day 21. Lipid peroxidation and DNA oxidation levels, apoptotic index and histopathological damage scores were compared. NEMFG rats exhibited irregularities in seminiferous tubule basal membrane and epithelium, immature germ cells in the lumen, and a decreased diameter in seminiferous tubules and thickness of epithelium. Apoptotic index, lipid peroxidation and DNA oxidation were higher in NEMFG rats than in NCG. 21-day-old rat testicles exposed to 900-MHz EMF in the prenatal term may be adversely affected, and this effect persists after birth.

**Hancı H, Türedi S, Topal Z, Mercantepe T, Bozkurt I, Kaya H, Ersöz Ş, Ünal B, Odacı E. Can prenatal exposure to a 900 MHz electromagnetic field affect the morphology of the spleen and thymus, and alter biomarkers of oxidative damage in 21-day-old male rats? Biotech Histochem. 2015 May 19:1-9. [Epub ahead of print]**

We investigated the effects of a 900 Megahertz (MHz) electromagnetic field (EMF), applied during the prenatal period, on the spleen and thymus of 21-day-old male rat pups. Pregnant Sprague-Dawley rats were divided into control and EMF groups. We applied 900 MHz EMF for 1 h/day to the EMF group of pregnant rats. Newborn male rat pups were removed from their mothers and sacrificed on postnatal day 21. Spleen and thymus tissues were excised and examined. Compared to the control group, thymus tissue malondialdehyde levels were significantly higher in the group exposed to EMF, while glutathione levels were significantly decreased. Increased malondialdehyde and glutathione levels were observed in splenic tissue of rats exposed to EMF, while a significant decrease occurred in superoxide dismutase values compared to controls. Transmission electron microscopy showed pathological changes in cell morphology in the thymic and splenic tissues of newborn rats exposed to EMF. Exposure to 900 MHz EMF during the prenatal period can cause pathological and biochemical changes that may compromise the development of the male rat thymus and spleen.

**Hanson Mild, K, Oftedal, G, Sandstrom, M, Wilen, J, Tynes, T, Haugsdal, B, Hauger E, Comparison of symptoms experienced by users of analogue and digital mobile phones: a Swedish-Norwegian epidemiological study. Arbetslivsrapport 1998:23.**

Study of mobile phone users showed a statistically significant association between calling time/number of calls per day and the prevalence of warmth behind/around the ear, headaches, and fatigue.

**Hansson Mild K, Hardell L, Carlberg M. Pooled analysis of two Swedish case-control studies on the use of mobile and cordless telephones and the risk of brain tumours diagnosed during 1997-2003. Int J Occup Saf Ergon 13(1):63-71, 2007.**

Here we present the pooled analysis of 2 case-control studies on the association of brain tumours with mobile phone use. Use of analogue cellular phones increased the risk for acoustic neuroma by 5%, 95% confidence interval (CI) = 2-9% per 100 hrs of use. The risk increased for astrocytoma grade III-IV with latency period with highest estimates using >10-year time period from first use of these phone types. The risk

increased per one year of use of analogue phones by 10%, 95% CI = 6-14%, digital phones by 11%, 95% CI = 6-16%, and cordless phones by 8%, 95% CI = 5-12%. For all studied phone types OR for brain tumours, mainly acoustic neuroma and malignant brain tumours, increased with latency period, especially for astrocytoma grade III-IV.

**Hansson B, Thors B, Törnevik C. Analysis of the effect of mobile phone base station antenna loading on localized SAR and its consequences for measurements. Bioelectromagnetics. 32(8):664-672, 2011.**

In this work, the effect of antenna element loading on the localized specific absorption rate (SAR) has been analyzed for base station antennas. The analysis was conducted in order to determine whether localized SAR measurements of large multi-element base station antennas can be conducted using standardized procedures and commercially available equipment. More specifically, it was investigated if the antenna shifting measurement procedure, specified in the European base station exposure assessment standard EN 50383, will produce accurate localized SAR results for base station antennas larger than the specified measurement phantom. The obtained results show that SAR accuracy is affected by the presence of lossy material within distances of one wavelength from the tested antennas as a consequence of coupling and redistribution of transmitted power among the antenna elements. It was also found that the existing standardized phantom is not optimal for SAR measurements of large base station antennas. A new methodology is instead proposed based on a larger, box-shaped, whole-body phantom.

**Hansteen IL, Lågeide L, Clausen KO, Haugan V, Svendsen M, Eriksen JG, Skiaker R, Hauger E, Vistnes AI, Kure EH. Cytogenetic effects of 18.0 and 16.5 GHz microwave radiation on human lymphocytes in vitro. Anticancer Res. 29(8):2885-2892, 2009.**

BACKGROUND: There are few cell studies on the direct genotoxic effects of microwave radiation. In this study, cytogenetic effects of microwave radiation alone or in combination with mitomycin C (MMC) were investigated. MATERIALS AND METHODS: Lymphocytes from two smoking and four non-smoking donors were exposed for 53 hours in vitro to 1.0 W/m(2) continuous-wave radiation at 18.0 GHz or 10 W/m(2) pulsed-wave at 16.5 GHz, alone or in combination with MMC. DNA synthesis and repair were inhibited in vitro in some cultures. RESULTS: No synergistic effect was observed in cells exposed to combinations of microwave radiation and in vitro exposure to MMC, or to cells pre-exposed in vivo to tobacco smoke. For the 16.5 GHz pulsed exposure, a non-significant trend consisting of an increase in aberration frequencies with microwave radiation was shown for the DNA synthesis and repair inhibited cultures both with and without MMC. CONCLUSION: Neither 18.0 GHz continuous-wave nor 16.5 GHz pulsed-wave exposure to human lymphocytes in vitro induced statistically significant increases in chromosomal aberration frequencies. 16.5 GHz pulsed-wave exposure requires further documentation before a true negative conclusion can be drawn.

**Hansteen IL, Clausen KO, Haugan V, Svendsen M, Svendsen MV, Eriksen JG,**

**Skiaker R, Hauger E, Lågeide L, Vistnes AI, Kure EH. Cytogenetic effects of exposure to 2.3 GHz radiofrequency radiation on human lymphocytes in vitro. Anticancer Res. 29(11):4323-4330, 2009.**

BACKGROUND: No previous in vitro studies have tested radio frequency radiation for at least one full cell cycle in culture. The aim was to test if exposure used in mobile phones and wireless network technologies would induce DNA damage in cultured human lymphocytes with and without a known clastogen. MATERIALS AND METHODS: Lymphocytes from six donors were exposed to 2.3 GHz, 10 W/m(2) continuous waves, or 2.3 GHz, 10 W/m(2) pulsed waves (200 Hz pulse frequency, 50% duty cycle). Mitomycin C was added to half of the cultures. DNA synthesis and repair were inhibited in one experiment. RESULTS: No statistically significant differences were observed between control and exposed cultures. A weak trend for more chromosomal damage with the interaction of pulsed fields with mitomycin C compared to a constant field was observed. CONCLUSION: Exposure during the whole cell cycle in inhibited cultures did not resulted in significant differences in chromosomal aberrations as compared to controls.

**Hao D, Yang L, Chen S, Tong J, Tian Y, Su B, Wu S, Zeng Y. Effects of long-term electromagnetic field exposure on spatial learning and memory in rats. Neurol Sci. 2012 Feb 24. [Epub ahead of print]**

With the development of communications industry, mobile phone plays an important role in daily life. Whether or not the electromagnetic radiation emitted by mobile phone causes any adverse effects on brain function has become of a great concern. This paper investigated the effect of electromagnetic field on spatial learning and memory in rats. 32 trained Wistar rats were divided into two groups: exposure group and control group. The exposure group was exposed to 916 MHz, 10w/m2 mobile phone electromagnetic field (EMF) 6 h a day, 5 days a week, 10 weeks. The completion time, number of total errors and the neuron discharge signals were recorded while the rats were searching for food in an eight-arm radial maze at every weekend. The neuron signals of one exposed rat and one control rat in the maze were obtained by the implanted microelectrode arrays in their hippocampal regions. It can be seen that during the weeks 4-5 of the experiment, the average completion time and error rate of the exposure group were longer and larger than that of control group ($p < 0.05$). During the weeks 1-3 and 6-9, they were close to each other. The hippocampal neurons showed irregular firing patterns and more spikes with shorter interspike interval during the whole experiment period. It indicates that the 916 MHz EMF influence learning and memory in rats to some extent in a period during exposure, and the rats can adapt to long-term EMF exposure.

**Hao YT, Pei LP, Chen CH, Yang XS, Zhang GB, Deng ZH, Yu ZP. [Effects of occupational microwave irradiation on heat shock protein 70 expressions in rat hippocampus.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):553-556, 2009.** [Article in Chinese]

OBJECTIVE: To study the change of heat shock protein (HSP)70 expression after exposure to occupational microwave in rats hippocampus, and explore the role of

HSP70 in the mechanism of bio-effect of microwave irradiation. METHODS: The animal model was established by whole body exposures in 90, 5 W/cm(2) microwave irradiation field for 20 min in rats. Changes of the mRNA of hsp70 expressions in rat hippocampus at different time were studied by RT-PCR, and the protein change by Western blot. RESULTS: The mRNA and protein expression of hsp70 in rat hippocampus increased after 90 W/cm(2) and 5 W/cm(2) microwave irradiation for 20 min. The anal temperature and the value of SAR increased significantly. These changes were positively correlated with power and irradiation time of microwave. The results indicated that microwave irradiation led to HSP70 syntheses effectively. CONCLUSION: Microwave irradiation can obviously induce the thermal effect and activate HSP70, and initiate the endogens protective mechanism of central nervous system.

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**Hao Y, Yang X, Chen C, Yuan-Wang, Wang X, Li M, Yu Z. STAT3 signalling pathway is involved in the activation of microglia induced by 2.45 GHz electromagnetic fields. Int J Radiat Biol. 86(1):27-36, 2010.**

**PURPOSE:** Microglia activation plays a pivotal role in the initiation and progression of central nervous system (CNS) insult. The aim of the present work was to investigate theactivation of microglia and involvement of signal transducer and activator of transcription 3 (STAT3) in microglia activation after 2.45 GHz electromagnetic fields (EMF) exposure. **MATERIALS AND METHODS:** In this study, murine N9 microglial cells were exposed to 2.45 GHz EMF, the protein expressions of STAT3, Janus Tyrosine kinase 1 and 2(JAK1 and JAK2), phosphor-(Try705)STAT3 and DNA binding activity of STAT3 were examined by Western blot analysis and electrophoresis mobility shift assay (EMSA). Levels of the nitric oxide (NO) derivative nitrite were determined in the culture medium by the Griess reaction. The mRNA expression of tumour necrosis factor alpha (TNF-alpha) and inducible nitric oxide synthase (iNOS) were detected by reverse transcription and polymerase chain reaction (RT-PCR). **RESULTS:** A significant increase of STAT3 DNA-binding ability was noted after exposure. Consistent with this, EMF rapidly induced phosphorylation of STAT3 and activated JAK1 and JAK2. In addition, EMF exposure increased transcription levels of the inflammation-associated genes, iNOS and TNF-alpha, which are reported to contain STAT-binding elements in their promoter region. P6, a JAK inhibitor, reduced induction of iNOS and TNF-alpha, nuclear factor binding activity, and activation of STAT3 in EMF-stimulated microglia. **CONCLUSION:** These results provide evidence that EMF exposure can initiate the activation of microglia cells and STAT3 signalling involves in EMF-induced microglial activation.

**Hardell L, Carlberg M. Mobile phones, cordless phones and the risk for brain tumours. Int J Oncol. 35(1):5-17, 2009.**

The Hardell-group conducted during 1997-2003 two case control studies on brain tumours including assessment of use of mobile phones and cordless phones. The questionnaire was answered by 905 (90%) cases with malignant brain tumours, 1,254 (88%) cases with benign tumours and 2,162 (89%) population-based controls. Cases were reported from the Swedish Cancer Registries. Anatomical area in the brain for the

tumour was assessed and related to side of the head used for both types of wireless phones. In the current analysis we defined ipsilateral use (same side as the tumour) as >/=50% of the use and contralateral use (opposite side) as <50% of the calling time. We report now further results for use of mobile and cordless phones. Regarding astrocytoma we found highest risk for ipsilateral mobile phone use in the >10 year latency group, OR=3.3, 95% CI=2.0-5.4 and for cordless phone use OR=5.0, 95% CI=2.3-11. In total, the risk was highest for cases with first use <20 years age, for mobile phone OR=5.2, 95% CI=2.2-12 and for cordless phone OR=4.4, 95% CI=1.9-10. For acoustic neuroma, the highest OR was found for ipsilateral use and >10 year latency, for mobile phone OR=3.0, 95% CI=1.4-6.2 and cordless phone OR=2.3, 95% CI=0.6-8.8. Overall highest OR for mobile phone use was found in subjects with first use at age <20 years, OR=5.0, 95% CI 1.5-16 whereas no association was found for cordless phone in that group, but based on only one exposed case. The annual age-adjusted incidence of astrocytoma for the age group >19 years increased significantly by +2.16%, 95% CI +0.25 to +4.10 during 2000-2007 in Sweden in spite of seemingly underreporting of cases to the Swedish Cancer Registry. A decreasing incidence was found for acoustic neuroma during the same period. However, the medical diagnosis and treatment of this tumour type has changed during recent years and underreporting from a single center would have a large impact for such a rare tumour.

**Hardell L, Hansson Mild K, Pahlson A, Hallquist A, Ionizing radiation, cellular telephones and the risk of brain tumours. Europ J Cancer Prevent 10:523-529, 2001.**

A case-control study on brain tumours included 233 patients aged 20-80 years and alive at the study time. They had histopathologically verified brain tumour and lived in the Upsala-Orebro region (1994-1996) or in Stockholm region (1995-1996). Two matched controls to each case were selected from the Swedish Population Register. Two hundred and nine cases (90%) and 425 controls (91%) answered the questionnaire. Results are presented for the whole study group, as given here, and for malignant and benign tumours separately. For workers in the chemical industry the odds ratio (OR) was 4.10, 95% confidence interval (95% CI) 1.25-13.4 and laboratory workers OR 3.21, 95%CI 1.16-8.85. Radiotherapy of the head and neck region gave OR 3.61, 95% CI 0.65-19.9. Medical diagnostic X-ray of the same area yielded OR 1.64, 95% CI 1.04-2.58. Work as a physician gave OR 6.00, 95% CI 0.62-57.7. All three cases had worked with fluoroscopy. Ipsilateral (same side) use of a cellular telephone increased the risk of tumours in the temporal, temporo-parietal and occipital areas, with OR 2.42, 95% CI 0.97-6.05 (i.e., the anatomical areas with highest exposure to microwaves from a mobile phone).

**Hardell, L, Reizenstein, J, Johansson, B, Gertzen, H, Mild, KH, Angiosarcoma of the scalp and use of a cordless (portable) telephone. Epidemiology 10(6):785-786, 1999.**

This is a case study of a 57-year old woman who was diagnosed in January 1999 with an angiosarcoma of the scalp on the left side of her head (2 cm above her ear). Angiosarcoma is a rare type of soft tissue sarcoma (STS). Since 1988, the patient had, on a regular basis (1 hr per day), used a cordless (portable) phone, always using her left

ear. Starting in 1994, she also used a GSM (digital) mobile phone on her left ear (a few minutes per week). The exposure to microwaves from a cordless phone in this patient is of interest because she had exposure on a daily basis starting 10 years before the first clinical signs of her angiosarcoma. Moreover, the tumor developed in the anatomical area with the highest exposure to microwaves on the same side of the head that she had used the phone. She also reported no exposure to other know risk factors for STS.

**Hardell L, Nasman A, Ohlson CG, Fredrikson M. Case-control study on risk factors for testicular cancer. Int J Oncol 13(6):1299-1303, 1998.**

Occupational exposures were assessed in a case-control study on testicular cancer using self administered questionnaires. Answers were obtained for 148 (91%) cases and 314 (87%) controls. Of the cases 101 had seminoma and 47 had embryonal testicular cancer. Occupational plastics work yielded odds ratio (OR) 2.9 with 95% confidence interval (CI) 1.3-6.5. Increased risk was found for embryonal cancer regarding farming (OR 3.1; CI 1.03-9.1) and contact with farm animals (OR 3.3; CI 1.00-10.9), but not for seminoma. For all testicular cancer exposure to insects repellents, mostly containing N,N-diethyl-m-toluamide (DEET) gave OR 1.7; CI 1.03-2.8, with a dose-response effect. Somewhat increased risks were found for amateur radio operators (OR 2.2; CI 0.7-6.6), work with radar equipment (OR 2.0; CI 0.3-14.2) and engineers in electronics and telecommunication industry (OR 2.3; CI 0.8-6.7) based on few exposed subjects, however. Video display unit work gave OR 1.5; CI 0.98-2.3 and for exposure 480 working days (median number) the risk increased further to OR 1.8; CI 1.1-3.2. Because of low numbers of exposed subjects in some calculations some of these results might be spurious and need to be further studied.

**Hardell, L, Nasman, A, Pahlson, A, Hallquist, A, Hansson Mild, K, Use of cellular telephones and the risk for brain tumours: A case-control study. Int J Oncol 15(1):113-116, 1999.**

The use of cellular telephones has increased dramatically during the 1990's in the world. In the 1980's the analogue NMT system was used whereas the digital GSM system was introduced in early 1990's and is now the preferred system. Case reports of brain tumours in users initiated this case-control study on brain tumours and use of cellular telephones. Also other exposures were assessed. All cases, both males and females, with histopathologically verified brain tumour living in Uppsala-Orebro region (1994-96) and Stockholm region (1995-96) aged 20-80 at the time of diagnosis and alive at start of the study were included, 233 in total. Two controls to each case were selected from the Swedish Population Register matched for sex, age and study region. Exposure was assessed by questionnaires supplemented over the phone. The analyses were based on answers from 209 (90%) cases and 425 (91%) controls. Use of cellular telephone gave odds ratio (OR) = 0.98 with 95% confidence interval (CI) = 0. 69-1.41. For the digital GSM system OR = 0.97, CI = 0.61-1.56 and for the analogue NMT system OR = 0.94, CI = 0.62-1.44 were calculated. Dose-response analysis and using different tumour induction periods gave similar results. Non-significantly increased risk was found for tumour in the temporal or occipital lobe on the same side as a cellular phone had been used, right side OR = 2.45, CI = 0.78-7.76, left side OR = 2.40, CI = 0.52-10.9 Increased risk was found only for use of the NMT system. For GSM use the observation time is still too short for

definite conclusions. An increased risk for brain tumour in the anatomical area close to the use of a cellular telephone should be especially studied in the future.

**Hardell L, Nasman A, Pahlson A, Hallquist A. Case-control study on radiology work, medical x-ray investigations, and use of cellular telephones as risk factors for brain tumors. Medscape General Medicine May 4, 2000.**

Abstract. Context. Ionizing radiation is a well-established risk factor for brain tumors. During recent years, microwave exposure from the use of cellular telephones has been discussed as a potential risk factor. Objective. To determine risk factors for brain tumors. Design. A case-control study, with exposure assessed by questionnaires. Participants. A total of 233 currently living men and women, aged 20 to 80 years, were included. The case patients had histopathologically verified brain tumors and lived in the Uppsala-Orebro region (1994-1996) or the Stockholm region (1995-1996). Two matched controls to each case were selected from the Swedish Population Register. Main Outcome Measures. Ionizing radiation and use of cellular telephones as risk factors for brain tumors. Results. A total of 209 cases (90%) and 425 controls (91%) answered the questionnaire. Work as a physician yielded an odds ratio (OR) of 6.00, with a 95% confidence interval (CI) of 0.62 to 57.7. All three case patients had worked with fluoroscopy. Radiotherapy of the head and neck region yielded an OR of 3.61 (95% CI, 0.65-19.9). Medical diagnostic x-ray examination of the same area yielded an OR of 2.10 (95% CI, 1.25-3.53), with a tumor induction period of 5 years or more. Chemical industry work yielded an OR of 4.10 (95% CI, 1.25-13.4), and laboratory work yielded an OR of 3.21 (95% CI, 1.16-8.85). Ipsilateral use of cellular telephones increased the risk for tumors in the temporal, temporoparietal, and occipital lobes (OR, 2.42; 95% CI, 0.97-6.05), ie, the anatomic areas with highest exposure to microwaves from a mobile telephone. The result was further strengthened (OR, 2.62; 95% CI, 1.02-6.71) in a multivariate analysis that included laboratory work and medical diagnostic x-ray investigations of the head and neck. Conclusion. Exposure to ionizing radiation, work in laboratories, and work in the chemical industry increased the risk of brain tumors. Use of a cellular telephone was associated with an increased risk in the anatomic area with highest exposure.

**Hardell L, Hallquist A, Hansson Mild K, Carlberg M, Pahlson A, Lilja A. cellular and cordless telephones and the risk for brain tumours. Europ J Cancer Prevent 11:377-386, 2002.**

Microwave exposure from the use of cellular telephones ahs been discussed in recently years as a potential risk factor for brain tumours. We included in a case-control study 1617 patients aged 20-80 years of both sexes with brain tumour diagnosed between 1 January 1997 and 30 June 2000. They were alive at the study time and had histopathologically verified brain tumour. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppsala-Orebro, Stockholm, Linkoping and Goteborg medical regions of Sweden. Exposure was assessed by a questionnaire that was answered by 1429 (88%) cases and 1470 (91%) controls. In total, use of analogue cellular telephones gave an increased risk with an odds ratio (OR) of 1.3 (95% confidence interval (CI) 1.02-1.6). With a tumour induction period of >10 years the risk increased further; OR 1.8 (95% CI 1.1-2.9). No clear association was found

for digital or cordless telephones. With regard to the anatomical area of the tumour and exposure to microwaves, the risk was increased for tumours located in the temporal area on the same side of the brain that was used during phone calls; for analogue cellular telephones the OR was 2.5 (95% CI 1.3-4.9). Use of a telephone on the opposite side of the brain was not associated with an increased risk for brain tumours. With regard to different tumour types, the highest risk was for acoustic neurinoma (OR 3.5, 95% CI 1.8-6.8) among analogue cellular telephone users.

**Hardell L, Mild KH, Carlsberg M. Case-control study on the use of cellular and cordless phones and the risk for malignant brain tumours. Int. J. Radiat. Biol. 78:931-936, 2002.**

Purpose: To investigate the use of cellular and cordless phones and the risk for malignant brain tumours. Materials and Methods: A case-control study was performed on 649 patents aged 20-80 years of both sexes with malignant brain tumour diagnosed from 1 January 1997 to 30 June 2000. All patients were alive during the time of the study and had histopathology verified brain tumours. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppasala-Orebro, Stockholm, Linkoping and Goteborg medical regions of Sweden. Results: Exposure was assessed by a questionnaire answered by 588 (91%) cases and 581 (90%) controls. Phone usage was defined as 'ever use' and usage starting 1 year before dagnosis was disregarded. Overall, no significantly increased risks were found: analogue cellular phones yielded an odds ratio (OR) =1.13, 95% confidence interval (CI) = 0.82-1.57, digital cellular phones OR = 1.13, CI = 0.86-1.48, and cordless phones OR = 1.13, CI =0.85-1.50. For ipsilateral (same side) radiofrequency exposure, analogue mobile phones gave OR = 1.85, CI = 1.16-2.96, for all malignant brain tumours. For astrocytoma, this risk was OR = 1.95, CI = 1.12-3.39. For all malignant brain tumours, digital mobile phones yielded OR = 1.59, CI = 1.05-2.41, and cordless phones yielded OR = 1.46, CI = 0.96-2.23, in the analysis of ipsilateral exposure. Conclusion: The ipsilateral use of an analogue cellular phone yielded a significantly increased risk for malignant brain tumours.

**Hardell L, Mild KH, Carlberg M. Further aspects on cellular and cordless telephones and brain tumours. Int J Oncol 22(2):399-407, 2003.**

We included in a case-control study on brain tumours and mobile and cordless telephones 1,617 patients aged 20-80 years of both sexes diagnosed during January 1, 1997 to June 30, 2000. They were alive at the study time and had histopathology verified brain tumour. One matched control to each case was selected from the Swedish Population Register. The study area was the Uppsala-Orebro, Stockholm, Linkoping and Goteborg medical regions of Sweden. Exposure was assessed by a questionnaire that was answered by 1,429 (88%) cases and 1,470 (91%) controls. In total use of analogue cellular telephones gave an increased risk with odds ratio (OR)=1.3, 95% confidence interval (CI)=1.04-1.6, whereas digital and cordless phones did not overall increase the risk significantly. Ipsilateral use of analogue phones gave OR=1.7, 95% CI=1.2-2.3, digital phones OR=1.3, 95% CI=1.02-1.8 and cordless phones OR=1.2, 95% CI=0.9-1.6. The risk for ipsilateral use was significantly increased for astrocytoma for all studied phone types, analogue phones OR=1.8,95% CI=1.1-3.2, digital phones OR=1.8, 95% CI=1.1-2.8, cordless phones OR=1.8, 95% CI=1.1-2.9. Use of a telephone on the opposite side

of the brain was not associated with a significantly increased risk for brain tumours. Regarding anatomical area of the tumour and exposure to microwaves, the risk was increased for tumours located in the temporal area on the same side of the brain that was used during phone calls, significantly so for analogue cellular telephones OR=2.3, 95% CI=1.2-4.1. For acoustic neurinoma OR=4.4, 95% CI=2.1-9.2 was calculated among analogue cellular telephone users. When duration of use was analysed as a continuous variable in the total material, the risk increased per year for analogue phones with OR=1.04, 95% CI=1.01-1.08. For astrocytoma and ipsilateral use the trend was for analogue phones OR=1.10, 95% CI=1.02-1.19, digital phones OR=1.11, 95% CI=1.01-1.22, and cordless phones OR=1.09, 95% CI=1.01-1.19. There was a tendency of a shorter tumour induction period for ipsilateral exposure to microwaves than for contralateral, which may indicate a tumour promotor effect.

**Hardell L, Mild KH, Sandstrom M, Carlberg M, Hallquist A, Pahlson A. Vestibular schwannoma, tinitus and cellular telephones. Neuroepidemiol 22:124-129, 2003.**

Cases with tinnitus after using analogue cellular telephones are presented. An increased odds radio of 3.45, 95% confidence interval (CI) 1.77-6.76, was found for vestibular schwannoma (VS) associated with the use of analogue cell phones. During the time period 1960-1998, the age-standardized incidence of VS in Sweden significantly increased yearly by +2.53% (CI 1.71-3.35). A significant increases in the incidence of VS was only found for the latter of the two time period 1960-1979 and 1980-1998. For all other brain tumors taken together, the incidence significantly increased yearly by +0.80% (CI 0.59-1.02) for the time period 1960-1998, although the increase was only significant for benign tumors other than VS during 1960-1979.

**Hardell L, Hallquist A, Hansson Mild K, Carlberg M, Gertzen H, Schildt EB, Dahlqvist A. No association between the use of cellular or cordless telephones and salivary gland tumours. Occup Environ Med. 61(8):675-679, 2004.**

AIM: To investigate the association between the use of cellular or cordless telephones and the risk for salivary gland tumours. METHODS: Cases were assessed from the six regional cancer registries in Sweden. Four controls matched for sex and age in five year age groups were selected for each case. A total of 293 living cases and 1172 controls were included. RESULTS: There were 267 (91%) participating cases and 1053 (90%) controls. Overall no significantly increased risk was found. Odds ratios were 0.92 (95% CI 0.58 to 1.44) for use of analogue phones, 1.01 (95% CI 0.68 to 1.50) for use of digital phones, and 0.99 (95% CI 0.68 to 1.43) for use of cordless phones. Similar results were found for different salivary gland localisations. No effect of tumour induction period or latency was seen, although few subjects reported use for more than 10 years. CONCLUSIONS: No association between the use of cellular or cordless phones and salivary gland tumours was found, although this study does not permit conclusions for long term heavy use.

**Hardell L, Carlberg M, Hansson Mild K. Use of cellular telephones and brain tumour risk in urban and rural areas. Occup Environ Med 62:390-394, 2005.**

Aim: To investigate the association between the use of cellular or cordless telephones and the risk for brain tumours in different geographical areas, urban and rural. Methods:

patients aged 20-80 years, living in the middle part of Sweden, and diagnosed between 1 January 1997 and 30 June 2000 were included. One control matched for sex and age in five year age groups was selected for each case. Use of different phone types was assessed by a questionnaire. Results: The number of participating cases was 1429; there were 1470 controls. An effect of rural living was most pronounced for digital cellular telephones. Living in rural areas yielded an odd ratio (OR) of 1.4 (95% CI 0.98 to 2.0), increasing to 3.2 (95% CI 1.2 to 8.4) with > 5 year latency time for digital phones. The corresponding Ors for living in urban areas were 0.9 (95% CI 0.8 to 1.2) and 0.9 (95% CI 0.6 to 1.4), respectively. This effect was most obvious for malignant brain tumours. Conclusion: In future studies, place of residence should be considered in assessment of exposure to microwaves from cellular telephone, although the results in this study must be interpreted with caution due to low numbers in some of the calculations.

**Hardell L, Carlberg M, Hansson Mild K. Case-control study on cellular and cordless telephones and the risk for acoustic neuroma or meningioma in patients diagnosed 2000-2003. Neuroepidemiology 25:120-128, 2005.**

We performed a case-control study on the use of cellular and cordless telephones and the risk for brain tumors. We report the results for benign brain tumors with data from 413 cases (89% response rate), 305 with meningioma, 84 with acoustic neuroma, 24 with other types and 692 controls (84% response rate). For meningioma, analogue phones yielded odds ratio (OR) = 1.7, 95% confidence interval (CI) = 0.97-3.0, increasing to OR = 2.1, 95% CI = 1.1-4.3 with a >10-year latency period. Also digital cellular phones and cordless phones increased the risk to some extent. For acoustic neuroma, analogue phones gave OR = 4.2, 95% CI = 1.8-10 increasing to OR = 8.4, 95% CI = 1.6-45 with a >15-year latency period, but based on low numbers. Digital phones yielded OR = 2.0, 95% CI = 1.05-3.8, whereas for cordless phones OR was not significantly increased. In the multivariate analysis, analogue phones represented a significant risk factor for acoustic neuroma.

**Hardell L, Eriksson M, Carlberg M, Sundstrom C, Mild KH. Use of cellular or cordless telephones and the risk for non-Hodgkin's lymphoma. Int Arch Occup Environ Health. 78(8):625-632, 2005.**

Objectives: To evaluate the use of cellular and cordless telephones as the risk factor for non-Hodgkin's lymphoma (NHL). Methods: Male and female subjects aged 18-74 years living in Sweden were included during a period from 1 December 1999 to 30 April 2002. Controls were selected from the national population registry. Exposure to different agents was assessed by questionnaire. Results: In total, 910 (91%) cases and 1016 (92%) controls participated. NHL of the B-cell type was not associated with the use of cellular or cordless telephones. Regarding T-cell NHL and >5 year latency period, the use of analogue cellular phones yielded: odds ratio (OR) = 1.46, 95%; confidence interval (CI) = 0.58-3.70, digital: OR=1.92, 95%; CI=0.77-4.80 and cordless phones: OR=2.47; CI=1.09-5.60. The corresponding results for certain, e.g. cutaneous and leukaemia, T-cell lymphoma for analogue phones were: OR=3.41, 95%; CI=0.78-15.0, digital: OR=6.12, 95%; CI=1.26-29.7 and cordless phones: OR=5.48, 95%; CI=1.26-23.9. Conclusions: The results indicate an association between T-cell NHL and the use of cellular and cordless telephones, however based on low numbers and must be interpreted with

caution. Regarding B-cell NHL no association was found.

**Hardell, L., Carlberg, M., Mild, K., 2005. Case-control study of the association between the use of cellular and cordless telephones and malignant brain tumors diagnosed during 2000-2003. Environ Res 100(2):232-241, 2006.**

We performed a case–control study on the use of cellular and cordless telephones and the risk for brain tumors diagnosed during 2000–2003. We report the results for malignant brain tumors with data from 317 cases (88%) and 692 controls (84%). The use of analog cellular phones yielded odds ratio (OR) of 2.6 and a 95% confidence interval (CI) of 1.5–4.3, increasing to OR=3.5 and 95% CI=2.0–6.4 with a >10-year latency period. Regarding digital cellular telephones, the corresponding results were OR=1.9, 95% CI=1.3–2.7 and OR=3.6, 95% CI=1.7–7.5, respectively. Cordless telephones yielded OR=2.1, 95% CI=1.4–3.0, and with a >10-year latency period, OR=2.9, 95% CI=1.6–5.2. The OR increased with the cumulative number of hours of use and was highest for high-grade astrocytoma. A somewhat increased risk was also found for low-grade astrocytoma and other types of malignant brain tumors, although not significantly so. In multivariate analysis, all three phone types studied showed an increased risk.

**Hardell L, Carlberg M, Hansson Mild K. Pooled analysis of two case-control studies on the use of cellular and cordless telephones and the risk of benign brain tumours diagnosed during 1997-2003. Int J Oncol. 28(2):509-518, 2006.**

The use of cellular and cordless telephones and the risk of brain tumours is of concern since the brain is a high exposure area. We present the results of a pooled analysis of two case-control studies on benign brain tumours diagnosed during 1997-2003 including answers from 1,254 (88%) cases and 2,162 (89%) controls aged 20-80 years. For acoustic neuroma, the use of analogue cellular phones gave an odds ratio (OR) of 2.9 and a 95% confidence interval (CI) of 2.0-4.3; for digital cellular phones, OR=1.5; 95% CI=1.1-2.1; and for cordless telephones, OR=1.5, 95% CI=1.04-2.0. The highest OR was found for analogue phones with a latency period of >15 years; OR=3.8, 95% CI=1.4-10. Regarding meningioma, the results were as follows: for analogue phones, OR=1.3, 95% CI=0.99-1.7; for digital phones, OR=1.1, 95% CI=0.9-1.3; and for cordless phones, OR=1.1, 95% CI=0.9-1.4. In the multivariate analysis, a significantly increased risk of acoustic neuroma was found with the use of analogue phones.

**Hardell L, Carlberg M, Hansson Mild K. Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997-2003. Int Arch Occup Environ Health. 79(8):630-639, 2006.**

Objectives: To study the use of cellular and cordless telephones and the risk for malignant brain tumours. Methods: Two case-control studies on malignant brain tumours diagnosed during 1997-2003 included answers from 905 (90%) cases and 2,162 (89%) controls aged 20-80 years. We present pooled analysis of the results in the two studies. Results: Cumulative lifetime use for >2,000 h yielded for analogue cellular phones odds ratio (OR)=5.9, 95% confidence interval (CI)=2.5-14, digital cellular phones OR=3.7, 95% CI=1.7-7.7, and for cordless phones OR=2.3, 95% CI=1.5-3.6. Ipsilateral exposure increased the risk for malignant brain tumours; analogue OR=2.1, 95% CI=1.5-2.9, digital

OR=1.8, 95% CI=1.4-2.4, and cordless OR=1.7, 95% CI=1.3-2.2. For high-grade astrocytoma using >10 year latency period analogue phones yielded OR=2.7, 95% CI=1.8-4.2, digital phones OR=3.8, 95% CI=1.8-8.1, and cordless phones OR=2.2, 95% CI=1.3-3.9. In the multivariate analysis all phone types increased the risk. Regarding digital phones OR=3.7, 95% CI=1.5-9.1 and cordless phones OR=2.1, 95% CI=0.97-4.6 were calculated for malignant brain tumours for subjects with first use use <20 years of age, higher than in older persons. Conclusion: Increased risk was obtained for both cellular and cordless phones, highest in the group with >10 years latency period.

**Hardell L**, **Carlberg M**, **Ohlson CG**, **Westberg H**, **Eriksson M**, **Hansson Mild K**. **Use of cellular and cordless telephones and risk of testicular cancer. Int J Androl.30(2):115-122, 2007.**

A case-control study on testicular cancer included use of cellular and cordless telephones. The results were based on answers from 542 (92%) cases with seminoma, 346 (89%) with non-seminoma, and 870 (89%) controls. Regarding seminoma the use of analog cellular phones gave odds ratio (OR) = 1.2, 95% confidence interval (CI) = 0.9-1.6, digital phones OR = 1.3, CI = 0.9-1.8, and cordless phones OR = 1.1, CI = 0.8-1.5. The corresponding results for non-seminoma were OR = 0.7, CI = 0.5-1.1, OR = 0.9, CI = 0.6-1.4, and OR = 1.0, CI = 0.7-1.4, respectively. There was no dose-response effect and OR did not increase with latency time. No association was found with place of keeping the mobile phone during standby, such as trousers pocket. Cryptorchidism was associated both with seminoma (OR = 4.2, CI = 2.7-6.5) and non-seminoma (OR = 3.3, CI = 2.0-5.6), but no interaction was found with the use of cellular or cordless telephones.

**Hardell LO, Carlberg M, Soderqvist F, Hansson Mild K, Morgan LL Long-term use of cellular phones and brain tumours - increased risk associated with use for > 10 years. Occup Environ Med.64(9):626-632, 2007.**

AIM: To evaluate brain tumour risk among long-term users of cellular telephones. METHODS: One cohort study and 13 case-control studies were identified on this topic. Data were scrutinized for use of mobile phone for > 10 years and ipsilateral exposure if presented. RESULTS: The cohort study was of limit value due to methodological shortcomings in the study. Of the 13 case-control studies, 9 gave results for > 10 years use or latency period. Most of these results were based on low numbers. Clearly an association with acoustic neuroma was found in four studies with two- to three-fold increased risk in the group with at least 10 years use of a mobile phone. No risk was found in one study, but the tumour size was significantly larger among users. Five studies gave results for malignant brain tumours in that latency group. All gave increased OR especially for ipsilateral exposure. Highest OR = 5.4, 95 % CI = 3.0-9.6 was calculated for high-grade glioma and ipsilateral exposure in one study. CONCLUSIONS: Results from present studies on use of mobile phones for > 10 years give a consistent pattern of an increased risk for acoustic neuroma and glioma, most pronounced for high-grade glioma. The risk is highest for ipsilateral exposure.

**Hardell L, Carlberg M, Söderqvist F, Hansson Mild K. Meta-analysis of long-term mobile phone use and the association with brain tumours. Int J Oncol. 32(5):1097-**

**1103, 2008.**

We evaluated long-term use of mobile phones and the risk for brain tumours in case-control studies published so far on this issue. We identified ten studies on glioma and meta-analysis yielded OR = 0.9, 95% CI = 0.8-1.1. Latency period of >/=10-years gave OR = 1.2, 95% CI = 0.8-1.9 based on six studies, for ipsilateral use (same side as tumour) OR = 2.0, 95% CI = 1.2-3.4 (four studies), but contralateral use did not increase the risk significantly, OR = 1.1, 95% CI = 0.6-2.0. Meta-analysis of nine studies on acoustic neuroma gave OR = 0.9, 95% CI = 0.7-1.1 increasing to OR = 1.3, 95% CI = 0.6-2.8 using >/=10-years latency period (four studies). Ipsilateral use gave OR = 2.4, 95% CI = 1.1-5.3 and contra-lateral OR = 1.2, 95% CI = 0.7-2.2 in the >/=10-years latency period group (three studies). Seven studies gave results for meningioma yielding overall OR = 0.8, 95% CI = 0.7-0.99. Using >/=10-years latency period OR = 1.3, 95% CI = 0.9-1.8 was calculated (four studies) increasing to OR = 1.7, 95% CI = 0.99-3.1 for ipsilateral use and OR = 1.0, 95% CI = 0.3-3.1 for contralateral use (two studies). We conclude that this meta-analysis gave a consistent pattern of an association between mobile phone use and ipsilateral glioma and acoustic neuroma using >/=10-years latency period.

**Hardell L, Carlberg M, Hansson Mild K. Mobile phone use and the risk for malignant brain tumors: A case-control study on deceased cases and controls. Neuroepidemiology. 35(2):109-114, 2010.**

We investigated the use of mobile or cordless phones and the risk for malignant brain tumors in a group of deceased cases. Most previous studies have either left out deceased cases of brain tumors or matched them to living controls and therefore a study matching deceased cases to deceased controls is warranted. Recall error is one issue since it has been claimed that increased risks reported in some studies could be due to cases blaming mobile phones as a cause of the disease. This should be of less importance for deceased cases and if cancer controls are used. In this study brain tumor cases aged 20-80 years diagnosed during 1997-2003 that had died before inclusion in our previous studies on the same topic were included. Two control groups were used: one with controls that had died from another type of cancer than brain tumor and one with controls that had died from other diseases. Exposure was assessed by a questionnaire sent to the next-of-kin for both cases and controls. Replies were obtained for 346 (75%) cases, 343 (74%) cancer controls and 276 (60%) controls with other diseases. Use of mobile phones gave an increased risk, highest in the >10 years' latency group yielding odds ratio (OR) = 2.4, and 95% confidence interval (CI) = 1.4-4.1. The risk increased with cumulative number of lifetime hours for use, and was highest in the >2,000 h group (OR = 3.4, 95% CI = 1.6-7.1). No clear association was found for use of cordless phones, although OR = 1.7, 95% CI = 0.8-3.4 was found in the group with >2,000 h of cumulative use. This investigation confirmed our previous results of an association between mobile phone use and malignant brain tumors.

**Hardell L, Carlberg M, Söderqvist F, Mild KH. Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. Int J Oncol. 43(6):1833-1845, 2013.**

Previous studies have shown a consistent association between long-term use of mobile and cordless phones and glioma and acoustic neuroma, but not for meningioma. When used these phones emit radiofrequency electromagnetic fields (RF-EMFs) and the brain is the main target organ for the handheld phone. The International Agency for Research on Cancer (IARC) classified in May, 2011 RF-EMF as a group 2B, i.e. a 'possible' human carcinogen. The aim of this study was to further explore the relationship between especially long-term (>10 years) use of wireless phones and the development of malignant brain tumours. We conducted a new case-control study of brain tumour cases of both genders aged 18-75 years and diagnosed during 2007-2009. One population-based control matched on gender and age (within 5 years) was used to each case. Here, we report on malignant cases including all available controls. Exposures on e.g. use of mobile phones and cordless phones were assessed by a self-administered questionnaire. Unconditional logistic regression analysis was performed, adjusting for age, gender, year of diagnosis and socio-economic index using the whole control sample. Of the cases with a malignant brain tumour, 87% (n=593) participated, and 85% (n=1,368) of controls in the whole study answered the questionnaire. The odds ratio (OR) for mobile phone use of the analogue type was 1.8, 95% confidence interval (CI)=1.04-3.3, increasing with >25 years of latency (time since first exposure) to an OR=3.3, 95% CI=1.6-6.9. Digital 2G mobile phone use rendered an OR=1.6, 95% CI=0.996-2.7, increasing with latency >15-20 years to an OR=2.1, 95% CI=1.2-3.6. The results for cordless phone use were OR=1.7, 95% CI=1.1-2.9, and, for latency of 15-20 years, the OR=2.1, 95% CI=1.2-3.8. Few participants had used a cordless phone for >20-25 years. Digital type of wireless phones (2G and 3G mobile phones, cordless phones) gave increased risk with latency >1-5 years, then a lower risk in the following latency groups, but again increasing risk with latency >15-20 years. Ipsilateral use resulted in a higher risk than contralateral mobile and cordless phone use. Higher ORs were calculated for tumours in the temporal and overlapping lobes. Using the meningioma cases in the same study as reference entity gave somewhat higher ORs indicating that the results were unlikely to be explained by recall or observational bias. This study confirmed previous results of an association between mobile and cordless phone use and malignant brain tumours. These findings provide support for the hypothesis that RF-EMFs play a role both in the initiation and promotion stages of carcinogenesis.

**Hardell L, Söderqvist F, Carlberg M, Zetterberg H, Mild KH. Exposure to wireless phone emissions and serum beta-trace protein. Int J Mol Med. 26(2):301-306, 2010.**

The lipocalin type of prostaglandin D synthase or beta-trace protein is synthesized in the choroid plexus, lepto-meninges and oligodendrocytes of the central nervous system and is secreted into the cerebrospinal fluid. beta-trace protein is the key enzyme in the synthesis of prostaglandin D2, an endogenous sleep-promoting neurohormone in the brain. Electromagnetic fields (EMF) in the radio frequency (RF) range have in some studies been associated with disturbed sleep. We studied the concentration of beta-trace protein in blood in relation to emissions from wireless phones. This study included 62 persons aged 18-30 years. The concentration of beta-trace protein decreased with increasing number of years of use of a wireless

phone yielding a negative beta coefficient = -0.32, 95% confidence interval -0.60 to -0.04. Also cumulative use in hours gave a negative beta coefficient, although not statistically significant. Of the 62 persons, 40 participated in an experimental study with 30 min exposure to an 890-MHz GSM signal. No statistically significant change of beta-trace protein was found. In a similar study of the remaining 22 participitants with no exposure, beta-trace protein increased significantly over time, probably due to a relaxed situation. EMF emissions may down-regulate the synthesis of beta-trace protein. This mechanism might be involved in sleep disturbances reported in persons exposed to RF fields. The results must be interpreted with caution since use of mobile and cordless phones were self-reported. Awareness of exposure condition in the experimental study may have influenced beta-trace protein concentrations.

**Hardell L, Carlberg M, Hansson Mild K, Eriksson M. Case-control study on the use of mobile and cordless phones and the risk for malignant melanoma in the head and neck region. Pathophysiology. 18(4):325-333, 2011.**

The incidence of cutaneous malignant melanoma has increased during the last decades in Sweden as in many other countries. Besides of ultraviolet radiation and constitutional factors such as light-sensitive skin and poor ability to tan few risk factors are established. Some studies indicate that electromagnetic fields might be of concern. In this case-control study we assessed use of mobile and cordless phones in 347 cases with melanoma in the head and neck region and 1184 controls. These subjects constituted 82% and 80%, respectively, that answered the questionnaire. Overall no increased risk was found. However, in the most exposed area; temporal, cheek and ear, cumulative use >365h of mobile phone yielded in the >1-5-year latency group odds ratio (OR)=2.1, 95% confidence interval (CI)=0.7-6.1 and cordless phone use gave OR=2.1, 95% CI=1.1-3.8. Highest OR was calculated for first use of mobile or cordless phone before the age of 20 years regardless of anatomical localisation in the head and neck region. No interaction was found with established risk factors such as red, medium blond or fair hair colour, blue eyes, skin type I or II (never or sometimes tanned), severe sunburns as teenager or heredity. The results must be interpreted with caution due to low numbers and potential methodological shortcomings in a case-control study. However, the findings might be consistent with a late carcinogenic effect from microwaves, i.e. tumour promotion, but need to be confirmed.

**Hardell L, Carlberg M, Hansson Mild K. Pooled analysis of case-control studies on malignant brain tumours and the use of mobile and cordless phones including living and deceased subjects. Int J Oncol. 38(5):1465-1474, 2011.**

We studied the association between use of mobile and cordless phones and malignant brain tumours. Pooled analysis was performed of two case-control studies on patients with malignant brain tumours diagnosed during 1997-2003 and matched controls alive at the time of study inclusion and one case-control study on deceased patients and controls diagnosed during the same time period. Cases and controls or relatives to deceased subjects were interviewed using a structured questionnaire. Replies were obtained for 1,251 (85%) cases and 2,438 (84%) controls. The risk increased with latency period and cumulative use in hours for both mobile and

cordless phones. Highest risk was found for the most common type of glioma, astrocytoma, yielding in the >10 year latency group for mobile phone use odds ratio (OR) = 2.7, 95% confidence interval (CI) = 1.9-3.7 and cordless phone use OR = 1.8, 95% CI = 1.2-2.9. In a separate analysis, these phone types were independent risk factors for glioma. The risk for astrocytoma was highest in the group with first use of a wireless phone before the age of 20; mobile phone use OR = 4.9, 95% CI = 2.2-11, cordless phone use OR = 3.9, 95% CI = 1.7-8.7. In conclusion, an increased risk was found for glioma and use of mobile or cordless phone. The risk increased with latency time and cumulative use in hours and was highest in subjects with first use before the age of 20.

**Hardell L, Carlberg M. Use of Mobile and Cordless Phones and Survival of Patients with Glioma. Neuroepidemiology. 40(2):101-108, 2012.**

Background: We analysed the survival of patients after glioma diagnosis in relation to the use of wireless phones. Methods: All cases diagnosed between 1997 and 2003 with a malignant brain tumour (n = 1,251) in our case-control studies were included and followed from the date of diagnosis to the date of death or until May 30, 2012. Results: For glioma, the use of wireless phones (mobile and cordless phones) gave a hazard ratio (HR) = 1.1 (95% confidence interval, CI = 0.9-1.2), with >10-year latency HR = 1.2 (95% CI = 1.002-1.5, p trend = 0.02). For astrocytoma grade I-II (low-grade), the results were, HR = 0.5 (95% CI = 0.3-0.9) and for astrocytoma grade IV (glioblastoma), HR = 1.1 (95% CI = 0.95-1.4), with >10 year latency HR = 1.3 (95% CI = 1.03-1.7). In the highest tertile (>426 h) of cumulative use, HR = 1.2 (95% CI = 0.95-1.5) was found for glioblastoma. The results were similar for mobile and cordless phones. Conclusions: Decreased survival of glioma cases with long-term and high cumulative use of wireless phones was found. A survival disadvantage for astrocytoma grade IV, but a survival benefit for astrocytoma grade I-II was observed which could be due to exposure-related tumour symptoms leading to earlier diagnosis and surgery in that patient group.

**Hardell L, Carlberg M, Cell and cordless phone risk for glioma - Analysis of pooled case-control studies in Sweden, 1997-2003 and 2007-2009, Pathophysiology (2014),** ***Available online 29 October 2014.*** **http://dx.doi.org/10.1016/j.pathophys.2014.10.001**

We made a pooled analysis of 2 case-control studies on malignant brain tumours with patients diagnosed during 1997-2003 and 2007-2009. They were aged 20-80 years and 18-75 years, respectively, at the time of diagnosis. Only cases with histopathological verification of the tumour were included. Population-based controls, matched on age and gender, were used. Exposures were assessed by questionnaire. The whole reference group was used in the unconditional regression analysis adjusted for gender, age, year of diagnosis and socio-economic index.

In total 1,498 (89%) cases and 3,530 (87%) controls participated. Mobile phone use increased the risk of glioma, OR = 1.3, 95% CI = 1.1-1.6 overall, increasing to OR = 3.0, 95% CI = 1.7-5.2 in the > 25 year latency group. Use of cordless phones increased the risk to OR = 1.4, 95% CI = 1.1-1.7, with highest risk in the >15-20 year latency group

yielding OR = 1.7, 95% CI = 1.1-2.5. The OR increased statistically significant both per 100 h of cumulative use, and per year of latency for mobile and cordless phone use. Highest ORs overall were found for ipsilateral mobile or cordless phone use, OR = 1.8, 95% CI = 1.4-2.2 and OR = 1.7, 95% CI = 1.3-2.1, respectively. The highest risk was found for glioma in the temporal lobe. First use of mobile or cordless phone before the age of 20 gave higher OR for glioma than in later age groups

**Hardell L, Carlberg M, Hansson Mild K. Use of mobile phones and cordless phones is associated with increased risk for glioma and acoustic neuroma. Pathophysiology. 2012 Dec 20. pii: S0928-4680(12)00110-1. doi: 10.1016/j.pathophys.2012.11.001. [Epub ahead of print]**

The International Agency for Research on Cancer (IARC) at WHO evaluation of the carcinogenic effect of RF-EMF on humans took place during a 24-31 May 2011 meeting at Lyon in France. The Working Group consisted of 30 scientists and categorised the radiofrequency electromagnetic fields from mobile phones, and from other devices that emit similar non-ionising electromagnetic fields (RF-EMF), as Group 2B, i.e., a 'possible', human carcinogen. The decision on mobile phones was based mainly on the Hardell group of studies from Sweden and the IARC Interphone study. We give an overview of current epidemiological evidence for an increased risk for brain tumours including a meta-analysis of the Hardell group and Interphone results for mobile phone use. Results for cordless phones are lacking in Interphone. The meta-analysis gave for glioma in the most exposed part of the brain, the temporal lobe, odds ratio (OR)=1.71, 95% confidence interval (CI)=1.04-2.81 in the ≥10 years (>10 years in the Hardell group) latency group. Ipsilateral mobile phone use ≥1640h in total gave OR=2.29, 95% CI=1.56-3.37. The results for meningioma were OR=1.25, 95% CI=0.31-4.98 and OR=1.35, 95% CI=0.81-2.23, respectively. Regarding acoustic neuroma ipsilateral mobile phone use in the latency group ≥10 years gave OR=1.81, 95% CI=0.73-4.45. For ipsilateral cumulative use ≥1640h OR=2.55, 95% CI=1.50-4.40 was obtained. Also use of cordless phones increased the risk for glioma and acoustic neuroma in the Hardell group studies. Survival of patients with glioma was analysed in the Hardell group studies yielding in the >10 years latency period hazard ratio (HR)=1.2, 95% CI=1.002-1.5 for use of wireless phones. This increased HR was based on results for astrocytoma WHO grade IV (glioblastoma multiforme). Decreased HR was found for low-grade astrocytoma, WHO grades I-II, which might be caused by RF-EMF exposure leading to tumour-associated symptoms and earlier detection and surgery with better prognosis. Some studies show increasing incidence of brain tumours whereas other studies do not. It is concluded that one should be careful using incidence data to dismiss results in analytical epidemiology. The IARC carcinogenic classification does not seem to have had any significant impact on governments' perceptions of their responsibilities to protect public health from this widespread source of radiation.

**Hardell L, Carlberg M.  Mobile phones, cordless phones and rates of brain tumors in different age groups in the Swedish National Inpatient Register and the Swedish Cancer Register during 1998-2015. PLoS One. 12(10):e0185461, 2017.**

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We used the Swedish Inpatient Register (IPR) to analyze rates of brain tumors of unknown type (D43) during 1998-2015. Average Annual Percentage Change (AAPC) per 100,000 increased with +2.06%, 95% confidence interval (CI) +1.27, +2.86% in both genders combined. A joinpoint was found in 2007 with Annual Percentage Change (APC) 1998-2007 of +0.16%, 95% CI -0.94, +1.28%, and 2007-2015 of +4.24%, 95% CI +2.87, +5.63%. Highest AAPC was found in the age group 20-39 years. In the Swedish Cancer Register the age-standardized incidence rate per 100,000 increased for brain tumors, ICD-code 193.0, during 1998-2015 with AAPC in men +0.49%, 95% CI +0.05, +0.94%, and in women +0.33%, 95% CI -0.29, +0.45%. The cases with brain tumor of unknown type lack morphological examination. Brain tumor diagnosis was based on cytology/histopathology in 83% for men and in 87% for women in 1980. This frequency increased to 90% in men and 88% in women in 2015. During the same time period CT and MRI imaging techniques were introduced and morphology is not always necessary for diagnosis. If all brain tumors based on clinical diagnosis with CT or MRI had been reported to the Cancer Register the frequency of diagnoses based on cytology/histology would have decreased in the register. The results indicate underreporting of brain tumor cases to the Cancer Register. The real incidence would be higher. Thus, incidence trends based on the Cancer Register should be used with caution. Use of wireless phones should be considered in relation to the change of incidence rates.

**Hareuveny R, Eliyahu I, Luria R, Meiran N, Margaliot M. Cognitive effects of cellular phones: a possible role of non-radiofrequency radiation factors. Bioelectromagnetics. 32(7):585-588, 2011.**

Some studies found that cognitive functions of human beings may be altered while exposed to radiofrequency radiation (RFR) emitted by cellular phones. In two recent studies, we have found that experiment duration and exposure side (i.e., phone's location--right or left) may have a major influence on the detection of such effects. In this brief follow-up experiment, 29 right-handed male subjects were divided into two groups. Each subject had two standard cellular phones attached to both sides of his head. The subjects performed a spatial working memory task that required either a left-hand or a right-hand response under one of the two exposure conditions: left side of the head or right side. Contrary to our previous studies, in this work external antennas located far away from the subjects were connected to the cellular phones. This setup prevents any emission of RFR from the internal antenna, thus drastically reducing RFR exposure. Despite that, the results remain similar to those obtained in our previous work. These results indicate that some of the effects previously attributed to RFR can be the result of some confounders.

**Hatice Ş. Gürler, Birşen Bilgici, Ayşegül K. Akar, Leman Tomak & Abdülkerim Bedir. Increased DNA oxidation (8-OHdG) and protein oxidation (AOPP) by low level electromagnetic field (2.45 GHz) in rat brain and protective effect of garlic. International Journal of Radiation Biology. Posted online on August 4, 2014.**

*Purpose*: To investigate the oxidative damage and protective effect of garlic on rats exposed to low level of electromagnetic fields (EMF) at 2.45 GHz Microwave radiation (MWR). *Methods*: Thirty-six Wistar rats were divided into three groups. Group I was the control group and not exposed to EMF. Group II and III were exposed to low level EMF

(3.68 ± 0.36 V/m) at 2.45 GHz MWR for 1 hour/day for 30 consecutive days. Daily 500 mg/kg garlic was given to Group III during the study period. At the end of the study, thiobarbituric acid reactive substances (TBARS), advanced oxidation protein products (AOPP) and 8-hydroxydeoxyguanosine (8-OHdG) levels were investigated in brain tissue and blood samples. *Results*: Exposure to low level of EMF increased 8-OHdG level in both plasma and brain tissue whereas it increased AOPP level only in plasma. Garlic prevented the increase of 8-OHdG level in brain tissue and plasma AOPP levels. *Conclusions*: It may be concluded that low level EMF at 2.45 GHz MWR increases the DNA damage in both brain tissues and plasma of the rats whereas it increases protein oxidation only in plasma. It may also be argued that the use of garlic decreases these effects.

**Hartikka H, Heinävaara S, Mäntylä R, Kähärä V, Kurttio P, Auvinen A. Mobile phone use and location of glioma: A case-case analysis. Bioelectromagnetics. 30(3):176-182, 2009.**

We assessed a new approach for evaluating the glioma risk among users of mobile phones to focus on the part of the brain most heavily exposed to radiofrequency electromagnetic fields from mobile phones. The tumor midpoint was defined from radiological imaging. A case-case analysis with 99 gliomas was performed using logistic regression. The exposed cases were those with the tumor mid-point within 4.6 cm from the line between the mouth and the external meatus of the ear, representing the most likely location of the mobile phone (the source of exposure). Alternative analyses based on various indicators of mobile phone use as the outcome were also carried out. The majority of cases were regular mobile phone users. A slightly higher proportion of gliomas among mobile phone users than non-users occurred within 4.6 cm from the presumed location of the mobile phone (28% vs. 14%). Modestly elevated odds ratios were observed for several indicators of mobile phone use, but without an exposure gradient. The highest odds ratios were found for contralateral and short-term use. Our results, though limited by the small sample size, demonstrate that detailed information on tumor location allows evaluation of the risk related to the most heavily exposed part of the brain, representing direct evaluation of the possible local carcinogenic effects of the radiofrequency fields. However, field strength varies between users and over time also within a given anatomic site, due to the output power of the phone. Collaborative analysis of a larger sample is planned.

**Harvey C, French PW, Effects on protein kinase C and gene expression in a human mast cell line, HMC-1, following microwave exposure. Cell Biol Int 23(11):739-748, 2000.**

We used a resonant cavity which delivered a continuous wave exposure at 864.3 MHz at an average specific absorption rate (SAR) of 7 W/kg to determine non-thermal biological effects of microwave exposure. A human mast cell line, HMC-1, was used as the biological target. Cells were given three exposures each of 20-min duration daily for 7 days. The temperature of the cell culture medium during the exposure fell to 26.5 degrees C. Effects were seen on localization of protein kinase C, and expression of three genes of 588 screened. The affected genes included the proto-oncogene c-kit, the transcription factor Nucleoside diphosphate kinase B and the apoptosis-associated gene DAD-1.

Stress response genes were variably upregulated. No significant effect on morphology or on F-actin distribution was detected. We conclude that low-power microwave exposure may act on HMC-1 cells by altering gene expression via a mechanism involving activation of protein kinase C, and at temperatures well below those known to induce a heat shock response.

**Hashemipour MS, Yarbakht M, Gholamhosseinian A, Famori H. Effect of mobile phone use on salivary concentrations of protein, amylase, lipase, immunoglobulin A, lysozyme, lactoferrin, peroxidase and C-reactive protein of the parotid gland. J Laryngol Otol. 2014 Apr 17:1-9. [Epub ahead of print]**

Background: The possibility of side effects associated with the electromagnetic waves emitted from mobile phones is a controversial issue. The present study aimed to evaluate the effect of mobile phone use on parotid gland salivary concentrations of protein, amylase, lipase, immunoglobulin A, lysozyme, lactoferrin, peroxidase and C-reactive protein. Methods: Stimulated salivary samples were collected simultaneously from both parotid glands of 86 healthy volunteers. Salivary flow rate and salivary concentrations of proteins, amylase, lipase, lysozyme, lactoferrin, peroxidase, C-reactive protein and immunoglobulin A, were measured. Data were analysed using t-tests and one-way analyses of variance. Results: Salivary flow rate and parotid gland salivary concentrations of protein were significantly higher on the right side compared to the left in those that predominantly held mobile phones on the right side. In addition, there was a decrease in concentrations of amylase, lipase, lysozyme, lactoferrin and peroxidase. Conclusion: The side of dominant mobile phone use was associated with differences in salivary flow rate and parotid gland salivary concentrations, in right-dominant users. Although mobile phone use influenced salivary composition, the relationship was not significant.

**Hassanshahi A, Shafeie SA, Fatemi I, Hassanshahi E, Allahtavakoli M, Shabani M, Roohbakhsh A, Shamsizadeh A. The effect of Wi-Fi electromagnetic waves in unimodal and multimodal object recognition tasks in male rats.Neurol Sci. 2017 Mar 22. doi: 10.1007/s10072-017-2920-y. [Epub ahead of print]**

Wireless internet (Wi-Fi) electromagnetic waves (2.45 GHz) have widespread usage almost everywhere, especially in our homes. Considering the recent reports about some hazardous effects of Wi-Fi signals on the nervous system, this study aimed to investigate the effect of 2.4 GHz Wi-Fi radiation on multisensory integration in rats. This experimental study was done on 80 male Wistar rats that were allocated into exposure and sham groups. Wi-Fi exposure to 2.4 GHz microwaves [in Service Set Identifier mode (23.6 dBm and 3% for power and duty cycle, respectively)] was done for 30 days (12 h/day). Cross-modal visual-tactile object recognition (CMOR) task was performed by four variations of spontaneous object recognition (SOR) test including standard SOR, tactile SOR, visual SOR, and CMOR tests. A discrimination ratio was calculated to assess the preference of animal to the novel object. The expression levels of M1 and GAT1 mRNA in the hippocampus were assessed by quantitative real-time RT-PCR. Results demonstrated that rats in Wi-Fi exposure groups could not discriminate significantly between the novel and familiar objects in any of the standard SOR, tactile SOR, visual SOR, and CMOR

tests. The expression of M1 receptors increased following Wi-Fi exposure. In conclusion, results of this study showed that chronic exposure to Wi-Fi electromagnetic waves might impair both unimodal and cross-modal encoding of information.

**Hässig M**, **Jud F**, **Naegeli H**, **Kupper J**, **Spiess B**. **Prevalence of nuclear cataract in Swiss veal calves and its possible association with mobile telephone antenna base stations. Schweiz Arch Tierheilkd. 151(10):471-478, 2009.**

The purpose of this study was to valuate the prevalence of nuclear cataract in veal calves and to elucidate a possible impact by mobile phone base stations (MPBS). For this experiment a cohort study was conducted. A follow-up of the geographical location of each dam and its calf from conception through the fetal period up to slaughter was performed. The first trimester of gestation (organogenesis) was particularly emphasized. The activities of selected protective antioxidants (superoxide dismutase, catalase, glutathione peroxidase [GPx]) were assessed in aqueous humor of the eye to evaluate the redox status. Of 253 calves, 79 (32 %) had various degrees of nuclear cataract, but only 9 (3.6 %) calves had severe nuclear cataract. Results demonstrate a relation between the location of veals calves with nuclear cataracts in the first trimester of gestation and the strength of antennas. The number of antennas within 100 to 199 meters was associated with oxidative stress and there was an association between oxidative stress and the distance to the nearest MPBS. Oxidative stress was increased in eyes with cataract (OR per kilometer: 0.80, confidence interval 95 % 0.62,0.93). It has not been shown that the antennas actually affected stress. Hosmer-Lemeshow statistics showed an accuracy of 100 % in negative cases with low radiation, and only 11.11 % accuracy in positive cases with high radiation. This reflects, that there are a lot of other possibilities for nuclear cataract beside MPBS. Further studies on the influence of electromagnetic fields during embryonic development animal or person at risk are indicated.

**Hässig M, Jud F, Spiess B. [Increased occurrence of nuclear cataract in the calf after erection of a mobile phone base station]. Schweiz Arch Tierheilkd. 154(2):82-86, 2012.**[Article in German]

We examined and monitored a dairy farm in which a large number of calves were born with nuclear cataracts after a mobile phone base station had been erected in the vicinity of the barn. Calves showed a 3.5 times higher risk for heavy cataract if born there compared to Swiss average. All usual causes such as infection or poisoning, common in Switzerland, could be excluded. The real cause of the increased incidence of cataracts remains unknown.

**Hässig M, Wullschleger M, Naegeli HP, Kupper J, Spiess B, Kuster N, Capstick M, Murbach M. Influence of non ionizing radiation of base stations on the activity of redox proteins in bovines. BMC Vet Res. 2014 Jun 19;10(1):136. [Epub ahead of print]**

BACKGROUND: The influence of electromagnetic fields on the health of humans and animals is still an intensively discussed and scientifically investigated issue (Prakt Tierarzt

11:15-20, 2003; Umwelt Medizin Gesellschaft 17:326-332, 2004; J Toxicol Environment Health, Part B 12:572-597, 2009). We are surrounded by numerous electromagnetic fields of variable strength, coming from electronic equipment and its power cords, from high-voltage power lines and from antennas for radio, television and mobile communication. Particularly the latter cause's controversy, as everyone likes to have good mobile reception at anytime and anywhere, whereas nobody wants to have such a base station antenna in their proximity. RESULTS: In this experiment, the non-ionizing radiation (NIR) has resulted in changes in the enzyme activities. Certain enzymes were disabled, others enabled by NIR. Furthermore, individual behavior patterns were observed. While certain cows reacted to NIR, others did not react at all, or even inversely. CONCLUSION: The present results coincide with the information from the literature, according to which NIR leads to changes in redox proteins, and that there are individuals who are sensitive to radiation and others that are not. However, the latter could not be distinctly attributed - there are cows that react clearly with one enzyme while they do not react with another enzyme at all, or even the inverse. The study approach of testing ten cows each ten times during three phases has proven to be appropriate. Future studies should however set the post-exposure phase later on.

**Hassoy H, Durusoy R, Karababa AO. Adolescents' risk perceptions on mobile phones and their base stations, their trust to authorities and incivility in using mobile phones: a cross-sectional survey on 2240 high school students in Izmir, Turkey. Environ Health. 2013 Jan 25;12(1):10. [Epub ahead of print]**

ABSTRACT: BACKGROUND: Use of mobile phones has rapidly risen among adolescents despite a lack of scientific certainty on their health risks. Risk perception is an important determinant of behavior, and studies on adolescents' risk perceptions of mobile phones or base stations are very scarce. This study aims to evaluate high school students' risk perceptions on mobile phones and base stations, their trust to authorities, their opinions regarding incivility while using mobile phones and to assess associated factors. METHODS: For this cross-sectional study, 2530 students were chosen with stratified cluster sampling among 20,493 high school students studying in Bornova district of Izmir, Turkey, among whom 2240 (88.5%) participated. Risk perceptions and opinions were questioned with a 5-point Likert scale for 24 statements grouped under four dimensions. The mean responses to the four dimensions were categorized as <3.5 (low) and >=3.5 (high) and the determinants were analyzed with logistic regression. RESULTS: Mean risk perception scores for the mobile phone, base station, trust to authority and incivility dimensions were 3.69 +/- 0.89, 4.34 +/- 0.78, 3.77 +/- 0.93, 3.16 +/- 0.93 and the prevalence of high risk perception was 65.1%, 86.7%, 66.2%, 39.7%, respectively. In the mobile phone dimension; students attending industrial technical high school had lower risk perceptions while female students, lower mothers' education groups and students not using mobile phones (OR = 2.82, 95% CI = 1.80-4.40) had higher risk perceptions. In the base station dimension girls had higher risk perceptions (OR = 1.68, 95% CI = 1.20-2.37). Girls and students attending industrial technical high school had significantly lower risk perception however 11-12th grade group perceived the risk higher (OR = 1.45 95% CI = 1.15-1.84) in the trust to authority dimension. For the incivility dimension, female students (OR = 1.44, 95% CI = 1.14-1.82), illiterate/only literate mothers (OR = 1.79, 95% CI =

1.04-2.75) and students not using mobile phones (OR = 2.50, 95% CI = 1.62-3.87) perceived higher risk. CONCLUSIONS: Understanding the effects of these determinants might aid in developing more effective educational interventions to specific subgroups on this topic. As debates on the health consequences of electromagnetic fields continue, it would be cautious to approach this issue with a preventive perspective. Efforts should be made to equalize the varying level of knowledge and to ensure that students are informed accurately.

**Hata K, Yamaguchi H, Tsurita G, Watanabe S, Wake K, Taki M, Ueno S, Nagawa H. Short term exposure to 1439 MHz pulsed TDMA field does not alter melatonin synthesis in rats. Bioelectromagnetics. 26(1):49-53, 2005.**

The widespread use of the mobile phone has initiated many studies on the possible adverse effects of a high frequency electromagnetic field (EMF), which is used in mobile phones. A low frequency EMF is reported to suppress melatonin synthesis. The aim of this study was to clarify the effects on melatonin synthesis in rats after short term exposure to a 1439 MHz time division multiple access (TDMA) EMF. The average specific absorption ratio (SAR) of the brain was 7.5 W/kg, and the average SARs of the whole body were 1.9 and 2.0 W/kg for male and female rats, respectively. A total of 208 male and female rats were investigated. After acclimatization to a 12 h light-dark (LD) cycle, serum and pineal melatonin levels together with pineal serotonin level under a dark condition (less than 1 lux) were examined by radioimmunoassay. No significant differences in melatonin and serotonin levels were observed between the exposure, sham, and cage control groups. These results suggest that short term exposure to a 1439 MHz TDMA EMF, which is about four times stronger than that emitted by mobile phones, does not alter melatonin and serotonin synthesis in rats. Further investigations on the effects of long term exposure are warranted.

**Hauri DD, Spycher B, Huss A, Zimmermann F, Grotzer M, von der Weid, Spoerri A, Kuehni CE, Röösli M*, the Swiss National Cohort and the Swiss Paediatric Oncology Group. Exposure to Radio-Frequency Electromagnetic Fields From Broadcast Transmitters and Risk of Childhood Cancer: A Census-based Cohort Study. Am. J. Epidemiol. (2014) doi: 10.1093/aje/kwt442 First published online: February 19, 2014.**

We investigated the association between exposure to radio-frequency electromagnetic fields (RF-EMFs) from broadcast transmitters and childhood cancer. First, we conducted a time-to-event analysis including children under age 16 years living in Switzerland on December 5, 2000. Follow-up lasted until December 31, 2008. Second, all children living in Switzerland for some time between 1985 and 2008 were included in an incidence density cohort. RF-EMF exposure from broadcast transmitters was modeled. Based on 997 cancer cases, adjusted hazard ratios in the time-to-event analysis for the highest exposure category (>0.2 V/m) as compared with the reference category (<0.05 V/m) were 1.03 (95% confidence interval (CI): 0.74, 1.43) for all cancers, 0.55 (95% CI: 0.26, 1.19) for childhood leukemia, and 1.68 (95% CI: 0.98, 2.91) for childhood central nervous system (CNS) tumors. Results of the incidence density analysis, based on 4,246 cancer cases, were similar for all types of cancer and leukemia but did not indicate a CNS tumor

risk (incidence rate ratio = 1.03, 95% CI: 0.73, 1.46). This large census-based cohort study did not suggest an association between predicted RF-EMF exposure from broadcasting and childhood leukemia. Results for CNS tumors were less consistent, but the most comprehensive analysis did not suggest an association.

**Havas M. Electromagnetic hypersensitivity: biological effects of dirty electricity with emphasis on diabetes and multiple sclerosis.Electromagn Biol Med. 25(4):259-268, 2006.**

Dirty electricity is a ubiquitous pollutant. It flows along wires and radiates from them and involves both extremely low frequency electromagnetic fields and radio frequency radiation. Until recently, dirty electricity has been largely ignored by the scientific community. Recent inventions of metering and filter equipment provide scientists with the tools to measure and reduce dirty electricity on electrical wires. Several case studies and anecdotal reports are presented. Graham/Stetzer (GS) filters have been installed in schools with sick building syndrome and both staff and students reported improved health and more energy. The number of students needing inhalers for asthma was reduced in one school and student behavior associated with ADD/ADHD improved in another school. Blood sugar levels for some diabetics respond to the amount of dirty electricity in their environment. Type 1 diabetics require less insulin and Type 2 diabetics have lower blood sugar levels in an electromagnetically clean environment. Individuals diagnosed with multiple sclerosis have better balance and fewer tremors. Those requiring a cane walked unassisted within a few days to weeks after GS filters were installed in their home. Several disorders, including asthma, ADD/ADHD, diabetes, multiple sclerosis, chronic fatigue, fibromyalgia, are increasing at an alarming rate, as is electromagnetic pollution in the form of dirty electricity, ground current, and radio frequency radiation from wireless devices. The connection between electromagnetic pollution and these disorders needs to be investigated and the percentage of people sensitive to this form of energy needs to be determined.

**Havas M, Marrongelle J. Replication of heart rate variability provocation study with 2.4-GHz cordless phone confirms original findings. Electromagn Biol Med. 32(2):253-266, 2013.**

This is a replication of a study that we previously conducted in Colorado with 25 subjects designed to test the effect of electromagnetic radiation generated by the base station of a cordless phone on heart rate variability (HRV). In this study, we analyzed the response of 69 subjects between the ages of 26 and 80 in both Canada and the USA. Subjects were exposed to radiation for 3-min intervals generated by a 2.4-GHz cordless phone base station (3-8 μW/cm$^2$). A few participants had a severe reaction to the radiation with an increase in heart rate and altered HRV indicative of an alarm response to stress. Based on the HRV analyses of the 69 subjects, 7% were classified as being "moderately to very" sensitive, 29% were "little to moderately" sensitive, 30% were "not to little" sensitive and 6% were "unknown". These results are not psychosomatic and are not due to electromagnetic interference. Twenty-five percent of the subjects' self-proclaimed

sensitivity corresponded to that based on the HRV analysis, while 32% overestimated their sensitivity and 42% did not know whether or not they were electrically sensitive. Of the 39 participants who claimed to experience some electrical hypersensitivity, 36% claimed they also reacted to a cordless phone and experienced heart symptoms and, of these, 64% were classified as having some degree of electrohypersensitivity (EHS) based on their HRV response. Novel findings include documentation of a delayed response to radiation. Orthostatic HRV testing combined with provocation testing may provide a diagnostic tool for some sufferers of EHS when they are exposed to electromagnetic emitting devices. The protocol used underestimates reaction to electromagnetic radiation for those who have a delayed autonomic nervous system reaction and it may under diagnose those who have adrenal exhaustion as their ability to mount a response to a stressor is diminished.

**Hayes DL, Wang PJ, Reynolds DW, Estes M 3rd, Griffith JL, Steffens RA, Carlo GL, Findlay GK, Johnson CM. Interference with cardiac pacemakers by cellular telephones. N Engl J Med 336(21):1473-1479, 1997.**

BACKGROUND: A growing body of evidence suggests that electromagnetic interference may occur between cardiac pacemakers and wireless hand-held (cellular) telephones, posing a potential public health problem. Electromagnetic interference may occur when the pacemaker is exposed to an electromagnetic field generated by the cellular telephone. METHODS: In this multicenter, prospective, crossover study, we tested 980 patients with cardiac pacemakers with five types of telephones (one analogue and four digital) to assess the potential for interference. Telephones were tested in a test mode and were programmed to transmit at the maximal power, simulating the worst-case scenario; in addition, one telephone was tested during actual transmission to simulate actual use. Patients were electrocardiographically monitored while the telephones were tested at the ipsilateral ear and in a series of maneuvers directly over the pacemaker. Interference was classified according to the type and clinical significance of the effect. RESULTS: The incidence of any type of interference was 20 percent in the 5533 tests, and the incidence of symptoms was 7.2 percent. The incidence of clinically significant interference was 6.6 percent. There was no clinically significant interference when the telephone was placed in the normal position over the ear. Interference that was definitely clinically significant occurred in only 1.7 percent of tests, and only when the telephone was held over the pacemaker. Interference was more frequent with dual-chamber pacemakers (25.3 percent) than with single-chamber pacemakers (6.8 percent, $P<0.001$) and more frequent with pacemakers without feed-through filters (28.9 to 55.8 percent) than with those with such filters (0.4 to 0.8 percent, $P=0.01$). CONCLUSIONS: Cellular telephones can interfere with the function of implanted cardiac pacemakers. However, when telephones are placed over the ear, the normal position, this interference does not pose a health risk.

**He Q, Sun Y, Zong L, Tong J, Cao Y. Induction of Poly(ADP-ribose) Polymerase in Mouse Bone Marrow Stromal Cells Exposed to 900 MHz Radiofrequency Fields: Preliminary Observations. Biomed Res Int. 2016;2016:4918691.**

Background. Several investigators have reported increased levels of poly(ADP-ribose) polymerase-1 (PARP-1), a nuclear enzyme which plays an important role in the repair of damaged DNA, in cells exposed to extremely low dose ionizing radiation which does not cause measurable DNA damage. Objective. To examine whether exposure of the cells to nonionizing radiofrequency fields (RF) is capable of increasing messenger RNA of PARP-1 and its protein levels in mouse bone marrow stromal cells (BMSCs). Methods. BMSCs were exposed to 900 MHz RF at 120 μW/cm(2) power intensity for 3 hours/day for 5 days. PARP-1 mRNA and its protein levels were examined at 0, 0.5, 1, 2, 4, 6, 8, and 10 hours after exposure using RT-PCR and Western blot analyses. Sham-exposed (SH) cells and those exposed to ionizing radiation were used as unexposed and positive control cells. Results. BMSCs exposed to RF showed significantly increased expression of PARP-1 mRNA and its protein levels after exposure to RF while such changes were not observed in SH-exposed cells. Conclusion. Nonionizing RF exposure is capable of inducing PARP-1.

**Hedendahl LK, Carlberg M, Koppel T, Hardell L. Measurements of Radiofrequency Radiation with a Body-Borne Exposimeter in Swedish Schools with Wi-Fi. Front. Public Health, 20 November 2017 | https://doi.org/10.3389/fpubh.2017.00279**

Introduction: Wireless access to the Internet is now commonly used in schools. Many schools give each student their own laptop and utilize the laptops and wireless fidelity (Wi-Fi) connection for educational purposes. Most children also bring their own mobile phones to school. Since children are obliged by law to attend school, a safe environment is important. Lately, it has been discussed if radiofrequency (RF) radiation can have long-term adverse effects on children's health. Method: This study conducted exposimetric measurements in schools to assess RF emissions in the classroom by measuring the teachers' RF exposure in order to approximate the children's exposure. Teachers in grades 7–12 carried a body-borne exposimeter, EME-Spy 200, in school during 1–4 days of work. The exposimeter can measure 20 different frequency bands from 87 to 5,850 MHz. Results: Eighteen teachers from seven schools participated. The mean exposure to RF radiation ranged from 1.1 to 66.1 μW/$m^2$. The highest mean level, 396.6 μW/$m^2$, occurred during 5 min of a lesson when the teacher let the students stream and watch YouTube videos. Maximum peaks went up to 82,857 μW/$m^2$ from mobile phone uplink. Discussion: Our measurements are in line with recent exposure studies in schools in other countries. The exposure levels varied between the different Wi-Fi systems, and if the students were allowed to use their own smartphones on the school's Wi-Fi network or if they were connected to GSM/3G/4G base stations outside the school. An access point over the teacher's head gave higher exposure compared with a school with a wired Internet connection for the teacher in the classroom. All values were far below International Commission on Non-Ionizing Radiation Protection's reference values, but most mean levels measured were above the precautionary target level of 3–6 μW/$m^2$ as proposed by the Bioinitiative Report. The length of time wireless devices are used is an essential determinant in overall exposure. Measures to minimize children's exposure to RF radiation in school would include preferring wired connections, allowing laptops, tablets and mobile phones only in flight mode and deactivating Wi-Fi access points, when not used for learning purposes.

**Heikkinen P, Kosma VM, Hongisto T, Huuskonen H, Hyysalo P, Komulainen H, Kumlin T, Lahtinen T, Lang S, Puranen L, Juutilainen J. Effects of mobile phone radiation on x-ray-induced tumorigenesis in mice. Radiat Res 156(6):775-785, 2001.**

The increased use of mobile phones has raised the question of possible health effects of such devices, particularly the risk of cancer. It seems unlikely that the low-level radiofrequency (RF) radiation emitted by them would damage DNA directly, but its ability to act as a tumor promoter is less well characterized. In the current study, we evaluated the effect of low-level RF radiation on the development of cancer initiated in mice by ionizing radiation. Two hundred female CBA/S mice were randomized into four equal groups at the age of 3 to 5 weeks. The mice in all groups except the cage-control group were exposed to ionizing radiation at the beginning of the study and then to RF radiation for 1.5 h per day, 5 days a week for 78 weeks. One group was exposed to continuous NMT (Nordic Mobile Telephones)-type frequency-modulated RF radiation at a frequency of 902.5 MHz and a nominal average specific absorption rate (SAR) of 1.5 W/kg. Another group was exposed to pulsed GSM (Global System for Mobile)-type RF radiation (carrier-wave frequency 902.4 MHz, pulse frequency 217 Hz) at a nominal average SAR of 0.35 W/kg. The control animals were sham-exposed. Body weight, clinical signs, and food and water consumption were recorded regularly. Hematological examinations and histopathological analyses of all lesions and major tissues were performed on all animals. The RF-radiation exposures did not increase the incidence of any neoplastic lesion significantly. We conclude that the results do not provide evidence for cancer promotion by RF radiation emitted by mobile phones.

**Heikkinen P, Kosma VM, Alhonen L, Huuskonen H, Komulainen H, Kumlin T, Laitinen JT, Lang S, Puranen L, Juutilainen J. Effects of mobile phone radiation on UV-induced skin tumourigenesis in ornithine decarboxylase transgenic and non-transgenic mice. Int J Radiat Biol 79(4):221-233, 2003.**

Purpose: The effects of low-level radiofrequency radiation (RFR) on ultraviolet (UV)-induced skin tumorigenesis were evaluated in ornithine decarboxylase (ODC) and non-transgenic mice. Materials and methods: Transgenic female mice over-expressing the human ODC gene and their non-transgenic littermates (20 animals in the cage control group, and 45-49 animals in the other groups) were exposed for 52 weeks to UV radiation or a combination of UV radiation and pulsed RFR. The UV dose was 240 Jm(-2) (1.2 x human minimum erythemal dose) delivered three times a week. One group of animals was exposed to Digital Advanced Mobile Phone System (DAMPS)-type RFR, the other group to Global System for Mobile (GSM)-type RFR at a nominal average specific absorption rate of 0.5 W kg(-1), 1.5 h day(-1), for 5 days a week. The skin was carefully palpated weekly for macroscopic tumours. Histopathological analyses of all skin lesions and of a specified dorsal skin area were performed on all animals. Results: UV exposure resulted in development of macroscopic skin tumours in 11.5 and 36.8% of non-transgenic and transgenic animals, respectively. The RFR exposures did not give a statistically significant effect on the development of skin tumours in either transgenic or non-transgenic animals, or in combined analysis, but tumour development appeared slightly accelerated especially in non-transgenic animals. No effects of RFR exposures

were found on excretion of 6-hydroxymelatonin sulphate into urine or on polyamine levels in dorsal skin. Conclusion: RFR exposures did not significantly enhance skin tumourigenesis. However, the slightly accelerated tumour development may warrant further evaluation.

**Heikkinen, P., Ernst, H., Huuskonen, H., Komulainen, H., Kumlin, T., Maki-Paakkanen, J., Puranen, L. and Juutilainen, J. No effects of radiofrequency radiation on 3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone-Induced tumorigenesis in female Wistar rats. Radiat. Res. 166, 397-408, 2006.**

This study evaluated possible effects of radiofrequency (RF) radiation on tumorigenesis induced by the mutagen 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) given in drinking water. Female Wistar rats aged 7 weeks at the beginning of the experiments were randomly divided into four groups of 72 animals: a cage-control group and three MX-exposed groups (a daily average dose of 1.7 mg MX/kg body weight for 104 weeks), of which two were exposed to 900 MHz pulsed RF radiation and the third served as a sham-RF-radiation group. The RF-radiation groups were exposed 2 h per day, 5 days per week for 104 weeks at nominal whole-body average SARs of 0.3 W/kg and 0.9 W/kg. Complete histopathology was performed on the rats of the three MX-exposed groups. The tumor types and incidences observed in the MX-exposed animals were similar to those reported earlier in MX-exposed female Wistar rats. RF radiation did not statistically significantly affect mortality or organ-specific incidence of any tumor type. The only statistically significant difference was an increase in the combined frequency of vascular tumors of the mesenteric lymph nodes in the high-RF-radiation group compared to the sham-RF-radiation group. However, additional histopathological analysis of the cage-control animals suggested that this difference was due to unusually low frequency of this type of tumor in the sham-RF-radiation group rather than a high frequency in the high-RF-radiation group. With respect to non-neoplastic findings, statistically significant differences between the RF-radiation groups and the sham-RF-radiation group were observed only for single findings in the lacrimal glands, lungs, liver and skin. Such changes are commonly seen in aged rats and were considered to be unrelated to RF radiation. The results of the present study do not support co-carcinogenic effects of low-level long-term RF-radiation exposure in rats.

**Heinrich S, Thomas S, Heumann C, von Kries R, Radon K. Association between exposure to radiofrequency electromagnetic fields assessed by dosimetry and acute symptoms in children and adolescents: a population based cross-sectional study. Environ Health. 9:75, 2010.**

BACKGROUND: The increase in numbers of mobile phone users was accompanied by some concern that exposure to radiofrequency electromagnetic fields (RF EMF) might adversely affect acute health especially in children and adolescents. The authors investigated this potential association using personal dosimeters. METHODS: A 24-hour exposure profile of 1484 children and 1508 adolescents was generated in a population-based cross-sectional study in Germany between 2006 and 2008 (participation 52%). Personal interview data on socio-demographic characteristics, self-reported exposure and

potential confounders were collected. Acute symptoms were assessed twice during the study day using a symptom diary. RESULTS: Only few of the large number of investigated associations were found to be statistically significant. At noon, adolescents with a measured exposure in the highest quartile during morning hours reported a statistically significant higher intensity of headache (Odd Ratio: 1.50; 95% confidence interval: 1.03, 2.19). At bedtime, adolescents with a measured exposure in the highest quartile during afternoon hours reported a statistically significant higher intensity of irritation in the evening (4th quartile 1.79; 1.23, 2.61), while children reported a statistically significant higher intensity of concentration problems (4th quartile 1.55; 1.02, 2.33). *CONCLUSIONS: We observed few statistically significant results which are not consistent over the two time points.* Furthermore, when the 10% of the participants with the highest exposure are taken into consideration the significant results of the main analysis could not be confirmed.Based on the pattern of these results, we assume that the few observed significant associations are not causal but rather occurred by chance.

**Heinrich S, Thomas S, Heumann C, von Kries R, Radon K. The impact of exposure to radio frequency electromagnetic fields on chronic well-being in young people - A cross-sectional study based on personal dosimetry. Environ Int. 37(1):26-30, 2011.**

A possible influence of radio frequency electromagnetic field (RF EMF) exposure on health outcomes was investigated in various studies. The main problem of previous studies was exposure assessment. The aim of our study was the investigation of a possible association between RF EMF and chronic well-being in young persons using personal dosimetry. 3022 children and adolescents were randomly selected from the population registries of four Bavarian cities in Germany (participation 52%). Personal interview data on chronic symptoms, socio-demographic characteristics and potential confounders were collected. A 24-h radio frequency exposure profile was generated using a personal dosimeter. Exposure levels over waking hours were expressed as mean percentage of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference level. Half of the children and nearly every adolescent owned a mobile phone which was used only for short durations per day. Measured exposure was far below the current ICNIRP reference levels. The most reported chronic symptom in children and adolescents was fatigue. No statistically significant association between measured exposure and chronic symptoms was observed. Our results do not indicate an association between measured exposure to RF EMF and chronic well-being in children and adolescents. Prospective studies investigating potential long-term effects of RF EMF are necessary to confirm our results.

**Hekmat A, Saboury AA, Moosavi-Movahedi AA.The toxic effects of mobile phone radiofrequency (940MHz) on the structure of calf thymus DNA.Ecotoxicol Environ Saf. 2012 Nov 16. pii: S0147-6513(12)00368-5. doi: 10.1016/j.ecoenv.2012.10.016. [Epub ahead of print]**

Currently, the biological effects of nonionizing electromagnetic fields (EMFs) including radiofrequency (RF) radiation have been the subject of numerous experimental and theoretical studies. The aim of this study is to evaluate the possible biological effects of

mobile phone RF (940MHz, 15V/m and SAR=40mW/kg) on the structure of calf thymus DNA (ct DNA) immediately after exposure and 2h after 45min exposure via diverse range of spectroscopic instruments. The UV-vis and circular dichroism (CD) experiments depict that mobile phone EMFs can remarkably cause disturbance on ct DNA structure. In addition, the DNA samples, immediately after exposure and 2h after 45min exposure, are relatively thermally unstable compared to the DNA solution, which was placed in a small shielded box (unexposed ct DNA). Furthermore, the exposed DNA samples (the DNA samples that were exposed to 940MHz EMF) have more fluorescence emission when compared with the unexposed DNA, which may have occurred attributable to expansion of the exposed DNA structure. The results of dynamic light scattering (DLS) and zeta potential experiments demonstrate that RF-EMFs lead to increment in the surface charge and size of DNA. The structure of DNA immediately after exposure is not significantly different from the DNA sample 2h after 45min exposure. In other words, the EMF-induced conformational changes are irreversible. Collectively, our results reveal that 940MHz can alter the structure of DNA. The displacement of electrons in DNA by EMFs may lead to conformational changes of DNA and DNA disaggregation. Results from this study could have an important implication on the health effects of RF-EMFs exposure. In addition, this finding could proffer a novel strategy for the development of next generation of mobile phone.

**Henderson SI, Bangay MJ. Survey of RF exposure levels from mobile telephone base stations in Australia. Bioelectromagnetics. 27(1):73-76, 2006.**

This paper reports the results of an exposure level survey of radiofrequency electromagnetic energy originating from mobile telephone base station antennas. Measurements of CDMA800, GSM900, GSM1800, and 3G(UMTS) signals were performed at distances ranging over 50 to 500 m from 60 base stations in five Australian cities. The exposure levels from these mobile telecommunications base stations were found to be well below the general public exposure limits of the ICNIRP guidelines and the Australian radiofrequency standard (ARPANSA RPS3). The highest recorded level from a single base station was 7.8 x 10(-3) W/m(2), which translates to 0.2% of the general public exposure limit.

**Hepworth SJ, Schoemaker MJ, Muir KR, Swerdlow AJ, van Tongeren MJ, McKinney PA. Mobile phone use and risk of glioma in adults: case-control study. BMJ.332(7546):883-7, 2006.**

OBJECTIVE: To investigate the risk of glioma in adults in relation to mobile phone use. DESIGN: Population based case-control study with collection of personal interview data. SETTING: Five areas of the United Kingdom. PARTICIPANTS: 966 people aged 18 to 69 years diagnosed with a glioma from 1 December 2000 to 29 February 2004 and 1716 controls randomly selected from general practitioner lists. MAIN OUTCOME MEASURES: Odds ratios for risk of glioma in relation to mobile phone use. RESULTS: The overall odds ratio for regular phone use was 0.94 (95% confidence interval 0.78 to 1.13). There was no relation for risk of glioma and time since first use, lifetime years of use, and cumulative number of calls and hours of use. A significant excess risk for reported phone use ipsilateral to the tumour (1.24, 1.02 to 1.52) was paralleled by a significant reduction in risk (0.75, 0.61 to 0.93) for contralateral use. CONCLUSIONS:

Use of a mobile phone, either in the short or medium term, is not associated with an increased risk of glioma. This is consistent with most but not all published studies. The complementary positive and negative risks associated with ipsilateral and contralateral use of the phone in relation to the side of the tumour might be due to recall bias.

**Hess DJ, Coley JS. Wireless smart meters and public acceptance: The environment, limited choices, and precautionary politics. Public Underst Sci. 2012 Nov 6. [Epub ahead of print]**

Wireless smart meters (WSMs) promise numerous environmental benefits, but they have been installed without full consideration of public acceptance issues. Although societal-implications research and regulatory policy have focused on privacy, security, and accuracy issues, our research indicates that health concerns have played an important role in the public policy debates that have emerged in California. Regulatory bodies do not recognize non-thermal health effects for non-ionizing electromagnetic radiation, but both homeowners and counter-experts have contested the official assurances that WSMs pose no health risks. Similarities and differences with the existing social science literature on mobile phone masts are discussed, as are the broader political implications of framing an alternative policy based on an opt-out choice. The research suggests conditions under which health-oriented precautionary politics can be particularly effective, namely, if there is a mandatory technology, a network of counter-experts, and a broader context of democratic contestation.

**Hidisoglu E, Kantar Gok D, Er H, Akpinar D, Uysal F, Akkoyunlu G, Ozen S, Agar A, Yargicoglu P. 2100-MHz electromagnetic fields have different effects on visual evoked potentials and oxidant/antioxidant status depending on exposure duration. Brain Res. 2016 Jan 14. pii: S0006-8993(16)00031-7. doi: 10.1016/j.brainres.2016.01.018. [Epub ahead of print]**

The purpose of the present study was to investigate the duration effects of 2100-MHz electromagnetic field (EMF) on visual evoked potentials (VEPs) and to assess lipid peroxidation (LPO), nitric oxide (NO) production and antioxidant status of EMF exposed rats. Rats were randomized to following groups: Sham rats (S1 and S10) and rats exposed to 2100-MHz EMF (E1 and E10) for 2h/day for 1 or 10 weeks, respectively. At the end of experimental periods, VEPs were recorded under anesthesia. Brain thiobarbituric acid reactive substances (TBARS) and 4-hydroxy-2-nonenal (4-HNE) levels were significantly decreased in the E1 whereas increased in the E10 compared with their control groups. While brain catalase (CAT), glutathione peroxidase (GSH-Px) activities and NO and glutathione (GSH) levels were significantly increased in the E1, reduction of superoxide dismutase (SOD) activity was detected in the same group compared with the S1. Conversely, decreased CAT, GSH-Px activities and NO levels were observed in the E10 compared with the S10. Latencies of all VEP components were shortened in the E1 compared with the S1, whereas latencies of all VEP components, except P1, were prolonged in the E10 compared with the S10. There was a positive correlation between all VEP latencies and brain TBARS and 4-HNE values. Consequently, it could be concluded that different effects of EMFs on VEPs depend on exposure duration.

Additionally, our results indicated that short-term EMF could provide protective effects, while long-term EMF could have an adverse effect on VEPs and oxidant/antioxidant status.

**Hietanen M, Kovala T, Hamalainen AM, Human brain activity during exposure to radiofrequency fields emitted by cellular phones. Scand J Work Environ Health 26(2):87-92, 2000.**

OBJECTIVES: The aim of this study was to explore the possible influence of radiofrequency (RF) radiation exposure on human brain function. METHODS: The electroencephalographic (EEG) activity of 19 volunteers was quantitatively analyzed. Ten of the subjects were men (28-48 years of age) and 9 were women (32-57 years of age). The sources of exposure were 5 different cellular phones (analogue and digital models) operating at a frequency of 900 MHz or 1800 MHz. The EEG activity was recorded in an awake, closed-eyes situation. Six 30-minute experiments, including 1 sham exposure, were made for each subject. The duration of a real exposure phase was 20 minutes. RESULTS: Exposure to one of the phones caused a statistically significant change in the absolute power at the delta band of the EEG recording. However, no difference was seen in the relative power of the same band, and no changes occurred during exposure to other phones at any frequency bands. CONCLUSIONS: The findings of this study suggest that exposure to radiofrequency fields emitted by cellular phones has no abnormal effects on human EEG activity. The observed difference in 1 parameter was probably caused by statistical chance.

**Hietanen M, Sibakov V, Hallfors S, von Nandelstadh P, Safe use of mobile phones in hospitals. Health Phys 79(5 Suppl):S77-84, 2000.**

This research evaluated possibilities to use different types of mobile telephones in the hospital environment by testing the disturbances in medical equipment caused by radiofrequency fields emitted by the phones. The research was carried out by the Finnish Institute of Occupational Health (FIOH) in cooperation with the Technical Research Centre of Finland (VTT), and focused mainly on equipment situated within the Maria Hospital of the City of Helsinki. The Helsinki Hospital District and tile Medical Engineering Centre of the Helsinki University Central Hospital (HUCH) also participated in this project.

**Hietanen M, Hämäläinen A-M, Husman T. Hypersensitivity symptoms associated with exposure to cellular telephones: No causal link. Bioelectromagnetics 23:264-270, 2002.**

The hypothesis that there exist hypersensitive persons who perceive subjective symptoms from radiofrequency (RF) fields emitted by hand held mobile phones (cellular phones) was tested using double blind provocation experiments. We also tested whether sensitive subjects are able to determine whether the phone is on or off by sensing RF fields. The study group consisted of 20 volunteers (13 women and 7 men) who reported themselves as being sensitive to cellular phones. The RF exposure sources were one analogue NMT phone (900 MHz) and two digital GSM phones (900 and 1800 MHz). The duration of a test session was 30 min, and three or four sessions were performed in random order for each subject during 1 day. The subjects were asked to report symptoms or sensations as soon as they perceived any abnormal feelings. In addition, the subjects'

blood pressure, heart rate, and breathing frequency were monitored every 5 min. The results of the study indicated that various symptoms were reported, and most of them appeared in the head region. However, the number of reported symptoms was higher during sham exposure than during real exposure conditions. In addition, none of the test persons could distinguish real RF exposure from sham exposure. Hence, we conclude that adverse subjective symptoms or sensations, though unquestionably perceived by the test subjects, were not produced by cellular phones.

**Higashikubo R, Culbreth VO, Spitz DR, LaRegina MC, Pickard WF, Straube WL, Moros EG, Roti JL, Radiofrequency electromagnetic fields have no effect on the in vivo proliferation of the 9L brain tumor. Radiat Res 152(6):665-671, 1999.**

The intracranial 9L tumor model was used to determine if exposure to a radiofrequency (RF) electromagnetic field similar to those used in cellular telephone has any effects on the growth of a central nervous system tumor. Fischer 344 rats implanted with different numbers of 9L gliosarcoma cells were exposed to 835.62 MHz frequency-modulated continuous wave (FMCW) or 847.74 MHz code division multiple access (CDMA) RF field with nominal slot-average specific absorption rates in the brain of 0.75 +/- 0.25 W/kg. The animals were exposed to the RF field for 4 h a day, 5 days a week starting 4 weeks prior to and up to 150 days after the implantation of tumor cells. Among sham-exposed animals injected with 2 to 10 viable cells (group 1), the median survival was 70 days, with 27% of the animals surviving at 150 days. The median survival length and final survival fraction for animals injected with 11 to 36 viable cells (group 2) were 52 days and 14%, respectively, while the values for those injected with 37 to 100 cells (group 3) were 45 days and 0%. The animals exposed to CDMA or FMCW had similar survival parameters, and the statistical comparison of the survival curves for each of the groups 1, 2 and 3 showed no significant differences compared to sham-exposed controls.

**Higashikubo R, Ragouzis M, Moros EG, Straube WL, Roti Roti JL. Radiofrequency electromagnetic fields do not alter the cell cycle progression of C3H 10T and U87MG cells. Radiat Res 156(6):786-795, 2001.**

The effects of exposure to radiofrequency electromagnetic fields (RF EMFs) on cell cycle progression of mouse fibroblasts C3H 10T(1/2) and human glioma U87MG cells were determined by the flow cytometric bromodeoxyuridine pulse-chase method. Cells were exposed to a frequency-modulated continuous wave at 835.62 MHz or a code division multiple access RF EMF centered on 847.74 MHz at an average specific absorption rate of 0.6 W/kg. Five cell cycle parameters, including the transit of cells through G(1), G(2) and S phase and the probability of cell division, were examined immediately after the cells were placed in the fields or after they had been kept in the fields for up to 100 h. The only significant change observed in the study was that associated with C3H 10T(1/2) cell cultures moving into plateau phase toward the later times in the long-exposure experiment. No changes in the cell cycle parameters were observed in cells exposed to either mode of RF EMFs when compared to sham-exposed cells in either of the cell lines studied during the entire experimental period. The results show that exposure to RF EMFs, at the frequencies and power tested, does not have any effect on cell progression in vitro.

**Higuchi Y, Nashold BS Jr, Sluijter M, Cosman E, Pearlstein RD. Exposure of the**

**dorsal root ganglion in rats to pulsed radiofrequency currents activates dorsal horn lamina I and II neurons. Neurosurgery 50(4):850-856, 2002.**

OBJECTIVE: Application of pulsed radiofrequency (RF) currents to the dorsal ganglion has been reported to produce long-term relief of spinal pain without causing thermal ablation. The present study was undertaken to identify spinal cord neurons activated by exposure of the dorsal ganglion to pulsed RF currents in rats. METHODS: Left-sided hemilaminectomy was performed in adult Sprague-Dawley rats to expose the C6 dorsal root ganglion. An RF electrode (0.5 mm diameter) with a thermocouple for temperature monitoring was positioned on the exposed ganglion, and rats were assigned to one of three treatment groups: pulsed RF treatment (20 ms of 500-kHz RF pulses delivered at a rate of 2 Hz for 120 s to produce tissue heated to 38 degrees C), continuous RF (continuous RF currents for 120 s to produce tissue heated to 38 degrees C), or sham treatment (no RF current; electrode maintained in contact with ganglion for 120 s). RESULTS: Treatment with pulsed RF but not continuous RF was associated with a significant increase in the number of cFOS-immunoreactive neurons in the superficial laminae of the dorsal horn as observed 3 hours after treatment. CONCLUSION: Exposure of the dorsal ganglion to pulsed RF currents activates pain-processing neurons in the dorsal horn. This effect is not mediated by tissue heating.

**Hinrichs H, Heinze HJ.Effects of GSM electromagnetic field on the MEG during an encoding-retrieval task. Neuroreport. 15(7):1191-1194, 2004.**

Potential effects of GSM 1800 electromagnetic fields (EMF) on verbal memory encoding were investigated by recording event-related magnetic fields (ERMF) from the brain during subsequent memory retrieval. Twelve normal subjects participated in the study. After encoding words from a study list presented in the first phase they had to discriminate old from new words mixed together in a test list presented during the second phase. All subjects performed two experimental sessions, one with exposure to EMF during the study phase, and one without. Exposure to EMF changed an early (350-400 ms) task-specific component of the ERMF indicating an interference of EMF and item encoding. Behavioural measures were not significantly affected. Adverse health effects cannot be derived from these data.

**Hinrikus H, Parts M, Lass J, Tuulik V. Changes in human EEG caused by low level modulated microwave stimulation. Bioelectromagnetics. 25(6):431-440, 2004.**

This study focuses on the effect of low level microwave radiation on human EEG alpha and theta rhythms. During the experiment, 20 healthy volunteers were exposed to a 450 MHz microwaves with 7 Hz on-off modulation. The field power density at the scalp was 0.16 mW/cm2. Signals from the following EEG channels were used: FP1, FP2, P3, P4, T3, T4, O1, and O2. The experimental protocol consisted of one cycle of short term photic and ten cycles of the repetitive microwave stimulation. The changes caused by photic as well as microwave stimulation were more regular on the alpha rhythm. In the majority of cases, photic stimulation caused changes in the EEG energy level in the occipital and microwave stimulation in the frontal region. Our experimental results demonstrated that microwave stimulation effects became apparent, starting from the third stimulation cycle. Changes varied strongly from subject to subject. Therefore, photic and microwave exposure did not cause statistically significant changes in the EEG activity level for the

whole group. For some subjects, clear tendencies of changes in microwave on-off cycles were noticeable.

**Hinrikus H, Bachmann M, Lass J, Karai D, Tuulik V. Effect of low frequency modulated microwave exposure on human EEG: individual sensitivity. Bioelectromagnetics. 29(7):527-538, 2008.**

The aim of this study was to evaluate the effect of modulated microwave exposure on human EEG of individual subjects. The experiments were carried out on four different groups of healthy volunteers. The 450 MHz microwave radiation modulated at 7 Hz (first group, 19 subjects), 14 and 21 Hz (second group, 13 subjects), 40 and 70 Hz (third group, 15 subjects), 217 and 1000 Hz (fourth group, 19 subjects) frequencies was applied. The field power density at the scalp was 0.16 mW/cm(2). The calculated spatial peak SAR averaged over 1 g was 0.303 W/kg. Ten cycles of the exposure (1 min off and 1 min on) at fixed modulation frequencies were applied. All subjects completed the experimental protocols with exposure and sham. The exposed and sham-exposed subjects were randomly assigned. A computer also randomly assigned the succession of modulation frequencies. Our results showed that microwave exposure increased the EEG energy. Relative changes in the EEG beta1 power in P3-P4 channels were selected for evaluation of individual sensitivity. The rate of subjects significantly affected is similar in all groups except for the 1000 Hz group: in first group 3 subjects (16%) at 7 Hz modulation; in second group 4 subjects (31%) at 14 Hz modulation and 3 subjects (23%) at 21 Hz modulation; in third group 3 subjects (20%) at 40 Hz and 2 subjects (13%) at 70 Hz modulation; in fourth group 3 subjects (16%) at 217 Hz and 0 subjects at 1000 Hz modulation frequency.

**Hinrikus H, Bachmann M, Lass J, Tomson R, Tuulik V. Effect of 7, 14 and 21 Hz modulated 450 MHz microwave radiation on human electroencephalographic rhythms. Int J Radiat Biol. 84(1):69-79, 2008.**

PURPOSE: The aim of this study was to evaluate the effect of microwaves modulated at different frequencies on human electroencephalographic (EEG) rhythms. MATERIALS AND METHODS: Thirteen healthy volunteers were exposed to microwaves (450 MHz) pulse-modulated at frequencies of 7, 14 and 21 Hz. The field power density at the scalp was 0.16 mW/cm2. Our experimental protocol consisted of two five-cycle (1 min on and 1 min off) series of exposures at fixed modulation frequencies. A relative change in the EEG power with and without exposure was used as a quantitative measure. EEG frequencies recorded in the theta (4-6.8 Hz), alpha (8-13 Hz), betal (15-20 Hz), and beta2 (22-38 Hz) bands were analyzed. RESULTS: Modulated microwaves caused an increase in the average EEG alpha (17%) and beta (7%) power but the theta rhythm remained unaffected. Increases in the EEG alpha and beta power were statistically significant during the first half-period of the exposure interval (30 s) at the modulation frequencies of 14 and 21 Hz. Differences were found in individual sensitivity to exposure. Increases in the EEG beta power appeared statistically significant in the case of four subjects. CONCLUSIONS: Our findings suggest that the effect of the 450 MHz microwave radiation modulated at 7, 14 and 21 Hz varies depending on the modulation frequency. The microwave exposure modulated at 14 and 21 Hz enhanced the EEG power in the alpha and beta frequency bands, whereas no enhancement occurred during exposure to

the modulation frequency of 7 Hz.

**Hinrikus H, Lass J, Karai D, Pilt K, Bachmann M. Microwave effect on diffusion: a possible mechanism for non-thermal effect. Electromagn Biol Med. 23:1-7, 2014.**

In this study, we assume that microwave radiation affects hydrogen bonding between dipolar water molecules and through that diffusion in water at constant temperature. The experimental study was performed on the setup of two identical reservoirs filled with pure water and 0.9% NaCl solution and connected by a thin tube. Alterations of NaCl concentration in the reservoir initially filled with pure water were measured using the resistance of the solution as an indicator. The applied 450 MHz continuous-wave microwave field had the maximal specific absorption rate of 0.4 W/kg on the connecting tube. The standard deviation of water temperature in the setup was 0.02 °C during an experiment. Our experimental data demonstrated that microwave exposure makes faster the process of diffusion in water. The time required for reduction of initial resistance of the solution by 10% was 1.7 times shorter with microwave. This result is consistent with the proposed mechanism of low-level microwave effect: microwave radiation, rotating dipolar water molecules, causes high-frequency alterations of hydrogen bonds between water molecules, thereby affects its viscosity and makes faster diffusion.

**Hintzsche H, Stopper H. Micronucleus frequency in buccal mucosa cells of mobile phone users. Toxicol Lett. 193(1):124-130, 2010.**

Mobile phones are being used extensively throughout the world, with more than four billion accounts existing in 2009. This technology applies electromagnetic radiation in the microwave range. Health effects of this radiation have been subject of debate for a long time, both within the scientific community and within the general public. This study investigated the effect of mobile phone use on genomic instability of the human oral cavity's mucosa cells. 131 Individuals donated buccal mucosa cells extracted by slightly scraping the oral cavity with a cotton swab. Every participant filled out a questionnaire about mobile phone use including duration of weekly use, overall period of exposure and headset usage. 13 Individuals did not use mobile phones at all, 85 reported using the mobile phone for three hours per week or less, and 33 reported use of more than three hours per week. Additionally, information on age, gender, body weight, smoking status, medication and nutrition was retrieved. For staining of the cells a procedure using alpha-tubulin-antibody and chromomycin A(3) was applied. Micronuclei and other markers were evaluated in 1000 cells per individual at the microscope. A second scorer counted another 1000 cells, resulting in 2000 analyzed cells per individual. Mobile phone use did not lead to a significantly increased frequency of micronuclei.

**Hintzsche H, Jastrow C, Kleine-Ostmann T, Schrader T, Stopper H. 900 MHz radiation does not induce micronucleus formation in different cell types. Mutagenesis. 27(4):477-483, 2012.**

The exposure of the population to non-ionising electromagnetic radiation is still increasing, mainly due to mobile communication. Whether low-intensity electromagnetic fields can cause other effects apart from heating has been a subject

of debate. One of the effects, which were proposed to be caused by mobile phone radiation, is the occurrence of mitotic disturbances. The aim of this study was to investigate possible consequences of these mitotic disturbances as manifest genomic damage, i.e. micronucleus induction. Cells were irradiated at a frequency of 900 MHz, which is located in one of the main frequency bands applied for mobile communication. Two cell types were used, HaCaT cells as human cells and A(L) cells (human-hamster hybrid cells), in which mitotic disturbances had been reported to occur. After different post-exposure incubation periods, cells were fixed and micronucleus frequencies were evaluated. Both cell types did not show any genomic damage after exposure. To adapt the protocol for the micronucleus test into the direction of the protocol for mitotic disturbances, the post-exposure incubation period was reduced and exposure time was extended to one cell cycle length. This did not result in any increase of the genomic damage. In conclusion, micronucleus induction was not observed as a consequence of exposure to non-ionising radiation, even though this agent was reported to cause mitotic disturbances under similar experimental conditions.

**Hirata A, Kojima M, Kawai H, Yamashiro Y, Watanabe S, Sasaki H, Fujiwara O. Acute dosimetry and estimation of threshold inducing behavioral signs of thermal stress in rabbits at 2.45-GHz microwave exposure. IEEE Trans Biomed Eng. 57(5):1234-42, 2010.**

In the current international guidelines and standards for human exposure to microwaves, the basic restriction is determined by the whole-body average specific absorption rate (SAR). The basis for the guidelines is the adverse effect such as work stoppage in animals for whole-body average SARs above a certain level. Although it is known that absorbed microwave energy causes the behavioral sign of thermal stress, the relationship of whole-body average SAR with temperature/temperature elevation has not been sufficiently investigated. In the present study, we performed experiments on rabbits exposed to 2.45-GHz microwaves. A total of 24 measurements were conducted for power densities from approximately 100 to 1,000 W/m2. Our computational code for electromagnetic-thermal dosimetry was used to set the exposure time duration and incident power density. Our experimental results suggest that a core temperature elevation of 1oC is an estimate of the threshold inducing complex behavioral signs of microwave-induced thermal stress in rabbits for different whole-body average SARs and exposure time durations. The whole-body average SAR required for microwave-induced behavioral sign in rabbits was estimated as approximately 1.3 W/kg for 2.45-GHz microwaves.

**Hirose H, Sakuma N, Kaji N, Suhara T, Sekijima M, Nojima T, Miyakoshi J. Phosphorylation and gene expression of p53 are not affected in human cells exposed to 2.1425 GHz band CW or W-CDMA modulated radiation allocated to mobile radio base stations. Bioelectromagnetics.27(6):494-504, 2006.**

A large-scale in vitro study focusing on low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the hypothesis that modulated RF fields induce apoptosis or other cellular stress response that activate p53 or the p53-signaling

pathway. First, we evaluated the response of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole-body SAR for general public exposure defined as a basic restriction by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and wideband code division multiple access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced apoptosis or any signs of stress. Human glioblastoma A172 cells were exposed to W-CDMA radiation at SARs of 80, 250, and 800 mW/kg, and CW radiation at 80 mW/kg for 24 or 48 h. Human IMR-90 fibroblasts from fetal lungs were exposed to both W-CDMA and CW radiation at a SAR of 80 mW/kg for 28 h. Under the RF field exposure conditions described above, no significant differences in the percentage of apoptotic cells were observed between the test groups exposed to RF signals and the sham-exposed negative controls, as evaluated by the Annexin V affinity assay. No significant differences in expression levels of phosphorylated p53 at serine 15 or total p53 were observed between the test groups and the negative controls by the bead-based multiplex assay. Moreover, microarray hybridization and real-time RT-PCR analysis showed no noticeable differences in gene expression of the subsequent downstream targets of p53 signaling involved in apoptosis between the test groups and the negative controls. Our results confirm that exposure to low-level RF signals up to 800 mW/kg does not induce p53-dependent apoptosis, DNA damage, or other stress response in human cells.

**Hirose H, Sakuma N, Kaji N, Nakayama K, Inoue K, Sekijima M, Nojima T, Miyakoshi J. Mobile phone base station-emitted radiation does not induce phosphorylation of Hsp27. Bioelectromagnetics.28(2):99-108, 2007.**

An in vitro study focusing on the effects of low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the hypothesis that modulated RF fields act to induce phosphorylation and overexpression of heat shock protein hsp27. First, we evaluated the responses of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole-body SAR for general public exposure defined as a basic restriction in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced activation or gene expression of hsp27 and other heat shock proteins (hsps). Human glioblastoma A172 cells were exposed to W-CDMA radiation at SARs of 80 and 800 mW/kg for 2-48 h, and CW radiation at 80 mW/kg for 24 h. Human IMR-90 fibroblasts from fetal lungs were exposed to W-CDMA at 80 and 800 mW/kg for 2 or 28 h, and CW at 80 mW/kg for 28 h. Under the RF field exposure conditions described above, no significant differences in the expression levels of phosphorylated hsp27 at serine 82 (hsp27[pS82]) were observed between the test groups exposed to W-CDMA or CW signal and the sham-exposed negative controls, as evaluated immediately after the exposure periods by bead-based multiplex assays. Moreover, no noticeable differences in the gene expression of hsps were observed between the test groups and the negative controls by DNA Chip analysis. Our results confirm that exposure to low-level RF field up to 800 mW/kg does not

induce phosphorylation of hsp27 or expression of hsp gene family.

**Hirose H, Suhara T, Kaji N, Sakuma N, Sekijima M, Nojima T, Miyakoshi J. Mobile phone base station radiation does not affect neoplastic transformation in BALB/3T3 cells. Bioelectromagnetics. 29(1): 55-64, 2008.**

A large-scale in vitro study focusing on low-level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system was conducted to test the hypothesis that modulated RF fields affect malignant transformation or other cellular stress responses. Our group previously reported that DNA strand breaks were not induced in human cells exposed to 2.1425 GHz Wideband Code Division Multiple Access (W-CDMA) radiation up to 800 mW/kg from mobile radio base stations employing the IMT-2000 cellular system. In the current study, BALB/3T3 cells were continuously exposed to 2.1425 GHz W-CDMA RF fields at specific absorption rates (SARs) of 80 and 800 mW/kg for 6 weeks and malignant cell transformation was assessed. In addition, 3-methylcholanthrene (MCA)-treated cells were exposed to RF fields in a similar fashion, to assess for effects on tumor promotion. Finally, the effect of RF fields on tumor co-promotion was assessed in BALB/3T3 cells initiated with MCA and co-exposed to 12-O-tetradecanoylphorbol-13-acetate (TPA). At the end of the incubation period, transformation dishes were fixed, stained with Giemsa, and scored for morphologically transformed foci. No significant differences in transformation frequency were observed between the test groups exposed to RF signals and the sham-exposed negative controls in the non-, MCA-, or MCA plus TPA-treated cells. Our studies found no evidence to support the hypothesis that RF fields may affect malignant transformation. Our results suggest that exposure to low-level RF radiation of up to 800 mW/kg does not induce cell transformation, which causes tumor formation.

**Hirose H**, **Sasaki A**, **Ishii N**, **Sekijima M**, **Iyama T**, **Nojima T**, **Ugawa Y**. **1950 MHz IMT-2000 field does not activate microglial cells in vitro. Bioelectromagnetics.31(2):104-112, 2010.**

Given the widespread use of the cellular phone today, investigation of potential biological effects of radiofrequency (RF) fields has become increasingly important. In particular, much research has been conducted on RF effects on brain function. To examine any biological effects on the central nervous system (CNS) induced by 1950 MHz modulation signals, which are controlled by the International Mobile Telecommunication-2000 (IMT-2000) cellular system, we investigated the effect of RF fields on microglial cells in the brain. We assessed functional changes in microglial cells by examining changes in immune reaction-related molecule expression and cytokine production after exposure to a 1950 MHz Wideband Code Division Multiple Access (W-CDMA) RF field, at specific absorption rates (SARs) of 0.2, 0.8, and 2.0 W/kg. Primary microglial cell cultures prepared from neonatal rats were subjected to an RF or sham field for 2 h. Assay samples obtained 24 and 72 h after exposure were processed in a blind manner. Results showed that the percentage of cells positive for major histocompatibility complex (MHC) class II, which is the most common marker for activated microglial cells, was similar between cells exposed to W-CDMA radiation and sham-exposed controls. No statistically

significant differences were observed between any of the RF field exposure groups and the sham-exposed controls in percentage of MHC class II positive cells. Further, no remarkable differences in the production of tumor necrosis factor-alpha (TNF-alpha), interleukin-1beta (IL-1beta), and interleukin-6 (IL-6) were observed between the test groups exposed to W-CDMA signal and the sham-exposed negative controls. These findings suggest that exposure to RF fields up to 2 W/kg does not activate microglial cells in vitro.

**Hirsch J, Menzebach A, Welters ID, Dietrich GV, Katz N, Hempelmann G. Indicators of erythrocyte damage after microwave warming of packed red blood cells. Clin Chem 49(5):792-799, 2003.**

BACKGROUND: Localized overheating of packed red blood cells (PRBCs) after microwave warming with consequent damage to erythrocytes has been reported. We therefore compared possible cellular markers of erythrocyte damage, as measured by flow cytometry, with laboratory indicators of hemolysis to evaluate the effects of microwave warming on PRBCs. METHODS: PRBC samples were warmed to room temperature or to 37, 42, 47, 52, or 57 degrees C in a water bath. Flow cytometry was performed after fluorescein labeling using antibodies to spectrin, Ca(2+)-ATPase, and Na(+)-K(+)-ATPase. The forward-to-sideward scatter (FSC/SSC) ratio and antibody binding were evaluated. Plasma free hemoglobin (FHb) and alpha-hydroxybutyrate dehydrogenase (HBDH) were measured immediately after heating and after 48 h. In addition, all measurements were made before and after the heating of PRBCs to 35 degrees C by a microwave blood warmer. RESULTS: Analysis of 15 000 erythrocytes showed a decrease in the FSC/SSC ratio and antibody binding above 47 degrees C [at 37 degrees C, median (SD) of 94.2 (7.4) with 0.07 (0.05)% fluorescein-positive; at 52 degrees C, median (SD) of 177.0 (19.0) with 18.5 (6.4)% positively gated; P <0.001]. FHb [room temperature, 0.3 (0.2) g/L] was increased 2-fold at 37 and 42 degrees C, 4-fold at 47 degrees C, and 25-fold at 52 degrees C. HBDH increased in parallel. Hemolysis markers showed an additional twofold increase 48 h after heating to 42 and 47 degrees C. Microwave heating to 35 degrees C did not produce significant changes of any marker. CONCLUSIONS: All markers of cellular damage were altered after heating to >47 degrees C, and a substantial part of hemolysis was delayed. The methodology can be used for future testing of other blood warming devices.

**Hjollund NH, Bonde JP, Skotte J, Semen analysis of personnel operating military radar equipment. Reprod Toxicol 11(6):897, 1997.**

This is a preliminary survey of semen quality among Danish military personnel operating mobile ground-to-air missile units that use several microwave emitting radar systems. The maximal mean exposure was estimated to be 0.01 mW/cm2. The median sperm density of the military personnel was significantly low compared to the references. The difference is either due to chance, uncontrolled bias, or nonthermal effects of transitory microwaves.

**Hladky, A, Musil, J, Roth, Z, Urban, P, Blazkova, V, Acute effects of using a mobile phone on CNS functions. Cent Eur J Public Health 7(4):165-167. 1999.**

Twenty volunteers participated in two experiments exploring the acute effects of using the

mobile phone Motorola GSM 8700 on the functions of the CNS. When speaking (5 minutes reading a text from daily newspapers) the electromagnetic fields from the mobile apparatus did not affect the visual evoked potentials. Also a 6-min exposure did not reveal any effect of electromagnetic fields on the results in two tests (memory and attention) performed while speaking into the mobile. On the other hand the phone call itself strongly influenced the performance in a secondary task applying a test of switching attention which is a good model for driving a car. The response and decision speed were significantly worse. This is a proof that even a slight psychological stress involved in calling while driving can be a great risk.

**Hocking, B, Preliminary report: symptoms associated with mobile phone use. Occup Med (Lond);48(6):357-360, 1998.**

Mobile phone use is ubiquitous, although the alleged health effects of low level radio-frequency radiation (RFR) used in transmission are contentious. Following isolated reports of headache-like symptoms arising in some users, a survey has been conducted to characterize the symptoms sometimes associated with mobile phone usage. A notice of interest in cases was placed in a major medical journal and this was publicized by the media. Respondents were interviewed by telephone using a structured questionnaire. Forty respondents from diverse occupations described unpleasant sensations such as a burning feeling or a dull ache mainly occurring in the temporal, occipital or auricular areas. The symptoms often began minutes after beginning a call, but could come on later during the day. The symptoms usually ceased within an hour after the call, but could last until evening. Symptoms did not occur when using an ordinary handset, and were different from ordinary headaches. There were several reports suggestive of intra-cranial effects. Three respondents reported local symptoms associated with wearing their mobile phone on their belts. There was one cluster of cases in a workplace. Seventy-five per cent of cases were associated with digital mobile phones. Most of the respondents obtained relief by altering their patterns of telephone usage or type of phone. Cranial and other diverse symptoms may arise associated with mobile phone usage. Physicians and users alike should be alert to this. Further work is needed to determine the range of effects, their mechanism and the possible implications for safety limits of RFR.

**Hocking B , Microwave sickness: a reappraisal. Occup Med (Lond) 51(1):66-69, 2001.**

Microwave sickness (MWS) has been a disputed condition. The syndrome involves the nervous system and includes fatigue, headaches, dysaesthesia and various autonomic effects in radiofrequency radiation workers. This paper describes the early reports of the syndrome from Eastern Europe and notes the scepticism expressed about them in the West, before considering comprehensive recent reports by Western specialists and a possible neurological basis for the condition. It is concluded that MWS is a medical entity which should be recognized as a possible risk for radiofrequency radiation workers.

**Hocking B. Management of radiofrequency radiation overexposures. Aust Fam Physician 30(4):339-342, 2001.**

BACKGROUND: Radiofrequency radiation (RFR) has been in use for some time but is now proliferative with the burgeoning radiocommunications industry. OBJECTIVE: To

inform the profession of the possible health effects from overexposure to radiofrequency radiation (RFR) and the clinical approach to cases. An introduction to the health effects of overexposure to RFR is given. A clinical approach to integrating the patient's symptoms and the circumstances of the exposure is given. Emergency treatment and ongoing care is outlined, and sources of expert advice given. CONCLUSION: Overexposure to RFR is a complex injury. Advice is given in this article for emergency care and planning ongoing care.

**Hocking B, Gordon IR, Grain HL, Hatfield GE, Cancer incidence and mortality and proximity to TV towers. Med J Aust 165(11-12):601-605, 1996. (Published erratum appears in Med J Aust 166(2):80, 1997.)**

OBJECTIVE: To determine whether there is an increased cancer incidence and mortality in populations exposed to radiofrequency radiations from TV towers. DESIGN: An ecological study comparing cancer incidence and mortality, 1972-1990, in nine municipalities, three of which surround the TV towers and six of which are further away from the towers. (TV radiofrequency radiation decreases with the square of the distance from the source.) Cancer incidence and mortality data were obtained from the then Commonwealth Department of Human Services and Health. Data on frequency, power, and period of broadcasting for the three TV towers were obtained from the Commonwealth Department of Communications and the Arts. The calculated power density of the radiofrequency radiation in the exposed area ranged from 8.0 microW/cm2 near the towers to 0.2 microW/cm2 at a radius of 4km and 0.02 microW/cm2 at 12 km. SETTING: Northern Sydney, where three TV towers have been broadcasting since 1956. OUTCOME MEASURES: Rate ratios for leukaemia and brain tumour incidence and mortality, comparing the inner with the outer areas. RESULTS: For all ages, the rate ratio for total leukaemia incidence was 1.24 (95% confidence interval [CI], 1.09-1.40). Among children, the rate ratio for leukaemia incidence was 1.58 (95% CI, 1.07-2.34) and for mortality it was 2.32 (95% CI, 1.35-4.01). The rate ratio for childhood lymphatic leukaemia (the most common type) was 1.55 (95% CI, 1.00-2.41) for incidence and 2.74 (95% CI, 1.42-5.27) for mortality. Brain cancer incidence and mortality were not increased. CONCLUSION: We found an association between increased childhood leukaemia incidence and mortality and proximity to TV towers.

**Hocking B, Gordon I. Decreased survival for childhood leukemia in proximity to television towers. Arch Environ Health. 58(9):560-564, 2003.**

Previously, an increased risk of childhood leukemia was identified among children who resided in an inner ring (radius -4 km) of 3 municipalities surrounding television towers, compared with children who resided in an outer ring (radius approximately 4-12 km) of 6 municipalities surrounding, but farther away from, the towers, which are situated in North Sydney, Australia. In the current study, the authors examined the survival experience of these children for all childhood leukemias, and for acute lymphatic leukemia (International Statistical Classification of Diseases and Related Health Problems, 9th revision [ICD-9] rubric 204.0) in particular. Of 123 cases of acute lymphatic leukemia, 29 cases (16 of whom died) were in the inner ring of municipalities nearest the towers, and 94 cases (34 of whom died) occurred in the outer, more-distant ring. There was a significant difference in survival rates between the 2 groups (log-rank test, p = 0.03; Wilcoxon, p = 0.05). The 5-

yr survival in the inner ring of municipalities was 55%, and in the outer ring was 71% (i.e., subjects in the inner ring were 23% less likely to survive than those in the outer ring); at 10 yr, survival in the inner and outer rings was 33% and 62%, respectively. Following adjustment, the mortality rate ratio that the authors used to compare the inner ring with the outer ring was 2.1 (95% confidence interval = 1.1, 4.0). There was an association between residential proximity to the television towers and decreased surv

**Hocking B, Westerman R, Neurological abnormalities associated with Mobile phone use. Occup Med 50: 366-368, 2000.**

Dysaesthesiae of the scalp after mobile phone use have been previously reported but the pathological basis of these symptoms has been unclear. We report finding a neurological abnormality in a patient after prolonged use of a mobile phone. He had permanent unilateral dysaesthesiae of the scalp, slight loss of sensation, and abnormalities on current perception threshold testing of cervical and trigeminal nerves. A neurologist found no other disease. The implications regarding health effects of mobile phones and radio-frequency radiation is discussed.

**Hocking B, Westerman R. Neurological abnormalities associated with CDMA exposure. Occup Med (Lond) 51(6):410-413, 2001.**

Dysaesthesiae of the scalp and neurological abnormality after mobile phone use have been reported previously, but the roles of the phone per se or the radiations in causing these findings have been questioned. We report finding a neurological abnormality in a patient after accidental exposure of the left side of the face to mobile phone radiation [code division multiple access (CDMA)] from a down-powered mobile phone base station antenna. He had headaches, unilateral left blurred vision and pupil constriction, unilateral altered sensation on the forehead, and abnormalities of current perception thresholds on testing the left trigeminal ophthalmic nerve. His nerve function recovered during 6 months follow-up. His exposure was 0.015-0.06 mW/cm(2) over 1-2 h. The implications regarding health effects of radiofrequency radiation are discussed.

**Hocking B, Westerman R. Neurological changes induced by a mobile phone. Occup Med (Lond) 52(7):413-415, 2002.**

Dysaesthesiae of the scalp after mobile phone use have been previously reported, but the basis for this has not been clear. We report a case of a 34-year-old journalist who complained of symptoms associated with use of a mobile phone. She agreed to a provocation study with her phone. Current perception threshold testing before and after exposure showed marked changes in the C-fibre nerves of the affected area compared with the opposite side. The case is supportive of a neurological basis for some cases of dysaesthesiae associated with mobile phone use.

**Hocking B, Westerman R. Neurological effects of radiofrequency radiation. Occup Med (Lond) 53(2):123-127, 2003.**

BACKGROUND: The health effects of radiofrequency radiation (RFR) and the adequacy of the safety standards are a subject of debate. One source of human data is case reports regarding peripheral neurological effects of RFR, mainly noxious sensations or dysaesthesiae. Aim To investigate health effects, neurophysiological mechanisms and

safety levels for RFR. METHODS: We conducted a literature search for case reports and case series associated with mobile phone technology as well as other RFR sources using specific search terms on PubMed. RESULTS: We identified 11 original articles detailing case reports or case series and matching the search criteria. Five of the identified papers were written by at least one of the authors (B.H. or R.W.). CONCLUSIONS: Cases have arisen after exposure to much of the radiofrequency range. In some cases, symptoms are transitory but lasting in others. After very high exposures, nerves may be grossly injured. After lower exposures, which may result in dysaesthesia, ordinary nerve conduction studies find no abnormality but current perception threshold studies have found abnormalities. Only a small proportion of similarly exposed people develop symptoms. The role of modulations needs clarification. Some of these observations are not consistent with the prevailing hypothesis that all health effects of RFR arise from thermal mechanisms.

**Hofgartner F, Muller T, Sigel H, [Could C- and D-network mobile phones endanger patients with pacemakers]? Dtsch Med Wochenschr 121(20):646-652, 1996.** [Article in German]

OBJECTIVE: To investigate prospectively the extent of potentially harmful interference of cardiac pacemakers by mobile phones in the C (analog) and D (digital) networks in use in Germany. PATIENTS AND METHODS: 104 patients (54 men, 50 women; mean age 75.8 [40-100] years) with 58 different implanted pacemaker models (43 one-chamber and 15 two-chamber systems) underwent uniform tests at various functional states with three different telephones (D1 portable 8 Watt, D1 Handy model 2 Watt, C Handy model 0.5 Watt). The distances between telephone aerial and pacemaker, as well as reception sensitivity and polarity of the pacemaker were varied. All tests were done during continuous ECG monitoring. RESULTS: 28 different pacemaker types (48.3%) in 43 patients (41.3%) showed interference in the form of pacemaker inhibition and switching to interference frequencies as well as triggering of pacemaker-mediated tachycardias in the DDD mode, as well as in the temperature-regulated frequency-adaptive function. D portables influenced pacemaker function more often and at greater distance than the D Handy model, which was little different from the c network hand phone. Reduction in pacemaker sensitivity as well as switching to bipolar reception only partly eliminated the interference. CONCLUSIONS: Patients with implanted pacemakers should if possible not use mobile phones in the C and D networks. Individual testing with suitable programming of pacemaker sensitivity and polarity can reduce the risk of interference.

**Holly EA, Aston DA, Ahn DK, Smith AH. Intraocular melanoma linked to occupations and chemical exposures. Epidemiology 7(1):55-61, 1996.**

We conducted a case-control study in the western United States to determine the relation between occupations or chemical exposures and increased risk of uveal melanoma. Among men (221 patients, 447 controls), we found increased risks for occupational groups who had intense exposure to ultraviolet light [odds ratio (OR) = 3.0; 95% confidence interval (CI) = 1.2-7.8], welding exposure (OR = 2.2; 95% CI = 1.3-3.5), and asbestos exposure (OR = 2.4; 95% CI = 1.5-3.9 for most likely exposed). The highest odds ratio was for the small number of men (nine cases, three controls) who were chemists, chemical engineers, and chemical technicians (OR = 5.9; 95% CI = 1.6-22.7).

Odds ratios also were elevated for exposures to antifreeze, formaldehyde, pesticides, and carbon tetrachloride, but these findings, based on recall of specific chemical exposures, are more subject to recall bias than the findings based on occupational groups. (Also reported a significant increase risk in uveal melanoma with microwave/radar exposure.)

**Holovská K, Almášiová V, Cigánková V, Beňová K, Račeková E, Martončíková M. Structural and Ultrastructural Study of Rat Liver Influenced by Electromagnetic Radiation. J Toxicol Environ Health A. 78(6):353-356, 2015.**

Mobile communication systems are undoubtedly an environmental source of electromagnetic radiation (EMR). There is an increasing concern regarding the interactions of EMR with the humans. The aim of this study was to examine the effects of EMR on Wistar rat liver. Mature rats were exposed to electromagnetic field of frequency 2.45 GHz and mean power density of 2.8 mW/cm$^2$ for 3 h/d for 3 wk. Samples of the liver were obtained 3 h after the last irradiation and processed histologically for light and transmission electron microscopy. Data demonstrated the presence of moderate hyperemia, dilatation of liver sinusoids, and small inflammatory foci in the center of liver lobules. Structure of hepatocytes was not altered and all described changes were classified as moderate. Electron microscopy of hepatocytes revealed vesicles of different sizes and shapes, lipid droplets, and proliferation of smooth endoplasmic reticulum. Occasionally necrotizing hepatocytes were observed. Our observations demonstrate that EMR exposure produced adverse effects on rat liver.

**Hong MN, Kim BC, Ko YG, Lee YS, Hong SC, Kim T, Pack JK, Choi HD, Kim N, Lee JS. Effects of 837 and 1950 MHz radiofrequency radiation exposure alone or combined on oxidative stress in MCF10A cells. Bioelectromagnetics. 33(7):604-11, 2012.**

The aim of this study was to determine whether the exposure to either single or multiple radio-frequency (RF) radiation frequencies could induce oxidative stress in cell cultures. Exposures of human MCF10A mammary epithelial cells to either a single frequency (837 MHz alone or 1950 MHz alone) or multiple frequencies (837 and 1950 MHz) were conducted at specific absorption rate (SAR) values of 4 W/kg for 2 h. During the exposure period, the temperature in the exposure chamber was maintained isothermally. Intracellular levels of reactive oxygen species (ROS), the antioxidant enzyme activity of superoxide dismutase (SOD), and the ratio of reduced/oxidized glutathione (GSH/GSSG) showed no statistically significant alterations as the result of either single or multiple RF radiation exposures. In contrast, ionizing radiation-exposed cells, used as a positive control, showed evident changes in all measured biological endpoints. These results indicate that single or multiple RF radiation exposure did not elicit oxidative stress in MCF10A cells under our exposure conditions.

**Hook GJ, Zhang P, Lagroye I, Li L, Higashikubo R, Moros EG, Straube WL, Pickard WF, Baty JD, Roti Roti JL. Measurement of DNA damage and apoptosis in molt-4 cells after in vitro exposure to radiofrequency radiation. Radiat Res. 161(2): 193-200, 2004.**

To determine whether exposure to radiofrequency (RF) radiation can induce DNA damage or apoptosis, Molt-4 T lymphoblastoid cells were exposed with RF fields at frequencies and modulations of the type used by wireless communication devices. Four types of frequency/modulation forms were studied: 847.74 MHz code-division multiple-access (CDMA), 835.62 MHz frequency-division multiple-access (FDMA), 813.56 MHz iDEN(R) (iDEN), and 836.55 MHz time-division multiple-access (TDMA). Exponentially growing cells were exposed to RF radiation for periods up to 24 h using a radial transmission line (RTL) exposure system. The specific absorption rates used were 3.2 W/kg for CDMA and FDMA, 2.4 or 24 mW/kg for iDEN, and 2.6 or 26 mW/kg for TDMA. The temperature in the RTLs was maintained at 37 degrees C +/- 0.3 degrees C. DNA damage was measured using the single-cell gel electrophoresis assay. The annexin V affinity assay was used to detect apoptosis. No statistically significant difference in the level of DNA damage or apoptosis was observed between sham-treated cells and cells exposed to RF radiation for any frequency, modulation or exposure time. Our results show that exposure of Molt-4 cells to CDMA, FDMA, iDEN or TDMA modulated RF radiation does not induce alterations in level of DNA damage or induce apoptosis.

**Hook, G. J., Spitz, D. R., Sim, J. E., Higashikubo, R., Baty, J. D., Moros, E. G. and Roti Roti, J. L. Evaluation of parameters of oxidative stress after in vitro exposure to FMCW- and CDMA-modulated radiofrequency radiation fields. Radiat. Res. 162, 497–504, 2004.**

The goal of this study was to determine whether radiofrequency (RF) radiation is capable of inducing oxidative stress or affecting the response to oxidative stress in cultured mammalian cells. The two types of RF radiation investigated were frequency-modulated continuous-wave with a carrier frequency of 835.62 MHz (FMCW) and code division multiple access centered on 847.74 MHz (CDMA). To evaluate the effect of RF radiation on oxidative stress, J774.16 mouse macrophage cells were stimulated with γ-interferon (IFN) and bacterial lipopolysaccharide (LPS) prior to exposure. Cell cultures were exposed for 20–22 h to a specific absorption rate of 0.8 W/kg at a temperature of 37.0 ± 0.3°C. Oxidative stress was evaluated by measuring oxidant levels, antioxidant levels, oxidative damage and nitric oxide production. Oxidation of thiols was measured by monitoring the accumulation of glutathione disulfide (GSSG). Cellular antioxidant defenses were evaluated by measuring superoxide dismutase activity (CuZnSOD and MnSOD) as well as catalase and glutathione peroxidase activity. The trypan blue dye exclusion assay was used to measure any changes in viability. The results of these studies indicated that FMCW- and CDMA-modulated RF radiation did not alter parameters indicative of oxidative stress in J774.16 cells. FMCW- and CDMA-modulated fields did not alter the level of intracellular oxidants, accumulation of GSSG or induction of antioxidant defenses in IFN/LPS-stimulated cells. Consistent with the lack of an effect on oxidative stress parameters, no change in toxicity was observed in J774.16 cells after either optimal (with or without inhibitors of nitric oxide synthase) or suboptimal stimulation.

**Horberry T, Anderson J, Regan MA, Triggs TJ, Brown J. Driver distraction: The effects of concurrent in-vehicle tasks, road environment complexity and age on driving performance. Accid Anal Prev. 38(1):185-191. 2006.**

This paper presents the findings of a simulator study that examined the effects of

distraction upon driving performance for drivers in three age groups. There were two in-vehicle distracter tasks: operating the vehicle entertainment system and conducting a simulated hands-free mobile phone conversation. The effect of visual clutter was examined by requiring participants to drive in simple and complex road environments. Overall measures of driving performance were collected, together with responses to roadway hazards and subjective measures of driver perceived workload. The two in-vehicle distraction tasks degraded overall driving performance, degraded responses to hazards and increased subjective workload. The performance decrements that occurred as a result of in-vehicle distraction were observed in both the simple and complex highway environments and for drivers in different age groups. One key difference was that older drivers traveled at lower mean speeds in the complex highway environment compared with younger drivers. The conclusions of the research are that both in-vehicle tasks impaired several aspects of driving performance, with the entertainment system distracter having the greatest negative impact on performance, and that these findings were relatively stable across different driver age groups and different environmental complexities.

**Hossain MI, Faruque MRI, Islam MT. Analysis on the Effect of the Distances and Inclination Angles between Human Head and Mobile Phone on SAR. Prog Biophys Mol Biol. 119(2):103-110, 2015.**

The aim of this paper is to investigate the effects of the distances between the human head and internal cellular device antenna on the specific absorption rate (SAR). This paper also analyzes the effects of inclination angles between user head and mobile terminal antenna on SAR values. The effects of the metal-glass casing of mobile phone on the SAR values were observed in the vicinity of the human head model. Moreover, the return losses were investigated in all cases to mark antenna performance. This analysis was performed by adopting finite-difference time-domain (FDTD) method on Computer Simulation Technology (CST) Microwave Studio. The results indicate that by increasing the distance between the user head and antenna, SAR values are decreased. But the increase in inclination angle does not reduce SAR values in all cases. Additionally, this investigation provides some useful indication for future design of low SAR mobile terminal antenna.

**Hou Q, Wang M, Wu S, Ma X, An G, Liu H, Xie F. Oxidative changes and apoptosis induced by 1800-MHz electromagnetic radiation in NIH/3T3 cells. Electromagn Biol Med. 2014 Mar 25. [Epub ahead of print]**

To investigate the potential adverse effects of mobile phone radiation, we studied reactive oxygen species (ROS), DNA damage and apoptosis in mouse embryonic fibroblasts (NIH/3T3) after intermittent exposure (5 min on/10 min off, for various durations from 0.5 to 8 h) to an 1800-MHz GSM-talk mode electromagnetic radiation (EMR) at an average specific absorption rate of 2 W/kg. A 2',7'-dichlorofluorescin diacetate fluorescence probe was used to detect intracellular ROS levels, immunofluorescence was used to detect γH2AX foci as a marker for DNA damage, and flow cytometry was used to measure apoptosis. Our results showed a significant increase in intracellular ROS levels after EMR

exposure and it reached the highest level at an exposure time of 1 h ($p < 0.05$) followed by a slight decrease when the exposure continued for as long as 8 h. No significant effect on the number of γH2AX was detected after EMR exposure. The percentage of late-apoptotic cells in the EMR-exposed group was significantly higher than that in the sham-exposed groups ($p < 0.05$). These results indicate that an 1800-MHz EMR enhances ROS formation and promotes apoptosis in NIH/3T3 cells.

**Hountala CD, Maganioti AE, Papageorgiou CC, Nanou ED, Kyprianou MA, Tsiafakis VG, Rabavilas AD, Capsalis CN.The spectral power coherence of the EEG under different EMF conditions.Neurosci Lett.441(2):188-192, 2008.**

The present study introduces the concept of spectral power coherence (SPC), which reflects the pattern of coordination of the four basic EEG bands (delta, theta, alpha, and beta) at a specific location of the brain. The SPC was calculated for the pre-stimulus EEG signal during an auditory memory task under different electromagnetic field (EMF) conditions (900 MHz and 1800 MHz). The results showed that delta rhythm is less consequential in the overall cooperation between the bands than the higher frequency theta, alpha and beta rhythms. Additionally, it has been shown that the radiation effect on SPC is different for the two genders. In the absence of radiation males exhibit higher overall SPC than females. These differences disappear in the presence of 900 MHz and are reversed in the presence of 1800 MHz.

**Hours M, Bernard M, Montestrucq L, Arslan M, Bergeret A, Deltour I, Cardis E. [Cell Phones and Risk of brain and acoustic nerve tumours: the French INTERPHONE case-control study.] Rev Epidemiol Sante Publique.55(5):321-32,2007.** [Article in French]

BACKGROUND: Use of cell phones has increased dramatically since 1992 when they were first introduced in France. Certain electromagnetic fields (at extremely low frequency) have been recognized as possibly carcinogenic by the International Agency for Research on Cancer. Given the use of radiofrequency technology in cell phones, the rapid increase in the number of cell phones has generated concerns about the existence of a potential health hazard. To evaluate the relationship between the use of cell phones and the development of tumors of the head, a multicentric international study (INTERPHONE), coordinated by the International Agency for Research on Cancer, was carried out in 13 countries. This publication reports the results of the French part of the INTERPHONE study. METHODS: INTERPHONE is a case-control study focused on tumors of the brain and central nervous system: gliomas, meningiomas and neuromas of cranial nerves. Eligible cases were men and women, residents of Paris or Lyon, aged 30-59, newly diagnosed with a first primary tumor between February 2001 and August 2003. The diagnoses were all either histologically confirmed or based upon unequivocal radiological images. Controls were matched for gender, age (+/-5 years) and place of residence. They were randomly drawn from electoral rolls. Detailed information was collected for all subjects during a computer-assisted face-to-face interview. Conditional logistic regression was used to estimate the odds ratio (OR) for an association between the use of cell phones and risk of each type of cancer.

RESULTS: Regular cell phone use was not associated with an increased risk of neuroma (OR=0,92; 95% confidence interval=[0.53-1.59]), meningioma (OR=0,74; 95% confidence interval=[0.43-1.28]) or glioma (OR=1.15; 95% confidence interval=[0.65-2.05]). Although these results are not statistically significant, a general tendency was observed for an increased risk of glioma among the heaviest users: long-term users, heavy users, users with the largest numbers of telephones. CONCLUSION: No significant increased risk for glioma, meningioma or neuroma was observed among cell phone users participating in Interphone. The statistical power of the study is limited, however. Our results, suggesting the possibility of an increased risk among the heaviest users, therefore need to be verified in the international INTERPHONE analyses.

**Hoyto A, Sihvonen AP, Alhonen L, Juutilainen J, Naarala J Modest increase in temperature affects ODC activity in L929 cells: low-level radiofrequency radiation does not. Radiat Environ Biophys.45(3):231-235, 2006.**

The effects of low-level radiofrequency (RF) radiation and elevated temperature on ornithine decarboxylase (ODC) activity were investigated in murine L929 fibroblasts. The cells were exposed at 900 MHz either to a pulse-modulated (pulse frequency 217 Hz; GSM-type modulation) or a continuous wave signal at specific absorption rate (SAR) levels of 0.2 W kg(-1) (0.1-0.3 W kg(-1)) and 0.4 W kg(-1) (0.3-0.5 W kg(-1)) for 2, 8, or 24 h. RF radiation did not affect cellular ODC activity. However, a slight increase in temperature (0.8-0.9 degrees C) in the exposure system lead to decreased ODC activity in cell cultures. This was verified by tests in which cells were exposed to different temperatures in incubators. The results show that ODC activity is sensitive to small temperature differences in cell cultures. Hence, a precise temperature control in cellular ODC activity studies is needed.

**Höytö A**, **Luukkonen J**, **Juutilainen J**, **Naarala J**. **Proliferation, oxidative stress and cell death in cells exposed to 872 MHz radiofrequency radiation and oxidants. Radiat. Res. 170(2):235-243, 2008.**

Human SH-SY5Y neuroblastoma and mouse L929 fibroblast cells were exposed to 872 MHz radiofrequency (RF) radiation using continuous waves (CW) or a modulated signal similar to that emitted by GSM mobile phones at a specific absorption rate (SAR) of 5 W/kg in isothermal conditions. To investigate possible combined effects with other agents, menadione was used to induce reactive oxygen species, and tert-butylhydroperoxide (t-BOOH) was used to induce lipid peroxidation. After 1 or 24 h of exposure, reduced cellular glutathione levels, lipid peroxidation, proliferation, caspase 3 activity, DNA fragmentation and viability were measured. Two statistically significant differences related to RF radiation were observed: Lipid peroxidation induced by t-BOOH was increased in SH-SY5Y (but not in L929) cells, and menadione-induced caspase 3 activity was increased in L929 (but not in SH-SY5Y) cells. Both differences were statistically significant only for the GSM-modulated signal. The other end points were not significantly affected in any of the experimental conditions, and no effects were observed from exposure to RF radiation alone. The positive findings may be due to chance, but they may also reflect effects that occur only in cells sensitized by chemical stress. Further studies are required to investigate the reproducibility and dose response of the possible

effects.

**Hruby R, Neubauer G, Kuster N, Frauscher M Study on potential effects of "902-MHz GSM-type Wireless Communication Signals" on DMBA-induced mammary tumours in Sprague-Dawley rats. Mutat Res. 649(1-2):34-44, 2008.**

The aim of the study was to detect whether long-term exposure to "902-MHz GSM-type Wireless Communication Signals" ("radio-frequency (RF)-exposure") would affect 7,12-dimethylbenz(a)anthracene (DMBA)-induced mammary tumours in female Sprague-Dawley rats. Five hundred female rats were each given a single oral dose of 17mg DMBA per kg body weight (bw) at an age of 46-48 days. Three groups of 100 animals each were RF-exposed (902MHz; crest factor 8; pulse width=0.57ms) from the next day onwards to normal whole-body averaged doses (expressed as specific absorption rate, SAR) of 0.4, 1.3 or 4.0W/kg bw (low/mid/high-dose group) for 4h/d, 5d/week, during 6 months. A sham-exposed and a cage-control group remained without RF-exposure (<<0.01mW/kg). Animals were weekly weighed and palpated for mammary tumours; all mammary glands were examined histopathologically. There were several statistically significant differences between RF-exposed groups and the sham-exposed group, as follows: All RF-exposed groups had, at different times, significantly more palpable tissue masses. There were fewer animals with benign neoplasms, but more with malignant tumours in the high-dose group. In addition, there were more adenocarcinomas in the low-dose group, more malignant neoplasms in the low- and high-dose groups, more animals with adenocarcinomas in the high-dose group, and fewer animals with fibroadenomas in the low- and mid-dose groups. The cage-control group had, when compared with the sham-exposed group, statistically significantly more palpable tissue masses, more benign and also more malignant neoplasms. The cage-control group had in most aspects the highest incidence and malignancy of neoplasms among all groups. None of the above findings in RF-exposed animals produced a clear dose-response relation and the responses of the cage-control group were either similar to or stronger than those of any of the RF-exposed group. The significant differences between the sham-exposed animals and one or more RF-exposed groups may be interpreted as evidence of an effect of RF-exposure. In the context of the results of the cage-control group, in the light of controversial results reported in the literature, and given the fact that the DMBA-mammary tumour model is known to be prone to high variations in the results, it is the authors' opinion that the differences between the groups are rather incidental ones.

**Hsu MH, Syed-Abdul S, Scholl J, Jian WS, Lee P, Iqbal U, Li YC. The incidence rate and mortality of malignant brain tumors after 10 years of intensive cell phone use in Taiwan. Eur J Cancer Prev. 2013 Apr 14. [Epub ahead of print]**

The issue of whether cell phone usage can contribute toward the development of brain tumors has recently been reignited with the International Agency for Research on Cancer classifying radiofrequency electromagnetic fields as 'possibly' carcinogenic to humans in a WHO report. To our knowledge, this is the largest study reporting on the incidence and mortality of malignant brain tumors after long-term use of the cell phone by more than 23 million users. A population-based study was carried out the numbers of cell phone users were collected from the official statistics provided by the National Communication Commission. According to National Cancer Registry, there were 4 incidences and 4

deaths due to malignant neoplasms in Taiwan during the period 2000-2009. The 10 years of observational data show that the intensive user rate of cell phones has had no significant effect on the incidence rate or on the mortality of malignant brain tumors in Taiwan. In conclusion, we do not detect any correlation between the morbidity/mortality of malignant brain tumors and cell phone use in Taiwan. We thus urge international agencies to publish only confirmatory reports with more applicable conclusions in public. This will help spare the public from unnecessary worries.

**Hu J, Lu Y, Zhang H, Xie H, Yang X. [Level of microwave radiation from mobile phone base stations built in residential districts] Wei Sheng Yan Jiu. 38(6):712-716, 2009.** [Article in Chinese]

OBJECTIVE: To investigate the condition of microwave radiation pollution from mobile phone base station built in populated area. METHODS: Random selected 18 residential districts where had base station and 10 residential districts where had no base stations. A TES-92 electromagnetic radiation monitor were used to measure the intensity of microwave radiation in external and internal living environment. RESULTS: The intensities of microwave radiation in the exposure residential districts were more higher than those of the control residential districts ($p < 0.05$). There was a intensity peak at about 10 m from the station, it would gradually weaken with the increase of the distance. The level of microwave radiation in antenna main lobe region is not certainly more higher than the side lobe direction, and the side lobe direction also is not more lower. At the same district, where there were two base stations, the electromagnetic field nestification would take place in someplace. The intensities of microwave radiation outside the exposure windows in the resident room not only changed with distance but also with the height of the floor. The intensities of microwave radiation inside the aluminum alloys security net were more lower than those of outside the aluminum alloys security net ($p < 0.05$), but the inside or outside of glass-window appears almost no change ($p > 0.05$). CONCLUSIONS: Although all the measure dates on the ground around the base station could be below the primary standard in "environment electromagnetic wave hygienic standard" (GB9175-88), there were still a minorities of windows which exposed to the base station were higher, and the outside or inside of a few window was even higher beyond the primary safe level defined standard. The aluminum alloys security net can partly shield the microwave radiation from the mobile phone base station.

**Hu S, Peng R, Wang C, Wang S, Gao Y, Dong J, Zhou H, Su Z, Qiao S, Zhang S, Wang L, Wen X.Neuroprotective effects of dietary supplement Kang-fu-ling against high-power microwave through antioxidant action. Food Funct. 2014 Jul 24. [Epub ahead of print]**

Kang-fu-ling (KFL) is a polybotanical dietary supplement with antioxidant properties. This study aimed to evaluate the potential protective effects of KFL on cognitive deficit induced by high-power microwave (HPM) and the underlying mechanism for this neuroprotection. The electron spin resonance technique was employed to evaluate the free radical scavenging activity of KFL in vitro and KFL exhibited scavenging hydroxyl radical activity. KFL at doses of 0.75, 1.5 and 3 g kg-1 and vehicle were administered orally once daily for

14 days to male Wistar rats after being exposed to 30 mW cm-2 HPM for 15 minutes. KFL reversed HPM-induced memory loss and the histopathological changes in hippocampus of rats. In addition, KFL displayed a protective effect against HPM-induced oxidative stress and activated the nuclear factor-E2-related factor 2 (Nrf2) and its target genes in the hippocampus of rats. The Nrf2-antioxidant response element (ARE) signaling pathway may be involved in the neuroprotective effects of KFL against HPM-induced oxidative stress. In summary, the dietary supplement KFL is a promising natural complex, which ameliorates oxidative stress, with neuroprotective effects against HPM.

**Huang D, Dong ZF, Chen Y, Wang FB, Wei Z, Zhao WB, Li S, Liu MY, Zhu W, Wei M, Li JB. Interference of GSM mobile phones with communication between Cardiac Rhythm Management devices and programmers: A combined in vivo and in vitro study. Bioelectromagnetics. 2015 Apr 10. doi: 10.1002/bem.21911. [Epub ahead of print]**

To investigate interference, and how to avoid it, by high-frequency electromagnetic fields (EMFs) of Global System for Mobile Communications (GSM) mobile phone with communication between cardiac rhythm management devices (CRMs) and programmers, a combined in vivo and in vitro testing was conducted. During in vivo testing, GSM mobile phones interfered with CRM-programmer communication in 33 of 65 subjects tested (50.8%). Losing ventricle sensing was representative in this study. In terms of clinical symptoms, only 4 subjects (0.6%) felt dizzy during testing. CRM-programmer communication recovered upon termination of mobile phone communication. During in vitro testing, electromagnetic interference by high-frequency (700-950 MHz) EMFs reproducibly occurred in duplicate testing in 18 of 20 CRMs (90%). During each interference, the pacing pulse signal on the programmer would suddenly disappear while the synchronous signal was normal on the amplifier-oscilloscope. Simulation analysis showed that interference by radiofrequency emitting devices with CRM-programmer communication may be attributed to factors including materials, excitation source distance, and implant depth. Results suggested that patients implanted with CRMs should not be restricted from using GSM mobile phones; however, CRMs should be kept away from high-frequency EMFs of GSM mobile phone during programming.

**Huang TQ, Lee JS, Kim TH, Pack JK, Jang JJ, Seo JS. Effect of radiofrequency radiation exposure on mouse skin tumorigenesis initiated by 7,12-dimethybenz[alpha]anthracene. Int J Radiat Biol. 81(12):861-867, 2005.**

Purpose: Although radiofrequency (RF) radiation is not considered mutagenic, it has been suggested as a promoter of tumorigenesis. To study if RF radiation has a tumor promoting effect, we exposed mice with skin tumorigenesis initiated by 7,12-dimethybenz[a]anthracene (DMBA) to RF radiation.Materials and methods: Eighty male ICR mice were subjected to a single DMBA application (100 microg/100 microl acetone/mouse) on shaved dorsal skin at the age of 7 weeks. After one week, the mice were randomized into four equal groups of 20 mice each: i.e., sham-, 849 MHz-, 1,763 MHz-exposed, and 12-O-tetradecanoylphorbol-13-acetate (TPA)-treated groups. The RF exposure was conducted at a whole body average specific absorption rate (SAR) of 0.4

W/Kg, for 2 cycles of 45 min exposure with a 15 min interval each day, 5 days a week for 19 weeks. The TPA-treated group served as a positive control for skin tumorigenesis and were administered TPA (4 microg/100 microl acetone/mouse) twice weekly without RF exposure.Results: All mice were examined weekly at a macroscopic level. No skin tumors were observed in any groups except in the TPA-treated positive control group. TPA is known tumor promoter in DMBA-induced skin carcinogenesis and tumor incidence in the TPA treated group was 95%. At week 20 after DMBA initiation, skin tissues were analyzed immunohistochemically using anti-proliferating cell nuclear antigen (PCNA) antibody. No differences were observed by pathological examination or by PCNA staining between the sham- and the RF-exposed groups. The expression of cyclin D1 and c-fos were detected only in the tumorous skin tissues of the TPA-treated group.Conclusion: No evidence was found that RF radiation serves as a tumor promoter for skin tumors. Our data suggests that 849 MHz and 1,763 MHz RF radiations, similar to those emitted from mobile phones, do not have any promoting effect on skin tumor development in DMBA-initiated mice.

**Huang TQ, Lee MS, Oh E, Zhang BT, Seo JS, Park WY. Molecular responses of Jurkat T-cells to 1763 MHz radiofrequency radiation. Int J Radiat Biol. 84(9):734-741, 2008.**

PURPOSE: The biological effects of exposure to mobile phone emitted radiofrequency (RF) radiation are the subject of intense study, yet the hypothesis that RF exposure is a potential health hazard remains controversial. In this paper, we monitored cellular and molecular changes in Jurkat human T lymphoma cells after irradiating with 1763 MHz RF radiation to understand the effect on RF radiation in immune cells. MATERIALS AND METHODS: Jurkat T-cells were exposed to RF radiation to assess the effects on cell proliferation, cell cycle progression, DNA damage and gene expression. Jurkat cells were exposed to 1763 MHz RF radiation at 10 W/kg specific absorption rate (SAR) and compared to sham exposed cells. RESULTS: RF exposure did not produce significant changes in cell numbers, cell cycle distributions, or levels of DNA damage. In genome-wide analysis of gene expressions, there were no genes changed more than two-fold upon RF-radiation while ten genes change to 1.3 approximately 1.8-fold. Among ten genes, two cytokine receptor genes such as chemokine (C-X-C motif) receptor 3 (CXCR3) and interleukin 1 receptor, type II (IL1R2) were down-regulated upon RF radiation, but they were not directly related to cell proliferation or DNA damage responses. CONCLUSION: These results indicate that the alterations in cell proliferation, cell cycle progression, DNA integrity or global gene expression was not detected upon 1763 MHz RF radiation under 10 W/kg SAR for 24 h to Jurkat T cells.

**Huang TQ, Lee MS, Oh EH, Kalinec F, Zhang BT, Seo JS, Park WY. Characterization of biological effect of 1763 MHz radiofrequency exposure on auditory hair cells. Int J Radiat Biol. 84(11):909-915, 2008.**

Purpose: Radiofrequency (RF) exposure at the frequency of mobile phones has been reported not to induce cellular damage in in vitro and in vivo models. We chose HEI-OC1 immortalized mouse auditory hair cells to characterize the cellular response to 1763 MHz RF exposure, because auditory cells could be exposed to mobile phone

frequencies. Materials and methods: Cells were exposed to 1763 MHz RF at a 20 W/kg specific absorption rate (SAR) in a code division multiple access (CDMA) exposure chamber for 24 and 48 h to check for changes in cell cycle, DNA damage, stress response, and gene expression. Results: Neither of cell cycle changes nor DNA damage was detected in RF-exposed cells. The expression of heat shock proteins (HSP) and the phosphorylation of mitogen-activated protein kinases (MAPK) did not change, either. We tried to identify any alteration in gene expression using microarrays. Using the Applied Biosystems 1700 full genome expression mouse microarray, we found that only 29 genes (0.09% of total genes examined) were changed by more than 1.5-fold on RF exposure. Conclusion: From these results, we could not find any evidence of the induction of cellular responses, including cell cycle distribution, DNA damage, stress response and gene expression, after 1763 MHz RF exposure at an SAR of 20 W/kg in HEI-OC1 auditory hair cells.

**Huber R, Graf T, Cote KA, Wittmann L, Gallmann E, Matter D, Schuderer J, Kuster N, Borbely AA, Achermann P**, **Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG. Neuroreport 11(15):3321-3325, 2000.**

The aim of the study was to investigate whether the electromagnetic field (EMF) emitted by digital radiotelephone handsets affects brain physiology. Healthy, young male subjects were exposed for 30 min to EMF (900 MHz; spatial peak specific absorption rate 1 W/kg) during the waking period preceding sleep. Compared with the control condition with sham exposure, spectral power of the EEG in non-rapid eye movement sleep was increased. The maximum rise occurred in the 9.75-11.25 Hz and 12.5-13.25 Hz band during the initial part of sleep. These changes correspond to those obtained in a previous study where EMF was intermittently applied during sleep. Unilateral exposure induced no hemispheric asymmetry of EEG power. The present results demonstrate that exposure during waking modifies the EEG during subsequent sleep. Thus the changes of brain function induced by pulsed high-frequency EMF outlast the exposure period.

**HuberR, TreyerV, BorbélyAA, SchudererJ, GottseligJM, LandoltH-P, WerthE, BertholdT, KusterN, BuckA, AchermannP, Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG**. **J Sleep Res 11: 289-295, 2002.**

Usage of mobile phones is rapidly increasing, but there is limited data on the possible effects of electromagnetic field (EMF) exposure on brain physiology. We investigated the effect of EMF vs. sham control exposure on waking regional cerebral blood flow (rCBF) and on waking and sleep electroencephalogram (EEG) in humans. In Experiment 1, positron emission tomography (PET) scans were taken after unilateral head exposure to 30-min pulse-modulated 900 MHz electromagnetic field (pm-EMF). In Experiment 2, night-time sleep was polysomnographically recorded after EMF exposure. Pulse-modulated EMF exposure increased relative rCBF in the dorsolateral prefrontal cortex ipsilateral to exposure. Also, pm-EMF exposure enhanced EEG power in the alpha frequency range prior to sleep onset and in the spindle frequency range during stage 2 sleep. Exposure to EMF without pulse modulation did not enhance power in the waking or sleep EEG. We previously observed EMF effects on the sleep EEG (A. A. Borbély, R. Huber, T. Graf, B. Fuchs, E. Gallmann and P. Achermann. Neurosci. Lett., 1999, 275:

207-210; R. Huber, T. Graf, K. A. Cote, L. Wittmann, E. Gallmann, D. Matter, J. Schuderer, N. Kuster, A. A. Borbély, and P. Achermann. Neuroreport, 2000, 11: 3321-3325), but the basis for these effects was unknown. The present results show for the first time that (1) pm-EMF alters waking rCBF and (2) pulse modulation of EMF is necessary to induce waking and sleep EEG changes. Pulse-modulated EMF exposure may provide a new, non-invasive method for modifying brain function for experimental, diagnostic and therapeutic purposes.

**Huber R, Schuderer J, Graf T, Jutz K, Borbely AA, Kuster N, Achermann P. Radio frequency electromagnetic field exposure in humans: Estimation of SAR distribution in the brain, effects on sleep and heart rate. Bioelectromagnetics 24(4):262-276, 2003.**

In two previous studies we demonstrated that radiofrequency electromagnetic fields (RF EMF) similar to those emitted by digital radiotelephone handsets affect brain physiology of healthy young subjects exposed to RF EMF (900 MHz; spatial peak specific absorption rate [SAR] 1 W/kg) either during sleep or during the waking period preceding sleep. In the first experiment, subjects were exposed intermittently during an 8 h nighttime sleep episode and in the second experiment, unilaterally for 30 min prior to a 3 h daytime sleep episode. Here we report an extended analysis of the two studies as well as the detailed dosimetry of the brain areas, including the assessment of the exposure variability and uncertainties. The latter enabled a more in depth analysis and discussion of the findings. Compared to the control condition with sham exposure, spectral power of the non-rapid eye movement sleep electroencephalogram (EEG) was initially increased in the 9-14 Hz range in both experiments. No topographical differences with respect to the effect of RF EMF exposure were observed in the two experiments. Even unilateral exposure during waking induced a similar effect in both hemispheres. Exposure during sleep reduced waking after sleep onset and affected heart rate variability. Exposure prior to sleep reduced heart rate during waking and stage 1 sleep. The lack of asymmetries in the effects on sleep EEG, independent of bi- or unilateral exposure of the cortex, may indicate involvement of subcortical bilateral projections to the cortex in the generation of brain function changes, especially since the exposure of the thalamus was similar in both experiments (approx. 0.1 W/kg).

**Huber R, Treyer V, Schuderer J, Berthold T, Buck A, Kuster N, Landolt HP, Achermann P. Exposure to pulse-modulated radio frequency electromagnetic fields affects regional cerebral blood flow. Eur J Neurosci. 21(4):1000-1006, 2005.**

We investigated the effects of radio frequency electromagnetic fields (RF EMF) similar to those emitted by mobile phones on waking regional cerebral blood flow (rCBF) in 12 healthy young men. Two types of RF EMF exposure were applied: a 'base-station-like' and a 'handset-like' signal. Positron emission tomography scans were taken after 30 min unilateral head exposure to pulse-modulated 900 MHz RF EMF (10 g tissue-averaged spatial peak-specific absorption rate of 1 W/kg for both conditions) and sham control. We observed an increase in relative rCBF in the dorsolateral prefrontal cortex on the side of exposure. The effect depended on the spectral power in the amplitude modulation of the RF carrier such that only 'handset-like' RF EMF exposure with its stronger low-frequency components but not the 'base-station-like' RF EMF exposure affected rCBF. This finding

supports our previous observation that pulse modulation of RF EMF is necessary to induce changes in the waking and sleep EEG, and substantiates the notion that pulse modulation is crucial for RF EMF-induced alterations in brain physiology.

**Hung CS, Anderson C, Horne JA, McEvoy P. Mobile phone 'talk-mode' signal delays EEG-determined sleep onset. Neurosci Lett. 421: 82-86, 2007.**

Mobile phones signals are pulse-modulated microwaves, and EEG studies suggest that the extremely low-frequency (ELF) pulse modulation has sleep effects. However, 'talk', 'listen' and 'standby' modes differ in the ELF (2, 8, and 217Hz) spectral components and specific absorption rates, but no sleep study has differentiated these modes. We used a GSM900 mobile phone controlled by a base-station simulator and a test SIM card to simulate these three specific modes, transmitted at 12.5% (23dBm) of maximum power. At weekly intervals, 10 healthy young adults, sleep restricted to 6h, were randomly and single-blind exposed to one of: talk, listen, standby and sham (nil signal) modes, for 30min, at 13:30h, whilst lying in a sound-proof, lit bedroom, with a thermally insulated silent phone beside the right ear. Bipolar EEGs were recorded continuously, and subjective ratings of sleepiness obtained every 3min (before, during and after exposure). After exposure the phone and base-station were switched off, the bedroom darkened, and a 90min sleep opportunity followed. We report on sleep onset using: (i) visually scored latency to onset of stage 2 sleep, (ii) EEG power spectral analysis. There was no condition effect for subjective sleepiness. Post-exposure, sleep latency after talk mode was markedly and significantly delayed beyond listen and sham modes. This condition effect over time was also quite evident in 1-4Hz EEG frontal power, which is a frequency range particularly sensitive to sleep onset. It is possible that 2, 8, 217Hz modulation may differentially affect sleep onset.

**Hunton J, Rose JM. Cellular telephones and driving performance: the effects of attentional demands on motor vehicle crash risk. Risk Anal. 25(4):855-866, 2005.**

This study examines the effects of conversation mode and split-attention communication training on driving performance. The study is based on an experiment where drivers with and without communication training (pilots vs. nonpilots) completed a simulated driving course while involved in one of three conversation modes: no conversation, conversation with passenger, or conversation on a hands-free cellular telephone. Results indicate that cellular telephone conversations consume more attention and interfere more with driving than passenger conversations. Cell phone conversations lack the nonverbal cues available during close-contact conversations and conversation participants expend significant cognitive resources to compensate for the lack of such cues. The results also demonstrate that communication training may reduce the hazardous effects of cell phone conversations on driving performance.

**Huss A, Egger M, Hug K, Huwiler-Müntener K, Röösli M, Gomes D, Da Ros MA Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Cien Saude Colet. 13(3):1005-1012, 2008.**

There is concern regarding the possible health effects of cellular telephone use. We conducted a systematic review of studies of controlled exposure to radiofrequency

radiation with health-related outcomes (electroencephalogram, cognitive or cardiovascular function, hormone levels, symptoms, and subjective well-being). We searched Embase, Medline, and a specialist database in February 2005 and scrutinized reference lists from relevant publications. Data on the source of funding, study design, methodologic quality, and other study characteristics were extracted. The primary outcome was the reporting of at least one statistically significant association between the exposure and a health-related outcome. Data were analyzed using logistic regression models. Of 59 studies, 12 (20%) were funded exclusively by the telecommunications industry, 11 (19%) were funded by public agencies or charities, 14 (24%) had mixed funding (including industry), and in 22 (37%) the source of funding was not reported. Studies funded exclusively by industry reported the largest number of outcomes, but were least likely to report a statistically significant result. The interpretation of results from studies of health effects of radiofrequency radiation should take sponsorship into account.

**Hutter HP, Moshammer H, Wallner P, Kundi M. Public perception of risk concerning cell towers and mobile phones. Soz Praventivmed. 49(1):62-66, 2004.**

OBJECTIVE: The controversy about health risks of electromagnetic fields (EMF) has contributed in raising fears concerning emissions from celltowers. The study was to examine whether or not neighbours of celltowers are particularly concerned about adverse health effects of mobile phones and their base stations. METHODS: Prior to information delivered by medical doctors of the Institute of Environmental Health at public hearings a questionnaire was handed out to participants asking for their personal rating of several environmental health risks including those of mobile telecommunication (n = 123, response rate approx. 48%). Medical students (n = 366) served as a contrast group. RESULTS: Participants rated health risk for both, mobile phones and celltowers higher as students. A trend for higher ratings was also seen with older subjects and female sex. The risk ratings of both exposures correlated well with each other. The magnitude of the perceived risks, however, resembled that of other ubiquitous exposures like traffic noise and air pollution. CONCLUSION: Contrary to the claims of the telecommunication industry, opponents of celltowers generally do not express unusual fears concerning electromagnetic field exposure. The outcome of our study indicates that the risk rating is comparable with other perceived common hazards of the civilised world. It is hypothesised that offering information and participation to the concerned population will be efficient in reducing exaggerated fears.

**Hutter HP, Moshammer H, Wallner P, Kundi M. Subjective symptoms, sleeping problems, and cognitive performance in subjects living near mobile phone base stations. Occup Environ Med. 63(5):307-313, 2006.**

BACKGROUND: The erection of mobile telephone base stations in inhabited areas has raised concerns about possible health effects caused by emitted microwaves. METHODS: In a cross-sectional study of randomly selected inhabitants living in urban and rural areas for more than one year near to 10 selected base stations, 365 subjects were investigated. Several cognitive tests were performed, and wellbeing and sleep quality were assessed. Field strength of high-frequency electromagnetic fields (HF-EMF) was measured in the bedrooms of 336 households. RESULTS: Total HF-EMF and

exposure related to mobile telecommunication were far below recommended levels (max. 4.1 mW/m2). Distance from antennae was 24-600 m in the rural area and 20-250 m in the urban area. Average power density was slightly higher in the rural area (0.05 mW/m2) than in the urban area (0.02 mW/m2). Despite the influence of confounding variables, including fear of adverse effects from exposure to HF-EMF from the base station, there was a significant relation of some symptoms to measured power density; this was highest for headaches. Perceptual speed increased, while accuracy decreased insignificantly with increasing exposure levels. There was no significant effect on sleep quality. CONCLUSION: Despite very low exposure to HF-EMF, effects on wellbeing and performance cannot be ruled out, as shown by recently obtained experimental results; however, mechanisms of action at these low levels are unknown.

**Hutter HP, Moshammer H, Wallner P, Cartellieri M, Denk-Linnert DM, Katzinger M, Ehrenberger K, Kundi M. Tinnitus and mobile phone use. Occup Environ Med. 67(12):804-808, 2010.**

Objectives The mechanisms that produce tinnitus are not fully understood. While tinnitus can be associated with diseases and disorders of the ear, retrocochlear diseases and vascular pathologies, there are few known risk factors for tinnitus apart from these conditions. There is anecdotal evidence of an link between mobile phone use and tinnitus, but so far there have been no systematic investigations into this possible association. Methods 100 consecutive patients presenting with tinnitus were enrolled in an individually matched case-control study. For each case a control subject was randomly selected from visiting outpatients matched for sex and age. The patient's history was obtained and clinical examinations were conducted to exclude patients with known underlying causes of tinnitus. Mobile phone use was assessed based on the Interphone Study protocol. ORs were computed by conditional logistic regression with years of education and living in an urban area as covariates. Results Mobile phone use up to the index date (onset of tinnitus) on the same side as the tinnitus did not have significantly elevated ORs for regular use and intensity or for cumulative hours of use. The risk estimate was significantly elevated for prolonged use (>/=4 years) of a mobile phone (OR 1.95; CI 1.00 to 3.80). Conclusions Mobile phone use should be included in future investigations as a potential risk factor for developing tinnitus.

**Hutter HP, Ehrenhöfer L, Freuis E, Hartl P, Kundi M.Poor-to-moderate agreement between self and proxy interviews of mobile phone use.Bioelectromagnetics. 33(7):561-567, 2012.**

In epidemiological studies, cases cannot always be interviewed due to them being too ill or already deceased. Under these circumstances, proxy interviews are often conducted; however, the veridicality of information about mobile phone use gained by proxy interviews has been doubted. The issue is undecided due to the lack of empirical data. We conducted a study of 119 heterosexual couples. Both partners answered two questionnaires about mobile phone use, one about their own use and one about their partner's use. Overall agreement assessed using Cohen's kappa, Passing and Bablok regression, and concordance coefficients between self and proxy data was poor to moderate (e.g., concordance coefficients of 0.55 for duration of use). The only item with

good agreement was whether or not a prepaid phone was used (Cohen's kappa 0.78 and 0.63 for male and female estimates, respectively), and to a lesser degree, the onset of mobile phone use (concordance coefficients of 0.66 and 0.61). Poorest agreement was obtained for the side of the head the mobile phone was held during calls (kappa coefficients of 0.20 and 0.24 for female and male estimates, respectively). We conclude that the assessment of mobile phone use by proxy data cannot be relied on except for information about onset of mobile phone use, use of prepaid or contract phones, and, to a lesser degree, duration of daily use. Agreement concerning the important information about side of the head the mobile phone is held during calls was poorest and only slightly better than chance.

**Hwang Y, Ahn J, Mun J, Bae S, Jeong YU, Vinokurov NA, Kim P. In vivo analysis of THz wave irradiation induced acute inflammatory response in skin by laser-scanning confocal microscopy. Opt Express. 22(10):11465-11475, 2014.**

The recent development of THz sources in a wide range of THz frequencies and power levels has led to greatly increased interest in potential biomedical applications such as cancer and burn wound diagnosis. However, despite its importance in realizing THz wave based applications, our knowledge of how THz wave irradiation can affect a live tissue at the cellular level is very limited. In this study, an acute inflammatory response caused by pulsed THz wave irradiation on the skin of a live mouse was analyzed at the cellular level using intravital laser-scanning confocal microscopy. Pulsed THz wave (2.7 THz, 4 μs pulsewidth, 61.4 μJ per pulse, 3Hz repetition), generated using compact FEL, was used to irradiate an anesthetized mouse's ear skin with an average power of 260 mW/cm<sup>2</sup> for 30 minutes using a high-precision focused THz wave irradiation setup. In contrast to in vitro analysis using cultured cells at similar power levels of CW THz wave irradiation, no temperature change at the surface of the ear skin was observed when skin was examined with an IR camera. To monitor any potential inflammatory response, resident neutrophils in the same area of ear skin were repeatedly visualized before and after THz wave irradiation using a custom-built laser-scanning confocal microscopy system optimized for in vivo visualization. While non-irradiated control skin area showed no changes in the number of resident neutrophils, a massive recruitment of newly infiltrated neutrophils was observed in the THz wave irradiated skin area after 6 hours, which suggests an induction of acute inflammatory response by the pulsed THz wave irradiation on the skin via a non-thermal process.

**Ibitayo AO, Afolabi OB, Akinyemi AJ, Ojiezeh TI, Adekoya KO, Ojewunmi OO. RAPD Profiling, DNA Fragmentation, and Histomorphometric Examination in Brains of Wistar Rats Exposed to Indoor 2.5 Ghz Wi-Fi Devices Radiation. Biomed Res Int. 2017;2017:8653286.**

The advent of Wi-Fi connected high technology devices in executing day-to-day activities is fast evolving especially in developing countries of the world and hence the need to assess its safety among others. The present study was conducted to investigate the injurious effect of radiofrequency emissions from installed Wi-Fi devices in brains of young male rats. Animals were divided into four equal groups; group 1 served as control

while groups 2, 3, and 4 were exposed to 2.5 Ghz at intervals of 30, 45, and 60 consecutive days with free access to food and water ad libitum. Alterations in harvested brain tissues were confirmed by histopathological analyses which showed vascular congestion and DNA damage in the brain was assayed using agarose gel electrophoresis. Histomorphometry analyses of their brain tissues showed perivascular congestion and tissue damage as well.

**Ibitoye ZA, Aweda AM. Assessment of radiofrequency power density distribution around GSM and broadcast antenna masts in Lagos City, Nigeria.Nig Q J Hosp Med. 21(1):35-40, 2011.**

**BACKGROUND:** Global system of mobile communication (GSM) and other telecommunication technologies are now common place in Lagos state Nigeria. The introduction of GSM in 2002 considerably increased radiofrequency (RF) radiation exposure of the public from telecommunications transmitting and receiving antennae. The RF radiation emanating from these devices, if above international limits may pose health risk to the public. **OBJECTIVE:** There is need for database of RF distribution level in Nigeria for safety assessment. The purpose of this study is to determine power density around different telecommunications antenna base stations and compare the measured values with the international recommended exposure limits in order to assess the safety of the members of the public. **METHODS:** A radiofrequency meter, Electrosmog from LESSEMF USA was used for the measurement. It is a highly sensitive device capable of measuring frequency between 50 MHz and 3.5 GHz. Measurements were taken at distances of 25, 50, 100, 150 and 200 m from selected antenna base stations in Lagos state. The results were compared with the International Commission of NonIonizing Radiation and Protection (ICNIRP) and the Institute of Electrical and Electronics Engineering/American National Standard Institute (IEEE/ANSI). **RESULTS:** Power densities obtained varied between 0.219 and 302.40 mW.m(-2) from the studied base stations. Comparison of the results with the ICNIRP and IEEE/ANSI recommended safety standards of 12000 mW x m(-2) and 5700 mW x m(-2) showed that the exposure levels are very low. **CONCLUSION:** Power densities of the RF radiation from telecommunication transmitting/receiving antennae were far below international standard limits. The measured values are not likely capable of inducing significant hazardous health effects among the people that are at least 6 m away from the antennae.

**Ikeda K, Nakamura K. Association between mobile phone use and depressed mood in Japanese adolescents: a cross-sectional study. Environ Health Prev Med. 2013 Dec 18. [Epub ahead of print]**

OBJECTIVES: Mobile phones are commonly used by adolescents. The aim of this study was to clarify associations between duration of mobile phone use and psychological mood in high school students. METHODS: This cross-sectional study included 2,785 high school students in Niigata, Japan. A self-administered questionnaire was used to elicit information on sex, school year, hours of mobile phone use, psychological mood status, and possible confounders. Psychological mood outcomes were evaluated with the Mood Inventory, developed and validated in 1994, which includes five subcomponents with total scores ranging from 8 to 32 (higher score indicates stronger feeling): "Tension

and excitement," "Refreshing mood," "Fatigue," "Depressed mood," and "Anxious mood." Analysis of covariance with Bonferroni's multiple comparison was used to compare mean values among quartiles of hours of mobile phone use. RESULTS: Among the respondents, mean mobile phone use per week was 24 (median 18) h. Long-duration mobile phone use was associated with female students, no participation in sports club activities, early mobile phone use, and fewer hours spent sleeping (all P < 0.001). Overall associations between hours of mobile phone use and total scores were significant for "Depressed mood" (P for trend = 0.005), "Tension and excitement" (P for trend <0.001), and "Fatigue" (P for trend < 0.001). Total scores for "Depressed mood," "Tension and excitement," and "Fatigue" of the fourth quartile (≥33 h/week) of mobile phone use were significantly higher than for other quartiles (all P < 0.05). CONCLUSIONS: Increased duration of mobile phone use is associated with unfavorable psychological mood, in particular, a depressed mood. Decreasing mobile phone use may help maintain appropriate mental health in very long-duration users.

**Ikeda N, Hayashida O, Kameda H, Ito H, Matsuda T**, **Experimental study on thermal damage to dog normal brain.Int J Hyperthermia 10(4):553-561, 1994**.

We investigated the temperature changes and their distribution in agar phantoms and dog normal brains induced by 8 MHz radiofrequency interstitial hyperthermia and observed the histological changes, with respect to the neurons and myelinated nerve fibres, induced by the same heat source in dog normal brains. We also examined the change of blood-brain barrier permeability using Evans blue solution. The heating limits of dog normal brain were 42 degrees C for 45 min or 43 degrees C for 15 min and the breakdown of the BBB was observed at 43 degrees C for 60 min.

**İkinci A, Mercantepe T, Unal D, Erol HS, Şahin A, Aslan A, Baş O, Erdem H, Sönmez OF, Kaya H, Odacı E. Morphological and antioxidant impairments in the spinal cord of male offspring rats following exposure to a continuous 900-MHz electromagnetic field during early and mid-adolescence. J Chem Neuroanat. 2015 Dec 17. pii: S0891-0618(15)00096-4. doi: 10.1016/j.jchemneu.2015.11.006. [Epub ahead of print]**

The effects on human health of devices emitting electromagnetic field (EMF) have become the subject of intense research among scientists due to the rapid increase in their use. Children and adolescents are particularly attracted to the use of devices emitting EMF, such as mobile phones. The aim of this study was therefore to investigate changes in the spinal cords of male rat pups exposed to the effect of 900 megahertz (MHz) EMF. The study began with 24 Sprague Dawley male rats aged 3 weeks. Three groups containing equal numbers of rats were established - control group (CG), sham group (SG) and EMF group (EMFG). EMFG rats were placed inside an EMF cage every day between postnatal days (PD) 21 and 46 and exposed to the effect of 900MHz EMF for 1hour. SG rats were kept in the EMF cage for 1hour without being exposed to the effect of EMF. At the end of the study, the spinal cords in the upper thoracic region of all rats were removed. Tissues were collected for biochemistry, light microscopy (LM) and transmission electron microscopic (TEM) examination. Biochemistry results revealed

significantly increased malondialdehyde and glutathione levels in EMFG compared to CG and SG, while SG and EMFG catalase and superoxide dismutase levels were significantly higher than those in CG. In EMFG, LM revealed atrophy in the spinal cord, vacuolization, myelin thickening and irregularities in the perikarya. TEM revealed marked loss of myelin sheath integrity and invagination into the axon and broad vacuoles in axoplasm. The study results show that biochemical alterations and pathological changes may occur in the spinal cords of male rats following exposure to 900MHz EMF for 1hour a day on PD 21-46.

**İkinci A, Odacı E, Yıldırım M, Kaya H, Akça M, Hancı H, Aslan A, Sönmez OF, Baş O.The Effects of Prenatal Exposure to a 900 Megahertz Electromagnetic Field on Hippocampus Morphology and Learning Behavior in Rat Pups. NeuroQuantology. 11(4):582-590, 2013.**

The purpose of this study was to examine the effect on hippocampus morphology and learning behavior in rat pups following prenatal exposure to a 900 megahertz (MHz) electromagnetic field (EMF). Female Sprague Dawley rats weighing 180-250 g were left to mate with males. The following day, pregnant rats identified as such by the vaginal smear test were divided into two groups, control (n=3) and EMF (n=3). No procedures were performed on the control group. The rats in the EMF group were exposed to 900 MHz EMF on days 13 to 21 of pregnancy, for 1 h a day. Female rat pups were removed from their mothers at 22 days old. We then established two newborn rat groups, a 13 member control group and a 10 member EMF group. Radial arm maze and passive avoidance tests were used to measure rat pups' learning and memory performance. All rats were decapitated on the postnatal 32nd day. Routine histological procedures were performed on the brain tissues, and sections were stained with Cresyl fast violet. The radial arm maze (p=0.007) and passive avoidance (p=0.032) tests were administered to both groups under identical conditions, and compromised learning behavior was determined in the EMF group rats. Morphological compromise was also determined in the EMF group sections. Our results show that the application of a 900 MHz EMF in the prenatal period adversely affected female pups' learning behavior and also resulted in histopathological changes appearing in the hippocampus.

**Ilhan A, Gurel A, Armutcu F, Kamisli S, Iraz M, Akyol O, Ozen S. Ginkgo biloba prevents mobile phone-induced oxidative stress in rat brain. Clin Chim Acta. 340(1-2): 153-162, 2004.**

BACKGROUND: The widespread use of mobile phones (MP) in recent years has raised the research activities in many countries to determine the consequences of exposure to the low-intensity electromagnetic radiation (EMR) of mobile phones. Since several experimental studies suggest a role of reactive oxygen species (ROS) in EMR-induced oxidative damage in tissues, in this study, we investigated the effect of Ginkgo biloba (Gb) on MP-induced oxidative damage in brain tissue of rats. METHODS: Rats (EMR+) were exposed to 900 MHz EMR from MP for 7 days (1 h/day). In the EMR+Gb groups, rats were exposed to EMR and pretreated with Gb. Control and Gb-administrated groups were produced by turning off the mobile phone while the animals were in the same

exposure conditions. Subsequently, oxidative stress markers and pathological changes in brain tissue were examined for each groups. RESULTS: Oxidative damage was evident by the: (i) increase in malondialdehyde (MDA) and nitric oxide (NO) levels in brain tissue, (ii) decrease in brain superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px) activities and (iii) increase in brain xanthine oxidase (XO) and adenosine deaminase (ADA) activities. These alterations were prevented by Gb treatment. Furthermore, Gb prevented the MP-induced cellular injury in brain tissue histopathologically. CONCLUSION: Reactive oxygen species may play a role in the mechanism that has been proposed to explain the biological side effects of MP, and Gb prevents the MP-induced oxidative stress to preserve antioxidant enzymes activity in brain tissue.

**Ilvonen S, Sihvonen AP, Karkkainen K, Sarvas J. Numerical assessment of induced ELF Currents in the human head due to the battery current of a digital mobile phone. Bioelectromagnetics. 26(8):648-656,2005.**

In this study, the extremely low frequency (ELF) fields induced in the human head by the battery currents of a mobile phone are considered. The magnetic field induced by the phone was measured, and this data was used to calculate the resulting currents induced in the human head and brain. Both the finite element method (FEM) and finite integration technique (FIT) were used for numerical computations. The computed current density values were then compared with the guidelines given by the International Commission on Non-Ionising Radiation Protection (ICNIRP). The comparison showed that the computed exposure is well within the limits of those guidelines

**Imai N, Kawabe M, Hikage T, Nojima T, Takahashi S, Shirai T. Effects on rat testis of 1.95-GHz W-CDMA for IMT-2000 cellular phones. Syst Biol Reprod Med. 57(4):204-209,2011.**

Abstract. In recent years concern has arisen whether carrying a cellular phone near the reproductive organs such as the testes may cause dysfunction and particularly decrease in sperm development and production, and thus fertility in men. The present study was performed to investigate the effects of a 1.95GHz electromagnetic field on testicular function in male Sprague-Dawley rats. Five week old animals were divided into 3 groups of 24 each and a 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is used for the freedom of mobile multimedia access (FOMA), was employed for whole body exposure for 5 hours per day, 7 days a week for 5 weeks (the period from the age of 5 to 10 weeks, corresponding to reproductive maturation in the rat). Whole-body average specific absorption rates (SAR) for individuals were designed to be 0.4 and 0.08 W/kg respectively. The control group received sham exposure. There were no differences in body weight gain or weights of the testis, epididymis, seminal vesicles, and prostate among the groups. The number of sperm in the testis and epididymis were not decreased in the electromagnetic field (EMF) exposed groups, and, in fact, the testicular sperm count was significantly increased with the 0.4 SAR. Abnormalities of sperm motility or morphology and the histological appearance of seminiferous tubules, including the stage of the spermatogenic cycle, were not observed. Thus, under the present exposure conditions, no testicular toxicity was evident.

**Imaida, K, Taki, M, Watanabe, S, Kamimura, Y, Ito, T, Yamaguchi, T, Ito, N, Shirai, T,**

**The 1.5 GHz electromagnetic near-field used for cellular phones does not promote rat liver carcinogenesis in a medium-term liver bioassay. Jpn J Cancer Res 89(10):995-1002, 1998.**

We have recently established that local exposure to a 929.2 MHz electromagnetic near-field, used for cellular phones, does not promote rat liver carcinogenesis in a medium-term bioassay system. In the present study, a 1.439 GHz electromagnetic near-field (EMF), another microwave band employed for cellular phones in Japan, was similarly investigated. Time division multiple access (TDMA) signals for the Personal Digital Cellular (PDC) Japanese cellular telephone standard system were directed to rats through a quarter-wavelength monopole antenna. Numerical dosimetry showed that the peak SARs within the liver were 1.91-0.937 W/kg, while the whole-body average specific absorption rates (SARs) were 0.680-0.453 W/kg, when the time-averaged antenna radiation power was 0.33 W. Exposure was for 90 min a day, 5 days a week, over 6 weeks, to male F344 rats given a single dose of diethylnitrosamine (200 mg/kg, i.p.) 2 weeks previously. At week 3, all rats were subjected to a two-thirds partial hepatectomy. At week 8, the experiment was terminated and the animals were killed. Carcinogenic potential was scored by comparing the numbers and areas of the induced glutathione S-transferase placental form (GST-P)-positive foci in the livers of exposed (48) and sham-exposed rats (48). Despite increased serum levels of corticosterone, adrenocorticotropic hormone (ACTH) and melatonin, the numbers and the areas of GST-P-positive foci were not significantly altered by the exposure. These findings clearly indicated that local body exposure to a 1.439 GHz EMF, as in the case of a 929.2 MHz field, has no promoting effect on rat liver carcinogenesis in the present model.

**Imaida K, Taki M, Yamaguchi T, Ito T, Watanabe S, Wake K, Aimoto A, Kamimura Y, Ito N, Shirai T, Lack of promoting effects of the electromagnetic near-field used for cellular phones (929.2 MHz) on rat liver carcinogenesis in a medium-term liver bioassay. Carcinogenesis 19(2):311-314, 1998**.

The possible cancer promotion potential of local exposure to a pulse modulated 929.2 MHz electromagnetic near-field on chemically-initiated rat liver carcinogenesis was investigated employing a medium-term bioassay. A 929.2-MHz electromagnetic near-field of time division multiple access (TDMA) signal for PDC (Personal Digital Cellular, Japanese cellular telephone standard) system was directed to rats through a quarter-wavelength monopole antenna. Maximum local specific absorption rates (SARs) on temporal average were 7.2-6.6 W/kg within the whole body and 2.0-1.7 W/kg within the liver, which was the target organ. The whole-body average SARs on temporal average were 0.80-0.58 W/kg. Temporal peak SARs had three times these values due to the duty ratio of the PDC signal. Exposure was for 90 min a day, 5 days a week, over 6 weeks. The exposure apparatus was specially designed for this experiment, to allow exposure of the lateral mid-section of the rat body to the electromagnetic near-field. Male F344 rats, 6 week-old, were initially (at week 0) given a single dose of diethylnitrosamine (DEN, 200 mg/kg body wt, i.p.). At 2 weeks later, exposure (48 rats) or sham-exposure (48 rats) was started. The exposure of electromagnetic near-fields was performed using the exposure apparatus mentioned above. At week 3, all rats were subjected to a 2/3 partial hepatectomy. At week 8 (i.e. after 6 weeks exposure or sham-exposure), the experiment was terminated and all rats were killed. Carcinogenic potential was scored by comparing

the numbers and areas of the induced glutathione S-transferase placental form (GST-P) positive foci in the livers of the exposed and sham-exposed rats. A further group of 24 animals, given only DEN and partial hepatectomy, served as the controls. The numbers (no./cm2) of GST-P positive foci were 4.61 +/- 1.77, 5.21 +/- 1.92 ($P < 0.05$, versus control) and 4.09 +/- 1.47 and the areas (mm2/cm2) were 0.30 +/- 0.16, 0.36 +/- 0.21 and 0.28 +/- 0.15, for the exposed, sham-exposed and control groups, respectively. There were no significant differences between the exposed and sham-exposed groups. These findings clearly indicated that local body exposure to a 929.2-MHz field, modulated in a PDC waveform, has no significant effect on rat liver carcinogenesis under the experimental conditions employed.

**Imaida K, Hagiwara A, Yoshino H, Tamano S, Sano M, Futakuchi M, Ogawa K, Asamoto M, Shirai T, Inhibitory effects of low doses of melatonin on induction of preneoplastic liver lesions in a medium-term liver bioassay in F344 rats: relation to the influence of electromagnetic near field exposure. Cancer Lett 155(1):105-114, 2000.**

We have previously reported that exposures of F344 male rats to both 900 MHz and 1.5 GHz electro-magnetic near fields (EMFs) results in slightly decreased numbers and areas of glutathione S-transferase (GST-P)-positive liver foci, liver preneoplastic lesions in rats, in a medium-term liver bioassay (K. Imaida, M. Taki, T. Yamaguchi, T. Ito, S. Watanabe, K. Wake, A. Aimoto, Y. Kamimura, N. Ito, T. Shirai, Lack of promoting effects of the electromagnetic near-field used for cellular phones (929.2 MHz) on rat liver carcinogenesis in a medium-term liver bioassay, Carcinogenesis 19 (1998) 311-314; K. Imaida, M. Taki, S. Watanabe, Y. Kamimura, T. Ito, T. Yamaguchi, N. Ito, T. Shirai, The 1.5 GHz electromagnetic near-field used for cellular phones does not promote rat liver carcinogenesis in a medium-term liver bioassay, Jpn. J. Cancer Res. 89 (1998) 995-1002.). In both experiments, the melatonin serum levels were significantly decreased in both 900 MHz and 1.5 GHz exposed groups as compared with sham-exposed control group values. Therefore, changes of serum melatonin levels may modify the development of preneoplastic lesions in the livers of rats exposed by EMF. In order to clarify this question, the effects of different doses of melatonin (1, 5, 10 and 20 ppm in the drinking water) were analyzed in the same bioassay system employed for our previously reported EMF exposure studies. Six-week-old male F344 rats were given a single dose of diethylnitrosamine (DEN, 200 mg/kg b.w., i.p.). Starting 2 weeks later, they were treated with 0, 1, 5, 10 and 20 ppm melatonin in their drinking water for 6 weeks. Melatonin treatment were performed only during the night (between 18:00 to 09:00) in order to maintain their circadian rhythm, since serum melatonin levels are high at midnight. At week 3, all rats were subjected to a two-thirds partial hepatectomy. At week 8, the experiment was terminated and the animals were sacrificed. Serum hormone levels of melatonin, adrenocorticotropic hormone (ACTH), corticosterone, luteinizing hormone (LH), follicle-stimulating hormone (FSH) and testosterone at this time point were measured, only the first being elevated, while LH and testosterone were reduced. Although clear dose dependence was not apparent, both numbers and areas of GST-P-positive foci in the liver were decreased in the melatonin treated groups, this being significant for numbers in the 10 ppm melatonin group. Comparison of the current results with the

previously reported findings for EMF exposure experiments, suggests that increase in melatonin serum levels is a possible reason for the associated tendency for decreased preneoplastic hepatocyte foci development.

**Imge EB, Kiliçoğlu B, Devrim E, Cetin R, Durak I. Effects of mobile phone use on brain tissue from the rat and a possible protective role of vitamin C - a preliminary study. Int J Radiat Biol.86(12):1044-1049, 2010.**

Purpose: To evaluate effects of mobile phone use on brain tissue and a possible protective role of vitamin C. Materials and methods: Forty female rats were divided into four groups randomly (Control, mobile phone, mobile phone plus vitamin C and, vitamin C alone). The mobile phone group was exposed to a mobile phone signal (900 MHz), the mobile phone plus vitamin C group was exposed to a mobile phone signal (900 MHz) and treated with vitamin C administered orally (per os). The vitamin C group was also treated with vitamin C per os for four weeks. Then, the animals were sacrificed and brain tissues were dissected to be used in the analyses of malondialdehyde (MDA), antioxidant potential (AOP), superoxide dismutase, catalase (CAT), glutathione peroxidase (GSH-Px), xanthine oxidase, adenosine deaminase (ADA) and 5'nucleotidase (5'-NT). Results: Mobile phone use caused an inhibition in 5'-NT and CAT activities as compared to the control group. GSH-Px activity and the MDA level were also found to be reduced in the mobile phone group but not significantly. Vitamin C caused a significant increase in the activity of GSH-Px and non-significant increase in the activities of 5'-NT, ADA and CAT enzymes. Conclusion: Our results suggest that vitamin C may play a protective role against detrimental effects of mobile phone radiation in brain tissue.

**Inaba R, Shishido K, Okada A, Moroji T. Effects of whole body microwave exposure on the rat brain contents of biogenic amines. Eur J Appl Physiol Occup Physiol. 65(2):124-128, 1992.**

The effects of whole body microwave exposure on the central nervous system (CNS) of the rat were investigated. Rats weighing from 250 to 320 g were exposed for 1 h to whole body microwave with a frequency of 2450 MHz at power densities of 5 and 10 mW.cm-2 at an ambient temperature of 21-23 degrees C. The rectal temperatures of the rats were measured just before and after microwave exposure and mono-amines and their metabolites in various discrete brain regions were determined after microwave exposure. Microwave exposure at power densities of 5 and 10 mW.cm-2 increased the mean rectal temperature by 2.3 degrees C and 3.4 degrees C, respectively. The noradrenaline content in the hypothalamus was significantly reduced after microwave exposure at a power density of 10 mW.cm-2. There were no differences in the dopamine (DA) content of any region of the brain between microwave exposed rats and control rats. The dihydroxyphenyl acetic acid (DOPAC) content, the main metabolite of DA, was significantly increased in the pons plus medulla oblongata only at a power density of 10 mW.cm-2. The DA turnover rates, the DOPAC:DA ratio, in the striatum and cerebral cortex were significantly increased only at a power density of 10 mW.cm-2. The serotonin (5-hydroxytryptamine, 5-HT) content in all regions of the brain of microwave exposed rats was not different from that of the control rats. The 5-hydroxyindoleacetic acid (5-HIAA) content in the cerebral cortex of microwave exposed rats was significantly increased at

power densities of 5 and 10 mW.cm-2.

**Indulski JA, Makowiec-Dabrowska T, Zmyslony M, Siedlecka J, [Electromagnetic poles and reproduction]. Med Pr 48(5):585-603, 1997.** [Article in Polish]

The authors review epidemiological data concerning the relationship between reproduction disorders and the exposure to electromagnetic fields (EMF) emitted by power lines, industrial power-charged devices, diagnostic and therapeutical appliances, video display terminals (VDTs) and electric household devices. The studies involved the analysis of the EMF effect on female and male reproduction, including the risk of spontaneous abortion, still birth and premature birth, low birth weight and congenital malformations as well as on the progeny gender proportion, among persons employed under the condition of EMF exposure. It was observed that the findings were frequently inconsistent, i.e. under the same conditions of EMF exposure some date indicated its negative effect on the reproduction process and some did not. No data confirming an acute effect of occupational exposure to EMF on the risk of spontaneous abortion, low birth weight, congenital malformations or other reproduction disorders were obtained, however, the negative effect of EMF cannot be explicitly excluded.

Ingole IV, Ghosh SK. **Effect of exposure to radio frequency radiation emitted by cell phone on the developing dorsal root ganglion of chick embryo: a light microscopic study.** Nepal Med Coll J. **14(4):337-341, 2012.**

With an ever increasing number of cell phone users since late twenty first century, magnitude of the problem of exposure to radiation emitted by cell phone is self evident. Extensive research had been devoted to incriminate or absolve it as a health hazard. Radiofrequency radiation emitted by cell phone had been stated to be a potent carcinogen, cytotoxic, genotoxic, mutagenic and neurobehavioral teratogen. Its effect on the brain had been a subject of extensive research evidently due to its proximity to the user's brain. While considering the biological effects of radiofrequency radiation, its intensity, frequency and the duration of exposure are important determinants. Nevertheless the results of these different studies have not been unequivocal. Considering the contradictory reports, the present work was undertaken to study the effect of such an exposure on the developing neural tissue of chick embryo. The processes of cell division and differentiation are fundamental to the development of any living being and are a sensitive index of any insult sustained at this stage. Neurons of dorsal root ganglion were selected for the present study as these ganglia were fully differentiated as early as fourth day of embryonic life. By varying duration of exposure, the embryos were exposed to different doses of radiation, sacrificed at different periods of incubation and subjected to histological processing. On light microscopic study it was observed that developing neurons of dorsal root ganglion suffered a damage which was dose dependent and persisted in spite of giving the exposure-free period between two exposures.

**Inomata-Terada S, Okabe S, Arai N, Hanajima R, Terao Y, Frubayashi T, Ugawa Y. Effects of high frequency electromagnetic field (EMF) emitted by mobile phones on the human motor cortex. Bioelectromagnetics.28(7):553-561, 2007.**

We investigated whether the pulsed high frequency electromagnetic field (EMF) emitted by a mobile phone has short term effects on the human motor cortex. We measured motor evoked potentials (MEPs) elicited by single pulse transcranial magnetic stimulation (TMS), before and after mobile phone exposure (active and sham) in 10 normal volunteers. Three sites were stimulated (motor cortex (CTX), brainstem (BST) and spinal nerve (Sp)). The short interval intracortical inhibition (SICI) of the motor cortex reflecting GABAergic interneuronal function was also studied by paired pulse TMS method. MEPs to single pulse TMS were also recorded in two patients with multiple sclerosis showing temperature dependent neurological symptoms (hot bath effect). Neither MEPs to single pulse TMS nor the SICI was affected by 30 min of EMF exposure from mobile phones or sham exposure. In two MS patients, mobile phone exposure had no effect on any parameters of MEPs even though conduction block occurred at the corticospinal tracts after taking a bath. As far as available methods are concerned, we did not detect any short-term effects of 30 min mobile phone exposure on the human motor cortical output neurons or interneurons even though we can not exclude the possibility that we failed to detect some mild effects due to a small sample size in the present study. This is the first study of MEPs after electromagnetic exposure from a mobile phone in neurological patients.

**Inoue S, Motoda H, Koike Y, Kawamura K, Hiragami F, Kano Y. Microwave irradiation induces neurite outgrowth in PC12m3 cells via the p38 mitogen-activated protein kinase pathway. Neurosci Lett.432(1):35-39,2008.**

The increasing use of mobile phone communication has raised concerns about possible health hazard effects of microwave irradiation. We investigated damage and differentiation caused by microwave irradiation on drug-hypersensitive PC12 cell line (PC12m3). These cells showed enhancement of neurite outgrowth to various stimulants. The frequency of neurite outgrowth induced by 2.45GHz (200W) of microwave irradiation was approximately 10-fold greater than that of non-irradiated control cells. Incubation of PC12m3 cells with SB203580, a specific inhibitor of p38 MAPK, resulted in marked inhibition of the microwave radiation-induced neurite outgrowth. Also, activation of the transcription factor CREB induced by microwave irradiation was inhibited by SB203580. Heat shock treatment at 45 degrees C had a strong toxic effect on PC12m3 cells, whereas microwave treatment had no toxic effect on PC12m3 cells. These findings indicate that p38 MAPK is responsible for the survival of PC12m3 cells and might induce neurite outgrowth via a CREB signaling pathway when subjected to microwave irradiation.

**Inskip PD, Tarone RE, Hatch EE, Wilcosky TC, Shapiro WR, Selker RG, Fine HA, Black PM, Loeffler JS, Linet MS, Cellular-telephone use and brain tumors. N Engl J Med 344(2):79-86, 2001.**

Background: Concern has arisen that the use of hand-held cellular telephones might cause brain tumors. If such a risk does exist, the matter would be of considerable public health importance, given the rapid increase worldwide in the use of these devices. Methods: We examined the use of cellular telephones in a case-control study of intracranial tumors of the nervous system conducted between 1994 and 1998. We

enrolled 782 patients through hospitals in Phoenix, Arizona; Boston; and Pittsburgh; 489 had histologically confirmed glioma, 197 had meningioma, and 96 had acoustic neuroma. The 799 controls were patients admitted to the same hospitals as the patients with brain tumors for a variety of nonmalignant conditions. Results: As compared with never, or very rarely, having used a cellular telephone, the relative risks associated with a cumulative use of a cellular telephone for more than 100 hours were 0.9 for glioma (95 percent confidence interval, 0.5 to 1.6), 0.7 for meningioma (95 percent confidence interval, 0.3 to 1.7), 1.4 for acoustic neuroma (95 percent confidence interval, 0.6 to 3.5), and 1.0 for all types of tumors combined (95 percent confidence interval, 0.6 to 1.5). There was no evidence that the risks were higher among persons who used cellular telephones for 60 or more minutes per day or regularly for five or more years. Tumors did not occur disproportionately often on the side of head on which the telephone was typically used. Conclusions: These data do not support the hypothesis that the recent use of hand-held cellular telephones causes brain tumors, but they are not sufficient to evaluate the risks among long-term, heavy users and for potentially long induction periods.

**Inskip PD, Hoover RN, Devesa SS. Brain cancer incidence trends in relation to cellular telephone use in the United States. Neuro Oncol.12(11):1147-1151, 2010.**

The use of cellular telephones has grown explosively during the past two decades, and there are now more than 279 million wireless subscribers in the United States. If cellular phone use causes brain cancer, as some suggest, the potential public health implications could be considerable. One might expect the effects of such a prevalent exposure to be reflected in general population incidence rates, unless the induction period is very long or confined to very long-term users. To address this issue, we examined temporal trends in brain cancer incidence rates in the United States, using data collected by the Surveillance, Epidemiology, and End Results (SEER) Program. Log-linear models were used to estimate the annual percent change in rates among whites. With the exception of the 20-29-year age group, the trends for 1992-2006 were downward or flat. Among those aged 20-29 years, there was a statistically significant increasing trend between 1992 and 2006 among females but not among males. The recent trend in 20-29-year-old women was driven by a rising incidence of frontal lobe cancers. No increases were apparent for temporal or parietal lobe cancers, or cancers of the cerebellum, which involve the parts of the brain that would be more highly exposed to radiofrequency radiation from cellular phones. Frontal lobe cancer rates also rose among 20-29-year-old males, but the increase began earlier than among females and before cell phone use was highly prevalent. Overall, these incidence data do not provide support to the view that cellular phone use causes brain cancer.

**The INTERPHONE Study Group. Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. Int J Epidemiol.39(3):675-94,2010.**

BACKGROUND: The rapid increase in mobile telephone use has generated concern about possible health risks related to radiofrequency electromagnetic fields from this technology. METHODS: An interview-based case-control study with 2708 glioma and

2409 meningioma cases and matched controls was conducted in 13 countries using a common protocol. RESULTS: A reduced odds ratio (OR) related to ever having been a regular mobile phone user was seen for glioma [OR 0.81; 95% confidence interval (CI) 0.70-0.94] and meningioma (OR 0.79; 95% CI 0.68-0.91), possibly reflecting participation bias or other methodological limitations. No elevated OR was observed >/=10 years after first phone use (glioma: OR 0.98; 95% CI 0.76-1.26; meningioma: OR 0.83; 95% CI 0.61-1.14). ORs were <1.0 for all deciles of lifetime number of phone calls and nine deciles of cumulative call time. In the 10th decile of recalled cumulative call time, >/=1640 h, the OR was 1.40 (95% CI 1.03-1.89) for glioma, and 1.15 (95% CI 0.81-1.62) for meningioma; but there are implausible values of reported use in this group. ORs for glioma tended to be greater in the temporal lobe than in other lobes of the brain, but the CIs around the lobe-specific estimates were wide. ORs for glioma tended to be greater in subjects who reported usual phone use on the same side of the head as their tumour than on the opposite side. CONCLUSIONS: Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

**Irgens A, Kruger K, Ulstein M, The effect of male occupational exposure in infertile couples in Norway. J Occup Environ Med 41(12):1116-1120, 1999.**

The objective of the study was to assess whether reduced semen quality in infertile couples is associated with occupational exposures known to be hazardous to fertility. Results of the first semen analysis were linked to occupational exposure data from a self-administered questionnaire. Reduced semen quality was found in men exposed to electromagnetic fields (odds ratio, 3.22; confidence interval, 1.46 to 7.09). A tendency toward reduced semen quality was seen in commuters (OR, 1.52; CI, 0.89 to 2.59), shift workers (OR, 1.46; CI, 0.89 to 2.40), and men exposed to heavy metals (OR, 1.47; CI, 0.76 to 2.87). In general, the impact of occupational exposure on semen quality in infertile couples in Norway seemed to be minor. However, occupational exposure mapping is still important in individual infertility investigations.

**Irlenbusch L, Bartsch B, Cooper J, Herget I, Marx B, Raczek J, Thoss F. Influence of a 902.4 MHz GSM signal on the human visual system: investigation of the discrimination threshold.Bioelectromagnetics. 28(8):648-654, 2007.**

The proximity of a mobile phone to the human eye raises the question as to whether radiofrequency (RF) electromagnetic fields (EMF) affect the visual system. A basic characteristic of the human eye is its light sensitivity, making the visual discrimination threshold (VDThr) a suitable parameter for the investigation of potential effects of RF exposure on the eye. The VDThr was measured for 33 subjects under standardized conditions. Each subject took part in two experiments (RF-exposure and sham-exposure experiment) on different days. In each experiment, the VDThr was measured continuously in time intervals of about 10 s for two periods of 30 min, having a break of 5 min in between. The sequence of the two experiments was randomized, and the study was single blinded. During the RF exposure, a GSM

signal of 902.4 MHz (pulsed with 217 Hz) was applied to the subjects. The power flux density of the electromagnetic field at the subject location (in the absence of the subject) was 1 W/m(2), and numerical dosimetry calculations determined corresponding maximum local averaged specific absorption rate (SAR) values in the retina of SAR(1 g) = 0.007 W/kg and SAR(10 g) = 0.003 W/kg. No statistically significant differences in the VDThr were found in comparing the data obtained for RF exposure with those for sham exposure.

**Irmak MK, Fadillioglu E, Gulec M, Erdogan H, Yagmurca M, Akyol O. Effects of electromagnetic radiation from a cellular telephone on the oxidant and antioxidant levels in rabbits. Cell Biochem Funct. 20(4):279-283, 2002.**

The number of reports on the effects induced by electromagnetic radiation (EMR) in various cellular systems is still increasing. Until now no satisfactory mechanism has been proposed to explain the biological effects of this radiation. Oxygen free radicals may play a role in mechanisms of adverse effects of EMR. This study was undertaken to investigate the influence of electromagnetic radiation of a digital GSM mobile telephone (900 MHz) on oxidant and antioxidant levels in rabbits. Adenosine deaminase, xanthine oxidase, catalase, myeloperoxidase, superoxide dismutase (SOD) and glutathione peroxidase activities as well as nitric oxide (NO) and malondialdehyde levels were measured in sera and brains of EMR-exposed and sham-exposed rabbits. Serum SOD activity increased, and serum NO levels decreased in EMR-exposed animals compared to the sham group. Other parameters were not changed in either group. This finding may indicate the possible role of increased oxidative stress in the pathophysiology of adverse effect of EMR. Decreased NO levels may also suggest a probable role of NO in the adverse effect.

**Irmak MK, Oztas E, Yagmurca M, Fadillioglu E, Bakir B. Effects of electromagnetic radiation from a cellular telephone on epidermal Merkel cells. J Cutan Pathol. 30(2):135-138, 2003.**

The number of reports on the effects induced by electromagnetic radiation (EMR) from cellular telephones in various cellular systems is still increasing. Until now, no satisfactory mechanism has been proposed to explain the biological effects of this radiation except a role suggested for mast cells. Merkel cells may also play a role in the mechanisms of biological effects of EMR. This study was undertaken to investigate the influence of EMR from a cellular telephone (900 MHz) on Merkel cells in rats. A group of rats was exposed to a cellular telephone in speech position for 30 min. Another group of rats was sham-exposed under the same environmental conditions for 30 min. Exposure led to significantly higher exocytotic activity in Merkel cells compared with the sham exposure group. This finding may indicate the possible role of Merkel cells in the pathophysiology of the effects of EMR.

**Irnich W, Tobisch R, [Effect of mobile phone on life-saving and life-sustaining systems]. Biomed Tech (Berl) 43(6):164-173, 1998.** [Article in German]

Since the beginning of the nineties there have been warnings not to use mobile phones in the vicinity of medical devices. Functional failures of dialysis machines, respirators and defibrillators prompted the banning of their use in many hospitals in Scandinavia, and

then in other countries. Since we believe that a general ban in hospitals is problematic, we decided to investigate the influence of mobile telephone on life-saving and/or life-support systems, with the aim of establishing rules for its use in hospitals. We investigated available phones of varying power of the C-, D- and E-net, as also of a cordless phone meeting the DECT standard. The aim was to identify the devices susceptible to interference and determine the minimum distances at which interference occurred. A total of 224 devices classified into 23 types of devices were examined. Nine different sets of transmission conditions were applied, giving a total of 2016 tests. Our results permit the conclusion that the ban on mobile phones in hospitals is based not on actual events, but on theoretical considerations in the absence of any practical information on the actual susceptibility of devices and their reaction to the electromagnetic fields involved. The fact that hazardous situations are very rare is due firstly to the need for the simultaneous occurrence of four coincidences, and the fail-save feature of medical devices. We would therefore recommend that all life-saving and life-support systems that can also be used outside the hospital should be made mobile phone-proof. When apnoea monitors and respirators are protected from such interference, hazardous situations could be avoided by establishing the rule: "No portables, and mobile phones only at a distance of at least 1 metre from medical devices". With regard to emergency telephones, the minimum distance to medical devices should be at least 1.5 metres.

**Irnich W, Batz L, Muller R, Tobisch R, electromagnetic interference of pacemakers by mobile phones. Pacing Clin Electrophysiol 19(10):1431-1446, 1996.**

The topic of interference of pacemakers by mobile phones has evoked a surprisingly strong interest, not only in pacemaker patients, but also in the public opinion. The latter is the more surprising, as in the past, the problem of interference has scarcely found the attention that it deserves in the interest of the patient. It was the intention of our investigation to test as many pacemaker models as possible to determine whether incompatibility with mobile phones of different modes may exist, using an in vitro measuring setup. We had access to 231 different models of 20 manufacturers. During the measurements, a pulse generator together with a suitable lead was situated in a 0.9 g/L saline solution, and the antenna of a mobile phone was positioned as close as possible. If the pulse generator was disturbed, the antenna was elevated until interference ceased. The gap in which interference occurred was defined as "maximum interference distance." All three nets existing in Germany, the C-net (450 MHz, analogue), the D-net (900 MHz, digital pulsed), and the E-net (1,800 MHz, digital pulsed) were tested in succession. Out of 231 pulse generator models, 103 pieces corresponding to 44.6% were influenced either by C- or D-net, if both results were totaled. However, this view is misleading as no patient will use C- and D-net phones simultaneously. Separated into C- or D-net interference, the result is 30.7% for C or 34.2% for D, respectively, of all models tested. The susceptible models represent 18.6% or 27% of today's living patients, respectively. All models were resistant to the E-net. With respect to D-net phones, all pacemakers of six manufacturers proved to be unaffected. Eleven other manufacturers possessed affected and unaffected models as well. A C-net phone only prolonged up to five pacemaker periods within 10 seconds during dialing without substantial impairment to the patient. Bipolar pacemakers are as susceptible as unipolar ones. The following advice for patients and physicians can be derived from our investigations: though 27% of all patients

may have problems with D-net phones (not C- or E-net), the application should generally not be questioned. On the contrary, patients with susceptible devices should be advised that a distance of 20 cm is sufficient to guarantee integrity of the pacemaker with respect to hand held phones. Portables, on the other hand, should have a distance of about 0.5 m. Pacemaker patients really suffering from mobile phones are very rare unless the phone is just positioned in the pocket over the pulse generator. The contralateral pocket or the belt position guarantees, in 99% of all patients, undisturbed operation of the pacemaker. A risk analysis reveals that the portion of patients really suffering from mobile phones is about 1 out of 100,000. Nevertheless, it would be desirable in the future if implanting physicians would use only pacemakers with immunity against mobile phones as guaranteed by the manufacturers.

**Isa AR, Noor M, Non-ionizing radiation exposure causing ill-health and alopecia areata. Med J Malaysia 46(3):235-238, 1991.**

Three cases of occupational exposure to radio-frequency and microwave radiation were seen at the out-patient clinic, Hospital Universiti Sains Malaysia. They presented with run-down symptoms of neck strain associated with throbbing headache, irritability, loss of appetite, fatigue, memory difficulties, and numbness of extremities. They also presented with alopecia areata which is felt to be causally linked to the radiation exposure.

**Iudice A, Bonanni E, Gelli A, Frittelli C, Iudice G, Cignoni F, Ghicopulos I, Murri L. Effects of prolonged wakefulness combined with alcohol and hands-free cell phone divided attention tasks on simulated driving. Hum Psychopharmacol.20(2):125-132, 2005.**

Simulated driving ability was assessed following administration of alcohol, at an estimated blood level of 0.05%, and combined prolonged wakefulness, while participants were undertaking divided attention tasks over a hands-free mobile phone. Divided attention tasks were structured to provide a sustained cognitive workload to the subjects. Twenty three young healthy individuals drove 10 km simulated driving under four conditions in a counterbalanced, within-subject design: alcohol, alcohol and 19 h wakefulness, alcohol and 24 h wakefulness, and while sober. Study measures were: simulated driving, self-reported sleepiness, critical flicker fusion threshold (CFFT), Stroop word-colour interference test (Stroop) and simple visual reaction times (SVRT). As expected, subjective sleepiness was highly correlated with both sleep restriction and alcohol consumption. The combination of alcohol and 24 h sustained wakefulness produced the highest driving impairment, significantly beyond the alcohol effect itself. Concurrent alcohol and 19 h wakefulness significantly affected only driving time-to-collision. No significant changes of study measures occurred following alcohol intake in unrestricted sleep conditions. CFFT, SVRT and Stroop results showed a similar trend in the four study conditions. Thus apparently 'safe' blood alcohol levels in combination with prolonged wakefulness resulted in significant driving impairments. In normal sleep conditions alcohol effects on driving were partially counteracted by the concomitant hands-free phone based psychometric tasks.

**Ivanova Vlu, Martynova OV, Aleinik SV, Limarenko AV. [Effect of modified SHF and acoustic stimulation on spectral characteristics of the electroencephalograms of the cat brain] Biofizika. 45(5):935-940, 2000.** [Article in Russian]

The effect of modulated electromagnetic fields on the spectral parameters of bioelectric brain activity in awake cats was studied by registering the electroencephalogram from the skin surface in the vertex area using carbon electrodes. In the normal electroencephalogram, spectral components in the range above 20 Hz predominated. It was shown that, upon irradiation with electromagnetic field (basic frequency 980 MHz, power density 30-50 microW/cm2), spectral components in the range of 12-18 Hz begin to prevail. A similarity in the redistribution of the power of spectral components upon both acoustic and modulated electromagnetic influences was revealed. The results suggest that there is a a common neurophysiological mechanism by which modulated electromagnetic radiation and acoustic stimulation affect the electrical activity of the brain. This ia consistent with the assumption that the effect of the electromagnetic field on the central nervous system is mediated through the acoustic sensory system.

**Ivaschuk OI, Jones RA, Ishida-Jones T, Haggren W, Adey WR, Phillips JL, Exposure of nerve growth factor-treated PC12 rat pheochromocytoma cells to a modulated radiofrequency field at 836.55 MHz: effects on c-jun and c-fos expression. Bioelectromagnetics 18(3):223-229, 1997.**

Rat PC12 pheochromocytoma cells have been treated with nerve growth factor And then exposed to athermal levels of a packet-modulated radiofrequency field At 836.55 MHz. This signal was produced by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. Three slot average power densities were used: 0.09, 0.9, and 9 mW/cm2. Exposures were for 20, 40, and 60 min and included an intermittent exposure regimen (20 min on/20 min off), resulting in total incubation times of 20, 60, and 100 min, respectively. Concurrent controls were sham exposed. After extracting total cellular RNA, Northern blot analysis was used to assess the expression of the immediate early genes, c-fos and c-jun, in all cell populations. No change in c-fos transcript levels were detected after 20 min exposure at each field intensity (20 min was the only time period at which c-fos message could be detected consistently). Transcript levels for c-jun were altered only after 20 min exposure to 9 mW/cm2 (average 38% decrease).

**Janssen T, Boege P, von Mikusch-Buchberg J, Raczek J. Investigation of potential effects of cellular phones on human auditory function by means of distortion product otoacoustic emissions. J Acoust Soc Am. 117(3 Pt 1):1241-1247, 2005**.

Outer hair cells (OHC) are thought to act like piezoelectric transducers that amplify low sounds and hence enable the ear's exquisite sensitivity. Distortion product otoacoustic emissions (DPOAE) reflect OHC function. The present study investigated potential effects of electromagnetic fields (EMF) of GSM (Global System for Mobile Communication) cellular phones on OHCs by means of DPOAEs. DPOAE measurements were performed during exposure, i.e., between consecutive GSM signal pulses, and during sham exposure (no EMF) in 28 normally hearing subjects at tone frequencies around 4 kHz. For a reliable DPOAE measurement, a 900-MHz GSM-like signal was used where transmission pause was increased from 4.034 ms (GSM standard) to 24.204 ms. Peak transmitter power was set to 20 W, corresponding to a specific absorption rate (SAR) of 0.1 W/kg. No significant change in the DPOAE level in response to the EMF exposure was found. However, when undesired side effects on DPOAEs were compensated, in

some subjects an extremely small EMF-exposure-correlated change in the DPOAE level (< 1 dB) was observed. In view of the very large dynamic range of hearing in humans (120 dB), it is suggested that this observation is physiologically irrelevant.

**Jarupat S, Kawabata A, Tokura H, Borkiewicz A. Effects of the 1900 MHz electromagnetic field emitted from cellular phone on nocturnal melatonin secretion. J Physiol Anthropol Appl Human Sci 22(1):61-63, 2003.**

Exposure to cellular phone EMF caused a significant reduction in salivary melatonin in female human subjects.

**Jauchem, JR, Exposure to extremely-low-frequency electromagnetic fields and radiofrequency radiation: cardiovascular effects in humans. Int Arch Occup Environ Health 70(1):9-21, 1997.**

Cardiovascular changes in humans exposed to nonionizing radiation [including extremely-low-frequency electromagnetic fields (ELF EMFs) and radiofrequency radiation (RFR)] are reviewed. Both acute and long-term effects have been investigated. In general, if heating does not occur during exposure, current flow appears to be necessary for major cardiovascular effects to ensue, such as those due to electric shock. Whereas most studies have revealed no acute effect of static or time-varying ELF EMFs on the blood pressure, heart rate, or electrocardiogram waveform, others have reported subtle effects on the heart rate. The possible health consequences of these results are unknown. Regarding long-term effects of ELF EMFs, reports from the former Soviet Union in the early 1960s indicated arrhythmias and tachycardia in high-voltage-switchyard workers. Subsequent studies in Western countries, however, did not confirm these findings. These studies are limited by uncertainties regarding exposure durations and appropriate control groups. Investigations of acute cardiovascular changes in humans purposely exposed to RFR have been limited to studies of magnetic resonance imaging (which, in addition to RFR, involves static and time-varying magnetic fields). It has been concluded that such exposures, as presently performed, are not likely to cause adverse cardiovascular effects. Reports of hypertension in workers potentially exposed to high levels of RFR during accidents are considered to be incidental (due to anxiety and posttraumatic stress). Soviet investigators have also indicated that long-term RFR exposure may result in hypotension and bradycardia or tachycardia. Otherresearchers, however, have been incapable of replicating these results, and some scientists have attributed the effects to chance variations and mishandling of data. In summary, studies have not yielded any obvious cardiovascular-related hazards of acute or long-term exposures to ELF EMFs or RFR at levels below current exposure standards.

**Jauchem JR, Seaman RL, Lehnert HM, Mathur SP, Ryan KL, Frei MR, Hurt WD. Ultra-wideband electromagnetic pulses: lack of effects on heart rate and blood pressure during two-minute exposures of rats. Bioelectromagnetics 19(5):330-333, 1998.**

Exposure to fast-rise-time ultra-wideband (UWB) electromagnetic pulses has been postulated to result in effects on biological tissue (including the cardiovascular system). In the current study, 10 anesthetized Sprague-Dawley rats were exposed to pulses produced by a Sandia UWB pulse generator (average values of exposures over three

different pulse repetition rates: rise time, 174-218 ps; peak E field, 87-104 kV/m; pulse duration, 0.97-0.99 ns). Exposures to 50, 500 and 1000 pulses/s resulted in no significant changes in heart rate or mean arterial blood pressure measured every 30 s during 2 min of exposure and for 2 min after the exposure. The results suggest that acute UWB whole-body exposure under these conditions does not have an immediate detrimental effect on these cardiovascular system variables in anesthetized rats.

**Jauchem JR, Frei MR, Ryan KL, Merritt JH, Murphy MR, Lack of effects on heart rate and blood pressure in ketamine-anesthetized rats briefly exposed to ultra-wideband electromagnetic pulses. IEEE Trans Biomed Eng 46(1):117-120, 1999.**

Fourteen Sprague-Dawley rats were exposed to pulses produced by a Bournlea ultra-wideband (UWB) pulse generator (rise time, 318-337 ps; maximum E field, 19-21 kV/m). Exposures at a repetition frequency of 1 kHz for 0.5 s or to repetitive pulse trains (2-s exposure periods alternating with 2 s of no exposure, for a total of 2 min) resulted in no significant changes in heart rate or mean arterial blood pressure. These results suggest that acute whole-body exposure to UWB pulses does not have a detrimental effect on the cardiovascular system.

**Jauchem JR, Ryan KL, Freidagger MR, Cardiovascular and thermal effects of microwave irradiation at 1 and/or 10 GHz in anesthetized rats. Bioelectromagnetics 21(3):159-166, 2000.**

Relatively large thermal gradients may exist during exposure of an animal to microwaves (MWs), particularly at high frequencies. Differences in thermal gradients within the body may lead to noticeable differences in the magnitude of cardiovascular changes resulting from MW exposure. This study compares the thermal distribution and cardiovascular effects of exposure to a single MW frequency with effects of simultaneous exposure to two frequencies. Ketamine-anesthetized male Sprague-Dawley rats (n = 58) were exposed individually to one of three conditions: 1-GHz, 10-GHz, or combined 1- and 10-GHz MWs at an equivalent whole-body specific absorption rate of 12 W/kg. The continuous-wave irradiation was conducted under far-field conditions with animals in E orientation (left lateral exposure, long axis parallel to the electric field) or in H orientation (left lateral exposure, long axis perpendicular to the electric field). Irradiation was started when colonic temperature was 37.5 degrees C and was continued until lethal temperatures were attained. Colonic, tympanic, left and right subcutaneous, and tail temperatures, and arterial blood pressure, heart rate, and respiratory rate were continuously recorded. In both E and H orientations, survival time (i.e., time from colonic temperat ure of 37.5 degrees C until death) was lowest in animals exposed at 1-GHz, intermediate in those exposed at 1- and 10-GHz combined, and greatest in the 10-GHz group (most differences statistically significant). At all sites (with the exception of right subcutaneous), temperature values in the 1- and 10-GHz combined group were between those of the single-frequency exposure groups in both E and H orientations. During irradiation, arterial blood pressure initially increased and then decreased until death. Heart rate increased throughout the exposure period. The general, overall patterns of these changes were similar in all groups. The results indicate that no unusual physiological responses occur during multi-frequency MW exposure, when compared with results of single-frequency exposure.

**Jauchem JR, Frei MR, Dusch SJ, Lehnert HM, Kovatch RM, Repeated exposure of C3H/HeJ mice to ultra-wideband electromagnetic pulses: Lack of effects on mammary tumors. Radiat Res 155(2):369-377, 2001.**

Jauchem, J. R., Ryan, K. L., Frei, M. R., Dusch, S. J., Lehnert, H. M. and Kovatch, R. M. Repeated Exposure of C3H/HeJ Mice to Ultra-wideband Electromagnetic Pulses: Lack of Effects on Mammary Tumors. It has been suggested that chronic, low-level exposure to radiofrequency (RF) radiation may promote the formation of tumors. Previous studies, however, showed that low-level, long-term exposure of mammary tumor-prone mice to 435 MHz or 2450 MHz RF radiation did not affect the incidence of mammary tumors. In this study, we investigated the effects of exposure to a unique type of electromagnetic energy: pulses composed of an ultra-wideband (UWB) of frequencies, including those in the RF range. One hundred C3H/HeJ mice were exposed to UWB pulses (rise time 176 ps, fall time 3.5 ns, pulse width 1.9 ns, peak E-field 40 kV/m, repetition rate 1 kHz). Each animal was exposed for 2 min once a week for 12 weeks. One hundred mice were used as sham controls. There were no significant differences between groups with respect to incidence of palpated mammary tumors, latency to tumor onset, rate of tumor growth, or animal survival. Histopathological evaluations revealed no significant differences between the two groups in numbers of neoplasms in all tissues studied (lymphoreticular tissue, thymus, respiratory, digestive and urinary tracts, reproductive, mammary and endocrine systems, and skin). Our major finding was the lack of effects of UWB-pulse exposure on promotion of mammary tumors in a well-established animal model of mammary cancer.

**Jauchem JR. Effects of low-level radio-frequency (3kHz to 300GHz) energy on human cardiovascular, reproductive, immune, and other systems: A review of the recent literature. Int J Hyg Environ Health.211(1-2):1-29, 2008.**

OBJECTIVES: Occupational or residential exposures to radio-frequency energy (RFE), including microwaves, have been alleged to result in health problems. A review of recent epidemiological studies and studies of humans as subjects in laboratory investigations would be useful. METHODS: This paper is a narrative review of the recent medical and scientific literature (from mid-1998 through early 2006) dealing with possible effects of RFE on humans, relating to topics other than cancer, tumors, and central nervous system effects (areas covered in a previous review). Subject areas in this review include effects on cardiovascular, reproductive, and immune systems. RESULTS: A large number of studies were related to exposures from cellular telephones. Although both positive and negative findings were reported in some studies, in a majority of instances no significant health effects were found. Most studies had some methodological limitations. Although some cardiovascular effects due to RFE were reported in epidemiological studies (e.g., lower 24-h heart rate, blunted circadian rhythm of heart rate), there were no major effects on a large number of cardiovascular parameters in laboratory studies of volunteers during exposure to cell-phone RFE. In population-based studies of a wide range of RFE frequencies, findings were equivocal for effects on birth defects, fertility, neuroblastoma in offspring, and reproductive hormones. Some changes in immunoglobulin levels and in peripheral blood lymphocytes were reported in different studies of radar and radio/television-transmission workers. Due to variations in results and difficulties in comparing presumably exposed subjects with controls, however, it

is difficult to propose a unifying hypothesis of immune-system effects. Although subjective symptoms may be produced in some sensitive individuals exposed to RFE, there were no straightforward differences in such symptoms between exposed and control subjects in most epidemiological and laboratory studies. Consistent, strong associations were not found for RFE exposure and adverse health effects. The majority of changes relating to each of the diseases or conditions were small and not significant. CONCLUSIONS: On the basis of previous reviews of older literature and the current review of recent literature, there is only weak evidence for a relationship between RFE and any endpoint studied (related to the topics above), thus providing at present no sufficient foundation for establishing RFE as a health hazard.

**Jayanand, Behari J, Lochan R. Effects of low level pulsed radio frequency fields on induced osteoporosis in rat bone. Indian J Exp Biol. 41(6):581-586, 2003.**

Effect of modulated pulsed electromagnetic fields (PEMFs; carrier frequency, 14 MHz. modulated at 16 Hz of amplitude 10 V peak to peak) on sciatic neurectomy induced osteoporosis in rat femur and tibia resulted in statistically significant increase in bone mineral density, and deceleration in bone resorption process and consequently further osteoporosis in rat bone. These results suggest that such an effective window of pulsed radio frequency fields may be used therapeutically for the treatment of osteoporosis.

**Jech R, Sonka K, Ruzicka E, Nebuzelsky A, Bohm J, Juklickova M, Nevsimalova S. Electromagnetic field of mobile phones affects visual event related potential in patients with narcolepsy. Bioelectromagnetics 22(7):519-528, 2001.**

The effects of the mobile phone (MP) electromagnetic fields on electroencephalography (EEG) and event-related potentials (ERP) were examined. With regard to the reported effects of MP on sleep, 22 patients with narcolepsy-cataplexy were exposed or sham exposed for 45 min to the MP (900 MHz, specific absorption rate 0.06 W/kg) placed close to the right ear in a double blind study. There were no changes of the EEG recorded after the MP exposure. A subgroup of 17 patients was studied on visual ERP recorded during the MP exposure. Using an adapted "odd-ball" paradigm, each patient was instructed to strike a key whenever rare target stimuli were presented. There were three variants of target stimuli (horizontal stripes in (i) left, (ii) right hemifields or (iii) whole field of the screen). The exposure enhanced the positivity of the ERP endogenous complex solely in response to target stimuli in the right hemifield of the screen ($P < 0.01$). The reaction time was shortened by 20 ms in response to all target stimuli ($P < 0.05$). In conclusion, the electromagnetic field of MP may suppress the excessive sleepiness and improve performance while solving a monotonous cognitive task requiring sustained attention and vigilance.

**Jelodar G, Akbari A, Nazifi S. The prophylactic Effect of Vitamin C on Oxidative Stress Indexes in Rat Eyes Following Exposure to Radiofrequency Wave Generated by a BTS Antenna Model. Int J Radiat Biol. 89(2):128-131, 2013.**

Purpose: This study was conducted to evaluate the effect of radiofrequency wave (RFW)-induced oxidative stress in the eye and the prophylactic effect of vitamin C on this organ by measuring the antioxidant enzymes activity including: glutathione peroxidase (GPx), superoxide dismutase (SOD) and catalase (CAT), and malondialdehyde (MDA). Materials

and methods: Thirty-two adult male Sprague-Dawley rats were randomly divided into four experimental groups and treated daily for 45 days as follows: control, vitamin C (L-ascorbic acid 200 mg/kg of body weight/day by gavage), test (exposed to 900 MHz RFW) and the treated group (received vitamin C in addition to exposure to RFW). At the end of the experiment all animals were killed, their eyes were removed and were used for measurement of antioxidant enzymes and MDA activity. Results: The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($P<0.05$). In the treated group vitamin C improved antioxidant enzymes activity and reduced MDA compared to the test group ($P<0.05$). Conclusions: It can be concluded that RFW causes oxidative stress in the eyes and vitamin C improves the antioxidant enzymes activity and decreases MDA.

**Jelodar G, Nazifi S, Akbari A. The prophylactic effect of vitamin C on induced oxidative stress in rat testis following exposure to 900 MHz radio frequency wave generated by a BTS antenna model. Electromagn Biol Med. 2013 Jan 16. [Epub ahead of print]**

Radio frequency wave (RFW) generated by base transceiver station (BTS) has been reported to make deleterious effects on reproduction, possibly through oxidative stress. This study was conducted to evaluate the effect of RFW generated by BTS on oxidative stress in testis and the prophylactic effect of vitamin C by measuring the antioxidant enzymes activity, including glutathione peroxidase, superoxide dismutase (SOD) and catalase, and malondialdehyde (MDA). Thirty-two adult male Sprague-Dawley rats were randomly divided into four experimental groups and treated daily for 45 days as follows: sham, sham+vitamin C (l-ascorbic acid 200 mg/kg of body weight/day by gavage), RFW (exposed to 900 MHz RFW) 'sham' and 'RFW' animals were given the vehicle, i.e., distilled water and the RFW+vitamin C group (received vitamin C in addition to exposure to RFW). At the end of the experiment, all the rats were sacrificed and their testes were removed and used for measurement of antioxidant enzymes and MDA activity. The results indicate that exposure to RFW in the test group decreased antioxidant enzymes activity and increased MDA compared with the control groups ($p < 0.05$). In the treated group, vitamin C improved antioxidant enzymes activity and reduced MDA compared with the test group ($p < 0.05$). It can be concluded that RFW causes oxidative stress in testis and vitamin C improves the antioxidant enzymes activity and decreases MDA.

**Jenness JW, Lattanzio RJ, O'Toole M, Taylor N, Pax C. Effects of manual versus voice-activated dialing during simulated driving. Percept Mot Skills 94(2):363-379, 2002.**

We measured driving performance (lane-keeping errors, driving times, and glances away from the road scene) in a video driving simulator for 24 volunteers who each drove alone on a 10.6-km multicurved course while simultaneously placing calls on a mobile phone subscribed to a voice-activated dialing system. Driving performance also was measured for the same distance while participants manually dialed phone numbers and while they drove without dialing. There were 22% fewer lane-keeping errors ($p<.01$) and 56% fewer

glances away from the road scene (p<.01) when they used voice-activated dialing as compared to manual dialing. Significantly longer driving times in both of the dialing conditions as compared to the No Dialing condition are discussed in terms of the hypothesis that drivers decrease driving speed to compensate for the demands of the secondary phone tasks.

**Jensh RP, Behavioral teratologic studies using microwave radiation: is there an increased risk from exposure to cellular phones and microwave ovens? Reprod Toxicol 11(4):601-611, 1997.**

The objective of the investigations presented in this review was to determine if there are adverse effects due to chronic prenatal microwave exposure in rats at term and/or alterations in neonatal and adult offspring psychophysiologic development and growth. Following the establishment of a nonhyperthermal power density level of microwave radiation, pregnant rats were exposed throughout pregnancy to continuous wave 915 MHz, 2450 MHz, or 6000 MHz radiation at power density levels of 10, 20, or 35 mW/cm2, respectively. Teratologic evaluation included the following parameters: maternal weight and weight gain; mean litter size; maternal organ weight and organ weight/body weight ratios; body weight ratios of brain, liver, kidneys, and ovaries; maternal peripheral blood parameters including hematocrit, hemoglobin, and white cell counts; number of resorptions and resorption rate; number of abnormalities and abnormality rate; mean term fetal weight. Mothers were rebred, and the second, nonexposed litters were evaluated for teratogenic effects. Exposed offspring were evaluated using the following perinatal and adult tests: eye opening, surface righting, negative geotaxis, auditory startle, air righting, open field, activity wheel, swimming, and forelimb hanging. Offspring were also monitored for weekly weight and weight gain. Animals exposed to 915 MHz did not exhibit any consistent significant alterations in any of the above parameters. Exposure to 2450 MHz resulted only in a significantly increased adult offspring activity level compared to nonexposed offspring. Offspring exposed to 6000 MHz radiation exhibited an initial slight, but significant, retardation in term weight, while mothers had a significantly reduced monocyte count. No changes in any of the other term parameters were observed. A few postnatal parameters were affected in offspring exposed to 6000 MHz. Weekly weights were lower in the exposed offspring, but they recovered by the fifth week. Eye opening was delayed, and there were changes in the water T-maze and open field performance levels. Several organ/body weight ratios differed from those of the control offspring. These results indicate that exposure to 6000 MHz radiation at this power density level may result in subtle long-term neurophysiologic alterations. However, in the absence of a hyperthermic state, the microwave frequencies tested, which included frequencies used in cellular phones and microwave ovens, do not induce a consistent, significant increase in reproductive risk as assessed by classical morphologic and postnatal psychophysiologic parameters.

**Ji S, Oh E, Sul D, Choi JW, Park H, Lee E. DNA Damage of Lymphocytes in Volunteers after 4 hours Use of Mobile Phone. J Prev Med Public Health. 37(4):373-380, 2004.**

**OBJECTIVES:** There has been gradually increasing concern about the adverse health effects of electromagnetic radiation originating from cell phones which are widely used in modern life. Cell phone radiation may affect human health by increasing free radicals of human blood cells. This study has been designed to identify DNA damage of blood cells by electromagnetic radiation caused by cell phone use. **METHODS:** This study investigated the health effect of acute exposure to commercially available cell phones on certain parameters such as an indicator of DNA damage for 14 healthy adult volunteers. Each volunteer during the experiment talked over the cell phone with the keypad facing the right side of the face for 4 hours. The single cell gel electrophoresis assay (Comet assay), which is very sensitive in detecting the presence of DNA strand-breaks and alkali-labile damage in individual cells, was used to assess peripheral blood cells (T-cells, B-cells, granulocytes) from volunteers before and after exposure to cell phone radiation. The parameters of Comet assay measured were Olive Tail Moment and Tail DNA %. **RESULTS:** The Olive Tail Moment of B-cells and granulocytes and Tail DNA % of B-cells and granulocytes were increased by a statistically significant extent after 4- hour use of a cell phone compared with controls. **CONCLUSIONS:** It is concluded that cell phone radiation caused the DNA damage during the 4 hours of experimental condition. Nonetheless, this study suggested that cell phone use may increase DNA damage by electromagnetic radiation and other contributing factors.

**Ji Y, He Q, Sun Y, Tong J, Cao Y. Adaptive response in mouse bone-marrow stromal cells exposed to 900-MHz radiofrequency fields: Gamma-radiation-induced DNA strand breaks and repair. J Toxicol Environ Health A. 79(9-10):419-426, 2016.**

The aim of this study was to examine whether radiofrequency field (RF) preexposure induced adaptive responses (AR) in mouse bone-marrow stromal cells (BMSC) and the mechanisms underlying the observed findings. Cells were preexposed to 900-MHz radiofrequency fields (RF) at 120 μW/cm(2) power intensity for 4 h/d for 5 d. Some cells were subjected to 1.5 Gy γ-radiation (GR) 4 h following the last RF exposure. The intensity of strand breaks in the DNA was assessed immediately at 4 h. Subsequently, some BMSC were examined at 30, 60, 90, or 120 min utilizing the alkaline comet assay and γ-H2AX foci technique. Data showed no significant differences in number and intensity of strand breaks in DNA between RF-exposed and control cells. A significant increase in number and intensity of DNA strand breaks was noted in cells exposed to GR exposure alone. RF followed by GR exposure significantly decreased number of strand breaks and resulted in faster kinetics of repair of DNA strand breaks compared to GR alone. Thus, data suggest that RF preexposure protected cells from damage induced by GR. Evidence indicates that in RF-mediated AR more rapid repair kinetics occurs under conditions of GR-induced damage, which may be attributed to diminished DNA strand breakage.

**Jia F, Ushiyama A, Masuda H, Lawlor GF, Ohkubo C. Role of blood flow on RF exposure induced skin temperature elevations in rabbit ears. Bioelectromagnetics.28(3):163-172,2007.**

In this in vivo study, we measured local temperature changes in rabbit pinnae, which were evoked by radiofrequency (RF) exposure for 20 min at localized SAR levels of 0 (sham exposure), 2.3, 10.0, and 34.3 W/kg over 1.0 g rabbit ear tissue. The effects of RF exposures on skin temperature were measured under normal blood flow and without blood flow in the ear. The results showed: (1) physiological blood flow clearly modified RF induced thermal elevation in the pinna as blood flow significantly suppressed temperature increases even at 34.3 W/kg; (2) under normal blood flow conditions, exposures at 2.3 and 10.0 W/kg, approximating existing safety limits for the general public (2 W/kg) and occupational exposure (10 W/kg), did not induce significant temperature rises in the rabbit ear. However, 2.3 W/kg induced local skin temperature elevation under no blood flow conditions. Our results demonstrate that the physiological effects of blood flow should be considered when extrapolating modeling data to living animals, and particular caution is needed when interpreting the results of modeling studies that do not include blood flow.

**Jiang B, Nie J, Zhou Z, Zhang J, Tong J, Cao Y. Adaptive response in mice exposed to 900 MHz radiofrequency fields: primary DNA damage. PLoS One. 7(2):e32040, 2012.**

The phenomenon of adaptive response (AR) in animal and human cells exposed to ionizing radiation is well documented in scientific literature. We have examined whether such AR could be induced in mice exposed to non-ionizing radiofrequency fields (RF) used for wireless communications. Mice were pre-exposed to 900 MHz RF at 120 μW/cm(2) power density for 4 hours/day for 1, 3, 5, 7 and 14 days and then subjected to an acute dose of 3 Gy γ-radiation. The primary DNA damage in the form of alkali labile base damage and single strand breaks in the DNA of peripheral blood leukocytes was determined using the alkaline comet assay. The results indicated that the extent of damage in mice which were pre-exposed to RF for 1 day and then subjected to γ-radiation was similar and not significantly different from those exposed to γ-radiation alone. However, mice which were pre-exposed to RF for 3, 5, 7 and 14 days showed progressively decreased damage and was significantly different from those exposed to γ-radiation alone. Thus, the data indicated that RF pre-exposure is capable of inducing AR and suggested that the pre-exposure for more than 4 hours for 1 day is necessary to elicit such AR.

**Jiang B, Zong C, Zhao H, Ji Y, Tong J, Cao Y Induction of adaptive response in mice exposed to 900 MHz radiofrequency fields: Application of micronucleus assay Mutat Res 751(2): 127-129, 2013.**

Adult male ICR mice were pre-exposed to non-ionizing radiofrequency fields (RF), 900 MHz at 120 μW/cm$^2$ power density for 4 h/day for 7 days (adaptation dose, AD) and then subjected to an acute whole body dose of 3 Gy γ-radiation (challenge dose, CD). The classical micronucleus (MN) assay was used to determine the extent of genotoxicity in immature erythrocytes in peripheral blood and bone marrow. The data obtained in mice exposed to AD + CD were compared with those exposed to CD alone. The results indicated that in both tissues, the MN indices were similar in un-exposed controls and those exposed to AD alone while a significantly increased MN

frequency was observed in mice exposed to CD alone. Exposure of mice to AD + CD resulted in a significant decrease in MN indices compared to those exposed to CD alone. Thus, the data suggested that pre-exposure of mice to non-ionizing RF is capable of ‘protecting’ the erythrocytes in the blood and bone marrow from genotoxic effects of subsequent γ-radiation. Such protective phenomenon is generally described as ‘adaptive response’ (AR) and is well documented in human and animal cells which were pre-exposed to very low doses of ionizing radiation. It is interesting to observe AR being induced by non-ionizing RF.

**Jimenez A, Hernandez Madrid A, Pascual J, Gonzalez Rebollo JM, Fernandez E, Sanchez A, Ortega J, Lozano F, Munoz R, Moro C, [Electromagnetic interference between automatic defibrillators and digital and analog cellular telephones]. Rev Esp Cardiol 51(5):375-382, 1998.** [Article in Spanish]

BACKGROUND AND OBJECTIVES: Functional pacemaker interference by mobile telephones has been described with analogical systems and with possible greater influence, digital systems, including inhibition and inadequate pacing. The influence of both system has not been extensively studied in patients with implantable cardioverter defibrillators (ICD). PATIENTS AND METHODS: We studied the influence of mobile phones, both digital and analogic network, on the performance of several models of defibrillators, in a standardised test set up designed to provide high sensitivity. The purpose of our study was to establish whether there are any influences on ICD functions, both in in vivo and in in vitro models. Several mobile phones, with different transmission powers, were moved towards the defibrillator and the electrode, under continuous documentation of defibrillator sensing and interrogation afterwards. The experimental model was performed with the aid of an arrhythmia simulator (Intersim) and demo-defibrillators. The tests were repeated both in and out of a solution of saline water with an impedance within normal human limits. RESULTS: Partial loss of telemetry was found in 14 patients, 8 with analogical phones and 6 with digital phones. Fourteen patients showed alterations only on the surface electrocardiogram channel and five on the intracavitary channel. The same results were reproduced in the in vitro model. However, the in vitro test allowed us to simulate multiple ventricular arrhythmias, and demonstrate the normal sensing and functioning of the defibrillator during a "spontaneous" arrhythmia. After testing, we demonstrate that no real oversensing/undersensing was documented in any device. There was no evidence of ICD reprogramming or pacing inhibition. In particular, no inadequate therapies were delivered. CONCLUSIONS: a) in our series, we have not demonstrated clinically significant electromagnetic interferences with mobile phones of digital or analogical networks: b) the in vitro model allowed us to conclude that even if a spontaneous arrhythmia appears, the function of the defibrillator is not altered; c) the use of mobile phones seems to be safe for defibrillator patients, and d) however, some basic rules, such as to maintain the phone at least 15 cm away from the defibrillator, are advised.

**Jin YB, Lee HJ, Seon Lee J, Pack JK, Kim N, Lee YS. One-year, simultaneous combined exposure of CDMA and WCDMA radiofrequency electromagnetic fields to rats.Int J Radiat Biol. 87(4):416-423, 2011.**

**PURPOSE:** We investigated whether one-year, long-term, simultaneous exposure to code division multiple access (CDMA; 849 MHz) and wideband code division multiple access (WCDMA; 1.95 GHz) radiofrequencies (RF) would induce chronic illness in Sprague-Dawley (SD) rats. **MATERIALS AND METHODS:** Two groups of 40 SD rats (50% males and females in sham and exposed groups) were exposed to CDMA and WCDMA RF simultaneously at 2.0 W/kg for 45 min/day (total 4.0 W/kg), 5 days per week for a total of one year. Body and organ weight measurements, urinalysis, haematological and blood biochemical analysis, and histopathological evaluations were performed. **RESULTS:** The mortality patterns in male and female rats exposed to RF were compared with those found in gender-matched sham control animals. No significant alteration in body weight was observed with the simultaneous combined RF exposure. Most RF-exposed rats showed no significant alteration, based on urinalysis, haematology, blood biochemistry, or histopathology. However, some altered parameters of the complete blood count and serum chemistry were seen in RF-exposed rats. The total tumour incidence was not different between sham-exposed and RF-exposed animals. **CONCLUSIONS:** Our results suggest that one-year chronic exposure to CDMA (849 MHz) and WCDMA (1.95 GHz) RF simultaneously at 2.0 W/kg for 45-min RF exposure periods (total, 4 W/kg) did not increase chronic illness in rats, although there were some altered parameters in the complete blood count and serum chemistry.

**Jin Z, Zong C, Jiang B, Zhou Z, Tong J, Cao Y.The Effect of Combined Exposure of 900MHz Radiofrequency Fields and Doxorubicin in HL-60 Cells. PLoS One.7(9):e46102, 2012.**

Human promyelocytic leukemia HL-60 cells were pre-exposed to non-ionizing 900MHz radiofrequency fields (RF) at 12 μW/cm(2) power density for 1 hour/day for 3 days and then treated with a chemotherapeutic drug, doxorubicin (DOX, 0.125 mg/L). Several end-points related to toxicity, viz., viability, apoptosis, mitochondrial membrane potential (MMP), intracellular free calcium (Ca(2+)) and Ca(2+)-Mg(2+) -ATPase activity were measured. The results obtained in un-exposed and sham-exposed control cells were compared with those exposed to RF alone, DOX alone and RF+DOX. The results indicated no significant differences between un-exposed, sham-exposed control cells and those exposed to RF alone while treatment with DOX alone showed a significant decrease in viability, increased apoptosis, decreased MMP, increased Ca(2+) and decreased Ca(2+)-Mg(2+-)ATPase activity. When the latter results were compared with cells exposed RF+DOX, the data showed increased cell proliferation, decreased apoptosis, increased MMP, decreased Ca(2+) and increased Ca(2+)-Mg(2+)-ATPase activity. Thus, RF pre-exposure appear to protect the HL-60 cells from the toxic effects of subsequent treatment with DOX. These observations were similar to our earlier data which suggested that pre-exposure of mice to 900MHz RF at 120 μW/cm(2) power density for 1 hours/day for 14 days had a protective effect in hematopoietic tissue damage induced by subsequent gamma-irradiation.

**Jing J, Yuhua Z, Xiao-qian Y, Rongping J, Dong-mei G, Xi C. The influence of microwave radiation from cellular phone on fetal rat brain. Electromagn Biol Med.**

**31(1):57-66, 2012.**

The increasing use of cellular phones in our society has brought focus on the potential detrimental effects to human health by microwave radiation. The aim of our study was to evaluate the intensity of oxidative stress and the level of neurotransmitters in the brains of fetal rats chronically exposed to cellular phones. The experiment was performed on pregnant rats exposed to different intensities of microwave radiation from cellular phones. Thirty-two pregnant rats were randomly divided into four groups: CG, GL, GM, and GH. CG accepted no microwave radiation, GL group radiated 10 min each time, GM group radiated 30 min, and GH group radiated 60 min. The 3 experimental groups were radiated 3 times a day from the first pregnant day for consecutively 20 days, and on the 21st day, the fetal rats were taken and then the contents of superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), noradrenaline (NE), dopamine (DA), and 5-hydroxyindole acetic acid (5-HT) in the brain were assayed. Compared with CG, there were significant differences ($P<0.05$) found in the contents of SOD, GSH-Px, and MDA in GM and GH; the contents of SOD and GSH-Px decreased and the content of MDA increased. The significant content differences of NE and DA were found in fetal rat brains in GL and GH groups, with the GL group increased and the GH group decreased. Through this study, we concluded that receiving a certain period of microwave radiation from cellular phones during pregnancy has certain harm on fetal rat brains.

**Johansen C, Boice JD, McLaughlin JK, Olsen JH, Cellular Telephones and Cancer-a Nationwide Cohort Study in Denmark. J Natl Cancer Inst 93(3):203-207, 2001.**

BACKGROUND: Use of cellular telephones is increasing exponentially and has become part of everyday life. Concerns about possible carcinogenic effects of radiofrequency signals have been raised, although they are based on limited scientific evidence. METHODS: A retrospective cohort study of cancer incidence was conducted in Denmark of all users of cellular telephones during the period from 1982 through 1995. Subscriber lists from the two Danish operating companies identified 420 095 cellular telephone users. Cancer incidence was determined by linkage with the Danish Cancer Registry. All statistical tests are two-sided. RESULTS: Overall, 3391 cancers were observed with 3825 expected, yielding a significantly decreased standardized incidence ratio (SIR) of 0.89 (95% confidence interval [CI] = 0.86 to 0.92). A substantial proportion of this decreased risk was attributed to deficits of lung cancer and other smoking-related cancers. No excesses were observed for cancers of the brain or nervous system (SIR = 0.95; 95% CI = 0.81 to 1.12) or of the salivary gland (SIR = 0.72; 95% CI = 0.29 to 1.49) or for leukemia (SIR = 0.97; 95% CI = 0.78-1.21), cancers of a priori interest. Risk for these cancers also did not vary by duration of cellular telephone use, time since first subscription, age at first subscription, or type of cellular telephone (analogue or digital). Analysis of brain and nervous system tumors showed no statistically significant SIRs for any subtype or anatomic location. CONCLUSIONS: The results of this investigation, the first nationwide cancer incidence study of cellular phone users, do not support the hypothesis of an association between use of these telephones and tumors of the brain or salivary gland, leukemia, or other cancers.

**Johansen C, Boice JD Jr, McLaughlin JK, Christensen HC, Olsen JH. Mobile phones and malignant melanoma of the eye. Brit J Cancer 86:348-349, 2002.**

Recently a four-fold increase in the risk of malignant melanoma of the eye was associated with the use of radiofrequency transmitting devices, including mobile phones in Germany. We contrasted the incidence rates of this rare cancer with the number of mobile phone subscribers in Denmark. We observed no increasing trend in the incidence rate of melanoma, which was in sharp contrast to the exponentially increasing number of mobile phone subscribers starting in the early 1980s. Our study provides no support for an association between mobile phones and ocular melanoma.

**Johansson A, Forsgren S, Stenberg B, Wilén J, Kalezic N, Sandström M. No effect of mobile phone-like RF exposure on patients with atopic dermatitis.Bioelectromagnetics. 29(5):353-362, 2008.**

This study investigates the effect of exposure to a mobile phone-like radiofrequency (RF) electromagnetic field on people with atopic dermatitis (AD). Fifteen subjects with AD were recruited and matched with 15 controls without AD. The subjects were exposed for 30 min to an RF field at 1 W/kg via an indoor base station antenna attached to a 900 MHz GSM mobile phone. Blood samples for ELISA analysis of the concentration of substance P (SP), tumor necrosis factor receptor 1 (TNF R1), and brain derived neurotrophic factor (BDNF) in serum were drawn before and after the provocation (exposure/sham). Baseline heart rate and heart rate variability, local blood flow, and electrodermal activity were also recorded. No significant differences between the subject groups were found for baseline neurophysiological data. The cases displayed a serum concentration of TNF R1 significantly higher than the control subjects and a significantly lower serum concentration of BDNF in the baseline condition. For SP there was no difference between groups. However, no effects related to RF exposure condition were encountered for any of the measured substances. As to symptoms, a possible correlation with exposure could not be evaluated, due to too few symptom reports. The result of the study does not support the hypothesis of an effect of mobile phone-like RF exposure on serum levels of SP, TNF R1, and BDNF in persons with AD.

**Johansson A, Nordin S, Heiden M, Sandström M. Symptoms, personality traits, and stress in people with mobile phone-related symptoms and electromagnetic hypersensitivity. J Psychosom Res. 68(1):37-45, 2010.**

OBJECTIVE: Some people report symptoms that they associate with electromagnetic field (EMF) exposure. These symptoms may be related to specific EMF sources or to electrical equipment in general (perceived electromagnetic hypersensitivity, EHS). Research and clinical observations suggest a difference between mobile phone (MP)-related symptoms and EHS with respect to symptom prevalence, psychological factors, and health prognosis. This study assessed prevalence of EMF-related and EMF-nonrelated symptoms, anxiety, depression, somatization, exhaustion, and stress in people with MP-related symptoms or EHS versus a population-based sample and a control sample without EMF-related symptoms. METHODS: Forty-five participants with MP-related symptoms and 71 with EHS were compared with a

population-based sample (n=106) and a control group (n=63) using self-report questionnaires. RESULTS: The EHS group reported more symptoms than the MP group, both EMF-related and EMF-nonrelated. The MP group reported a high prevalence of somatosensory symptoms, whereas the EHS group reported more neurasthenic symptoms. As to self-reported personality traits and stress, the case groups differed only on somatization and listlessness in a direct comparison. In comparison with the reference groups, the MP group showed increased levels of exhaustion and depression but not of anxiety, somatization, and stress; the EHS group showed increased levels for all of the conditions except for stress. CONCLUSION: The findings support the idea of a difference between people with symptoms related to specific EMF sources and people with general EHS with respect to symptoms and anxiety, depression, somatization, exhaustion, and stress. The differences are likely to be important in the management of patients.

**Johnson EH, Chima SC, Muirhead DE, A cerebral primitive neuroectodermal tumor in a squirrel monkey (Saimiri sciureus). J Med Primatol 28(2):91-96, 1999.**

An adult squirrel monkey with a history of long-term exposure to microwave radiation was found at necropsy to have a malignant tumor of the right cerebral cortex. Gross examination revealed a mass with expanding borders in the right frontoparietal cortex with compression of the adjacent lateral ventricle. Microscopy revealed a tumor composed of sheets of moderate-sized cells, resembling an oligodendroglioma, with clear cytoplasm and central nuclei interrupted by delicate vasculature. Malignant features were present in the form of marked nuclear pleomorphism, frequent mitotic figures, and focal necrosis. A neuronal cell origin for this tumor was supported by immunohistochemical analysis, which revealed immunopositivity for neurofilament proteins and neuron-specific enolase. Staining for vimentin and glial fibrillary acid protein was negative, except in reactive astrocytes at the tumor margins and adjacent to intra-tumoral blood vessels. Antibody activity against Ki-67 antigen, a marker of rapidly proliferating tumor cells, and p53 oncoprotein was strongly positive, indicative of the aggressive and malignant nature of this tumor. The tumor was diagnosed as a cerebral primitive neuroectodermal tumor.

**Johnson Liakouris AG, Radiofrequency (RF) sickness in the Lilienfeld Study: an effect of modulated microwaves? Arch Environ Health 53(3):236-238, 1998.**

There is a controversy among professionals regarding whether radiofrequency radiation sickness syndrome is a medical entity. In this study, this controversy was evaluated with a methodology adapted from case studies. The author reviewed U.S. literature, which revealed that research results are sufficiently consistent to warrant further inquiry. A review of statistically significant health effects noted in the Lilienfeld Study provided evidence that the disregarded health conditions match the cluster attributed to the radiofrequency sickness syndrome, thus establishing a possible correlation between health effects and chronic exposure to low-intensity, modulated microwave radiation. The author discusses these health effects relative to (a) exposure parameters recorded at the U.S. Embassy in Moscow and (b) the Soviet 10-microwatt safety standard for the public. Given the evidence, new research-with current knowledge and technology-is proposed.

**Jokela K, Puranen L, Sihvonen AP. Assessment of the magnetic field exposure due to the battery current of digital mobile phones. Health Phys. 86(1):56-66, 2004.**

Hand-held digital mobile phones generate pulsed magnetic fields associated with the battery current. The peak value and the waveform of the battery current were measured for seven different models of digital mobile phones, and the results were applied to compute approximately the magnetic flux density and induced currents in the phone-user's head. A simple circular loop model was used for the magnetic field source and a homogeneous sphere consisting of average brain tissue equivalent material simulated the head. The broadband magnetic flux density and the maximal induced current density were compared with the guidelines of ICNIRP using two various approaches. In the first approach the relative exposure was determined separately at each frequency and the exposure ratios were summed to obtain the total exposure (multiple-frequency rule). In the second approach the waveform was weighted in the time domain with a simple low-pass RC filter and the peak value was divided by a peak limit, both derived from the guidelines (weighted peak approach). With the maximum transmitting power (2 W) the measured peak current varied from 1 to 2.7 A. The ICNIRP exposure ratio based on the current density varied from 0.04 to 0.14 for the weighted peak approach and from 0.08 to 0.27 for the multiple-frequency rule. The latter values are considerably greater than the corresponding exposure ratios 0.005 (min) to 0.013 (max) obtained by applying the evaluation based on frequency components presented by the new IEEE standard. Hence, the exposure does not seem to exceed the guidelines. The computed peak magnetic flux density exceeded substantially the derived peak reference level of ICNIRP, but it should be noted that in a near-field exposure the external field strengths are not valid indicators of exposure. Currently, no biological data exist to give a reason for concern about the health effects of magnetic field pulses from mobile phones.

**Jones RP, Conway DH. The effect of electromagnetic interference from mobile communication on the performance of intensive care ventilators. Eur J Anaesthesiol. 22(8):578-583, 2005.**

Electromagnetic interference produced by wireless communication can affect medical devices and hospital policies exist to address this risk. During the transfer of ventilated patients, these policies may be compromised by essential communication between base and receiving hospitals. Local wireless networks (e.g. Bluetooth) may reduce the 'spaghetti syndrome' of wires and cables seen on intensive care units, but also generate electromagnetic interference. The aim of this study was to investigate these effects on displayed and actual ventilator performance. METHODS: Five ventilators were tested: Drager Oxylog 2000, BREAS LTV-1000, Respironics BiPAP VISION, Puritan Bennett 7200 and 840. Electromagnetic interference was generated by three devices: Simoco 8020 radio handset, Nokia 7210 and Nokia 6230 mobile phone, Nokia 6230 communicating via Bluetooth with a Palm Tungsten T Personal Digital Assistant. We followed the American National Standard Recommended Practice for On-Site, Ad Hoc Testing (ANSI C63) for electromagnetic interference. We used a ventilator tester, to simulate healthy adult lungs and measure ventilator performance. The communication device under test was moved in towards each ventilator from a distance of 1 m in six axes. Alarms or error codes on the ventilator were recorded, as was ventilator performance. RESULTS: All ventilators tested, except for the Respironics VISION, showed a display error when subjected to electromagnetic interference from the Nokia phones and Simoco radio. Ventilator performance was only affected by the radio which

caused the Puritan Bennett 840 to stop functioning completely. The transfer ventilators' performance were not affected by radio or mobile phone, although the mobile phone did trigger a low-power alarm. Effects on intensive care ventilators included display reset, with the ventilator restoring normal display function within 2 s, and low-power/low-pressure alarms. Bluetooth transmission had no effect on the function of all the ventilators tested. CONCLUSION: In a clinical setting, high-power-output devices such as a two-way radio may cause significant interference in ventilator function. Medium-power-output devices such as mobile phones may cause minor alarm triggers. Low-power-output devices such as Bluetooth appear to cause no interference with ventilator function.

**Jorge-Mora T, Folgueiras MA, Leiro-Vidal JM, Jorge-Barreiro FJ, Ares-Pena FJ, López-Martin E.** Exposure to 2.45 GHz Microwave Radiation Provokes Cerebral Changes in Induction of Hsp-90 α/β Heat Shock Protein in Rat. **Prog Electromagn Res, 100:351-379, 2010.**

Physical agents such as non-ionizing continuous-wave 2.45 GHz radiation may cause damage that alters cellular homeostasis and may trigger activation of the genes that encode heat shock proteins (HSP). We used Enzyme-Linked ImmunoSorbent Assay (ELISA) and immunohistochemistry to analyze the changes in levels of HSP-90 and its distribution in the brain of Sprague-Dawley rats, ninety minutes and twenty-four hours after acute (30min) continuous exposure to 2.45 GHz radiation in a the Gigahertz Transverse Electromagnetic (GTEM cell). In addition, we studied further indicators of neuronal insult: dark neurons, chromatin condensation and nucleus fragmentation, which were observed under optical conventional or fluorescence microscopy after DAPI staining. The cellular distribution of protein HSP-90 in the brain increased with each corresponding SAR ($0.034 \pm 3.10^{-3}$, $0.069 \pm 5.10^{-3}$, $0.27 \pm 21.10^{-3}$ W/kg), in hypothalamic nuclei, limbic cortex and somatosensorial cortex after exposure to the radiation. At twenty-four hours post-irradiation, levels of HSP-90 protein remained high in all hypothalamic nuclei for all SARs, and in the parietal cortex, except the limbic system, HSP-90 levels were lower than in non-irradiated rats, almost half the levels in rats exposed to the highest power radiation. Non-apoptotic cellular nuclei and a some dark neurons were found ninety minutes and twenty-four hours after maximal SAR exposure. The results suggest that acute exposure to electromagnetic fields triggered an imbalance in anatomical HSP- 90 levels but the anti-apoptotic mechanism is probably sufficient to compensate the non-ionizing stimulus. Further studies are required to determine the regional effects of chronic electromagnetic pollution on heat shock proteins and their involvement in neurological processes and neuronal damage.

**Jorge-Mora T, Misa-Agustiño MJ, Rodríguez-González JA, Jorge-Barreiro FJ, Ares-Pena FJ, López-Martín E. The effects of single and repeated exposure to 2.45 GHz radiofrequency fields on c-Fos protein expression in the paraventricular nucleus of rat hypothalamus. Neurochem Res. 36(12):2322-2332, 2011.**

This study investigated the effects of microwave radiation on the PVN of the hypothalamus, extracted from rat brains. Expression of c-Fos was used to study the pattern of cellular activation in rats exposed once or repeatedly (ten times in 2 weeks) to 2.45 GHz radiation in a GTEM cell. The power intensities used were 3 and 12 W and the

Finite Difference Time Domain calculation was used to determine the specific absorption rate (SAR). High SAR triggered an increase of the c-Fos marker 90 min or 24 h after radiation, and low SAR resulted in c-Fos counts higher than in control rats after 24 h. Repeated irradiation at 3 W increased cellular activation of PVN by more than 100% compared to animals subjected to acute irradiation and to repeated non-radiated repeated session control animals. The results suggest that PVN is sensitive to 2.45 GHz microwave radiation at non-thermal SAR levels.

**Joseph W, Vermeeren G, Verloock L, Heredia MM, Martens LCharacterization of personal RF electromagnetic field exposure and actual absorption for the general public.Health Phys. 95(3):317-330, 2008.**

In this paper, personal electromagnetic field exposure of the general public due to 12 different radiofrequency sources is characterized. Twenty-eight different realistic exposure scenarios based upon time, environment, activity, and location have been defined and a relevant number of measurements were performed with a personal exposure meter. Indoor exposure in office environments can be higher than outdoor exposure: 95th percentiles of field values due to WiFi ranged from 0.36 to 0.58 V m(-1), and for DECT values of 0.33 V m(-1) were measured. The downlink signals of GSM and DCS caused the highest outdoor exposures up to 0.52 V m(-1). The highest total field exposure occurred for mobile scenarios (inside a train or bus) from uplink signals of GSM and DCS (e.g., mobile phones) due to changing environmental conditions, handovers, and higher required transmitted signals from mobile phones due to penetration through windows while moving. A method to relate the exposure to the actual whole-body absorption in the human body is proposed. An application is shown where the actual absorption in a human body model due to a GSM downlink signal is determined. Fiftieth, 95th, and 99 th percentiles of the whole-body specific absorption rate (SAR) due to this GSM signal of 0.58 microW kg(-1), 2.08 microW kg(-1), and 5.01 microW kg(-1) are obtained for a 95th percentile of 0.26 V m(-1). A practical usable function is proposed for the relation between the whole-body SAR and the electric fields. The methodology of this paper enables epidemiological studies to make an analysis in combination with both electric field and actual whole-body SAR values and to compare exposure with basic restrictions.

**Joseph W, Verloock L, Tanghe E, Martens L. In-situ measurement procedures for temporal RF electromagnetic field exposure of the general public.Health Phys. 96(5):529-542, 2009.**

In this paper, the general public's exposure to FM, GSM, and UMTS over 7 day's time is investigated. The purpose of this paper is to investigate how short-period measurements can be representative for the actual maximal and average exposure during longer periods such as 1 week. Locations of public RF exposure have been categorized according to the type of environment, population density, and the amount of mobile phone traffic. Five different sites have been selected to perform measurements of the electric fields over time. In total 352,800 time samples of the electric field were obtained from the measurement campaign. A factor X is defined as the ratio between the actual maximal

value of the temporal measurements and the estimated maximal value from short-period data. Three different methods to assess X are compared and an optimal method is proposed for an in-situ measurement procedure. Median values of X according to the proposed method are 1.05, 0.47, and 0.96, for FM, GSM, and UMTS, respectively. Moreover a factor R is defined as the ratio between the median and maximal value of the momentary temporal field measurements, indicating the level of variation of a certain signal over time. R enables to calculate maximal values from median values and vice versa. Median values of R are 0.92, 0.66, and 0.71 for FM, GSM, and UMTS, respectively. By combining X and R one can estimate the actual maximal and median exposure during longer periods from short-period measurements

**Joseph W, Frei P, Roösli M, Thuróczy G, Gajsek P, Trcek T, Bolte J, Vermeeren G, Mohler E, Juhász P, Finta V, Martens L. Comparison of personal radio frequency electromagnetic field exposure in different urban areas across Europe. Environ Res.110(7):658-663,2010.**

BACKGROUND: Only limited data are available on personal radio frequency electromagnetic field (RF-EMF) exposure in everyday life. Several European countries performed measurement studies in this area of research. However, a comparison between countries regarding typical exposure levels is lacking. OBJECTIVES: To compare for the first time mean exposure levels and contributions of different sources in specific environments between different European countries. METHODS: In five countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands), measurement studies were performed using the same personal exposure meters. The pooled data were analyzed using the robust regression on order statistics (ROS) method in order to allow for data below the detection limit. Mean exposure levels were compared between different microenvironments such as homes, public transports, or outdoor. RESULTS: Exposure levels were of the same order of magnitude in all countries and well below the international exposure limits. In all countries except for the Netherlands, the highest total exposure was measured in transport vehicles (trains, car, and busses), mainly due to radiation from mobile phone handsets (up to 97%). Exposure levels were in general lower in private houses or flats than in offices and outdoors. At home, contributions from various sources were quite different between countries. CONCLUSIONS: Highest total personal RF-EMF exposure was measured inside transport vehicles and was well below international exposure limits. This is mainly due to mobile phone handsets. Mobile telecommunication can be considered to be the main contribution to total RF-EMF exposure in all microenvironments.

**Joseph W, Verloock L. Influence of mobile phone traffic on base station exposure of the general public.Health Phys. 99(5):631-638, 2010.**

The influence of mobile phone traffic on temporal radiofrequency exposure due to base stations during 7 d is compared for five different sites with Erlang data (representing average mobile phone traffic intensity during a period of time). The time periods of high exposure and high traffic during a day are compared and good agreement is obtained. The minimal required measurement periods to obtain accurate estimates for maximal and

average long-period exposure (7 d) are determined. It is shown that these periods may be very long, indicating the necessity of new methodologies to estimate maximal and average exposure from short-period measurement data. Therefore, a new method to calculate the fields at a time instant from fields at another time instant using normalized Erlang values is proposed. This enables the estimation of maximal and average exposure during a week from short-period measurements using only Erlang data and avoids the necessity of long measurement times.

**Joseph W, Verloock L, Goeminne F, Vermeeren G, Martens L. Assessment of general public exposure to LTE and RF sources present in an urban environment.Bioelectromagnetics. 31(7):576-579, 2010.**

For the first time, in situ electromagnetic field exposure of the general public to fields from long term evolution (LTE) cellular base stations is assessed. Exposure contributions due to different radiofrequency (RF) sources are compared with LTE exposure at 30 locations in Stockholm, Sweden. Total exposures (0.2-2.6 V/m) satisfy the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference levels (from 28 V/m for frequency modulation (FM), up to 61 V/m for LTE) at all locations. LTE exposure levels up to 0.8 V/m were measured, and the average contribution of the LTE signal to the total RF exposure equals 4%.

**Joseph W, Vermeeren G, Verloock L, Martens L. Estimation of whole-body SAR from electromagnetic fields using personal exposure meters. Bioelectromagnetics. 31(4):286-295, 2010.**

In this article, personal electromagnetic field measurements are converted into whole-body specific absorption rates for exposure of the general public. Whole-body SAR values calculated from personal exposure meter data are compared for different human spheroid phantoms: the highest SAR values (at 950 MHz) are obtained for the 1-year-old child (99th percentile of 17.9 microW/kg for electric field strength of 0.36 V/m), followed by the 5-year-old child, 10-year-old child, average woman, and average man. For the 1-year-old child, whole-body SAR values due to 9 different radiofrequency sources (FM, DAB, TETRA, TV, GSM900 DL, GSM1800 DL, DECT, UMTS DL, WiFi) are determined for 15 different scenarios. An SAR matrix for 15 different exposure scenarios and 9 sources is provided with the personal field exposure matrix. Highest 95th percentiles of the whole-body SAR are equal to 7.9 microW/kg (0.36 V/m, GSM900 DL), 5.8 microW/kg (0.26 V/m, DAB/TV), and 7.1 microW/kg (0.41 V/m, DECT) for the 1-year-old child, with a maximal total whole-body SAR of 11.5 microW/kg (0.48 V/m) due to all 9 sources. All values are below the basic restriction of 0.08 W/kg for the general public. 95th percentiles of whole-body SAR per V/m are equal to 60.1, 87.9, and 42.7 microW/kg for GSM900, DAB/TV, and DECT sources, respectively. Functions of the SAR versus measured electric fields are provided for the different phantoms and frequencies, enabling epidemiological and dosimetric studies to make an analysis in combination with both electric field and actual whole-body SAR.

**Joseph W, Frei P, Röösli M, Vermeeren G, Bolte J, Thuróczy G, Gajšek P, Trček T,**

**Mohler E, Juhász P, Finta V, Martens L. Between-country comparison of whole-body SAR from personal exposure data in urban areas.Bioelectromagnetics. 33(8):682-694, 2012.**

In five countries (Belgium, Switzerland, Slovenia, Hungary, and the Netherlands), personal radio frequency electromagnetic field measurements were performed in different microenvironments such as homes, public transports, or outdoors using the same exposure meters. From the mean personal field exposure levels (excluding mobile phone exposure), whole-body absorption values in a 1-year-old child and adult male model were calculated using a statistical multipath exposure method and compared for the five countries. All mean absorptions (maximal total absorption of 3.4 μW/kg for the child and 1.8 μW/kg for the adult) were well below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) basic restriction of 0.08 W/kg for the general public. Generally, incident field exposure levels were well correlated with whole-body absorptions (SAR(wb) ), although the type of microenvironment, frequency of the signals, and dimensions of the considered phantom modify the relationship between these exposure measures. Exposure to the television and Digital Audio Broadcasting band caused relatively higher SAR(wb) values (up to 65%) for the 1-year-old child than signals at higher frequencies due to the body size-dependent absorption rates. Frequency Modulation (FM) caused relatively higher absorptions (up to 80%) in the adult male.

**Joseph W, Goeminne F, Verloock L, Vermeeren G, Martens L. In situ occupational and general public exposure to VHF/UHF transmission for air traffic communication.Radiat Prot Dosimetry.151(3):411-419, 2012.**

Occupational and general public exposure due to very high frequency (VHF)/ultra high frequency (UHF) transmission centres for verbal communication for air traffic control is investigated in situ for the first time. These systems are used for communication with aircraft, resulting in different human exposure from that of classical broadcasting. Measurement methods are proposed for the exposure assessment, and a measurement campaign is executed in three transmission centres. By investigating the temporal behaviour of the VHF signals for 6 d, a realistic worst-case duty cycle of 29 % is determined. Periods of high exposures corresponding with high aircraft traffic are from 7 a.m. to 1 p.m. and in the evening. All measured electric-field values satisfy the International Commission on Non-ionizing Radiation Protection guidelines. Fields vary from 0.2 to 21.1 V m(-1) for occupational exposure and from 0.007 to 8.0 V m(-1) for general public exposure. The average fields equal 5.2 V m(-1) for workers, and 0.7 V m(-1) for general public.

**Joseph W, Verloock L, Goeminne F, Vermeeren G, Martens L.In situ LTE exposure of the general public: Characterization and extrapolation.Bioelectromagnetics.33(6):466-475, 2012.**

In situ radiofrequency (RF) exposure of the different RF sources is characterized in Reading, United Kingdom, and an extrapolation method to estimate worst-case long-term evolution (LTE) exposure is proposed. All electric field levels satisfy the International

Commission on Non-Ionizing Radiation Protection (ICNIRP) reference levels with a maximal total electric field value of 4.5 V/m. The total values are dominated by frequency modulation (FM). Exposure levels for LTE of 0.2 V/m on average and 0.5 V/m maximally are obtained. Contributions of LTE to the total exposure are limited to 0.4% on average. Exposure ratios from 0.8% (LTE) to 12.5% (FM) are obtained. An extrapolation method is proposed and validated to assess the worst-case LTE exposure. For this method, the reference signal (RS) and secondary synchronization signal (S-SYNC) are measured and extrapolated to the worst-case value using an extrapolation factor. The influence of the traffic load and output power of the base station on in situ RS and S-SYNC signals are lower than 1 dB for all power and traffic load settings, showing that these signals can be used for the extrapolation method. The maximal extrapolated field value for LTE exposure equals 1.9 V/m, which is 32 times below the ICNIRP reference levels for electric fields.

**Joseph W, Goeminne F, Vermeeren G, Verloock L, Martens L. In situ exposure to non-directional beacons for air traffic control.Bioelectromagnetics. 33(3):274-277, 2012.**

In situ electromagnetic field exposure of workers and the general public due to non-directional beacons (NDB) for air traffic control is assessed and characterized. For occupational exposure, the maximal measured electric field value is 881.6 V/m and the maximal magnetic field value is 9.1 A/m. The maximum electric fields exceed the International Commission on Non-Ionizing Radiation Protection (ICNIRP) reference levels at all seven NDB sites, and the magnetic fields at two of the seven NDB sites (occupational exposure). Recommendations and compliance distances for workers and the general public are provided.

**Joseph W, Verloock L, Goeminne F, Vermeeren G, Martens L. Assessment of RF exposures from emerging wireless communication technologies in different environments.Health Phys. 102(2):161-172, 2012.**

In situ electromagnetic (EM) radio frequency (RF) exposure to base stations of emerging wireless technologies is assessed at 311 locations, 68 indoor and 243 outdoor, spread over 35 areas in three European countries (Belgium, The Netherlands, and Sweden) by performing narrowband spectrum analyzer measurements. The locations are selected to characterize six different environmental categories (rural, residential, urban, suburban, office, and industrial). The maximal total field value was measured in a residential environment and equal to 3.9 V m(-1), mainly due to GSM900 signals. Exposure ratios for maximal electric field values, with respect to ICNIRP reference levels, range from 0.5% (WiMAX) to 9.3% (GSM900) for the 311 measurement locations. Exposure ratios for total field values vary from 3.1% for rural environments to 9.4% for residential environments. Exposures are lognormally distributed and are the lowest in rural environments and the highest in urban environments. Highest median exposures were obtained in urban environments (0.74 V m(-1)), followed by office (0.51 V m(-1)), industrial (0.49 V m(-1)), suburban (0.46 V m(-1)), residential (0.40 V m(-1)), and rural (0.09 V m(-1)) environments. The average contribution to the total electric field is more than 60% for GSM. Except for the rural environment, average contributions of UMTS-HSPA are more

than 3%. Contributions of the emerging technologies LTE and WiMAX are on average less than 1%. The dominating outdoor source is GSM900 (95 percentile of 1.9 V m(-1)), indoor DECT dominates (95 percentile of 1.5 V m(-1)).

**Joseph W, Goeminne F, Vermeeren G, Verloock L, Martens L.Occupational and public field exposure from communication, navigation, and radar systems used for air traffic control.Health Phys. 103(6):750-762, 2012.**

ABSTRACT: Electromagnetic exposure (occupational and general public) to 14 types of air traffic control (ATC) systems is assessed. Measurement methods are proposed for in situ exposure assessment of these ATC systems. In total, 50 sites are investigated at 1,073 locations in the frequency range of 255 kHz to 24 GHz. For all installations, typical and maximal exposure values for workers and the general public are provided. Two of the 14 types of systems, Non-Directional Beacons (NDB) (up to 881.6 V m) and Doppler Very High Frequency (VHF) Omni-directional Range (DVOR) (up to 92.3 V m), exhibited levels requiring recommended minimum distances such that the ICNIRP reference levels are not exceeded. Cumulative exposure of all present radiofrequency (RF) sources is investigated, and it is concluded that the ATC source dominates the total exposure in its neighborhood.

**Joubert V, Leveque P, Rametti A, Collin A, Bourthoumieu S, Yardin C. Microwave exposure of neuronal cells in vitro: Study of apoptosis. Int J Radiat Biol. 82(4):267-275, 2006.**

Purpose:The aim of this study was to investigate microwave (MW) effects on neuronal apoptosis in vitro.Materials and methods:Human neuroblastoma cells SH-SY5Y were exposed to a 900 MHz global system for mobile communication (GSM) or continuous-wave (CW) radiofrequency fields for 24 h in a wire-patch cell. The specific absorption rates (SAR) used were 2 W/kg for CW and 0.25 W/kg average for GSM. During CW exposure, an increase of 2 degrees C was measured, and controls with cells exposed to 39 degrees C were then performed. Apoptosis rate was assessed immediately or 24 h after exposure using three methods: (i) 4',6-diamino-2-phenylindole (DAPI) staining; (ii) flow cytometry using double staining with TdT-mediated dUTP nick-end labeling (TUNEL) and propidium iodide (PI); and (iii) measurement of caspase-3 activity by fluorimetry.Results:No statistically significant difference in the apoptosis rate was observed between sham and 24 h MW-exposed cells, either GSM-900 at an average SAR of 0.25 W/kg, or CW 900 MHz at a SAR of 2 W/kg, either 0 h or 24 h post-exposure. Furthermore, for CW-exposure, apoptosis rates were comparable between sham-, CW-, 37 degrees C- and 39 degrees C-exposed cells. All three methods used to assess apoptosis were concordant.Conclusion:These results showed that, under the conditions of the present experiment, MW-exposure (either CW or GSM-900) does not significantly increase the apoptosis rate in the human neuroblastoma cell line SH-SY5Y.

**Joubert V, Leveque P, Cueille M, Bourthoumieu S, Yardin C. No apoptosis is induced in rat cortical neurons exposed to GSM phone fields. Bioelectromagnetics.38(2) 115-121, 2007.**

The aim of this study was to investigate the radiofrequency (RF) electromagnetic fields (EMF) effects on neuronal apoptosis in vitro. Primary cultured neurons from cortices of embryonic Wistar rats were exposed to a 900-MHz global system for mobile communication (GSM) RF field for 24 h in a wire-patch cell. The average-specific absorption rate (SAR) used was 0.25 W/kg. Apoptosis rate was assessed immediately or 24 h after exposure using three methods: (i) DAPI staining; (ii) flow cytometry using double staining with TdT-mediated dUTP nick-end labeling (TUNEL) and propidium iodide (PI); and (iii) measurement of caspase-3 activity by fluorimetry. No statistically significant difference in the apoptosis rate was observed between controls and 24 h GSM-exposed neurons, either 0 h or 24 h post-exposure. All three methods used to assess apoptosis were concordant. These results showed that, under the conditions of experiment used, GSM-exposure does not significantly increase the apoptosis rate in rat primary neuronal cultures. This work is in accordance with other studies performed on cell lines and, to our knowledge, is the first one performed on cultured cortical neurons.

**Joubert V, Bourthoumieu S, Leveque P, Yardin C. Apoptosis is Induced by Radiofrequency Fields through the Caspase-Independent Mitochondrial Pathway in Cortical Neurons. Radiat Res. 169(1):38-45, 2008.**

In the present study, we investigated whether continuous-wave (CW) radiofrequency (RF) fields induce neuron apoptosis in vitro. Rat primary neuronal cultures were exposed to a CW 900 MHz RF field with a specific absorption rate (SAR) of 2 W/kg for 24 h. During exposure, an increase of 2 degrees C was measured in the medium; control experiments with neurons exposed to 39 degrees C were then performed. Apoptosis was assessed by condensation of nuclei with 4',6-diamino-2-phenylindole (DAPI) staining observed with an epifluorescence microscope and fragmentation of DNA with TdT-mediated dUTP nick-end labeling (TUNEL) analyzed by flow cytometry. A statistically significant difference in the rate of apoptosis was found in the RF-field-exposed neurons compared to the sham-, 37 degrees C- and 39 degrees C-exposed neurons either 0 or 24 h after exposure using both methods. To assess whether the observed apoptosis was caspase-dependent or -independent, assays measuring caspase 3 activity and apoptosis-inducing factor (AIF) labeling were performed. No increase in the caspase 3 activity was found, whereas the percentage of AIF-positive nuclei in RF-field-exposed neurons was increased by three- to sevenfold compared to other conditions. Our results show that, under the experimental conditions used, exposure of primary rat neurons to CW RF fields may induce a caspase-independent pathway to apoptosis that involves AIF.

**Jovanovic D, Bragard G, Picard D, Chauvin S. Mobile telephones: A comparison of radiated power between 3G VoIP calls and 3G VoCS calls. J Expo Sci Environ Epidemiol. 2014 Nov 5. doi: 10.1038/jes.2014.74. [Epub ahead of print]**

The purpose of this study is to assess the mean RF power radiated by mobile telephones during voice calls in 3G VoIP (Voice over Internet Protocol) using an application well known to mobile Internet users, and to compare it with the mean power radiated during voice calls in 3G VoCS (Voice over Circuit Switch) on a traditional network. Knowing that the specific absorption rate (SAR) is proportional to the mean radiated power, the user's

exposure could be clearly identified at the same time. Three 3G (High Speed Packet Access) smartphones from three different manufacturers, all dual-band for GSM (900 MHz, 1800 MHz) and dual-band for UMTS (900 MHz, 1950 MHz), were used between 28 July and 04 August 2011 in Paris (France) to make 220 two-minute calls on a mobile telephone network with national coverage. The places where the calls were made were selected in such a way as to describe the whole range of usage situations of the mobile telephone. The measuring equipment, called "SYRPOM", recorded the radiation power levels and the frequency bands used during the calls with a sampling rate of 20,000 per second. In the framework of this study, the mean normalised power radiated by a telephone in 3G VoIP calls was evaluated at 0.75% maximum power of the smartphone, compared with 0.22% in 3G VoCS calls. The very low average power levels associated with use of 3G devices with VoIP or VoCS support the view that RF exposure resulting from their use is far from exceeding the basic restrictions of current exposure limits in terms of SAR.

**Júnior LC, Guimarães ED, Musso CM, Stabler CT, Garcia RM, Mourão-Júnior CA, Andreazzi AE. Behavior and memory evaluation of Wistar rats exposed to 1·8 GHz radiofrequency electromagnetic radiation. Neurol Res. 36(9):800-803, 2014.**

Background: The development of communication systems has brought great social and economic benefits to society. As mobile phone use has become widespread, concerns have emerged regarding the potential adverse effects of radiofrequency electromagnetic radiation (RF-EMR) used by these devices. Objective: To verify potential effects of mobile phone radiation on the central nervous system (CNS) in an animal model. Methods: Male Wistar rats (60 days old) were exposed to RF-EMR from a Global System for Mobile (GSM) cell phone (1·8 GHz) for 3 days. At the end of the exposure, the following behavioral tests were performed: open field and object recognition. Results: Our results showed that exposed animals did not present anxiety patterns or working memory impairment, but stress behavior actions were observe. Conclusion: Given the results of the present study, we speculate that RF-EMR does not promote CNS impairment, but suggest that it may lead to stressful behavioral patterns.

**Juutilainen J, Heikkinen P, Soikkeli H, Mäki-Paakkanen J. Micronucleus frequency in erythrocytes of mice after long-term exposure to radiofrequency radiation. Int J Radiat Biol. 83(4):213-220, 2007.**

PURPOSE: The aim of the study was to investigate genotoxicity of long-term exposure to radiofrequency (RF) electromagnetic fields by measuring micronuclei in erythrocytes. The blood samples were collected in two animal studies evaluating possible cocarcinogenic effects of RF fields. METHODS: In study A, female CBA/S mice were exposed for 78 weeks (1.5 h/d, 5 d/week) to either a continuous 902.5 MHz signal similar to that emitted by analog NMT (Nordic Mobile Telephone) phones at a whole-body specific absorption rate (SAR) of 1.5 W/kg, or to a pulsed 902.4 MHz signal similar to that of digital GSM (Global System for Mobile Communications) phones at 0.35 W/kg. A third group was sham-exposed, and a fourth group served as cage controls. All but the cage control animals were exposed to 4 Gy of x-rays during

three first weeks of the experiment. In study B, female transgenic mice (line K2) and their nontransgenic littermates were exposed for 52 weeks (1.5 h/d, 5 d/week). Two digital mobile phone signals, GSM and DAMPS (Digital Advanced Mobile Phone System), were used at 0.5 W/kg. All but the cage-control animals were exposed 3 times per week to an ultraviolet radiation dose of 1.2 MED (minimum erythema dose). RESULTS AND CONCLUSIONS: The results did not show any effects of RF fields on micronucleus frequency in polychromatic or normochromatic erythrocytes. The results were consistent in two mouse strains (and in a transgenic variant of the second strain), after 52 or 78 weeks of exposure, at three SAR levels relevant to human exposure from mobile phones, and for three different mobile signals.

**Kahn AA, O'Brien DF, Kelly P, Phillips JP, Rawluk D, Bolger C, Pidgeon CN. The anatomical distribution of cerebral gliomas in mobile phone users. Ir Med J. 96(8):240-242, 2003.**

We analysed the association between mobile phone use and the anatomical distribution of glial brain tumours in Irish neurosurgical patients. All patients with unilateral histologically proven glioma were enrolled over a 12 month period. We hypothesised that were a cellular phone to cause a glioma then it would do so on the dominant hand side. Fifty mobile phone users and twenty three non-users were identified. The vast majority of patients (69/73) were right handed and the right side of the brain was more common as the tumour site (48/73). Fisher's exact test revealed no statistical significance for glioma location based on the handedness of the patient in the mobile phone user group and location of the tumour in both user and non-user groups. We discuss our findings and the stable trend in the incidence of reported glioma cases.

**Kahya MC, Nazıroğlu M, Ciğ B. Selenium Reduces Mobile Phone (900 MHz)-Induced Oxidative Stress, Mitochondrial Function, and Apoptosis in Breast Cancer Cells. Biol Trace Elem Res. 2014 Jun 27. [Epub ahead of print]**

Exposure to mobile phone-induced electromagnetic radiation (EMR) may affect biological systems by increasing free oxygen radicals, apoptosis, and mitochondrial depolarization levels although selenium may modulate the values in cancer. The present study was designed to investigate the effects of 900 MHz radiation on the antioxidant redox system, apoptosis, and mitochondrial depolarization levels in MDA-MB-231 breast cancer cell line. Cultures of the cancer cells were divided into four main groups as controls, selenium, EMR, and EMR + selenium. In EMR groups, the cells were exposed to 900 MHz EMR for 1 h (SAR value of the EMR was 0.36 ± 0.02 W/kg). In selenium groups, the cells were also incubated with sodium selenite for 1 h before EMR exposure. Then, the following values were analyzed: (a) cell viability, (b) intracellular ROS production, (c) mitochondrial membrane depolarization, (d) cell apoptosis, and (e) caspase-3 and caspase-9 values. Selenium suppressed EMR-induced oxidative cell damage and cell viability (MTT) through a reduction of oxidative stress and restoring mitochondrial membrane potential. Additionally, selenium indicated anti-apoptotic effects, as demonstrated by plate reader analyses of apoptosis levels and caspase-3 and caspase-9 values. In conclusion, 900 MHz EMR appears to induce apoptosis effects through oxidative stress and mitochondrial

depolarization although incubation of selenium seems to counteract the effects on apoptosis and oxidative stress.

**Kainz W, Neubauer G, Alesch F, Schmid G, Jahn O. Electromagnetic compatibility of electronic implants--review of the literature. Wien Klin Wochenschr 113(23-24):903-914, 2001.**

The aim of the article was to provide an overview of published studies regarding the electromagnetic compatibility (EMC) of electronic implants. The available literature was sorted according to combinations of implant types and sources of interference. Several experiments concerning the susceptibility of pacemakers to mobile phones have been performed. The results of these experiments suggest measures that may be used to prevent the disturbance of pacemakers. For instance, instead of carrying the activated mobile phone in the breast pocket it is recommended that a distance of 30 cm be maintained between the pacemaker and the mobile phone, and that the mobile phone be used on the contralateral side of the pacemaker's location. Similar measures may be recommended for patients with implantable cardioverter defibrillators when using mobile phones. Patients with electronic implants should walk rapidly through anti theft-devices because some of these devices are liable to disturb implants. Patients with cardiac pacemakers should not be subjected to magnetic resonance imaging as far as possible. For a variety of combinations of implants and interference sources, e.g. cardiac pacemakers and base station antennas, no studies were found in the literature. It is strongly recommended that trials be carried out to evaluate the potential risk for patients in these settings.

**Kainz W, Alesch F, Chan DD. Electromagnetic interference of GSM mobile phones with the implantable deep brain stimulator, ITREL-III. Biomed Eng Online 2(1):11, 2003.**

BACKGROUND: The purpose was to investigate mobile phone interference with implantable deep brain stimulators by means of 10 different 900 Mega Hertz (MHz) and 10 different 1800 MHz GSM (Global System for Mobile Communications) mobile phones. METHODS: All tests were performed in vitro using a phantom especially developed for testing with deep brain stimulators. The phantom was filled with liquid phantom materials simulating brain and muscle tissue. All examinations were carried out inside an anechoic chamber on two implants of the same type of deep brain stimulator: ITREL-III from Medtronic Inc., USA. RESULTS: Despite a maximum transmitted peak power of mobile phones of 1 Watt (W) at 1800 MHz and 2 W at 900 MHz respectively, no influence on the ITREL-III was found. Neither the shape of the pulse form changed nor did single pulses fail. Tests with increased transmitted power using CW signals and broadband dipoles have shown that inhibition of the ITREL-III occurs at frequency dependent power levels which are below the emissions of GSM mobile phones. The ITREL-III is essentially more sensitive at 1800 MHz than at 900 MHz. Particularly the frequency range around 1500 MHz shows a very low interference threshold. CONCLUSION: These investigations do not indicate a direct risk for ITREL-III patients using the tested GSM phones. Based on the interference levels found with CW signals, which are below the mobile phone emissions, we recommend similar precautions as for patients with cardiac pacemakers: 1. The phone should be used at the ear at the opposite side of the implant and 2. The

patient should avoid carrying the phone close to the implant.

**Kakita Y, Kashige N, Murata K, Kuroiwa A, Funatsu M, Watanabe K, Inactivation of Lactobacillus bacteriophage PL-1 by microwave irradiation. Microbiol Immunol39(8):571-576, 1995.**

The effect of microwave irradiation on the survival of bacteriophage PL-1, which is specific for Lactobacillus casei, was studied using a commercial 2,450 MHz microwave oven. The phages were inactivated by microwave irradiation according to almost first-order reaction kinetics. The rate of phage inactivation was not affected by the difference in the continuous or intermittent irradiation, nor by the concentrations of phages used, but was affected by the volume of phage suspensions, which prevented the loss of generated heat. Microwave irradiation of phage suspensions produced a number of ghost phages with empty heads, but fragmentation of the tail was hardly noticed. The breakage of phage genome DNA was primarily caused by the heat generated by microwave irradiation, whereas the phage DNA was not affected by the same temperature achieved by heat from outside. Thus we concluded that the phage-inactivating effect of microwave irradiation was mainly attributed to a thermal microwave effect, which was much stronger than a simple thermal exposure.

**Kaliada TV, Nikitina VN, Liashko GG, Masterova Ilu, Shaposhnikova ES. [Experimental research on the biological action of the pulse-modulated microwave radiation created by shipboard radar stations]. Med Tr Prom Ekol (11):15-17, 1995.** [Article in Russian]

The article represents experimental data on influence of impulse modulated microwave irradiation with discontinuous effects varying in intensity and exposure. Becavior, peripheral blood, biochemical and morphologic parameters were assessed in the laboratory animals exposed. The response appeared to correlate with individual and typologic features of the examinees.

**Kalns J, Ryan KL, Mason PA, Bruno JG, Gooden R, Kiel JL. Oxidative stress precedes circulatory failure induced by 35-GHz microwave heating. Shock 13(1):52-59, 2000.**

Sustained whole-body exposure of anesthetized rats to 35-GHz radio frequency radiation produces localized hyperthermia and hypotension, leading to circulatory failure and death. The physiological mechanism underlying the induction of circulatory failure by 35-GHz microwave (MW) heating is currently unknown. We hypothesized that oxidative stress may play a role in the pathophysiology of MW-induced circulatory failure and examined this question by probing organs for 3-nitrotyrosine (3-NT), a marker of oxidative stress. Animals exposed to low durations of MW that increased colonic temperature but were insufficient to produce hypotension showed a 5- to 12-fold increase in 3-NT accumulation in lung, liver, and plasma proteins relative to the levels observed in control rats that were not exposed to MW. 3-NT accumulation in rats exposed to MW of sufficient duration to induce circulatory shock returned to low, baseline levels. Leukocytes obtained from peripheral blood showed significant accumulation of 3-NT only at exposure levels associated with circulatory shock. 3-NT was also found in the villus tips and vasculature of intestine and within the distal tubule of the kidney but not in the irradiated skin of rats

with MW-induced circulatory failure. The relationship between accumulation in liver, lung, and plasma proteins and exposure duration suggests either that nitro adducts are formed in the first 20 min of exposure and are then cleared or that synthesis of nitro adducts decreases after the first 20 min of exposure. Taken together, these findings suggest that oxidative stress occurs in many organs during MW heating. Because nitration occurs after microwave exposures that are not associated with circulatory collapse, systemic oxidative stress, as evidenced by tissue accumulation of 3-NT, is not correlated with circulatory failure in this model of shock.

**Kamali K, Atarod M, Sarhadi S, Nikbakht J, Emami M, Maghsoudi R, Salimi H, Fallahpour B, Kamali N, Momtazan A, Ameli M. Effects of electromagnetic waves emitted from 3G+wi-fi modems on human semen analysis. Urologia. 84(4):209-214, 2017.**

OBJECTIVE: The purpose of this study was to evaluate the effects of 3G+wifi modems on human sperm quality. A total of 40 semen specimens were gathered between March and September 2015, from healthy adult men. METHODS: The sperm samples were divided into two groups - 3G+wi-fi exposed and unexposed groups. In the unexposed group, the specimens were shielded by aluminum foil in three layers and put into an incubator at a temperature of 37°C for 50 minutes. The exposed group was positioned in another room in an incubator at a temperature of 37°C for 50 minutes. A 3G+wi-fi modem was put into the same incubator and a laptop computer was connected to the modem and was downloading for the entire 50 minutes. Semen analysis was done for each specimen and comparisons between parameters of the two groups were done by using Kolmogorov-Smirnov study and a paired t-test. RESULTS:  Mean percentage of sperm with class A and B motility were not significantly different in two groups ($p = 0.22$ and 0.54, respectively). In class C, it was significantly lower in the exposed group ($p = 0.046$), while in class D it was significantly higher ($p = 0.022$). Velocity curvilinear, velocity straight line, velocity average path, mean angular displacement, lateral displacement and beat cross frequency were significantly higher in the unexposed group. The limitation was the in vitro design. CONCLUSIONS: Electromagnetic waves (EMWs) emitted from 3G+wi-fi modems cause a significant decrease in sperm motility and velocity, especially in non-progressive motile sperms. Other parameters of semen analysis did not change significantly.EMWs, which are used in communications worldwide, are a suspected cause of male infertility. Many studies evaluated the effects of **cell phones** and wi-fi on fertility. To our knowledge, no study has yet been done to show the effects of EMWs emitted from 3G+wi-fi modems on fertility.Our study revealed a significant decrease in the quality of human semen after exposure to EMWs emitted from 3G+wi-fi modems.

**Kamibeppu K, Sugiura H. Impact of the mobile phone on junior high-school students' friendships in the Tokyo metropolitan area. Cyberpsychol Behav. 8(2):121-130, 2005.**

The proportion of having keitai (Japanese mobile phone) has increased rapidly in young children. To research how junior high school students use their own keitai and to examine the impact of using it on their psychology, especially on their friendship, we recruited 651 students, grade 8, from five public junior high schools in the Tokyo metropolitan area.

Each student participant completed a questionnaire that we had created. The response rates were 88.8% (n = 578) for participants. The proportion of having their own keitai was 49.3% (n = 285) and that of not having it was 50.7% (n = 293). We found that they used it much more frequently for e-mail than as a phone. Most of them exchanged e-mails between schoolmates, and more than a half of them exchanged e-mails more than 10 times a day. Sociable students estimated that their own keitai was useful for their friendship. But they experienced some insecurity or started staying up late at night engaged in e-mail exchanges, and they thought that they could not live without their own keitai. Our findings suggest that keitai having an e-mail function play a big part in the junior high-school students' daily life, and its impact on students' friendships, psychology, or health should be discussed among students to prevent keitai addiction.

**Kan P, Simonsen SE, Lyon JL, Kestle JR. Cellular phone use and brain tumor: a meta-analysis. J Neurooncol.86(1):71-78, 2007.**

BACKGROUND: The dramatic increase in the use of cellular phones has generated concerns about potential adverse effects, especially the development of brain tumors. We conducted a meta-analysis to examine the effect of cellular phone use on the risk of brain tumor development. METHODS: We searched the literature using MEDLINE to locate case-control studies on cellular phone use and brain tumors. Odds ratios (ORs) for overall effect and stratified ORs associated with specific brain tumors, long-term use, and analog/digital phones were calculated for each study using its original data. A pooled estimator of each OR was then calculated using a random-effects model. RESULTS: Nine case-control studies containing 5,259 cases of primary brain tumors and 12,074 controls were included. All studies reported ORs according to brain tumor subtypes, and five provided ORs on patients with >/=10 years of follow up. Pooled analysis showed an overall OR of 0.90 (95% confidence interval [CI] 0.81-0.99) for cellular phone use and brain tumor development. The pooled OR for long-term users of >/=10 years (5 studies) was 1.25 (95% CI 1.01-1.54). No increased risk was observed in analog or digital cellular phone users. CONCLUSIONS: We found no overall increased risk of brain tumors among cellular phone users. The potential elevated risk of brain tumors after long-term cellular phone use awaits confirmation by future studies.

**Kang KA, Lee HC, Lee JJ, Hong MN, Park MJ, Lee YS, Choi HD, Kim N, Ko YK, Lee JS. Effects of combined radiofrequency radiation exposure on levels of reactive oxygen species in neuronal cells.J Radiat Res. 2013 Oct 8. [Epub ahead of print]**

The objective of this study was to investigate the effects of the combined RF radiation (837 MHz CDMA plus 1950 MHz WCDMA) signal on levels of intracellular reactive oxygen species (ROS) in neuronal cells. Exposure of the combined RF signal was conducted at specific absorption rate values of 2 W/kg of CDMA plus 2 W/kg of WCDMA for 2 h. Co-exposure to combined RF radiation with either H2O2 or menadione was also performed. The experimental exposure groups were incubator control, sham-exposed, combined RF radiation-exposed with or without either H2O2 or menadione groups. The intracellular ROS level was measured by flow cytometry using the fluorescent probe dichlorofluorescein diacetate. Intracellular ROS levels

were not consistently affected by combined RF radiation exposure alone in a time-dependent manner in U87, PC12 or SH-SY5Y cells. In neuronal cells exposed to combined RF radiation with either H2O2 or menadione, intracellular ROS levels showed no statically significant alteration compared with exposure to menadione or H2O2 alone. These findings indicate that neither combined RF radiation alone nor combined RF radiation with menadione or H2O2 influences the intracellular ROS level in neuronal cells such as U87, PC12 or SH-SY5Y.

**Kao HK, Li Q, Flynn B, Qiao X, Ruberti JW, Murphy GF, Guo L. Collagen synthesis modulated in wounds treated by pulsed radiofrequency energy. Plast Reconstr Surg. 131(4):490e-498e, 2013.**

BACKGROUND: Chronic wounds are biochemically complex and are associated with insufficient cell proliferation, angiogenesis, and extracellular matrix remodeling. The mechanisms by which pulsed radiofrequency energy modulates wound healing are still unclear. METHODS: Db/db mice were wounded and exposed to pulsed radiofrequency energy. Gross closure, cell proliferation, and morphometric analysis of CD31-stained wound cross-sections were assessed. The mRNA expression of profibrotic factors (transforming growth factor-β and platelet-derived growth factor-A), angiogenetic factors (vascular endothelial growth factor and basic fibroblast growth factor), and extracellular matrix components (collagen I and α-smooth muscle actin) were evaluated by quantitative reverse-transcriptase polymerase chain reaction. Collagen protein level of the wound was determined by Western blot analysis. To test the effect of pulsed radiofrequency energy on cell movement in wound healing, cell migration was monitored in monolayer dermal fibroblast cultures. The degree of collagen alignment and gelation time was quantitatively assessed using image analysis techniques. RESULTS: Pulsed radiofrequency energy-treated wounds were characterized by dermal cell proliferation and increased collagen synthesis. By contrast, the CD31 density and the mRNA expression of vascular endothelial growth factor and basic fibroblast growth factor showed no significant difference between the pulsed radiofrequency energy-treated wounds and the sham group. The pulsed radiofrequency energy-treated dermal fibroblast cultures expressed a significantly longer gelation time compared with the sham-exposed cultures. CONCLUSIONS: Exposing wounds to pulsed radiofrequency accelerated wound healing in this diabetic mouse model by means of significantly increasing dermal cell proliferation and collagen synthesis. A cellular mechanism behind these observations has been proposed.

**Kaprana AE, Chimona TS, Papadakis CE, Velegrakis SG, Vardiambasis IO, Adamidis G, Velegrakis GA. Auditory brainstem response changes during exposure to GSM-900 radiation: An experimental study. Audiol Neurootol. 16(4):270-276, 2011.**

Abstract. The objective of the present study was to investigate the possible electrophysiological time-related changes in auditory pathway during mobile phone electromagnetic field exposure. Thirty healthy rabbits were enrolled in an experimental study of exposure to GSM-900 radiation for 60 min and auditory brainstem responses (ABRs) were recorded at regular time-intervals during exposure. The study subjects were radiated via an adjustable power and frequency

radio transmitter for GSM-900 mobile phone emission simulation, designed and manufactured according to the needs of the experiment. The mean absolute latency of waves III-V showed a statistically significant delay ($p < 0.05$) after 60, 45 and 15 min of exposure to electromagnetic radiation of 900 MHz, respectively. Interwave latency I-III was found to be prolonged after 60 min of radiation exposure in correspondence to wave III absolute latency delay. Interwave latencies I-V and III-V were found with a statistically significant delay ($p < 0.05$) after 30 min of radiation. No statistically significant delay was found for the same ABR parameters in recordings from the ear contralateral to the radiation source at 60 min radiation exposure compared with baseline ABR. The ABR measurements returned to baseline recordings 24 h after the exposure to electromagnetic radiation of 900 MHz. The prolongation of interval latencies I-V and III-V indicates that exposure to electromagnetic fields emitted by mobile phone can affect the normal electrophysiological activity of the auditory system, and these findings fit the pattern of general responses to a stressor.

**Karaca E, Durmaz B, Aktug H, Yildiz T, Guducu C, Irgi M, Koksal MG, Ozkinay F, Gunduz C, Cogulu O.The genotoxic effect of radiofrequency waves on mouse brain. J Neurooncol. 106(1):53-58, 2012.**

Concerns about the health effects of radiofrequency (RF) waves have been raised because of the gradual increase in usage of cell phones, and there are scientific questions and debates about the safety of those instruments in daily life. The aim of this study is to evaluate the genotoxic effects of RF waves in an experimental brain cell culture model. Brain cell cultures of the mice were exposed to 10.715 GHz with specific absorbtion rate (SAR) 0.725 W/kG signals for 6 h in 3 days at 25°C to check for the changes in the micronucleus (MNi) assay and in the expression of 11 proapoptotic and antiapoptotic genes. It was found that MNi rate increased 11-fold and STAT3 expression decreased 7-fold in the cell cultures which were exposed to RF. Cell phones which spread RF may damage DNA and change gene expression in brain cells.

**Karaman MI, Gökçe AM, Koca O, Karaman B, Öztürk MI, Yurdakul N, Ercan F. The effects of electromagnetic waves emitted by the** cell phones **on the testicular tissue. Arch Ital Urol Androl. 86(4):274-277, 2014.**

OBJECTIVES: Various risks have emerged in parallel to the rapidly increasing use of **cell phones**. Herein we studied the effects of **cell phone** emitted electromagnetic waves (EMW) on rat testes. MATERIAL AND METHODS: Twenty one adult male Albino rats were grouped into 3 groups each consisting of 7 rats. The first group was exposed to EMW on talk mode for 8 hours per day for 20 days and then their testes were extracted. The testes of the second group were extracted after 20 days of whole day EMW exposure. The third group was the control group. For the statistical analysis Mann-Whitney U analysis was performed. RESULTS: At light microscopic examination of the testicular tissue, the existence of a high number of immature cells in the lumen of the seminiferous tubule in addition to the normal seminiferous tubules, besides irregular tubules with a reduction in the spermatogenic **cell** lines and tubules without lumen were observed in groups 1 and 2. Histopathological alterations were scored as 0 = none, 1 =

low, 2 = medium, 3 = serious. The average scores of the three groups were found to be 4.25 ± 1.5 for the group 1, 4.33 ± 3.9 for the group 2 and 0.37 ± 1.1 for the group 3 respectively. As a result of the statistical evaluation, group 1 and group 2 had significantly higher scores than the control group (p = 0.001). CONCLUSION: Infertility is one of the current problems of today due to a rapid increase in its incidence and cost. The negative effects of the EMWs on the testis should be taken into account and the necessary measures should be taken for prevention.

**Karinen A, Heinavaara S, Nylund R, Leszczynski D. Mobile phone radiation might alter protein expression in human skin. BMC Genomics. 9(1):77, 2008.**

ABSTRACT: BACKGROUND: Earlier we have shown that the mobile phone radiation (radiofrequency modulated electromagnetic fields; RF-EMF) alters protein expression in human endothelial cell line. This does not mean that similar response will take place in human body exposed to this radiation. Therefore, in this pilot human volunteer study, using proteomics approach, we have examined whether a local exposure of human skin to RF-EMF will cause changes in protein expression in living people. RESULTS: Small area of forearm's skin in 10 female volunteers was exposed to RF-EMF (specific absorption rate SAR=1.3W/kg) and punch biopsies were collected from exposed and non exposed areas of skin. Proteins extracted from biopsies were separated using 2-DE and protein expression changes were analyzed using PDQuest software. Analysis has identified 8 proteins that were statistically significantly affected (Anova and Wilcoxon tests). Two of the proteins were present in all 10 volunteers. This suggests that protein expression in human skin might be affected by the exposure to RF-EMF. The number of affected proteins was similar to the number of affected proteins observed in our earlier in vitro studies. CONCLUSIONS: This is the first study showing that molecular level changes might take place in human volunteers in response to exposure to RF-EMF. Our study confirms that proteomics screening approach can identify protein targets of RF-EMF in human volunteers.

**Kato Y, Johansson O. Reported functional impairments of electrohypersensitive Japanese: A questionnaire survey. Pathophysiology.19(2) 95-100, 2012.**

An increasing number of people worldwide complain that they have become electromagnetic hypersensitive (EHS). We conducted a questionnaire survey of EHS persons in Japan. The aim was to identify electromagnetic fields (EMF) and plausible EMF sources that caused their symptoms. Postal questionnaires were distributed via a self-help group, and 75 participants (95% women) responded. Reported major complaints were "fatigue/tiredness" (85%), "headache", "concentration, memory, and thinking" difficulty (81%, respectively). Seventy-two per cent used some form of complementary/alternative therapy. The most plausible trigger of EHS onset was a mobile phone base station or personal handy-phone system (37%). Sixty-five percent experienced health problems to be due to the radiation from other passengers' mobile phones in trains or buses, and 12% reported that they could not use public transportation at all. Fifty-three percent had a job before the onset, but most had lost their work and/or experienced a decrease in income. Moreover, 85.3% had to take

measures to protect themselves from EMF, such as moving to low EMF areas, or buying low EMF electric appliances. EHS persons were suffering not only from their symptoms, but also from economical and social problems.

**Kawai H, Nagaoka T, Watanabe S, Saito K, Takahashi M, Ito K. Computational dosimetry in embryos exposed to electromagnetic plane waves over the frequency range of 10 MHz-1.5 GHz.Phys Med Biol. 55(1):N1-11, 2010.**

This paper presents calculated specific absorption rate (SAR) dosimetry in 4 and 8 week Japanese pregnant-woman models exposed to plane waves over the frequency range of 10 MHz-1.5 GHz. Two types of 2 mm spatial-resolution pregnant-woman models comprised a woman model, which is similar to the average-sized Japanese adult female in height and weight, with a cubic (4 week) embryo or spheroidal (8 week) one. The averaged SAR in the embryos exposed to vertically and horizontally polarized plane waves at four kinds of propagation directions are calculated from 10 MHz to 1.5 GHz. The results indicate that the maximum average SAR in the embryos exposed to plane waves is lower than 0.08 W kg(-1) when the incident power density is at the reference level of ICNIRP guideline for general public environment.

**Kayabasoglu G, Sezen OS, Eraslan G, Aydin E, Coskuner T, Unver S. Effect of chronic exposure to cellular telephone electromagnetic fields on hearing in rats. J Laryngol Otol. 125(4):348-353, 2011.**

OBJECTIVE: To study the effects of the electromagnetic field emitted by cellular telephones upon the inner ear of rats, using distortion product otoacoustic emissions.METHODS: Forty Wistar Albino rats were used. Twenty newborn and 20 adult rats were divided into two groups of 10, one to participate in the study and one as a control. The rats were exposed to the electromagnetic field for 6 hours per day, for 30 consecutive days. Before and after the 30 day exposure period, distortion product otoacoustic emissions were measured in each group and a signal-to-noise ratio calculated, which was later used in statistical analysis.RESULTS: For both the newborn and adult rat groups, there was no significant difference in distortion product otoacoustic emissions recorded before and after exposure to the cellular telephone electromagnetic field ($p>0.05$).CONCLUSION: Exposure to the electromagnetic field emitted by cellular telephones, for 6 hours a day for 30 consecutive days, had no effect on the hearing of newborn or adult rats, at the outer ear, middle ear or cochlear level.

**Keetley V, Wood AW, Spong J, Stough C. Neuropsychological sequelae of digital mobile phone exposure in humans. Neuropsychologia. 44(10):1843-1848,2006.**

The effect of electromagnetic fields from digital mobile phones (DMP) on cognitive functioning is an area receiving increased attention. This study compares the performance of 120 volunteers on 8 neuropsychological tests during real or sham exposure to a DMP set to maximum permissible radiofrequency power output. When results were adjusted for known covariates (gender, age, or education), several alterations at significance levels of $p<0.05$ were obtained. Of these, simple and

choice reaction times (CRT) showed strong evidence of impairment. Further, performance on the Trail Making Task (TMT) improved, supporting the hypothesis that DMP radiofrequency emissions improve the speed of processing of information held in working memory.

**Kellenyi, L, Thuroczy, G, Faludy, B, Lenard, L, Effects of mobile GSM radiotelephone exposure on the auditory brainstem response (ABR). Neurobiology 7:79-81, 1999.**

A 15-min exposure to GSM phone radiation caused an increase in auditory brainstem response in the exposed side of human subjects. Subjects also showed a hearing deficiency in the high frequency range (20 dB hearing deficiency from 2 KHz to 10 KHz).

**Kelsh MA, Shum M, Sheppard AR, McNeely M, Kuster N, Lau E, Weidling R, Fordyce T, Kühn S, Sulser C. Measured radiofrequency exposure during various mobile-phone use scenarios. J Expo Sci Environ Epidemiol.21(4):343-54, 2010.**

Epidemiologic studies of mobile phone users have relied on self reporting or billing records to assess exposure. Herein, we report quantitative measurements of mobile-phone power output as a function of phone technology, environmental terrain, and handset design. Radiofrequency (RF) output data were collected using software-modified phones that recorded power control settings, coupled with a mobile system that recorded and analyzed RF fields measured in a phantom head placed in a vehicle. Data collected from three distinct routes (urban, suburban, and rural) were summarized as averages of peak levels and overall averages of RF power output, and were analyzed using analysis of variance methods. Technology was the strongest predictor of RF power output. The older analog technology produced the highest RF levels, whereas CDMA had the lowest, with GSM and TDMA showing similar intermediate levels. We observed generally higher RF power output in rural areas. There was good correlation between average power control settings in the software-modified phones and power measurements in the phantoms. Our findings suggest that phone technology, and to a lesser extent, degree of urbanization, are the two stronger influences on RF power output. Software-modified phones should be useful for improving epidemiologic exposure assessment.

**Kemerov, S, Marinkev, M, Getova, D, Effects of low-intensity electromagnetic fields on behavioral activity of rats. Folia Med (Plovdiv) 41(3):75-80, 1999.**

The present study aimed at comparative assessment of the changes in behavioral activity of rats after exposing them to low intensity electromagnetic fields (EMFs) in the meter, decimeter and centimeter ranges. The experiments were carried out on 24 Wistar rats divided into 4 groups (1 control and 3 experimental), treated with different EMFs. The rats were irradiated on the head area at power density of 10 mW/cm2. Using a conventional shuttle box, the conditioned and non-conditioned responses and spontaneous motor activity of the rats were studied. The results suggest that exposure to EMFs in the three ranges can slow down the formation of conditioned responses--this was clearly marked in the rats exposed to meter EMFs, whereas the effects of centimeter EMFs were delayed in time. The behavioral effects were mild at athermal dosages and the animals adapted

easily to exposure conditions. This study shows that determination of the effects of different EMFs should be done for each of the ranges separately; determination of the exact dosage of the electromagnetic fields can help to avoid their negative biological effects.

**Keow MA, Radiman S. Assessment of radiofrequency/microwave radiation emitted by the antennas of rooftop-mounted mobile phone base stations. Radiat Prot Dosimetry.121(2):122-127, 2006.**

Radiofrequency (RF) and microwave (MW) radiation exposures from the antennas of rooftop-mounted mobile telephone base stations have become a serious issue in recent years due to the rapidly evolving technologies in wireless telecommunication systems. In Malaysia, thousands of mobile telephone base stations have been erected all over the country, most of which are mounted on the rooftops. In view of public concerns, measurements of the RF/MW levels emitted by the base stations were carried out in this study. The values were compared with the exposure limits set by several organisations and countries. Measurements were performed at 200 sites around 47 mobile phone base stations. It was found that the RF/MW radiation from these base stations were well below the maximum exposure limits set by various agencies.

**Kerbacher JJ, Meltz ML, Erwin DN, Influence of radiofrequency radiation on chromosome aberrations in CHO cells and its interaction with DNA-damaging agents. Radiat Res 123(3):311-319, 1990.**

A limited number of contradictory reports have appeared in the literature about the ability of radiofrequency (rf) radiation to induce chromosome aberrations in different biological systems. The technical documentation associated with such reports is often absent or deficient. In addition, no information is available as to whether any additional genotoxic hazard would result from a simultaneous exposure of mammalian cells to rf radiation and a chemical which (by itself) induces chromosome aberrations. In the work described, we have therefore tested two hypotheses. The first is that rf radiation by itself, at power densities and exposure conditions which are higher than is consistent with accepted safety guidelines, can induce chromosome aberrations in mammalian cells. The second is that, during a simultaneous exposure to a chemical known to be genotoxic, rf radiation can affect molecules, biochemical processes, or cellular organelles, and thus result in an increase or decrease in chromosome aberrations. Mitomycin C (MMC) and Adriamycin (ADR) were selected because they act by different mechanisms, and because they might put normal cells at risk during combined-modality rf radiation (hyperthermia)-chemotherapy treatment of cancer. The studies were performed with suitable 37 degrees C and equivalent convection heating-temperature controls in a manner designed to discriminate between any thermal and possible nonthermal action. Radiofrequency exposures were conducted for 2 h under conditions resulting in measurable heating (a maximum increase of 3.2 degrees C), with pulsed-wave rf radiation at a frequency of 2450 MHz and an average net forward power of 600 W, resulting in an SAR of 33.8 W/kg. Treatments with MMC or ADR were for a total of 2.5 h and encompassed the 2-h rf radiation exposure period. The CHO cells from each of the conditions were subsequently analyzed for chromosome aberrations. In cells exposed to rf radiation

alone, and where a maximum temperature of approximately 40 degrees C was achieved in the tissue culture medium, no alteration in the frequency from 37 degrees C control levels was observed. Relative to the chemical treatment with MMC alone at 37 degrees C, for two different concentrations, no alteration was observed in the extent of chromosome aberrations induced by either simultaneous rf radiation exposure or convection heating to equivalent temperatures. At the ADR concentration that was used, most of the indices of chromosome aberrations which were scored indicated a similar result.

**Kerekhanjanarong V, Supiyaphun P, Naratricoon J, Laungpitackchumpon P. The effect of mobile phone to audiologic system. J Med Assoc Thai.88 Suppl 4:S231-234, 2005.**

Mobile phones have come into widespread use. There are a lot of possible adverse effect to health. Use of mobile phone generate potentially harmful radiofrequency electromagnetic field (EMF) particularly for the hearing aspect. 98 subjects underwent hearing evaluations at Department of Otolaryngology, Faculty of Medicine, King Chulalongkorn Memorial Hospital, Chulalongkorn University. 31 males and 67females, mean age was 30.48 +/- 9.51 years old, all subjects were investigated the hearing level by audiometry, tympanometry, otoacoustic emission (OAE) and auditory brain stem evoked response (ABR). The average of using time were 32.54 +/- 27.64 months, 57 subjects usually used the right side and 41 the left side. Average time of use per day was 26.31 +/- 30.91 minutes (range from 3 to 180 mins). When the authors compared the audiogram, both pure tone and speech audiometry, between the dominant and nondominant side, it indicated that there is no significant different. When the authors focused on the 8 subjects that used the mobile phone more than 60 mins per day. It indicated that the hearing threshold of the dominant ears was worse than the nondominant ears.

**Kerimoğlu G, Mercantepe T, Erol HS, Turgut A, Kaya H, Çolakoğlu S, Odacı E. Effects of long-term exposure to 900 megahertz electromagnetic field on heart morphology and biochemistry of male adolescent rats. Biotech Histochem. 2016 Aug 11:1-10. [Epub ahead of print]**

The pathological effects of exposure to an electromagnetic field (EMF) during adolescence may be greater than those in adulthood. We investigated the effects of exposure to 900 MHz EMF during adolescence on male adult rats. Twenty-four 21-day-old male rats were divided into three equal groups: control (Cont-Gr), sham (Shm-Gr) and EMF-exposed (EMF-Gr). EMF-Gr rats were placed in an EMF exposure cage (Plexiglas cage) for 1 h/day between postnatal days 21 and 59 and exposed to 900 MHz EMF. Shm-Gr rats were placed inside the Plexiglas cage under the same conditions and for the same duration, but were not exposed to EMF. All animals were sacrificed on postnatal day 60 and the hearts were extracted for microscopic and biochemical analyses. Biochemical analysis showed increased levels of malondialdehyde and superoxide dismutase, and reduced glutathione and catalase levels in EMF-Gr compared to Cont-Gr animals. Hematoxylin and eosin stained sections from EMF-Gr animals exhibited structural changes and capillary congestion in the myocardium. The percentage of apoptotic myocardial cells in EMF-Gr was higher than in either Shm-Gr or Cont-Gr

animals. Transmission electron microscopy of myocardial cells of EMF-Gr animals showed altered structure of Z bands, decreased myofilaments and pronounced vacuolization. We found that exposure of male rats to 900 MHz EMF for 1 h/day during adolescence caused oxidative stress, which caused structural alteration of male adolescent rat heart tissue.

**Kerimoğlu G, Aslan A, Baş O, Çolakoğlu S, Odacı E. Adverse effects in lumbar spinal cord morphology and tissue biochemistry in Sprague Dawley male rats following exposure to a continuous 1-h a day 900-MHz electromagnetic field throughout adolescence. J Chem Neuroanat. 78:125-130, 2016.**

Cell phones, an indispensable element of daily life, are today used at almost addictive levels by adolescents. Adolescents are therefore becoming increasingly exposed to the effect of the electromagnetic field (EMF) emitted by cell phones. The purpose of this study was to investigate the effect of exposure to a 900-MHz EMF throughout adolescence on the lumbar spinal cord using histopathological, immunohistochemical and biochemical techniques. Twenty-four Sprague Dawley (28.3-43.9g) aged 21days were included in the study. These were divided equally into three groups - control (CG), sham (SG) and electromagnetic (ELMAG). No procedure was performed on the CG rats until the end of the study. SG and ELMAG rats were kept inside an EMF cage (EMFC) for 1h a day every day at the same time between postnatal days 22 and 60. During this time, ELMAG rats were exposed to the effect of a 900-MHz EMF, while the SG rats were kept in the EMFC without being exposed to EMF. At the end of the study, the lumbar regions of the spinal cords of all rats in all groups were extracted. Half of each extracted tissue was stored at -80°C for biochemical analysis, while the other half was used for histopathological and immunohistochemical analyses. In terms of histopathology, a lumbar spinal cord with normal morphology was observed in the other groups, while morphological irregularity in gray matter, increased vacuolization and infiltration of white matter into gray matter were pronounced in the ELMAG rats. The cytoplasm of some neurons in the gray matter was shrunken and stained dark, and vacuoles were observed in the cytoplasms. The apoptotic index of glia cells and neurons were significantly higher in ELMAG compared to the other groups. Biochemical analysis revealed a significantly increased MDA value in ELMAG compared to CG, while SOD and GSH levels decreased significantly. In conclusion, our study results suggest that continuous exposure to a 900-MHz EMF for 1h a day through all stages of adolescence can result in impairments at both morphological and biochemical levels in the lumbar region spinal cords of Sprague Dawley rats.

**Kerimoğlu G, Hancı H, Baş O, Aslan A, Erol HS, Turgut A, Kaya H, Çankaya S, Sönmez OF, Odacı E. Pernicious effects of long-term, continuous 900-MHz electromagnetic field throughout adolescence on hippocampus morphology, biochemistry and pyramidal neuron numbers in 60-day-old Sprague Dawley male rats. J Chem Neuroanat. 77:169-175, 2016.**

The central nervous system (CNS) begins developing in the intrauterine period, a process that continues until adulthood. Contact with chemical substances, drugs or environmental agents such as electromagnetic field (EMF) during adolescence therefore has the

potential to disturb the development of the morphological architecture of components of the CNS (such as the hippocampus). The hippocampus is essential to such diverse functions as memory acquisition and integration and spatial maneuvering. EMF can result in severe damage to both the morphology of the hippocampus and its principal functions during adolescence. Although children and adolescents undergo greater exposure to EMF than adults, the information currently available regarding the effects of exposure to EMF during this period is as yet insufficient. This study investigated the 60-day-old male rat hippocampus following exposure to 900 megahertz (MHz) EMF throughout the adolescent period using stereological, histopathological and biochemical analysis techniques. Eighteen male Sprague Dawley rats aged 21days were assigned into control, sham and EMF groups on a random basis. No procedure was performed on the control group rats. The EMF group (EMFGr) was exposed to a 900-MHz EMF for 1h daily from beginning to end of adolescence. The sham group rats were held in the EMF cage but were not exposed to EMF. All rats were sacrificed at 60days of age. Their brains were extracted and halved. The left hemispheres were set aside for biochemical analyses and the right hemispheres were subjected to stereological and histopathological evaluation. Histopathological examination revealed increased numbers of pyknotic neurons with black or dark blue cytoplasm on EMFGr slides stained with cresyl violet. Stereological analyses revealed fewer pyramidal neurons in EMFGr than in the other two groups. Biochemical analyses showed an increase in malondialdehyde and glutathione levels, but a decrease in catalase levels in EMFGr. Our results indicate that oxidative stress-related morphological damage and pyramidal neuron loss may be observed in the rat hippocampus following exposure to 900-MHz EMF throughout the adolescent period.

**Kesari KK, Behari J. Fifty-gigahertz Microwave exposure effect of radiations on rat brain. Appl Biochem Biotechnol. 158(1):126-139,2009.**

The object of this study is to investigate the effects of 50-GHz microwave radiation on the brain of Wistar rats. Male rats of the Wistar strain were used in the study. Animals of 60-day age were divided into two groups-group 1, sham-exposed, and group 2, experimental (microwave-exposed). The rats were housed in a temperature-controlled room (25 degrees C) with constant humidity (40-50%) and received food and water ad libitum. During exposure, rats were placed in Plexiglas cages with drilled ventilation holes and kept in an anechoic chamber. The animals were exposed for 2 h a day for 45 days continuously at a power level of 0.86 muW/cm(2) with nominal specific absorption rate 8.0 x 10(-4) w/kg. After the exposure period, the rats were killed and homogenized, and protein kinase C (PKC), DNA double-strand break, and antioxidant enzyme activity [superoxides dismutase (SOD), catalase, and glutathione peroxidase (GPx)] were estimated in the whole brain. Result shows that the chronic exposure to these radiations causes DNA double-strand break (head and tail length, intensity and tail migration) and a significant decrease in GPx and SOD activity ($p = <0.05$) in brain cells, whereas catalase activity shows significant increase in the exposed group of brain samples as compared with control ($p = <0.001$). In addition to these, PKC decreased significantly in whole brain and hippocampus ($p < 0.05$). All data are expressed as mean +/- standard deviation. We conclude that these radiations can have a significant effect on the whole brain.

**Kesari KK, Behari J. Microwave exposure affecting reproductive system in male rats. Appl Biochem Biotechnol. Microwave exposure affecting reproductive system in male rats 31(6):495-498, 2010.**

The object of present study is to investigate the effects of 50 GHz microwave frequency electromagnetic fields on reproductive system of male rats. Male rats of Wistar strain were used in the study. Animals 60 days old were divided into two groups-group I sham exposed and group II experimental (microwave exposed). During exposure, rats were confined in Plexiglas cages with drilled ventilation holes for 2 h a day for 45 days continuously at a specified specific absorption rate of 8.0 x 10(-4) W/kg. After the last exposure, the rats were sacrificed immediately and sperms were collected. Antioxidant enzyme (superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase), histone kinase, apoptosis, and cell cycle were analyzed in sperm cells. Result shows a significant decrease in the level of sperm GPx and SOD activity (p </= 0.05), whereas catalase shows significant increase in exposed group of sperm samples as compared with control (p < 0.02). We observed a statistically significant decrease in mean activity of histone kinase as compared to the control (p < 0.016). The percentage of cells dividing in a spermatogenesis was estimated by analyzing DNA per cell by flow cytometry. The percentage of apoptosis in electromagnetic field exposed group shows increased ratio as compared to sham exposed (p < 0.004). There were no significant differences in the G(0)/G(1) phase; however, a significant decrease (p < 0.026) in S phase was obtained. Results also indicate a decrease in percentage of G(2)/M transition phase of cell cycle in exposed group as compared to sham exposed (p < 0.019). We conclude that these radiations may have a significant effect on reproductive system of male rats, which may be an indication of male infertility.

**Kesari KK, Behari J, Kumar S. Mutagenic response of 2.45 GHz radiation exposure on rat brain. Int J Radiat Biol. 86(4):334-343, 2010.**

Purpose: To investigate the effect of 2.45 GHz microwave radiation on rat brain of male wistar strain. Material and methods: Male rats of wistar strain (35 days old with 130 +/- 10 g body weight) were selected for this study. Animals were divided into two groups: Sham exposed and experimental. Animals were exposed for 2 h a day for 35 days to 2.45 GHz frequency at 0.34 mW/cm(2) power density. The whole body specific absorption rate (SAR) was estimated to be 0.11 W/Kg. Exposure took place in a ventilated Plexiglas cage and kept in anechoic chamber in a far field configuration from the horn antenna. After the completion of exposure period, rats were sacrificed and the whole brain tissue was dissected and used for study of double strand DNA (Deoxyribonucleic acid) breaks by micro gel electrophoresis and the statistical analysis was carried out using comet assay (IV-2 version software). Thereafter, antioxidant enzymes and histone kinase estimation was also performed. Results: A significant increase was observed in comet head (P < 0.002), tail length (P < 0.0002) and in tail movement (P < 0.0001) in exposed brain cells. An analysis of antioxidant enzymes glutathione peroxidase (P < 0.005), and superoxide dismutase (P < 0.006) showed a decrease while an increase in catalase (P < 0.006) was observed. A significant decrease (P < 0.023) in histone kinase was also recorded in the exposed group as compared to the control (sham-exposed) ones. One-way

analysis of variance (ANOVA) method was adopted for statistical analysis. Conclusion: The study concludes that the chronic exposure to these radiations may cause significant damage to brain, which may be an indication of possible tumour promotion (Behari and Paulraj 2007 ).

**Kesari KK, Kumar S, Behari J. Mobile phone usage and male infertility in Wistar rats. Indian J Exp Biol. 48(10):987-992, 2010.**

A significant decrease in protein kinase C and total sperm count along with increased apoptosis were observed in male Wistar rats exposed to mobile phone frequencies (2 h/day x 35 days at 0.9 W/kg specific absorption rate). The results suggest that a reduction in protein kinase activity may be related to overproduction of reactive oxygen species (ROS) under microwave field exposure. Decrease in sperm count and an increase in apoptosis may be causative factor due to mobile radiation exposure leading to infertility.

**Kesari KK, Kumar S, Behari J. Effects of Radiofrequency Electromagnetic Wave Exposure from Cellular Phones on the Reproductive Pattern in Male Wistar Rats. Appl Biochem Biotechnol. 164(4):546-559, 2011.**

The present study investigates the effect of free radical formation due to mobile phone exposure and effect on fertility pattern in 70-day-old male Wistar rats (sham exposed and exposed). Exposure took place in Plexiglas cages for 2 h a day for 35 days to mobile phone frequency. The specific absorption rate was estimated to be 0.9 W/kg. An analysis of antioxidant enzymes glutathione peroxidase ($P < 0.001$) and superoxide dismutase ($P < 0.007$) showed a decrease, while an increase in catalase ($P < 0.005$) was observed. Malondialdehyde ($P < 0.003$) showed an increase and histone kinase ($P = 0.006$) showed a significant decrease in the exposed group. Micronuclei also show a significant decrease ($P < 0.002$) in the exposed group. A significant change in sperm cell cycle of G(0)-G(1) ($P = 0.042$) and G(2)/M ($P = 0.022$) were recorded. Generation of free radicals was recorded to be significantly increased ($P = 0.035$). Our findings on antioxidant, malondialdehyde, histone kinase, micronuclei, and sperm cell cycle are clear indications of an infertility pattern, initiated due to an overproduction of reactive oxygen species. It is concluded that radiofrequency electromagnetic wave from commercially available cell phones might affect the fertilizing potential of spermatozoa.

**Kesari KK, Kumar S, Behari J. 900-MHz microwave radiation promotes oxidation in rat brain. Electromagn Biol Med. 30(4):219-234, 2011.**

Recently, there have been several reports referring to detrimental effects due to radio frequency electromagnetic fields (RF-EMF) exposure. Special attention was given to investigate the effect of mobile phone exposure on the rat brain. Since the integrative mechanism of the entire body lies in the brain, it is suggestive to analyze its biochemical aspects. For this, 35-day old Wistar rats were exposed to a mobile phone for 2 h per day for a duration of 45 days where specific absorption rate (SAR) was 0.9 W/Kg. Animals were divided in two groups: sham exposed ($n = 6$) and exposed group ($n = 6$). Our observations indicate a significant decrease ($P < 0.05$) in

the level of glutathione peroxidase, superoxide dismutase, and an increase in catalase activity. Moreover, protein kinase shows a significant decrease in exposed group ($P < 0.05$) of hippocampus and whole brain. Also, a significant decrease ($P < 0.05$) in the level of pineal melatonin and a significant increase ($P < 0.05$) in creatine kinase and caspase 3 was observed in exposed group of whole brain as compared with sham exposed. Finally, a significant increase in the level of ROS (reactive oxygen species) ($P < 0.05$) was also recorded. The study concludes that a reduction or an increase in antioxidative enzyme activities, protein kinase C, melatonin, caspase 3, and creatine kinase are related to overproduction of reactive oxygen species (ROS) in animals under mobile phone radiation exposure. Our findings on these biomarkers are clear indications of possible health implications.

**Kesari KK, Behari J. Evidence for mobile phone radiation exposure effects on reproductive pattern of male rats: Role of ROS. Electromagn Biol Med. 31(3):213-22, 2012.**

The relationship between radiofrequency electromagnetic fields emitted from mobile phone and infertility is a matter of continuing debate. It is postulated that these radiations may affect the reproduction pattern spell by targeting biochemistry of sperm. In an attempt to expedite the issue, 70 days old Wistar rats ($n = 6$) were exposed to mobile phone radiofrequency (RF) radiation for 2 h per day for 45 days and data compared with sham exposed ($n = 6$) group. A significant decrease ($P < 0.05$) in the level of testosterone and an increase in caspase-3 activity were found in the RF-exposed animals. Distortions in sperm head and mid piece of sperm mitochondrial sheath were also observed as captured by Transmission Electron Microscope (TEM). In addition, progeny from RF-exposed rats showed significant decreases in number and weight as compared with that of sham-exposed animals. A reduction in testosterone, an increase in caspase-3, and distortion in spermatozoa could be caused by overproduction of reactive oxygen species (ROS) in animals under mobile phone radiation exposure. Our findings on these biomarkers are clear indications of possible health implications of repeated exposure to mobile phone radiation.

**Kesari KK, Kumar S, Behari J. Pathophysiology of microwave radiation: effect on rat brain.Appl Biochem Biotechnol. 166(2):379-388, 2012.**

The study aims to investigate the effect of 2.45 GHz microwave radiation on Wistar rats. Rats of 35 days old with $130 \pm 10$ g body weight were selected for this study. Animals were divided into two groups: sham exposed and experimental (six animals each). Animals were exposed for 2 h a day for 45 days at 2.45 GHz frequency (power density, 0.21 mW/cm(2)). The whole body specific absorption rate was estimated to be 0.14 W/kg. Exposure took place in a ventilated plexiglas cage and kept in an anechoic chamber under a horn antenna. After completion of the exposure period, rats were killed, and pineal gland and whole brain tissues were isolated for the estimation of melatonin, creatine kinase, caspase 3, and calcium ion concentration. Experiments were performed in a blind manner and repeated. A significant decrease ($P < 0.05$) was recorded in the

level of pineal melatonin of exposed group as compared with sham exposed. A significant increase ($P < 0.05$) in creatine kinase, caspase 3, and calcium ion concentration was observed in whole brain of exposed group of animals as compared to sham exposed. One-way analysis of variance method was adopted for statistical analysis. The study concludes that a reduction in melatonin or an increase in caspase-3, creatine kinase, and calcium ion may cause significant damage in brain due to chronic exposure of these radiations. These biomarkers clearly indicate possible health implications of such exposures.

**Kesari KK, Kumar S, Nirala J, Siddiqui MH, Behari J. Biophysical Evaluation of Radiofrequency Electromagnetic Field Effects on Male Reproductive Pattern. Cell Biochem Biophys. 65(2): 85-96, 2013 .**

There are possible hazardous health effects of exposure to radiofrequency electromagnetic radiations emitted from mobile phone on the human reproductive pattern. It is more effective while keeping mobile phones in pocket or near testicular organs. Present review examines the possible concern on radio frequency radiation interaction and biological effects such as enzyme induction, and toxicological effects, including genotoxicity and carcinogenicity, testicular cancer, and reproductive outcomes. Testicular infertility or testicular cancer due to mobile phone or microwave radiations suggests an increased level of reactive oxygen species (ROS). Though generation of ROS in testis has been responsible for possible toxic effects on physiology of reproduction, the reviews of last few decades have well established that these radiations are very harmful and cause mutagenic changes in reproductive pattern and leads to infertility. The debate will be focused on bio-interaction mechanism between mobile phone and testicular cancer due to ROS formation. This causes the biological damage and leads to several changes like decreased sperm count, enzymatic and hormonal changes, DNA damage, and apoptosis formation. In the present review, physics of mobile phone including future research on various aspects has been discussed.

**Kesari KK, Meena R, Nirala J, Kumar J, Verma HN. Effect of 3G cell phone exposure with computer controlled 2-D stepper motor on non-thermal activation of the hsp27/p38MAPK stress pathway in rat brain. Cell Biochem Biophys. 68(2):347-358, 2014.**

Cell phone radiation exposure and its biological interaction is the present concern of debate. Present study aimed to investigate the effect of 3G cell phone exposure with computer controlled 2-D stepper motor on 45-day-old male Wistar rat brain. Animals were exposed for 2 h a day for 60 days by using mobile phone with angular movement up to zero to 30°. The variation of the motor is restricted to 90° with respect to the horizontal plane, moving at a pre-determined rate of 2° per minute. Immediately after 60 days of exposure, animals were scarified and numbers of parameters (DNA double-strand break, micronuclei, caspase 3, apoptosis, DNA fragmentation, expression of stress-responsive genes) were performed. Result shows that microwave radiation emitted from 3G mobile phone significantly induced DNA strand breaks in brain. Meanwhile a significant increase

in micronuclei, caspase 3 and apoptosis were also observed in exposed group ($P < 0.05$). Western blotting result shows that 3G mobile phone exposure causes a transient increase in phosphorylation of hsp27, hsp70, and p38 mitogen-activated protein kinase (p38MAPK), which leads to mitochondrial dysfunction-mediated cytochrome c release and subsequent activation of caspases, involved in the process of radiation-induced apoptotic cell death. Study shows that the oxidative stress is the main factor which activates a variety of cellular signal transduction pathways, among them the hsp27/p38MAPK is the pathway of principle stress response. Results conclude that 3G mobile phone radiations affect the brain function and cause several neurological disorders.

**Keshvari J, Lang S. Comparison of radio frequency energy absorption in ear and eye region of children and adults at 900, 1800 and 2450 MHz. Phys Med Biol. 50(18):4355-4369, 2005.**

The increasing use of mobile communication devices, especially mobile phones by children, has triggered discussions on whether there is a larger radio frequency (RF) energy absorption in the heads of children compared to that of adults. The objective of this study was to clarify possible differences in RF energy absorption in the head region of children and adults using computational techniques. Using the finite-difference time-domain (FDTD) computational method, a set of specific absorption rate (SAR) calculations were performed for anatomically correct adult and child head models. A half-wave dipole was used as an exposure source at 900, 1800 and 2450 MHz frequencies. The ear and eye regions were studied representing realistic exposure scenarios to current and upcoming mobile wireless communication devices. The differences in absorption were compared with the maximum energy absorption of the head model. Four magnetic resonance imaging (MRI) based head models, one female, one adult, two child head models, aged 3 and 7 years, were used. The head models greatly differ from each other in terms of size, external shape and the internal anatomy. The same tissue dielectric parameters were applied for all models. The analyses suggest that the SAR difference between adults and children is more likely caused by the general differences in the head anatomy and geometry of the individuals rather than age. It seems that the external shape of the head and the distribution of different tissues within the head play a significant role in the RF energy absorption.

**Keshvari J, Heikkilä T. Volume-averaged SAR in adult and child head models when using mobile phones: a computational study with detailed CAD-based models of commercial mobile phones. Prog Biophys Mol Biol. 107(3):439-442, 2011.**

Previous studies comparing SAR difference in the head of children and adults used highly simplified generic models or half-wave dipole antennas. The objective of this study was to investigate the SAR difference in the head of children and adults using realistic EMF sources based on CAD models of commercial mobile phones. Four MRI-based head phantoms were used in the study. CAD models of Nokia 8310 and 6630 mobile phones were used as exposure sources. Commercially available FDTD software was used for the SAR calculations. SAR values were simulated at frequencies 900 MHz and 1747 MHz for Nokia 8310, and 900 MHz, 1747 MHz and

1950 MHz for Nokia 6630. The main finding of this study was that the SAR distribution/variation in the head models highly depends on the structure of the antenna and phone model, which suggests that the type of the exposure source is the main parameter in EMF exposure studies to be focused on. Although the previous findings regarding significant role of the anatomy of the head, phone position, frequency, local tissue inhomogeneity and tissue composition specifically in the exposed area on SAR difference were confirmed, the SAR values and SAR distributions caused by generic source models cannot be extrapolated to the real device exposures. The general conclusion is that from a volume averaged SAR point of view, no systematic differences between child and adult heads were found.

**Keshvari J, Keshvari R, Lang S. The effect of increase in dielectric values on specific absorption rate (SAR) in eye and head tissues following 900, 1800 and 2450 MHz radio frequency (RF) exposure. Phys Med Biol. 51(6):1463-1477, 2006.**

Numerous studies have attempted to address the question of the RF energy absorption difference between children and adults using computational methods. They have assumed the same dielectric parameters for child and adult head models in SAR calculations. This has been criticized by many researchers who have stated that child organs are not fully developed, their anatomy is different and also their tissue composition is slightly different with higher water content. Higher water content would affect dielectric values, which in turn would have an effect on RF energy absorption. The objective of this study was to investigate possible variation in specific absorption rate (SAR) in the head region of children and adults by applying the finite-difference time-domain (FDTD) method and using anatomically correct child and adult head models. In the calculations, the conductivity and permittivity of all tissues were increased from 5 to 20% but using otherwise the same exposure conditions. A half-wave dipole antenna was used as an exposure source to minimize the uncertainties of the positioning of a real mobile device and making the simulations easily replicable. Common mobile telephony frequencies of 900, 1800 and 2450 MHz were used in this study. The exposures of ear and eye regions were investigated. The SARs of models with increased dielectric values were compared to the SARs of the models where dielectric values were unchanged. The analyses suggest that increasing the value of dielectric parameters does not necessarily mean that volume-averaged SAR would increase. Under many exposure conditions, specifically at higher frequencies in eye exposure, volume-averaged SAR decreases. An increase of up to 20% in dielectric conductivity or both conductivity and permittivity always caused a SAR variation of less than 20%, usually about 5%, when it was averaged over 1, 5 or 10 g of cubic mass for all models. The thickness and composition of different tissue layers in the exposed regions within the human head play a more significant role in SAR variation compared to the variations (5-20%) of the tissue dielectric parameters.

**Ketabi N, Mobasheri H, Faraji-Dana R. Electromagnetic fields (UHF) increase voltage sensitivity of membrane ion channels; possible indication of cell phone effect on living cells. Electromagn Biol Med. 2013 Nov 15. [Epub ahead of print]**

The effects of ultra high frequency (UHF) nonionizing electromagnetic fields (EMF) on the channel activities of nanopore forming protein, OmpF porin, were investigated. The voltage clamp technique was used to study the single channel activity of the pore in an artificial bilayer in the presence and absence of the electromagnetic fields at 910 to 990 MHz in real time. Channel activity patterns were used to address the effect of EMF on the dynamic, arrangement and dielectric properties of water molecules, as well as on the hydration state and arrangements of side chains lining the channel barrel. Based on the varied voltage sensitivity of the channel at different temperatures in the presence and absence of EMF, the amount of energy transferred to nano-environments of accessible groups was estimated to address the possible thermal effects of EMF. Our results show that the effects of EMF on channel activities are frequency dependent, with a maximum effect at 930 MHz. The frequency of channel gating and the voltage sensitivity is increased when the channel is exposed to EMF, while its conductance remains unchanged at all frequencies applied. We have not identified any changes in the capacitance and permeability of membrane in the presence of EMF. The effect of the EMF irradiated by cell phones is measured by Specific Absorption Rate (SAR) in artificial model of human head, Phantom. Thus, current approach applied to biological molecules and electrolytes might be considered as complement to evaluate safety of irradiating sources on biological matter at molecular level.

**Khalil AM, Gagaa M, Alshamali A. 8-Oxo-7, 8-dihydro-2'-deoxyguanosine as a biomarker of DNA damage by mobile phone radiation. Hum Exp Toxicol.31(7):734-740, 2012.**

We examined the effect of exposure to mobile phone 1800 MHz radio frequency radiation (RFR) upon the urinary excretion of 8-oxo-7, 8-dihydro-2'-deoxyguanosine (8-oxodG), one major form of oxidative DNA damage, in adult male Sprague-Dawley rats. Twenty-four rats were used in three independent experiments (RFR exposed and control, 12 rats, each). The animals were exposed to RFR for 2 h from Global System for Mobile Communications (GSM) signal generator with whole-body-specific absorption rate of 1.0 W/kg. Urine samples were collected from the rat while housed in a metabolic cage during the exposure period over a 4-h period at 0.5, 1.0, 2.0 and 4.0 h from the beginning of exposure. In the control group, the signal generator was left in the turn-off position. The creatinine-standardized concentrations of 8-oxodG were measured. With the exception of the urine collected in the last half an hour of exposure, significant elevations were noticed in the levels of 8-oxodG in urine samples from rats exposed to RFR when compared to control animals. Significant differences were seen overall across time points of urine collection with a maximum at 1 h after exposure, suggesting repair of the DNA lesions leading to 8-oxodG formation.

**Khalil AM, Abu Khadra KM, Aljaberi AM, Gagaa MH, Issa HS. Assessment of oxidant/antioxidant status in saliva of cell phone users. Electromagn Biol Med. 2013 Jun 19. [Epub ahead of print]**

Hazardous health effects resulting from exposure to radiofrequency electromagnetic radiation (RF-EMR) emitted from cell phones have been reported in the literature. However, the cellular and molecular targets of RF-EMR are still controversial. The aim of this study was to examine the oxidant/antioxidant status in saliva of cell phone users. Saliva samples collected before using a cell phone as well as at the end of 15 and 30 min calls were tested for two commonly used oxidative stress biomarkers: malondialdehyde (MDA) and 8-oxo-7,8-dihydro-2'-deoxyguanosine (8-Oxo-dG). The 8-oxo-dG levels were determined by enzyme-linked immunosorbent (ELISA) competitive assay, while the MDA levels were measured using the OxiSelect MDA adduct ELISA Kit. The antioxidant capacity of the saliva was evaluated using the oxygen radical absorption capacity (ORAC) and the hydroxyl radical averting capacity (HORAC) assays according to the manufacture instructions. The mean 8-oxo-dG and the Bradford protein concentrations (ng/ml and mg/ml, respectively) peaked at 15 min. The levels of HORAC, ORAC and MDA progressively increased with time and reached maximum at 30 min. However, there was no significant effect of talking time on the levels of 8-OxodG and MDA. Similarly, there was no statistically significant effect of talking time on the oxygen and hydroxyl radicals averting capacities, (ORAC) and (HORAC), respectively. These findings suggest that there is no relationship between exposure to radio frequency radiation (RFR) and changes in the salivary oxidant/antioxidant profile.

**Khan MM. Adverse effects of excessive mobile phone use.Int J Occup Med Environ Health. 21(4):289-293, 2008.**

Introduction: Research findings indicate that the use of mobile phones may lead to a number of symptoms such as headache, impaired concentration and memory, and also fatigue. Materials and Methods: The present study was designed to investigate whether the symptoms of ill health reported by young people may be associated with the use of mobile phone (MP) and to analyze its influence on health and development of medical students. The questionnaire was designed specifically for this study and contained items regarding health condition and health complaints as well as the frequency of MP use. The response rate was 86.6% (286 of 330 forms, completed by 73.77% males and 26.22% females). Results: Most of the subjects (83.57%) had some knowledge about the adverse effects of MP use. 76.92% of the students carried one mobile, and 23.08% more than one. 55.94%, of the subjects reported the average daily MP use of less than 30 min, 27.97%, of 30-60 min, 11.53%, of 60-90 min and 4.54% of more than 90 min. 16.08% of the subjects complained of headache and 24.48% of fatigue. Impaired concentration was reported by 34.27% of respondents, memory disturbances by 40.56%, sleeplessness by 38.8%, hearing problems by 23.07%, and facial dermatitis by 16.78%. The sensation of warmth within the auricle and behind/around the ear was reported by 28.32%. Out of 286 subjects who participated in this study, 44.4% related their symptoms to mobile phone use. Conclusions: The findings of the present study indicate that mobile

phones play a large part in the daily life of medical students. Therefore, its impact on psychology and health should be discussed among the students to prevent the harmful effects of mobile phone use.

**Khramov RN, Sosunov EA, Koltun SV, Ilyasova EN, Lednev VV, Millimeter-wave effects on electric activity of crayfish stretch receptors. Bioelectromagnetics 12(4):203-214, 1991.**

The effects of super high frequency (SHF) microwaves (34-78 GHz) on rates of spontaneous firing of the slowly adapting, stretch-receptor neurons of crayfish were studied. Initially, irradiation of continuously perfused, fluid-cooled preparations at power densities to 250 mW/cm2 caused a transient decrease in the rate of spontaneous firing (the dynamic response). Subsequently, with extinction of the SHF field, the rate of firing increased, finally stabilizing at pre-exposure levels (stationary phase). Rates of firing also increased when the receptor muscle was stretched, and they were inversely correlated with small, field-induced increases of temperature (approximately 1.5 degrees C). The response to SHF radiation did not depend on frequency if temperature of the medium was constant. No resonant peaks were found when the millimeter range of frequencies was scanned.

**Khudnitskii, SS, Moshkarev, EA, Fomenko, TV, [On the evaluation of the influence of cellular phones on their users]. [Article in Russian] Med Tr Prom Ekol (9):20-24, 1999.**

The authors studied influence of ultrahigh frequency radiation caused by cellular phones on functional state of central nervous, cardiovascular systems and local temperature changes in cellular phones users. The head area near the phone antenna appeared to be under the most intensive heating. Ultrahigh frequency radiation induces significant changes in local temperature and in physiologic parameters of central nervous and cardiovascular systems.

**Khullar S1, Sood A2, Sood S3. Auditory Brainstem Responses and EMFs Generated by Mobile Phones. Indian J Otolaryngol Head Neck Surg. 65(Suppl 3):645-649, 2013.**

There has been a manifold increase in the number of mobile phone users throughout the world with the current number of users exceeding 2 billion. However this advancement in technology like many others is accompanied by a progressive increase in the frequency and intensity of electromagnetic waves without consideration of the health consequences. The aim of our study was to advance our understanding of the potential adverse effects of GSM mobile phones on auditory brainstem responses (ABRs). 60 subjects were selected for the study and divided into three groups of 20 each based on their usage of mobile phones. Their ABRs were recorded and analysed for latency of waves I-V as well as interpeak latencies I-III, I-V and III-V (in ms). Results revealed no significant difference in the ABR parameters between group A (control group) and group B (subjects using mobile phones for maximum 30 min/day for 5 years). However the latency of waves was significantly prolonged in group C (subjects using mobile phones for 10 years for a

maximum of 30 min/day) as compared to the control group. Based on our findings we concluded that long term exposure to mobile phones may affect conduction in the peripheral portion of the auditory pathway. However more research needs to be done to study the long term effects of mobile phones particularly of newer technologies like smart phones and 3G.

**Khurana VG, Hardell L, Everaert J, Bortkiewicz A, Carlberg M, Ahonen M. Epidemiological evidence for a health risk from mobile phone base stations.Int J Occup Environ Health. 16(3):263-267, 2010.**

Human populations are increasingly exposed to microwave/radiofrequency (RF) emissions from wireless communication technology, including mobile phones and their base stations. By searching PubMed, we identified a total of 10 epidemiological studies that assessed for putative health effects of mobile phone base stations. Seven of these studies explored the association between base station proximity and neurobehavioral effects and three investigated cancer. We found that eight of the 10 studies reported increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances < 500 meters from base stations. None of the studies reported exposure above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations. We believe that comprehensive epidemiological studies of long-term mobile phone base station exposure are urgently required to more definitively understand its health impact.

**Kilgallon SJ, Simmons LW. Image content influences men's semen quality. Biol Lett 1:252-255, 2005.**

There is increasing evidence from non-human animals that males adjust their ejaculation expenditure according to the risk of sperm competition. In this study we show that, after controlling for lifestyle factors known to influence semen quality, human males viewing images depicting sperm competition had a higher percentage of motile sperm in their ejaculates. Many lifestyle variables were confirmed to influence semen quality, including the recent suggestion that storage of mobile phones close to the testes can decrease semen quality.

**Kim BC, Park SO. Evaluation of RF electromagnetic field exposure levels from cellular base stations in Korea. Bioelectromagnetics. 31(6):495-498, 2010.**

This article presents the measurement results of human exposure to CDMA800 and CDMA1800 signals at locations in Korea where the general public has expressed concern. Measurements were performed at 50 locations across the country to compare the electromagnetic field levels with the general public exposure compliance limits. At each site, the distances between the nearest single or co-located base station and measurement positions were within a range of approximately 32-422 m. The measured exposure levels were very low compared with the international standard and the Korean human protection notice. The highest field level was 1.5 V/m, which corresponds to 0.15% of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for human exposure.

**Kim BC, Kim W-K, Lee G-T, Choi H-D, Kim N, Pack J-K. Evaluation of radiofrequency exposure levels from multiple wireless installations in population dense areas in Korea. Bioelectromagnetics. Published online: 4 SEP 2014 | DOI: 10.1002/bem.21874.**

This paper presents the results of measurements from simultaneous human exposure to various radiofrequency (RF) signals at densely populated areas. Measurements were performed at 1260 positions across Korea to determine exposure compliance to electromagnetic fields for the general public. The measured exposure levels were very low compared with the international exposure guidelines and Korean human protection notice. The highest total exposure ratio was $5.1 \times 10^{-3}$ (approximately 7.1% of guideline limits).

**Kim DW, Lee JH, Ji HC, Kim SC, Nam KC, Cha EJ. Physiological effects of RF exposure on hypersensitive people by a cell phone. Conf Proc IEEE Eng Med Biol Soc. 2008:2322-2325, 2008.**

Persons with electromagnetic hypersensitivity (EHS) complain of subjective symptoms such as headaches, insomnia, memory loss etc. resulting from radio frequency (RF) radiation by cellular phones. There have been various EHS provocation studies on heart rate, blood pressure, and subjective symptoms using GSM phones. However, there are few provocation studies on case-control study investigating simultaneously physiological parameters from CDMA phones. In this study, two volunteer groups of 18 self-declared EHS and 19 controls were exposed to both sham and real RF exposures by a CDMA cellular phone for half an hour each. We investigated the physiological parameters such as heart rates, respiration rates, and hear rate variability (HRV). In conclusion, the RF exposure by a CDMA cellular phone did not have any effects on the physiological parameters for both groups.

**Kim HS, An YS, Paik MJ, Lee YS, Choi HD, Kim BC, Pack JK, Kim N, Ahn YH. The effects of exposure to 915 MHz radiofrequency identification on cerebral glucose metabolism in rat: A [F-18] FDG micro-PET study. Int J Radiat Biol. 2013 May 7. [Epub ahead of print]**

Purpose: We investigated the effect of whole-body exposure to 915-MHz radiofrequency identification (RFID) on rat cortical glucose metabolism by using $^{18}$F-deoxyglucose positron emission tomography (FDG-PET). Materials and methods: Male Sprague-Dawley rats were divided into three groups: Cage-control, sham-exposed and RFID-exposed groups. Rats were exposed to the 915-MHz RFID for 8 h daily, 5 days per week, for 2 or 16 weeks. The whole-body average specific absorption rate (SAR) was 4 W/kg for the field of the 915 MHz RFID signal. FDG-PET images were obtained the day after RFID exposure, using micro-PET with a FDG tracer. With a Xeleris functional imaging workstation, absolute values in regions of interest (ROI) in the frontal, temporal and parietal cortexes and cerebellum were measured. Cortical ROI values were normalized to the cerebellar value and compared. Results: The data showed that the relative cerebral glucose metabolic rate

was unchanged in the frontal, temporal and parietal cortexes of the 915 MHz RFID-exposed rats, compared with rats in cage-control and sham-exposed groups. Conclusion: Our results suggest that 915_MHz_RFID radiation exposure did not cause a significant long lasting effect on glucose metabolism in the rat brain.

**Kim HS, Kim YJ, Lee YH, Lee YS, Choi HD, Pack JK, Kim N, Ahn YH. Effect of whole-body exposure to the 848.5-MHz code division multiple access (CDMA) electromagnetic field on adult neurogenesis in the young, healthy rat brain. Int J Radiat Biol. 2014 Dec 15:1-15. [Epub ahead of print]**

Introduction: Whether exposure to the 848.5-MHz code division multiple access (CDMA) signal affects adult neurogenesis is unclear. Materials and methods: An animal experiment was performed with a reverberation chamber designed as a whole-body CDMA exposure system. Male Sprague-Dawley rats were assigned to three groups (n = 6 per group): cage-control, sham-exposed, and CDMA-exposed groups. Rats in the CDMA-exposed group were exposed to the CDMA signal at a 2 W/kg whole-body specific absorption rate (SAR) for 1 or 8 h daily, 5 days per week, for 2 weeks. Rats received a single intraperitoneal injection of Bromodeoxyuridine (BrdU) to label proliferative cells daily for the last five consecutive days of CDMA signal exposure. An unbiased stereological method was used to estimate the number of $BrdU^+$ cells in the subventricular zone (SVZ) and dentate gyrus (DG). Results: We found no significant changes in the number of $BrdU^+$ cells in the SVZ or DG in the CDMA-exposed rats, compared with rats in the cage-control and sham-exposed groups ($p > 0.05$). Conclusion: Our results suggest that exposure to the CDMA signal does not affect neurogenesis in the adult rat brain, at least under our experimental conditions.

**Kim HS, Park JS, Jin YB, Do Choi H, Kwon JH, Pack JK, Kim N, Ahn YH. Effects of exposure to electromagnetic field from 915 MHz radiofrequency identification system on circulating blood cells in the healthy adult rat. Bioelectromagnetics. 2017 Nov 24. doi: 10.1002/bem.22093.**

We investigated whether exposure to the 915 MHz radiofrequency identification (RFID) signal affected circulating blood cells in rats. Sprague-Dawley rats were exposed to RFID at a whole-body specific absorption rate of 2 W/kg for 8 h per day, 5 days per week, for 2 weeks. Complete blood counts were performed after RFID exposure, and the CD4+ /CD8+ ratio was determined by flow cytometry. The number of red blood cells (RBCs) and the values of hemoglobin, hematocrit, and RBC indices were increased in the RFID-exposed group compared with those in the cage-control and sham-exposed groups ($P < 0.05$). However, the RBCs and platelet numbers were within normal physiologic response ranges. The number of white blood cells, including lymphocytes, was decreased in RFID-exposed rats. However, there was no statistically significant difference between the sham-exposed and RFID-exposed groups in terms of T-cell counts or CD4+ /CD8+.

**Kim JH, Kim HJ, Yu DH, Kweon HS, Huh YH, Kim HR. Changes in numbers and size of synaptic vesicles of cortical neurons induced by exposure to 835 MHz**

**radiofrequency-electromagnetic field. PLoS One. 2017 Oct 18;12(10):e0186416.**

We studied the effects of radiofrequency electromagnetic fields (RF-EMFs) exposure on neuronal functions of mice. Particularly, we focused on RF-EMF effects on synaptic vesicles (SVs), which store neurotransmitters at axon terminals or synaptic boutons. C57 BL/6 mice were exposed to 835 MHz RF-EMF (4.0 W/kg SAR, for 5 h daily) and alterations in SVs at presynaptic terminals in the cerebral cortex were determined. Ultrastructure of randomly selected cortical neurons was observed using typical electron microscopy and bio-high voltage electron microscopy (Bio-HVEM) methods, which enable the estimation of the numbers and size of SVs. The density of the SVs (number /10 μm2 or 40 μm3) was significantly decreased in the presynaptic boutons of cortical neurons after RF-EMF exposure. Furthermore, qPCR and immunoblotting analyses revealed that the expression of synapsins I/II (Syns I/II) genes and proteins were significantly decreased in the cortical neurons of RF-EMF exposed mice. The present study suggested that alteration of SVs and Syn levels may result in alterations of neurotransmitters in the cerebral cortex following RF-EMF exposure.

**Kim JY, Hong SY, Lee YM, Yu SA, Koh WS, Hong JR, Son T, Chang SK, Lee M. In vitro assessment of clastogenicity of mobile-phone radiation (835 MHz) using the alkaline comet assay and chromosomal aberration test. Environ Toxicol. 23(3):319-327, 2008.**

Recently we demonstrated that 835-MHz radiofrequency radiation electromagnetic fields (RF-EMF) neither affected the reverse mutation frequency nor accelerated DNA degradation in vitro. Here, two kinds of cytogenetic endpoints were further investigated on mammalian cells exposed to 835-MHz RF-EMF (the most widely used communication frequency band in Korean CDMA mobile phone networks) alone and in combination with model clastogens: in vitro alkaline comet assay and in vitro chromosome aberration (CA) test. No direct cytogenetic effect of 835-MHz RF-EMF was found in the in vitro CA test. The combined exposure of the cells to RF-EMF in the presence of ethylmethanesulfonate (EMS) revealed a weak and insignificant cytogenetic effect when compared to cells exposed to EMS alone in CA test. Also, the comet assay results to evaluate the ability of RF-EMF alone to damage DNA were nearly negative, although showing a small increase in tail moment. However, the applied RF-EMF had potentiation effect in comet assay when administered in combination with model clastogens (cyclophosphamide or 4-nitroquinoline 1-oxide). Thus, our results imply that we cannot confidently exclude any possibility of an increased risk of genetic damage, with important implications for the possible health effects of exposure to 835-MHz electromagnetic fields.

**Kim JY, Kim HJ, Kim N, Kwon JH, Park MJ. Effects of radiofrequency field exposure on glutamate-induced oxidative stress in mouse hippocampal HT22 cells. Int J Radiat Biol. 2016 Sep 20:1-22. [Epub ahead of print]**

PURPOSE: To define the impact of radiofrequency (RF) under in vitro experimental Alzheimer's disease conditions, we investigated the effect of RF radiation on glutamate-induced oxidative stress in mouse hippocampal neuronal HT22 cells. MATERIALS AND METHODS: Cell survival rate was measured by MTT and trypan blue exclusion assays.

Cell cycle distribution, cell death, and ROS production were analyzed using flow cytometry. Expression of proteins was analyzed by Western blot. RESULTS: RF exposure alone had a marginal impact on cell proliferation, however significantly enhanced glutamate-induced cytotoxicity in HT22 cells. Glutamate augmented the subG1 fraction of cell cycle, annexin/propidium iodide positive cell population, and expression of cleaved poly (ADP ribose) polymerase, which were further increased by RF exposure. Glutamate induced reactive oxygen species (ROS) generation and RF exposure further upregulated it. N-acetylcysteine (NAC) treatment completely abrogated glutamate- and RF-induced ROS production followed by cell death and restored cell proliferation in HT22 cells. Finally, glutamate phosphorylated c-Jun N-terminal kinase (JNK) and RF increased this event further. Treatment with NAC and inhibitor of JNK decreased JNK phosphorylation and restored cell proliferation, respectively. CONCLUSIONS: Our results demonstrate that RF exposure enhanced glutamate-induced cytotoxicity by further increase of ROS production in HT22 cells.

**Kim K, Kim HJ, Song DJ, Cho YM, Choi JW. Risk perception and public concerns of electromagnetic waves from cellular phones in Korea. Bioelectromagnetics. 35(4):235-344, 2014.**

In this study, the difference between the risk perception of electromagnetic waves from cellular phones and the risk perception of other factors such as environment and food was analyzed. The cause of the difference in the psychological and social factors that affect the group with high risk perception of electromagnetic waves was also analyzed. A questionnaire survey on the risk perception of electromagnetic waves from cellular phones was carried out on 1001 subjects (men and women) over the age of 20. In the group with high risk perception of electromagnetic waves from cellular phones, women had higher risk perception than men. Logistic regression analysis, where the group with high risk perception of electromagnetic waves and the group with low risk perception were used as dependent variables, indicated that the risk perception of electromagnetic waves in women was 1.815 times statistically significantly higher than the risk perception of men (95% CI: 1.340-2.457). Also, high risk perception of electromagnetic waves from cellular phones was observed when the subjects considered that they had more personal knowledge (OR: 1.416, 95% CI: 1.216-1.648), that the seriousness of the risk to future generations was high (OR: 1.410, 95% CI: 1.234-1.611), and their outrage for the occurrence of accidents related to electromagnetic waves was high (OR: 1.460, 95% CI: 1.264-1.686). The results of this study need to be sufficiently considered and reflected in designing the risk communication strategies and communication methods for the preventive measures and advice on electromagnetic waves from cellular phones.

**Kim KB, Byun HO, Han NK, Ko YG, Choi HD, Kim N, Pack JK, Lee JS. Two-dimensional electrophoretic analysis of radio-frequency radiation-exposed MCF7 breast cancer cells. J Radiat Res. 51(2):205-213, 2010.**

Although many in vitro studies have previously been conducted to elucidate the biological effects of radio frequency (RF) radiation over the past decades, the existence and nature of any effects is still inconclusive. In an effort to further elucidate this question, we have

monitored changes in protein expression profiles in RF-exposed MCF7 human breast cancer cells using two-dimensional gel electrophoresis. MCF7 cells were exposed to 849 MHz RF radiation for 1 h per day for three consecutive days at specific absorption rates (SARs) of either 2 W/Kg or 10 W/kg. During exposure, the temperature in the exposure chamber was kept in an isothermal condition. Twenty-four hours after the final RF exposure, the protein lysates from MCF cells were prepared and two-dimensional electrophoretic analyses were conducted. The protein expression profiles of the MCF cells were not significantly altered as the result of RF exposure. None of the protein spots on the two-dimensional electrophoretic gels showed reproducible changes in three independent experiments. To determine effect of RF radiation on protein expression profiles more clearly, three spots showing altered expression without reproducibility were identified using electrospray ionization tandem mass spectrometry analysis and their expressions were examined with RT-PCR and Western blot assays. There was no alteration in their mRNA and protein levels. As we were unable to observe any significant and reproducible changes in the protein expression profiles of the RF radiation-exposed MCF7 cells using high throughput and non-high throughput techniques, it seems unlikely that RF exposure modulates the protein expression profile.

**Kim JH, Yu DH, Kim HJ, Huh YH, Cho SW, Lee JK, Kim HG, Kim HR. Exposure to 835 MHz radiofrequency electromagnetic field induces autophagy in hippocampus but not in brain stem of mice. Toxicol Ind Health. 2017 Jan 1:748233717740066. doi: 10.1177/0748233717740066.**

The exploding popularity of mobile phones and their close proximity to the brain when in use has raised public concern regarding possible adverse effects from exposure to radiofrequency electromagnetic fields (RF-EMF) on the central nervous system. Numerous studies have suggested that RF-EMF emitted by mobile phones can influence neuronal functions in the brain. Currently, there is still very limited information on what biological mechanisms influence neuronal cells of the brain. In the present study, we explored whether autophagy is triggered in the hippocampus or brain stem after RF-EMF exposure. C57BL/6 mice were exposed to 835 MHz RF-EMF with specific absorption rates (SAR) of 4.0 W/kg for 12 weeks; afterward, the hippocampus and brain stem of mice were dissected and analyzed. Quantitative real-time polymerase chain reaction (qRT-PCR) analysis demonstrated that several autophagic genes, which play key roles in autophagy regulation, were significantly upregulated only in the hippocampus and not in the brain stem. Expression levels of LC3B-II protein and p62, crucial autophagic regulatory proteins, were significantly changed only in the hippocampus. In parallel, transmission electron microscopy (TEM) revealed an increase in the number of autophagosomes and autolysosomes in the hippocampal neurons of RF-EMF-exposed mice. The present study revealed that autophagy was induced in the hippocampus, not in the brain stem, in 835 MHz RF-EMF with an SAR of 4.0 W/kg for 12 weeks. These results could suggest that among the various adaptation processes to the RF-EMF exposure environment, autophagic degradation is one possible mechanism in specific brain regions.

**Kim MJ, Rhee SJ. Green tea catechins protect rats from microwave-induced**

**oxidative damage to heart tissue. J Med Food. 7(3):299-304, 2004.**

We investigated the effects of **greentea** catechin on oxidative damage in microwave-exposed rats. The microwave-exposed rats received one of three diets: catechin-free (MW-0C), 0.25% catechin (MW-0.25C), or 0.5% catechin (MW-0.5C). Rats were sacrificed 6 days after microwave irradiation (2.45 GHz, 15 minutes). Cytochrome P(450) levels in the MW-0C group was increased by 85% compared with normal, but was 11% and 14% lower in the MW-0.25C and MW-0.5C groups than in the MW-0C group. NADPH-cytochrome P(450) reductase activity in the MW-0C group was increased by 29%, compared with the normal group, but was significantly less in the MW-0.25C and MW-0.5C groups. Superoxide dismutase activity in the MW-0C group was decreased by 34%, compared with the normal group, but in the MW-0.25C and MW-0.5C groups was 19% and 25% higher. The activity of glutathione peroxidase in the MW-0C group was decreased by 28% but remained near normal with catechin supplements. Superoxide radical concentrations in the MW-0C group were increased by 35%, compared with the normal group. However, superoxide radicals in the MW-0.25C and MW-0.5C groups were 11% and 12% lower, respectively, compared with the MW-0C group. Microwave irradiation significantly increased levels of thiobarbituric acid-reactive substances, carbonyl values, and lipofuscin contents, but **greentea** catechin partially overcame the effects of the microwave irradiation. In conclusion, the mixed function oxidase system was activated, the formation of superoxide radical, lipid peroxide, oxidized protein, and lipofuscin was increased, and the antioxidative defense system was weakened in heart tissue of microwave-exposed rats, but the oxidative damage was significantly reduced by catechin supplementation.

**Kim SC, Nam KC, Kim DW. Estimation of relative exposure levels for cellular phone users using a neural network. Bioelectromagnetics. 27(6):440-444, 2006.**

The wide and growing use of cellular phones has raised questions about the possible health risks associated with radio frequency (RF) electromagnetic fields. It would be helpful for epidemiologists as well as cellular phone users to obtain the relative exposure levels, because the RF exposure level is very difficult to accurately measure and quantify for all individuals. In this study, a neural network model was developed to estimate relative exposure levels on a scale of 0-10 and thus rank the individual risk of exposure using available information. We used parameters such as usage time per day, total usage period, hands-free usage, extension of antenna, specific absorption rate (SAR) of the cellular phone, and flip or folder type, which are related to RF exposure. Using the relative exposure levels obtained from this model, epidemiologists can divide the subjects into exposed and nonexposed groups in a study investigating the relationship between exposure level and brain cancer in the future, provided that more knowledge between the cellular phone usage pattern and the exposure is available.

**Kim TH, Huang TQ, Jang JJ, Kim MH, Kim HJ, Lee JS, Pack JK, Seo JS, Park WY. Local exposure of 849 MHz and 1763 MHz radiofrequency radiation to mouse heads does not induce cell death or cell proliferation in brain.Exp Mol Med. 40(3):294-303, 2008.**

**Erratum in** Exp Mol Med. 2008 Aug 31;40(4):477. Kim, Tae-Hyoung [corrected to Kim,

Tae-Hyung].

Even though there is no direct evidence to prove the cellular and molecular changes induced by radiofrequency (RF) radiation itself, we cannot completely exclude the possibility of any biological effect of mobile phone frequency radiation. We established a carousel-type exposure chamber for 849 MHz or 1763 MHz of mobile phone RF radiation to expose RF to the heads of C57BL mice. In this chamber, animals were irradiated intermittently at 7.8 W/kg for a maximum of 12 months. During this period, the body weights of 3 groups-sham, 849 MHz RF, and 1763 MHz RF-did not show any differences between groups. The brain tissues were obtained from 3 groups at 6 months and 12 months to examine the differences in histology and cell proliferation between control and RF exposure groups, but we could not find any change upon RF radiation. Likewise, we could not find changes in the expression and distribution of NeuN and GFAP in hippocampus and cerebellum, or in cell death by TUNEL assay in RF exposure groups. From these data, we conclude that the chronic exposure to 849 MHz and 1763 MHz RF radiation at a 7.8 W/kg specific absorption rate (SAR) could not induce cellular alterations such as proliferation, death, and reactive gliosis.

**Kimata H. Enhancement of allergic skin wheal responses by microwave radiation from mobile phones in patients with atopic eczema/dermatitis syndrome. Int Arch Allergy Immunol 129(4):348-350, 2002.**

Microwave radiation from mobile phones enhanced skin wheal responses induced by house dust mite and Japanese cedar pollen while it had no effect on wheal responses induced by histamine in patients with atopic eczema/dermatitis syndrome (AEDS). Microwave radiation also increased plasma levels of substance P (SP) and vasoactive intestinal peptide (VIP) in patients with AEDS. These results indicate that microwave radiation from mobile phones may enhance allergen-induced wheal responses in association with the release of SP and VIP. This finding may be useful in elucidating the pathophysiology and treatment of AEDS.

**Kimata H. Enhancement of allergic skin wheal responses in patients with atopic eczema/dermatitis syndrome by playing video games or by a frequently ringing mobile phone. Eur J Clin Invest. 33(6):513-517, 2003**.

BACKGROUND: Playing video games causes physical and psychological stress, including increased heart rate and blood pressure and aggression-related feelings. Use of mobile phones is very popular in Japan, and frequent ringing is a common and intrusive part of Japanese life. Atopic eczema/dermatitis syndrome is often exacerbated by stress. Stress increases serum IgE levels, skews cytokine pattern towards Th2 type, enhances allergen-induced skin wheal responses, and triggers mast cell degranulation via substance P, vasoactive intestinal peptide and nerve growth factor. MATERIALS AND METHODS: (1) In the video game study, normal subjects (n = 25), patients with allergic rhinitis (n = 25) or atopic eczema/dermatitis syndrome (n = 25) played a video game (STREET FIGHTER II) for 2 h. Before and after the study, allergen-induced wheal responses, plasma levels of substance P, vasoactive intestinal peptide and nerve growth

factor, and in vitro production of total IgE, antihouse dust mite IgE and cytokines were measured. (2) In the mobile phone study, normal subjects (n = 27), patients with allergic rhinitis (n = 27) or atopic eczema/dermatitis syndrome (n = 27) were exposed to 30 incidences of ringing mobile phones during 30 min. Before and after the study, allergen-induced wheal responses, plasma levels of substance P, vasoactive intestinal peptide and nerve growth factor were measured. RESULTS: Playing video games had no effect on the normal subjects or the patients with allergic rhinitis. In contrast, playing video games significantly enhanced allergen-induced skin wheal responses and increased plasma levels of substance P, vasoactive intestinal peptide and nerve growth factors in the patients with atopic eczema/dermatitis syndrome. Moreover, playing video games enhanced in vitro production of total IgE and anti-house dust mite IgE with concomitant increased production of IL-4, IL-10 and IL-13 and decreased production of IFN-gamma and IL-12 in the patients with atopic eczema/dermatitis syndrome. However, exposure to frequently ringing mobile phones significantly enhanced allergen-induced skin wheal responses, plasma levels of substance P, vasoactive intestinal peptide and nerve growth factors in the patients with atopic eczema/dermatitis syndrome, but not in the normal subjects or the patients with allergic rhinitis. CONCLUSION: Playing video games enhanced allergic responses with a concomitant increased release of substance P, vasoactive intestinal peptide and nerve growth factor, and skewing of the cytokine pattern toward Th2 type in the patients with atopic eczema/dermatitis syndrome. In addition, exposure to frequently ringing mobile phones also enhanced allergic responses with a concomitant increased release of substance P, vasoactive intestinal peptide and nerve growth factor Collectively, high technology causes stress, which in turn may aggravate symptoms of atopic eczema/dermatitis syndrome.

**Kimata H. Laughter counteracts enhancement of plasma neurotrophin levels and allergic skin wheal responses by mobile phone-mediated stress. Behav Med. 29(4):149-152, 2004.**

Laughter caused by viewing a comic video (Rowan Atkinson's The Best Bits of Mr. Bean) reduced the plasma nerve growth factor, neurotrophin-3 levels, and allergic skin wheal responses in patients with atopic dermatitis, whereas viewing a nonhumorous video (weather information) failed to do so. In contrast, stress induced by writing mail on a mobile phone enhanced the plasma nerve growth factor, neurotrophin-3 levels, and allergic skin wheal responses. However, previewing the comic video counteracted mobile phone-mediated enhancement of plasma neurotrophins or allergic skin wheal responses, whereas previewing the weather information failed to do so. Taken together, these results suggest that, in patients with atopic dermatitis, writing mail on a mobile phone causes stress and enhances allergic responses with a concomitant increase in plasma neurotrophins that are counteracted by laughter. These results may be useful in the study of pathophysiology and treatment of atopic dermatitis.

**Kimata H. Microwave radiation from cellular phones increases allergen-specific IgE production. Allergy 60(6):838-839, 2005. (no abstract available).**

**Kirschvink JL, Microwave absorption by magnetite: a possible mechanism for**

**coupling nonthermal levels of radiation to biological systems. Bioelectromagnetics 17(3):187-194, 1996.**

The presence of trace amounts of biogenic magnetite (Fe3O4) in animal and human tissues and the observation that ferromagnetic particles are ubiquitous in laboratory materials (including tissue culture media) provide a physical mechanism through which microwave radiation might produce or appear to produce biological effects. Magnetite is an excellent absorber of microwave radiation at frequencies between 0.5 and 10.0 GHz through the process of ferromagnetic resonance, where the magnetic vector of the incident field causes precession of Bohr magnetons around the internal demagnetizing field of the crystal. Energy absorbed by this process is first transduced into acoustic vibrations at the microwave carrier frequency within the crystal lattice via the magnetoacoustic effect; then, the energy should be dissipated in cellular structures in close proximity to the magnetite crystals. Several possible methods for testing this hypothesis experimentally are discussed. Studies of microwave dosimetry at the cellular level should consider effects of biogenic magnetite.

**Kismali G, Ozgur E, Guler G, Akcay A, Sel T, Seyhan N. The influence of 1800 MHz GSM-like signals on blood chemistry and oxidative stress in non-pregnant and pregnant rabbits. Int J Radiat Biol. 88(5):414-419, 2012.**

PURPOSE: Environmental electromagnetic fields originate from man-made sources, such as mobile phones and base stations, and have led to increasing publicconcern about their possible adverse health effects. We aimed to investigate the possible effects of radiofrequency radiation (RFR) generated from these devices on oversensitive animals, such as pregnant rabbits. MATERIALS AND METHODS: In the present study, the effects of whole body 1800 MHz Global System for Mobile Communications (GSM)-like RFR exposure for 15 min/day for seven days on blood chemistry and lipid peroxidation levels in both non-pregnant and pregnant New Zealand White rabbits were investigated. Thirteen-month-old rabbits were studied in the following four groups: Non-pregnant control, non-pregnant RFR-exposed, pregnant control and pregnant RFR-exposed. RESULTS: Lipid peroxidation, namely malondialdehyde (MDA) levels, did not change after RFR exposure. However, blood chemistry parameters, such as cholesterol (CHO), total protein (TP), albumin (ALB), uric acid, creatinin and creatine kinase (CK) and creatine kinase-myocardial band isoenzyme (CK-MB) changed due to both pregnancy and RFR exposure. CONCLUSION: Our investigations have been shown that no indication for oxidative stress was detected in the blood of pregnant rabbits upon RF exposure at specific conditions employed in the present study. Minor changes in some blood chemistry parameters were detected but CK-MB and CK increases were found remarkable. Studies on RFR exposure during pregnancy will help establish international standards for the protection of pregnant women from environmental RFR.

**Kittel A, Siklos L, Thuroczy G, Somosy Z, Qualitative enzyme histochemistry and microanalysis reveals changes in ultrastructural distribution of calcium and calcium-activated ATPases after microwave irradiation of the medial habenula. Acta Neuropathol (Berl) 92(4):362-368, 1996.**

The localization of calcium and calcium-activated ATPases was investigated electron

microscopically in the medial habenula of mice after whole body irradiation with modulated microwaves. In non-irradiated animals calcium-containing precipitates were seen in different subcellular compartments and were often localized on the luminal side of membranes of synaptic vesicles in nerve terminals. At 1 h after 16-Hz modulated microwave irradiation, the number of synaptic vesicles containing calcium precipitates decreased, and reaction products appeared at new locations: in the synaptic clefts and on non-synaptic surfaces of the neuronal plasma membrane. This modified calcium distribution remained unchanged for 24 h following irradiation. Calcium-activated "ecto"-localized ATPase was detected as a punctuated-linear distribution of the reaction product outlining whole areas of glial and neuronal plasma membrane in the habenula of control animals. This pattern did not change on microwave irradiation. However, a quercetin-sensitive "endo"-localized Ca(2+)-ATPase activity appeared in some nerve terminals 24 h after irradiation. Thus, microwave irradiation can influence neuronal calcium homeostasis by inducing Ca2+ redistribution across the plasma membrane and by modifying Ca(2+)-ATPase activity. However, no direct correlation between these effects could be demonstrated by the present study.

**Kiyohara K, Wake K, Watanabe S, Arima T, Sato Y, Kojimahara N, Taki M, Yamaguchi N. Recall accuracy of mobile phone calls among Japanese young people. J Expo Sci Environ Epidemiol. 2015 Mar 18. doi: 10.1038/jes.2015.13. [Epub ahead of print]**

This study aimed to elucidate the recall accuracy of mobile phone calls among young people using new software-modified phone (SMP) technology. A total of 198 Japanese students aged between 10 and 24 years were instructed to use a SMP for 1 month to record their actual call statuses. Ten to 12 months after this period, face-to-face interviews were conducted to obtain the self-reported call statuses during the monitoring period. Using the SMP record as the gold standard of validation, the recall accuracy of phone calls was evaluated. A total of 19% of the participants (34/177) misclassified their laterality (i.e., the dominant side of ear used while making calls), with the level of agreement being moderate ($\kappa$-statistics, 0.449). The level of agreement between the self-reports and SMP records was relatively good for the duration of calls (Pearson's $r$, 0.620), as compared with the number of calls (Pearson's $r$, 0.561). The recall was prone to small systematic and large random errors for both the number and duration of calls. Such a large random recall error for the amount of calls and misclassification of laterality suggest that the results of epidemiological studies of mobile phone use based on self-assessment should be interpreted cautiously.

**Kizilay A, Ozturan O, Erdem T, Tayyar Kalcioglu M, Cem Miman M. Effects of chronic exposure of electromagnetic fields from mobile phones on hearing in rats. Auris Nasus Larynx. 30(3):239-245, 2003.**

OBJECTIVE: Little attention has been paid to the effects of electromagnetic field (EMF) of mobile phones on hearing. The aim of this study is to investigate the effects of chronic exposure to EMF emitting from mobile phones on the inner ear of adult and developing rats using distortion product otoacoustic emissions (DPOAEs). METHODS: EMF of mobile phones exposure was scheduled according to a sham-exposure controlled

experimental design. Every day seven of 14 adult and four newborn rats were exposed to 1-h mobile phone EMF for 30 days, while the other seven adult rats were assigned to control group. DPOAEs were measured in both groups before and after the chronic exposure to EMF. The newborn rats were tested following similar exposure beginning on the 2nd day after birth. RESULTS: No measurable EMF associated changes in DPOAEs either in adult or developing rat inner ears were determined (P>0.05). CONCLUSION: It was concluded that chronic exposure of EMF, as long as 30 days 1 h per day, emitting from a mobile phone did not cause any hearing deterioration in adult and developing rats, at least at outer and middle ear and cochlear levels.

**Klaeboe L, Blaasaas KG, Tynes T.Use of mobile phones in Norway and risk of intracranial tumours. Eur J Cancer Prev. 16(2):158-164, 2007.**

To test the hypothesis that exposure to radio-frequency electromagnetic fields from mobile phones increases the incidence of gliomas, meningiomas and acoustic neuromas in adults. The incident cases were of patients aged 19-69 years who were diagnosed during 2001-2002 in Southern Norway. Population controls were selected and frequency-matched for age, sex, and residential area. Detailed information about mobile phone use was collected from 289 glioma (response rate 77%), 207 meningioma patients (71%), and 45 acoustic neuroma patients (68%) and from 358 (69%) controls. For regular mobile phone use, defined as use on average at least once a week or more for at least 6 months, the odds ratio was 0.6 (95% confidence interval 0.4-0.9) for gliomas, 0.8 (95% confidence interval 0.5-1.1) for meningiomas and 0.5 (95% confidence interval 0.2-1.0) for acoustic neuromas. Similar results were found with mobile phone use for 6 years or more for gliomas and acoustic neuromas. An exception was meningiomas, where the odds ratio was 1.2 (95% confidence interval 0.6-2.2). Furthermore, no increasing trend was observed for gliomas or acoustic neuromas by increasing duration of regular use, the time since first regular use or cumulative use of mobile phones. The results from the present study indicate that use of mobile phones is not associated with an increased risk of gliomas, meningiomas or acoustic neuromas.

**Klaps A, Ponocny I, Winker R, Kundi M, Auersperg F, Barth A. Mobile phone base stations and well-being - A meta-analysis. Sci Total Environ. 544:24-30, 2015. doi: 10.1016/j.scitotenv.2015.11.009. [Epub ahead of print]**

It is unclear whether electromagnetic fields emitted by mobile phone base stations affect well-being in adults. The existing studies on this topic are highly inconsistent. In the current paper we attempt to clarify this question by carrying out a meta-analysis which is based on the results of 17 studies. Double-blind studies found no effects on human well-being. By contrast, field or unblinded studies clearly showed that there were indeed effects.
This provides evidence that at least some effects are based on a nocebo effect. Whether there is an influence of electromagnetic fields emitted by mobile phone base stations thus depends on a person's knowledge about the presence of the presumed cause. Taken together, the results of the meta-analysis show that the effects of mobile phone base stations seem to be rather unlikely. However, nocebo effects occur.

**Kleinlogel H, Dierks T, Koenig T, Lehmann H, Minder A, Berz R Effects of weak mobile Phone-Electromagnetic fields (GSM, UMTS) on well-being and resting EEG. Bioelectromagnetics. 29(6):479-487, 2008.**

Modern mobile phones emit electromagnetic fields (EMFs) ranging from 900 to 2000 MHz which are suggested to have an influence on well-being, attention and neurological parameters in mobile phone users. To date most studies have investigated Global System for Mobile Communications (GSM)-EMF and only very few studies were concerned with Universal Mobile Telecommunications System (UMTS)-EMF. Consequently, we tested the effects of both types of EMF, 1950 MHz UMTS (SAR 0.1 and 1 W/kg) and pulsed 900 MHz GSM (1 W/kg), on well-being and vigilance-controlled resting electroencephalogram (eyes closed) in 15 healthy, right-handed subjects. A double-blind, randomised, crossover application of the test procedure was used. Neither the UMTS- nor the GSM-EMF produced any significant changes in the measured parameters compared to sham exposure. The results do not give any evidence for a deleterious effect of the EMF on normal healthy mobile phone users.

**Kleinlogel H, Dierks T, Koenig T, Lehmann H, Minder A, Berz R. Effects of weak mobile phone - electromagnetic fields (GSM, UMTS) on event related potentials and cognitive functions. Bioelectromagnetics. 29(6):488-497, 2008.**

Modern mobile phones emit electromagnetic fields (EMF) ranging from 900 to 2000 MHz which are suggested to have an influence on well-being, attention and neurological parameters in mobile phone users. Until now most studies have investigated Global System for Mobile Communications (GSM)-EMF and only very few studies have focused on Universal Mobile Telecommunications System (UMTS)-EMF. Therefore, we tested the effects of both types of unilaterally presented EMF, 1950 UMTS (0.1 and 1 W/kg) and pulsed 900 MHz GSM (1 W/kg), on visually evoked occipital P100, the P300 of a continuous performance test, auditory evoked central N100 and the P300 during an oddball task as well as on the respective behavioral parameters, reaction time and false reactions, in 15 healthy, right handed subjects. A double-blind, randomized, crossover application of the test procedure was used. Neither the UMTS- nor the GSM-EMF produced any significant changes in the measured parameters compared to sham exposure. The results do not give any evidence for a deleterious effect of the EMF on normal healthy mobile phone users.

**Klug S, Hetscher M, Giles S, Kohlsmann S, Kramer K, The lack of effects of nonthermal RF electromagnetic fields on the development of rat embryos grown in culture. Life Sci 61(18):1789-1802, 1997.**

Rat embryos (9.5 days old) were exposed for up to 36 h to various radio frequency (RF) electric and magnetic fields (modulation frequency: 16, 60, 120 Hz; electric field strength: 60, 600 V/m; magnetic induction: 0.2, 2.0 microT). A resonator technique was used to generate standing waves thus fulfilling three conditions: The site of maximum electric and magnetic oscillations could be separated, the field strengths were known exactly and a high homogeneity over the sample volume was achieved. In each frequency region the transmitter power levels were set to give specific absorption rate (SAR) values spreading from far below to far above the values met in

the field of telecommunication (0.2, 1.0 and 5.0 W/kg). The criteria used to examine the embryos on day 11.5 for possible structural effects consisted of a scoring system, photographs, histology using both light and electron microscopy and determination of the protein content. All these data have been taken as sets of different intermediate frequency (IF) amplitude modulation of the RF carriers. Neither the electric nor the magnetic fields tested interfered significantly with the normal growth and differentiation of the embryos in vitro.

**Koca O, Gökçe AM, Oztürk MI, Ercan F, Yurdakul N, Karaman MI. Effects of intensive cell phone (philips genic 900) use on the rat kidney tissue. Urol J. 10(2):886-891. 2013.**

PURPOSE: To investigate effects of electromagnetic radiation (EMR) emitted by cell phones on the rat kidney tissue. MATERIALS AND METHODS: Twenty-one male Albino rats were divided into 3 groups, each comprising 7 rats. Group 1 was exposed to a cell phone in speech mode for 8 hours/day for 20 days and their kidneys were removed. Group 2 was exposed to EMR for 20 days and then their kidneys were removed after an interval of 20 days. Cell phone used in the present study was Philips Genie 900, which has the highest specific absorption rate on the market. RESULTS: Light microscopic examination of the kidney tissues obtained from the first group of rats revealed glomerular damage, dilatation of Bowman's capsule, formation of large spaces between the tubules, tubular damage, perivascular edema, and inflammatory cell infiltration. The mean severity score was 4.64 ± 1.7 in group 1, 4.50 ± 0.8 in group 2, and 0 in group 3. While there was no significant difference between group 1 and group 2 ($P > .05$), the mean severity scores of groups 1 and 2 were significantly higher than that of the control group ($P = .001$ for each). CONCLUSION: Considering the damage in rat kidney tissue caused by EMR-emitting cell phones, high-risk individuals should take protective measures.

**Koca O, Gokce AM, Akyuz M, Ercan F, Yurdakul N, Karaman MI. A new problem in inflammatory bladder diseases: Use of mobile phones! Int Braz J Urol. 40(4):520-525, 2014.**

PURPOSE: Technological developments provide a lot of conveniences to our lives. This issue is one of the risks that arise along with these conveniences. In our study we tried to understand the impact of electromagnetic waves from mobile phones on bladder tissue. MATERIALS AND METHODS: Twenty-one adult male albino rats were divided into three equal groups. Group 1 was exposed to electromagnetic wave for 8 hours per day for 20 days and then their bladders were taken off immediately. Group 2 was firstly exposed to electromagnetic wave for 8 hours per day for 20 days then secondly another for 20 days without exposition to electromagnetic wave and then their bladders were taken off. Group 3 was the control group and they were not exposed to electromagnetic wave. RESULTS: Under microscopic examination of bladder tissue, in the first group severe inflammatory cell infiltration was seen in lamina propria and muscle layer in contrast to intact urothelium. In the second group mild inflammatory cell infiltration was seen in lamina propria and muscle layer. The mean scores for the three groups were 5.5 ± 2.5, 0.8 ± 1.3 and 1.2 ± 1.5 respectively. Mean score of group 1 was statistically higher than others ($p = 0.001$). CONCLUSION: Intensive use of mobile phones has negative impact on bladder

tissue as well as the other organs. Keeping a minimum level of mobile phone use makes it easy to be kept under control of diseases in which inflammation is an etiologic factor.

**Kolosova LI, Akoev GN, Avelev VD, Riabchikova OV, Babu KS, Effect of low-intensity millimeter wave electromagnetic radiation on regeneration of the sciatic nerve in rats. Bioelectromagnetics 17(1):44-47, 1996.**

The effect of low-intensity millimeter wave electromagnetic radiation (MWR) on regeneration of the rat sciatic nerve after transection and microsurgical reapproximation was examined. Rats were exposed to 54 GHz MWR at a power density of 4 mW/cm2. It was found that MWR treatment of the femoral skin in the area of suture accelerated the regeneration of nerve fibers. At the twentieth postoperative day, the MWR-treated animals had a 32% increase in the regeneration distance compared to the control animals. The conduction velocity showed a 26% increase in the MWR-treated animals.

**Koivisto, M, Revonsuo, A, Krause, C, Haarala, C, Sillanmaki, L, Laine, M, Hamalainen, H, Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans. Neuroreport 11(2):413-415, 2000.**

The present study examined possible influences of a 902 MHz electromagnetic field emitted by cellular telephones on cognitive functioning in 48 healthy humans. A battery of 12 reaction time tasks was performed twice by each participant in a counterbalanced order: once with and once without the exposure to the field. The results showed that the exposure to the electromagnetic field speeded up response times in simple reaction time and vigilance tasks and that the cognitive time needed in a mental arithmetics task was decreased. The results suggest that exposure to the electromagnetic field emitted by cellular telephones may have a facilitatory effect on brain functioning, especially in tasks requiring attention and manipulation of information in working memory.

**Koivisto M, Krause CM, Revonsuo A, Laine M, Hamalainen H, The effects of electromagnetic field emitted by GSM phones on working memory. Neuroreport 11(8):1641-1643, 2000.**

The influence of pulsed radiofrequency (RF) electromagnetic fields of digital GSM mobile phones on working memory in healthy subjects were studied. Memory load was varied from 0 to 3 items in an n-back task. Each subject was tested twice within a single session, with and without the RF exposure (902MHz, 217Hz). The RF field speeded up response times when the memory load was three items but no effects of RF were observed with lower loads. The results suggest that RF fields have a measurable effect on human cognitive performance and encourage further studies on the interactions of RF fields with brain function.

**Koivisto M, Haarala C, Krause CM, Revonsuo A, Laine M, Hamalainen H, GSM phone signal does not produce subjective symptoms. Bioelectromagnetics 22(3):212-215, 2001.**

The influence of pulsed radiofrequency (RF) electromagnetic fields of digital GSM mobile phones (902 MHz, 217 Hz pulse modulation) on subjective symptoms or sensations in

healthy subjects were studied in two single-blind experiments. The duration of the RF exposure was about 60 min in Experiment 1 and 30 min in Experiment 2. Each subject rated symptoms or sensations in the beginning of the experimental session and at the end of both the exposure and the nonexposure conditions. The symptoms rated were headache, dizziness, fatigue, itching or tingling of the skin, redness on the skin, and sensations of warmth on the skin. The results did not reveal any differences between exposure and non-exposure conditions, suggesting that a 30-60 min exposure to this RF field does not produce subjective symptoms in humans.

**Kojima M, Hata I, Wake K, Watanabe S, Yamanaka Y, Kamimura Y, Taki M, Sasaki K. Influence of anesthesia on ocular effects and temperature in rabbit eyes exposed to microwaves. Bioelectromagnetics 25(3):228-233, 2004.**

To investigate the effect of systemic anesthesia on ocular effects and temperature in rabbit eyes exposed to microwaves, one eye each of 43 male pigmented rabbits (Dutch, 1.8-2.2 kg) was exposed at 2.45 GHz for 60-20 min (300 mW/cm2; 108 W/kg), either under anesthesia (ketamine hydrochloride (5 mg/kg) + xylazine (0.23 mg/kg)) or without anesthesia. Changes in the anterior segment were evaluated by image analysis utilizing a Scheimpflug camera, specular microscopy, and a laser flare cell meter. Temperatures within the eye were measured during microwave exposure by a Fluoroptic thermometer. The exposed eyes showed miosis, conjunctival congestion, corneal edema, and an increase in the light scattering of the anterior shallow cortex in the pupillary area of the lens. The group under systemic anesthesia showed much stronger symptoms than those treated without anesthesia. All of the anterior ocular changes disappeared within a week. The highest temperature during exposure was in the vitreous, followed by the anterior chamber, and the retrobulbar cavity of the orbit. The ocular temperatures of the rabbits under systemic anesthesia were 2-9 degrees C higher than those without anesthesia. Body temperature showed an increase of 1 degrees C during the exposure. Acute high intensity microwave exposure temporarily induced anterior segments inflammation and lens changes. The more pronounced ocular effects in the anesthetized rabbits were associated with the significantly higher ocular temperatures in the anesthetized animals. The influence of systemic anesthesia on ocular changes should be considered.

**Köktürk S, Yardimoglu M, Celikozlu SD, Dolanbay EG, Cimbiz A. Effect of Lycopersicon esculentum extract on apoptosis in the rat cerebellum, following prenatal and postnatal exposure to an electromagnetic field. Exp Ther Med. 6(1):52-56, 2013.**

The expansion of mobile phone technology has raised concerns regarding the effect of 900-MHz electromagnetic field (EMF) exposure on the central nervous system. At present, the developing human brain is regularly exposed to mobile telephones, pre- and postnatally. Several studies have demonstrated the acute effects of EMF exposure during pre- or postnatal periods; however, the chronic effects of EMF exposure are less understood. Thus, the aim of the present study was to determine the chronic effects of EMF on the pre- and postnatal rat cerebellum. The control group was maintained in the same conditions as the experimental groups, without the exposure to EMF. In the EMF1 group, the rats were exposed to EMF during pre- and postnatal periods (until postnatal day 80). In the EMF2 group, the rats were also

exposed to EMF pre- and postnatally; in addition, however, they were provided with a daily oral supplementation of *Lycopersicon esculentum* extract (~2 g/kg). The number of caspase-3-labeled Purkinje neurons and granule cells present in the rats in the control and experimental groups were then counted. The neurodegenerative changes were studied using cresyl violet staining, and these changes were evaluated. In comparison with the control animals, the EMF1 group demonstrated a significant increase in the number of caspase-3-labeled Purkinje neurons and granule cells present in the cerebellum ($P<0.001$). However, in comparison with the EMF1 group, the EMF2 group exhibited significantly fewer caspase-3-labeled Purkinje neurons and granule cells in the cerebellum. In the EMF1 group, the Purkinje neurons were revealed to have undergone dark neuron degenerative changes. However, the presence of dark Purkinje neurons was reduced in the EMF2 group, compared with the EMF1 group. The results indicated that apoptosis and neurodegeneration in rats exposed to EMF during pre- and postnatal periods may be reduced with *Lycopersicon esculentum* extract therapy.

**Koldayev VM, Shchepin YV, Effects of electromagnetic radiation on embryos of sea-urchins. Bioelectrochem Bioenerg 43:161-164, 1997.**

Electromagnetic radiation (EMR) causes a decrease in the number of fertilized eggs and an increase in the number of zygotes with abnormal fertilization envelopes in sea-urchins. The microstructural impairments of the cellular surface, the increase of lipid peroxidation and the changes of amino acid metabolism show that the impairments of the development of embryos exposed to EMR are caused by the damages of the membrane structures.

**Kolodynski AA, Kolodynska VV, Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. Sci Total Environ 180(1):87-93, 1996.**

This paper presents the results of experiments on school children living in the area of the Skrunda Radio Location Station (RLS) in Latvia. Motor function, memory and attention significantly differed between the exposed and control groups. Children living in front of the RLS had less developed memory and attention, their reaction time was slower and their neuromuscular apparatus endurance was decreased.

**Kolomytseva MP, Gapeev AB, Sadovnikov VB, Chemeris NK. [Suppression of nonspecific resistance of the body under the effect of extremely high frequency electromagnetic radiation of low intensity] Biofizika. 47(1):71-77, 2002.** [Article in Russian] **(I-M)**

The dynamics of leukocyte number and functional activity of peripheral blood neutrophils under whole-body exposure of healthy mice to low-intensity extremely-high-frequency electromagnetic radiation (EHF EMR, 42.0 GHz, 0.15 mW/cm2, 20 min daily) was studied. It was shown that the phagocytic activity of peripheral blood neutrophils was suppressed by about 50% ($p < 0.01$ as compared with the sham-exposed control) in 2-3 h after the single exposure to EHF EMR. The effect persisted for 1 day after the exposure, and then the phagocytic activity of neutrophils returned to the norm within 3 days. A significant modification of the leukocyte blood profile in mice exposed to EHF

EMR for 5 days was observed after the cessation of exposures: the number of leukocytes increased by 44% ($p < 0.05$ as compared with sham-exposed animals), mostly due to an increase in the lymphocyte content. The supposition was made that EHF EMR effects can be mediated via the metabolic systems of arachidonic acid and the stimulation of adenylate cyclase activity, with subsequent increase in the intracellular cAMP level. The results indicated that the whole-body exposure of healthy mice to low-intensity EHF EMR has a profound effect on the indices of nonspecific immunity.

**Kol'tsov IuV, Korolev VN, Kusakin SA, [Two-step exposure of biological objects to infrared laser and microwave radiation]. Biofizika 44(2):378-381, 1999.** [Article in Russian]

The effect of two-step exposure of bacterial objects to infrared laser and microwave pulse radiations was studied. The effect is determined by the time interval between two excitation steps and pulse duration. It was shown that the biologically active dose of microwave radiation is much lower than that of infrared laser radiation; however, laser radiation induces a stronger cellular response. It was found that microwaves enhance the efficiency of infrared laser radiation.

**Komatsubara Y, Hirose H, Sakurai T, Koyama S, Suzuki Y, Taki M, Miyakoshi J. Effect of high-frequency electromagnetic fields with a wide range of SARs on chromosomal aberrations in murine m5S cells. Mutat Res. 587(1-2):114-119, 2005.**

To investigate the induction of chromosomal aberrations in mouse m5S cells after exposure to high-frequency electromagnetic fields (HFEMFs) at 2.45GHz, cells were exposed for 2h at average specific absorption rates (SARs) of 5, 10, 20, 50 and 100W/kg with continuous wave-form (CW), or at a mean SAR of 100W/kg (with a maximum of 900W/kg) with pulse wave-form (PW). The effects of HFEMF exposure were compared with those in sham-exposed controls and with mitomycin C (MMC) or X-ray treatment as positive controls. We examined all structural, chromatid-type and chromosome-type changes after HFEMF exposures and treatments with MMC and X-rays. No significant differences were observed following exposure to HFEMFs at SARs from 5 to 100W/kg CW and at a mean SAR of 100W/kg PW (a maximum SAR of 900W/kg) compared with sham-exposed controls, whereas treatments with MMC and X-rays increased the frequency of chromatid-type and chromosome-type aberrations. In summary, HFEMF exposures at 2.45GHz for 2h with up to 100W/kg SAR CW and an average 100W/kg PW (a maximum SAR of 900W/kg) do not induce chromosomal aberrations in m5S cells. Furthermore, there was no difference between exposures to CW and PW HFEMFs.

**Kompis M, Negri S, Hausler R. Electromagnetic interference of bone-anchored hearing aids by cellular phones. Acta Otolaryngol 120(7):855-859, 2000.**

We report a case of electromagnetic interference between a bone-anchored hearing aid (BAHA) and a cellular phone. A 54-year-old women was successfully treated for severe mixed conductive and sensorineural hearing loss with a BAHA. Five years after implantation, the patient experienced a sudden feeling of dizziness, accompanied by a loud buzzing sound and by a sensation of head pressure while examining a digital mobile phone. During a subsequent experiment, the buzzing sound could be reproduced and was identified as electromagnetic interference between the BAHA and digital cellular

phones. Seventeen adult BAHA users from our clinic participated in a subsequent survey. Of the 13 patients with some experience of digital cellular phones, 11 reported hearing annoying noises elicited by these devices. However, no other sensation, such as dizziness, was described. Owing to the increasing number of users of both hearing aids and cellular phones, the incidence of electromagnetic interference must be expected to increase as well. Although to date there is no evidence that such interference may be harmful or dangerous to users of conventional or bone-anchored hearing aids, unexpected interference can be a frightening experience.

**Kompis M, Hausler R. Electromagnetic interference of bone-anchored hearing aids by cellular phones revisited. Acta Otolaryngol 122(5):510-512, 2002.**

The electromagnetic interference of the recently introduced bone-anchored hearing aid (BAHA) model "BAHA Compact" by digital cellular phones is investigated and compared with that of the older "BAHA Classic 300" model. Measurements with two different digital cellular phones in a laboratory setting indicated that the noise level due to electromagnetic interference was at least 10 dB lower for the BAHA Compact device than for the BAHA Classic 300. To compare the experience of patients using the BAHA Compact with those using a BAHA Classic 300 in an earlier study, a survey was performed. Six users of a BAHA Compact who used digital cellular phones participated in the survey. Four patients did not hear any noise associated with the use of a digital cellular phone. Two patients reported hearing quiet sounds when they were on the telephone, but not when somebody else in the vicinity used a digital cellular phone. These findings confirm that the susceptibility to electromagnetic interference of the BAHA Compact device is low.

**Kopecky R, Hamnerius Y, Persson M. Study of subgridding in SAR computation for the cochlea. Bioelectromagnetics. 26(6):520-522, 2005.**

A 3D subgridding technique is used to model the specific absorption rate (SAR) distribution in the isolated cochlea exposed to mobile phone radiation at 1750 MHz using the FDTD method. The cochlea is modeled using an increasing spatial resolutions of 1, 1/3, 1/5, and 1/7 mm. First simulations were performed at 1 mm spatial resolution. The numerical resolution was then increased to 1/3, 1/5, and 1/7 using subgridding without changing the spatial resolution. A second set of simulations was then performed when both the spatial and numerical resolution were increased together. From the obtained results, we conclude that subgridding is important only when both the numerical resolution of the computational grid and the spatial resolution of the model are increased together.

**Korpinen L, Pääkkönen R. Accidents and close call situations connected to the use of mobile phones. Accid Anal Prev. 45(2):75-82, 2012.**

Abstract. The aim of our work was to study the accidents and close call situations connected to the use of mobile phones. We have analyzed how the accidents/close call situations are connected to background information, in particular age, gender and self-reported symptoms. The study was carried out as a cross-sectional study by posting the questionnaire to 15,000 working-age Finns. The responses (6121) were analyzed using the logistic regression models. Altogether 13.7% of respondents had

close call situations and 2.4% had accidents at leisure, in which the mobile phone had a partial effect, and at work the amounts were 4.5% and 0.4% respectively, during the last 12 months. Essentially, we found that: (1) men tend to have more close calls and accidents while on a mobile phone, (2) younger people tend to have more accidents and close calls while on a mobile phone, but it does not appear to be large enough to warrant intervention, (3) employed people tend to have more problems with mobile phone usage and accidents/close calls, and (4) there was a slight increase in mobile-phone-related accidents/close calls if the respondent also reported sleep disturbances and minor aches and pains. In the future, it is important to take into account and study how symptoms can increase the risk of accidents or close call situations in which a mobile phone has a partial effect.

**Koprivica M, Neskovic N, Neskovic A, Paunovic G. Statistical analysis of electromagnetic radiation measurements in the vicinity of GSM/UMTS base station antenna masts. Radiat Prot Dosimetry. 158(3):263-275, 2014.**

As a result of dense installations of public mobile base station, additional electromagnetic radiation occurs in the living environment. In order to determine the level of radio-frequency radiation generated by base stations, extensive electromagnetic field strength measurements were carried out for 664 base station locations. Base station locations were classified into three categories: indoor, masts and locations with installations on buildings. Having in mind the large percentage (47 %) of sites with antenna masts, a detailed analysis of this location category was performed, and the measurement results were presented. It was concluded that the total electric field strength in the vicinity of base station antenna masts in no case exceeded 10 V m(-1), which is quite below the International Commission on Non-Ionizing Radiation Protection reference levels. At horizontal distances >50 m from the mast bottom, the median and maximum values were <1 and 2 V m(-1), respectively.

**Kos B, Valič B, Kotnik T, Gajšek P. Exposure assessment in front of a multi-band base station antenna. Bioelectromagnetics. 32(3):234-242, 2011.**

This study investigates occupational exposure to electromagnetic fields in front of a multi-band base station antenna for mobile communications at 900, 1800, and 2100 MHz. Finite-difference time-domain method was used to first validate the antenna model against measurement results published in the literature and then investigate the specific absorption rate (SAR) in two heterogeneous, anatomically correct human models (Virtual Family male and female) at distances from 10 to 1000 mm. Special attention was given to simultaneous exposure to fields of three different frequencies, their interaction and the additivity of SAR resulting from each frequency. The results show that the highest frequency--2100 MHz--results in the highest spatial-peak SAR averaged over 10 g of tissue, while the whole-body SAR is similar at all three frequencies. At distances > 200 mm from the antenna, the whole-body SAR is a more limiting factor for compliance to exposure guidelines, while at shorter distances the spatial-peak SAR may be more limiting. For the evaluation of combined exposure, a simple summation of spatial-peak SAR maxima at each

frequency gives a good estimation for combined exposure, which was also found to depend on the distribution of transmitting power between the different frequency bands.

**Kottou S, Nikolopoulos D, Yannakopoulos PH, Vogiannis E, Petraki E, Panagiotaras D, Koulougliotis D. Preliminary background indoor EMF measurements in Greece. Phys Med. 2015 May 21. pii: S1120-1797(15)00112-X. doi: 10.1016/j.ejmp.2015.05.002. [Epub ahead of print]**

The main purpose of this work was to investigate the fluctuation of Greek indoor electromagnetic field (EMF) intensity values and identify peaks that might occur. The scientific interest is mainly focused on the bands of extremely low-frequency (ELF) magnetic fields and radiofrequency (RF) electric fields which have been suggested to be possibly carcinogenic to humans by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). Electromagnetic radiation (EMR) measurements were performed in a variety of indoor dwellings, in Attica and in the islands of Zakynthos and Lesvos. A total number of 4540 measurements were taken in a wide frequency range (50 Hz-2100 MHz) of which 3301 in Attica, 963 in Lesvos and 276 in Zakynthos. Statistical analysis of the data revealed specific statistically significant differences between the mean values of the electric (ELF and RF) but not the magnetic (ELF) field strengths measured at different distances from the EMF source, as well as between some of the mean values of the RF electric field at different bands. Some statistically significant differences between mean electric field values at different geographic locations were also identified. As far as the RF electric field is concerned, the maximum values, in most cases, were below 0.5 V/m, however increased values above 1 V/m and up to 5.6 V/m were occasionally observed. The ELF magnetic field values were lower than 1 μT. It may be concluded that overall, the observed indoor EMF intensity values remained well below domestic and European established limits.

**Koveshnikova IV, Antipenko EN, [The participation of thyroid hormones in modifying the mutagenic effect of microwaves]. Radiobiologiia 31(1):147-149, 1991.** [Article in Russian]

The mutagenic effect of microwaves (2,450 or 2,750 MHz, 500 microW/cm2, 30 days, 7 h a day) increases with both low and high thyroid hormone content in rats. This indicates that normal functioning of the thyroid gland is an important condition for the stabilization of chromosome integrity under the effect of nonionizing radiation of microwaves.

**Koveshnikov IV, Antipenko EN, [Quantitative patterns in the cytogenetic action of microwaves]. Radiobiologiia 31(1):149-151, 1991.** [Article in Russian]

It was shown on hepatocytes of albino mongrel rats that the energy flow density (EFD) of 100 muW/cm2 approximated the level at which the mutagenic effects of microwaves started developing (3,000 MHz, pulse frequency 400 Hz, 60 days, 12 h a day). The severity of the mutagenic effects of radiation with EFD of 100, 500 and 2,500 muW/cm2 depended on the type of the microwave generation that was responsible for the energy loading variations. The increase in the total radiation

energy levelled the mutagenic effects of microwaves of all three intensities.

**Kowall B, Breckenkamp J, Heyer K, Berg-Beckhoff G. German wide cross sectional survey on health impacts of electromagnetic fields in the view of general practitioners. Int J Public Health.55(5):507-512, 2010.**

OBJECTIVES: The proportion of general practitioners (GPs) in Germany who assume health impacts of electromagnetic fields (EMF) is assessed. Moreover, factors associated with this risk perception are examined. METHODS: A 7% random sample was drawn from online lists of all the GPs working in Germany. 1,867 doctors received a long version of a self-administered postal questionnaire about EMF and health (response rate 23.3%), 928 doctors received a short version (response rate 49.1%). RESULTS: 37.3% of responders to the short and 57.5% of responders to the long questionnaire agreed "that there are persons whose health complaints are caused by EMF when legal limit values are met". A late responder analysis for the survey with the short questionnaire led to a still lower estimate of 29% for GPs believing in health-relevant effects of EMF. CONCLUSION: About a third of German GPs associate EMF with health complaints and thus deviate considerably from current scientific knowledge. To avoid a strong selection bias in the surveys of the perception of EMF risks, use of short questionnaires and late responder analysis are recommended.

**Kowalczuk C, Yarwood G, Blackwell R, Priestner M, Sienkiewicz Z, Bouffler S, Ahmed I, Abd-Alhameed R, Excell P, Hodzic V, Davis C, Gammon R, Balzano Q. Absence of nonlinear responses in cells and tissues exposed to RF energy at mobile phone frequencies using a doubly resonant cavity. Bioelectromagnetics.31(7):556-565,2010.**

A doubly resonant cavity was used to search for nonlinear radiofrequency (RF) energy conversion in a range of biological preparations, thereby testing the hypothesis that living tissue can demodulate RF carriers and generate baseband signals. The samples comprised high-density cell suspensions (human lymphocytes and mouse bone marrow cells); adherent cells (IMR-32 human neuroblastoma, G361 human melanoma, HF-19 human fibroblasts, N2a murine neuroblastoma (differentiated and non-differentiated) and Chinese hamster ovary (CHO) cells) and thin sections or slices of mouse tissues (brain, kidney, muscle, liver, spleen, testis, heart and diaphragm). Viable and non-viable (heat killed or metabolically impaired) samples were tested. Over 500 cell and tissue samples were placed within the cavity, exposed to continuous wave (CW) fields at the resonant frequency (f) of the loaded cavity (near 883 MHz) using input powers of 0.1 or 1 mW, and monitored for second harmonic generation by inspection of the output at 2f. Unwanted signals were minimised using low pass filters (</=1 GHz) at the input to, and high pass filters (>/=1 GHz) at the output from, the cavity. A tuned low noise amplifier allowed detection of second harmonic signals above a noise floor as low as -169 dBm. No consistent second harmonic of the incident CW signals was detected. Therefore, these results do not support the hypothesis that living cells can demodulate RF energy, since second harmonic generation is the necessary and sufficient condition for demodulation.

**Koyama S, Isozumi Y, Suzuki Y, Taki M, Miyakoshi J. Effects of 2.45-GHz electromagnetic fields with a wide range of SARs on micronucleus formation in CHO-K1 cells. ScientificWorldJournal 4 Suppl 2:29-40, 2004.**

There has been considerable discussion about the influence of high-frequency electromagnetic fields (HFEMF) on the human body. In particular, HFEMF used for mobile phones may be of great concern for human health. In order to investigate the properties of HFEMF, we have examined the effects of 2.45-GHz EMF on micronucleus (MN) formation in Chinese hamster ovary (CHO)-K1 cells. MN formation is induced by chromosomal breakage or inhibition of spindles during cell division and leads to cell damage. We also examined the influence of heat on MN formation, since HFEMF exposure causes a rise in temperature. CHO-K1 cells were exposed to HFEMF for 2 h at average specific absorption rates (SARs) of 5, 10, 20, 50, 100, and 200 W/kg, and the effects on these cells were compared with those in sham-exposed control cells. The cells were also treated with bleomycin alone as a positive control or with combined treatment of HFEMF exposure and bleomycin. Heat treatment was performed at temperatures of 37, 38, 39, 40, 41, and 42 degrees C. The MN frequency in cells exposed to HFEMF at a SAR of lower than 50 W/kg did not differ from the sham-exposed controls, while those at SARs of 100 and 200 W/kg were significantly higher when compared with the sham-exposed controls. There was no apparent combined effect of HFEMF exposure and bleomycin treatment. On heat treatment at temperatures from 38-42 degrees C, the MN frequency increased in a temperature-dependent manner. We also showed that an increase in SAR causes a rise in temperature and this may be connected to the increase in MN formation generated by exposure to HFEMF.

**Koyama S, Narita E, Suzuki Y, Taki M, Shinohara N, Miyakoshi J. Effect of a 2.45-GHz radiofrequency electromagnetic field on neutrophil chemotaxis and phagocytosis in differentiated human HL-60 cells.J Radiat Res. 2014 Sep 5. pii: rru075. [Epub ahead of print]**

The potential public health risks of radiofrequency (RF) fields have been discussed at length, especially with the use of mobile phones spreading extensively throughout the world. In order to investigate the properties of RF fields, we examined the effect of 2.45-GHz RF fields at the specific absorption rate (SAR) of 2 and 10 W/kg for 4 and 24 h on neutrophil chemotaxis and phagocytosis in differentiated human HL-60 cells. Neutrophil chemotaxis was not affected by RF-field exposure, and subsequent phagocytosis was not affected either compared with that under sham exposure conditions. These studies demonstrated an initial immune response in the human body exposed to 2.45-GHz RF fields at the SAR of 2 W/kg, which is the maximum value recommended by the International Commission for Non-Ionizing Radiation Protection (ICNIRP) guidelines. The results of our experiments for RF-field exposure at an SAR under 10 W/kg showed very little or no effects on either chemotaxis or phagocytosis in neutrophil-like human HL-60 cells.

**Koylu H, Mollaoglu H, Ozguner F, Nazyroglu M, Delibab N. Melatonin modulates 900 Mhz microwave-induced lipid peroxidation changes in rat brain. Toxicol Ind Health. 22(5):211-216, 2006.**

Microwaves (MW) from cellular phones may affect biological systems by increasing free radicals, which may enhance lipid peroxidation levels of the brain, thus leading to oxidative damage. Melatonin is synthesized in and secreted by the pineal gland at night and exhibits anti-oxidant properties. Several studies suggest that supplementation with anti-oxidant can influence MW-induced brain damage. The present study was designed to determine the effects of MW on the brain lipid peroxidation system, and the possible protective effects of melatonin on brain degeneration induced by MW. Twenty-eight Sprague-Dawley male rats were randomly divided into three groups as follows: (1) sham-operated control group (N = 8); (2) study 900-MHz MW-exposed group (N = 8); and (3) 900-MHz MW-exposed+melatonin (100 microg/kg sc before daily MW exposure treated group) (N = 10). Cortex brain and hippocampus tissues were removed to study the levels of lipid peroxidation as malonyl dialdehyde. The levels of lipid peroxidation in the brain cortex and hippocampus increased in the MW group compared with the control group, although the levels in the hippocampus were decreased by MW+melatonin administration. The brain cortex lipid peroxidation levels were unaffected by melatonin treatment. We conclude that melatonin may prevent MW-induced oxidative changes in the hippocampus by strengthening the anti-oxidant defense system, by reducing oxidative stress products.

**Koyu A, Ozguner F, Cesur G, Gokalp O, Mollaoglu H, Caliskan S, Delibas N. No effects of 900 MHz and 1800 MHz electromagnetic field emitted from cellular phone on nocturnal serum melatonin levels in rats. Toxicol Ind Health. 21(1-2):27-31, 2005.**

In this study, the effects of exposure to a 900 MHz and 1800 MHz electromagnetic field (EMF) on serum nocturnal melatonin levels of adult male Sprague-Dawley rats were studied. Thirty rats were used in three independent groups, 10 of which were exposed to 900 MHz, 10 of which were exposed to 1800 MHz and 10 of which were sham-exposed (control). The exposures were performed 30 min/day, for five days/week for four weeks to 900 MHz or 1800 MHz EMF Control animals were kept under the same environmental conditions as the study groups except with no EMF exposure. The concentration of nocturnal melatonin in the rat serum was measured by using a radioimmunoassay method. There were no statistically significant differences in serum melatonin concentrations between the 900 MHz EMF group and the sham-exposed group (P > 0.05). The values at 12:00 pm were 39.11 +/- 6.5 pg/mL in the sham-exposed group and 34.97 +/- 5.1 pg/mL in the 900 MHz EMF-exposed group. Also, there were no statistically significant differences in serum melatonin concentrations between the sham-exposed group and the 1800 MHz EMF-exposed group (P > 0.05). The values at 12:00 pm were 39.11 +/- 6.5 pg/mL in the sham-exposed group and 37.96 +/- 7.4 pg/mL in the exposed group. These results indicate that mobile phones, emitting 900 and 1800 MHz EMF, have no effect on nocturnal serum melatonin levels in rats.

**Koyu A, Cesur G, Ozguner F, Akdogan M, Mollaoglu H, Ozen S. Effects of 900MHz electromagnetic field on TSH and thyroid hormones in rats. Toxicol Lett. 157(3):257-262, 2005.**

In this study, the effects of exposure to a 900megahertz (MHz) electromagnetic field (EMF) on serum thyroid stimulating hormone (TSH) and triiodothronine-thyroxin (T(3)-

T(4)) hormones levels of adult male Sprague-Dawley rats were studied. Thirty rats were used in three independent groups, 10 of which were control (without stress and EMF), 10 of which were exposed to 900MHz EMF and 10 of which were sham-exposed. The exposures were performed 30min/day, for 5days/week for 4 weeks to 900MHz EMF. Sham-exposed animals were kept under the same environmental conditions as the study groups except with no EMF exposure. The concentration of TSH and T(3)-T(4) hormones in the rat serum was measured by using an immunoradiometric assay (IRMA) method for TSH and a radio-immunoassay (RIA) method for T(3) and T(4) hormones. TSH values and T(3)-T(4) at the 900MHz EMF group were significantly lower than the sham-exposed group ($p<0.01$). There were no statistically significant differences in serum TSH values and T(3)-T(4) hormone concentrations between the control and the sham-exposed group ($p>0.05$). These results indicate that 900MHz EMF emitted by cellular telephones decrease serum TSH and T(3)-T(4) levels.

**Kramarenko AV, Tan U. Effects of high-frequency electromagnetic fields on human eeg: A brain mapping study. Int J Neurosci. 113(7):1007-1019, 2003.**

Cell phones emitting pulsed high-frequency electromagnetic fields (EMF) may affect the human brain, but there are inconsistent results concerning their effects on electroencephalogram (EEG). We used a 16-channel telemetric electroencephalograph (ExpertTM), to record EEG changes during exposure of human skull to EMF emitted by a mobile phone. Spatial distribution of EMF was especially concentrated around the ipsilateral eye adjacent to the basal surface of the brain. Traditional EEG was full of noises during operation of a cellular phone. Using a telemetric electroencephalograph (ExpertTM) in awake subjects, all the noise was eliminated, and EEG showed interesting changes: after a period of 10-15 s there was no visible change, the spectrum median frequency increased in areas close to antenna; after 20-40 s, a slow-wave activity (2.5-6.0 Hz) appeared in the contralateral frontal and temporal areas. These slow waves lasting for about one second repeated every 15-20 s at the same recording electrodes. After turning off the mobile phone, slow-wave activity progressively disappeared; local changes such as increased median frequency decreased and disappeared after 15-20 min. We observed similar changes in children, but the slow-waves with higher amplitude appeared earlier in children (10-20 s) than adults, and their frequency was lower (1.0-2.5 Hz) with longer duration and shorter intervals. The results suggested that cellular phones may reversibly influence the human brain, inducing abnormal slow waves in EEG of awake persons.

**Krasil'nikov PM, [Resonance interactions of surface charged lipid vesicles with the microwave electromagnetic field]. Biofizika 44(6):1078-1082, 1999.** [Article in Russian]

The occurrence of collective excitations in an ionic medium on the surface of lipid membranes was shown. The excitations are due to a fast lateral mobility of ions and the excitation of high-frequency displacement currents in the Stern's layer at the charged surface of the membrane. These effects determine the mechanism of induction of resonant dipole moments on lipid vesicles which can underlie the effect of "recognition" and the autooscillation mode of aggegation of vesicles in a colloidal solution.

**Krause CM, Sillanmaki L, Koivisto M, Haggqvist A, Saarela C, Revonsuo A, Laine M, Hamalainen H, Effects of electromagnetic field emitted by cellular phones on the EEG during a memory task. Neuroreport 11(4):761-764, 2000.**

The effects of electromagnetic fields (EMF) emitted by cellular phones on the ERD/ERS of the 4-6 Hz, 6-8 Hz, 8-10 Hz and 10-12 Hz EEG frequency bands were studied in 16 normal subjects performing an auditory memory task. All subjects performed the memory task both with and without exposure to a digital 902 MHz EMF in counterbalanced order. The exposure to EMF significantly increased EEG power in the 8-10 Hz frequency band only. Nonetheless, the presence of EMF altered the ERD/ERS responses in all studied frequency bands as a function of time and memory task (encoding vs retrieval). Our results suggest that the exposure to EMF does not alter the resting EEG per se but modifies the brain responses significantly during a memory task.

**Krause CM, Sillanmaki L, Koivisto M, Haggqvist A, Saarela C, Revonsuo A, Laine M, Hamalainen H, Effects of electromagnetic fields emitted by cellular phones on the electroencephalogram during a visual working memory task. Int J Radiat Biol 76(12):1659-1667, 2000.**

PURPOSE: To examine the effects of electromagnetic fields (EMF) emitted by cellular phones on the event-related desynchronization/synchronization (ERD/ERS) responses of the 4-6, 6-8, 8-10 and 10-12Hz EEG frequency bands during cognitive processing. MATERIALS AND METHODS: Twenty-four subjects performed a visual sequential letter task (n-back task) with three different working memory load conditions: zero, one and two items. All subjects performed the memory task both with and without exposure to a digital 902 MHz EMF in counterbalanced order. RESULTS: The presence of EMF altered the ERD/ERS responses in the 6-8 and 8-10 Hz frequency bands but only when examined as a function of memory load and depending also on whether the presented stimulus was a target or not. CONCLUSIONS: The results suggest that the exposure to EMF modulates the responses of EEG oscillatory activity approximately 8 Hz specifically during cognitive processes.

**Krause CM, Haarala C, Sillanmaki L, Koivisto M, Alanko K, Revonsuo A, Laine M, Hamalainen H. Effects of electromagnetic field emitted by cellular phones on the EEG during an auditory memory task: a double blind replication study. Bioelectromagnetics. 25(1): 33-40, 2004**.

The effects of electromagnetic fields (EMF) emitted by cellular phones on the event related desynchronization/synchronization (ERD/ERS) of the 4-6, 6-8, 8-10, and 10-12 Hz electroencephalogram (EEG) frequency bands were studied in 24 normal subjects performing an auditory memory task. This study was a systematic replication of our previous work. In the present double blind study, all subjects performed the memory task both with and without exposure to a digital 902 MHz field in a counterbalanced order. We were not able to replicate the findings from our earlier study. All eight of the significant changes in our earlier study were not significant in the present double blind replication. Also, the effect of EMF on the number of incorrect answers in the memory task was inconsistent. We previously reported no significant effect of EMF exposure on the number of incorrect answers in the memory task, but a significant increase in errors was observed in the present study. We conclude that EMF effects on the EEG and on the performance

on memory tasks may be variable and not easily replicable for unknown reasons.

**Krause CM, Bjornberg CH, Pesonen M, Hulten A, Liesivuori T, Koivisto M, Revonsuo A, Laine M, Hamalainen H. Mobile phone effects on children's event-related oscillatory EEG during an auditory memory task. Int J Radiat Biol. 82(6):443-450, 2006.**

Purpose: To assess the effects of electromagnetic fields (EMF) emitted by mobile phones (MP) on the 1 - 20 Hz event-related brain oscillatory EEG (electroencephalogram) responses in children performing an auditory memory task (encoding and recognition).Materials and methods: EEG data were gathered while 15 subjects (age 10 - 14 years) performed an auditory memory task both with and without exposure to a digital 902 MHz MP in counterbalanced order.Results: During memory encoding, the active MP modulated the event-related desynchronization/synchronization (ERD/ERS) responses in the approximately 4 - 8 Hz EEG frequencies. During recognition, the active MP transformed these brain oscillatory responses in the approximately 4 - 8 Hz and approximately 15 Hz frequencies.Conclusions: The current findings suggest that EMF emitted by mobile phones has effects on brain oscillatory responses during cognitive processing in children.

**Krause CM, Pesonen M, Haarala Bjornberg C, Hamalainen H. Effects of pulsed and continuous wave 902 MHz mobile phone exposure on brain oscillatory activity during cognitive processing. Bioelectromagnetics.28(4):296-308, 2007.**

The aim of the current double-blind studies was to partially replicate the studies by Krause et al. [2000ab, 2004] and to further investigate the possible effects of electromagnetic fields (EMF) emitted by mobile phones (MP) on the event-related desynchronisation/synchronisation (ERD/ERS) EEG (electroencephalogram) responses during cognitive processing. Two groups, both consisting of 36 male participants, were recruited. One group performed an auditory memory task and the other performed a visual working memory task in six exposure conditions: SHAM (no EMF), CW (continuous wave EMF) and PM (pulse modulated EMF) during both left- and right-side exposure, while the EEG was recorded. In line with our previous studies, we observed that the exposure to EMF had modest effects on brain oscillatory responses in the alpha frequency range ( approximately 8-12 Hz) and had no effects on the behavioural measures. The effects on the EEG were, however, varying, unsystematic and inconsistent with previous reports. We conclude that the effects of EMF on brain oscillatory responses may be subtle, variable and difficult to replicate for unknown reasons.

**Krause D, Mullins JM, Penafiel LM, Meister R, Nardone RM, Microwave exposure alters the expression of 2-5A-dependent RNase. Radiat Res 127(2):164-170, 1991.**

The effects of 2.45-GHz continuous-wave microwaves (SAR = 130 mW/g) on the expression of the interferon-regulated enzymes 2'-5'-oligoadenylate (2-5A) synthetase(s) and 2-5A-dependent endoribonuclease (RNase L) were studied in murine L929 cells. Cells growing as monolayers were removed from the substratum and placed in suspension culture for a 4-h sham or microwave exposure. The cells

were returned to monolayer growth for 18 h, and then harvested and assayed to determine the amount of RNase L protein (via [32P]2-5A binding) and the specific activities of RNase L and 2-5A synthetase. Binding of radioactive 2-5A to RNase L for sham- and microwave-exposed samples was 14.5 and 36.4% above control, respectively (the microwave-exposed bound 19.0% more probe than the sham-exposed). The increases in 2-5A binding were accompanied by corresponding elevations of RNase L specific activity. In contrast, sham or microwave irradiation produced no alterations in 2-5A synthetase specific activity. No detectable differences were noted in the postexposure cell viability, plating efficiency, or proliferation rate. Also, there were no detectable differences in cell viability or plating efficiency between controls and cultures irradiated for 2 h when the temperature was simultaneously increased to above normal physiological limits (39 to 45 degrees C). The SAR (130 mW/g) and the power density (95 mW/cm2) used for the greater part of this study were nearly 20 times higher than the ANSI limit of 8 mW/g and 5 mW/cm2 for any 1 g of exposed human tissue.

**Kristiansen IS, Elstein AS, Gyrd-Hansen D, Kildemoes HW, Nielsen JB. Radiation from mobile phone systems: Is it perceived as a threat to people's health? Bioelectromagnetics. 30(5):393-401, 2009.**

The aim of this study was to explore the prevalence, nature and determinants of concerns about mobile phone radiation. We used data from a 2006 telephone survey of 1004 people aged 15+ years in Denmark. Twenty-eight percent of the respondents were concerned about exposure to mobile phone radiation; radiation from masts was of concern to about 15%. In contrast, 82% were concerned about pollution. Nearly half of the respondents considered the mortality risk of 3G phones and masts to be of the same order of magnitude as being struck by lightning (0.1 fatalities per million people per year) while 7% thought it was equivalent to tobacco-induced lung cancer (approximately 500 fatalities per million per year). Among women, concerns about mobile phone radiation were positively associated with educational attainment, perceived mobile phone mortality risk and concerns about unknown consequences of new technologies. More than two thirds of the respondents felt that they had received inadequate public information about the 3G system. The results of the study indicate that the majority of the population has little concern about mobile phone radiation while a small minority is very concerned.

**Krylov IN, Iasnetsov VV, Dukhanin AS, Pal'tsev IuP, [Pharmacologic correction of learning and memory disorders induced by exposure to high-frequency electromagnetic radiation]. Biull Eksp Biol Med 115(3):260-262, 1993.** [Article in Russian]

Acute exposure of rats to microwaves (12.6 chr, 2375 MHz, power density 1 mW/cm2) induced the retrograde amnesia. It was show the role of opioidergic, benzodiazepine, GABAergic and cholinergic components in the amnesic effects of microwaves. Piracetam (100 mg/kg, i. p.) and oxiracetam (10 mg/kg, i. p.) prevented the negative effects of microwaves on memory processes.

**Krylova IN, Dukhanin AS, Il'in AB, Kuznetsova Elu, Balaeva NV, Shimanovskii NL, Pal'tsev IuP, Iasnetsov VV, [The effect of ultrahigh-frequency electromagnetic radiation on learning and memory processes]. Biull Eksp Biol Med 114(11):483-484,**

**1994.** [Article in Russian]

Low-intensity electromagnetic field (12.6 cm, 2375 MHz, power density 1 mW/cm2) produced retrograde amnesia in the rat passive avoidance test. No effect was registered of microwave irradiation on the open field behavior and the pain sensitivity. Functional activity of the m-cholinergic receptors decreased, but their number increased in the brain cortex. It is suggested that cholinergic system plays an important role in the effects of electromagnetic field on memory processes.

**Kubinyi G, Thuroczy G, Bakos J, Boloni E, Sinay H, Szabo LD, Effect of continuous-wave and amplitude-modulated 2.45 GHz microwave radiation on the liver and brain aminoacyl-transfer RNA synthetases of in utero exposed mice. Bioelectromagnetics 17(6):497-503, 1996.**

Investigations have been carried out concerning the effects of microwave (MW) exposure on the aminoacyl-transfer ribonucleic acid (tRNA) synthetase of the progeny of females that were exposed during their entire period of gestation (19 days). The changes caused by continuous-wave (CW) and amplitude-modulated (AM) MW radiation have been compared. CFLP mice were exposed to MW radiation for 100 min each day in an anechoic room. The MW frequency was 2.45 GHz, and the amplitude modulation had a 50 Hz rectangular waveform (on/off ratio, 50/50%). The average power density exposure was 3 mW/cm2, and the whole body specific absorption rate (SAR) was 4.23 +/- 0.63 W/kg. The weight and mortality of the progeny were followed until postnatal day 24. Aminoacyl-tRNA synthetase enzymes and tRNA from the brains and livers of the offspring (461 exposed, 487 control) were isolated. The aminoacyl-tRNA synthetase activities were determined. The postnatal increase of body weight and organ weight was not influenced by the prenatal MW radiation. The activity of enzyme isolated from the brain showed a significant decrease after CW MW exposure, but the changes were not significant after 50 Hz AM MW exposure. The activity of the enzyme isolated from liver increased under CW and 50 Hz modulated MW.

**Kuehn S, Kelsh MA, Kuster N, Sheppard AR, Shum M. Analysis of mobile phone design features affecting radiofrequency power absorbed in a human head phantom. Bioelectromagnetics. 2013 Mar 26. doi: 10.1002/bem.21784. [Epub ahead of print]**

The US FCC mandates the testing of all mobile phones to demonstrate compliance with the rule requiring that the peak spatial SAR does not exceed the limit of 1.6 W/kg averaged over any 1 g of tissue. These test data, measured in phantoms with mobile phones operating at maximum antenna input power, permitted us to evaluate the variation in SARs across mobile phone design factors such as shape and antenna design, communication technology, and test date (over a 7-year period). Descriptive statistical summaries calculated for 850 MHz and 1900 MHz phones and ANOVA were used to evaluate the influence of the foregoing factors on SARs. Service technology accounted for the greatest variability in compliance test SARs that ranged from AMPS (highest) to CDMA, iDEN, TDMA, and GSM (lowest). However, the dominant factor for SARs during use is the time-averaged antenna input power, which may be much less than the maximum power used in testing. This factor is largely defined by the

communication system; e.g., the GSM phone average output can be higher than CDMA by a factor of 100. Phone shape, antenna type, and orientation of a phone were found to be significant but only on the order of up to a factor of 2 (3 dB). The SAR in the tilt position was significantly smaller than for touch. The side of the head did not affect SAR levels significantly. Among the remaining factors, external antennae produced greater SARs than internal ones, and brick and clamshell phones produced greater SARs than slide phones. Assuming phone design and usage patterns do not change significantly over time, we have developed a normalization procedure and formula that permits reliable prediction of the relative SAR between various communication systems. This approach can be applied to improve exposure assessment in epidemiological research.

**Kues HA, Monahan JC, D'Anna SA, McLeod DS, Lutty GA, Koslov S, Increased sensitivity of the non-human primate eye to microwave radiation following ophthalmic drug pretreatment. Bioelectromagnetics 13(5):379-393, 1992.**

Previous studies in our laboratory have established that pulsed microwaves at 2.45 GHz and 10 mW/cm2 are associated with production of corneal endothelial lesions and with disruption of the blood-aqueous barrier in the non-human primate eye. In the study reported here we examined ocular damage in monkeys (M. mulatta and M. fascicularis) following topical treatment with one of two ophthalmic drugs (timolol maleate and pilocarpine) that preceded exposure to pulsed microwaves. Anesthetized monkeys were sham exposed or exposed to pulsed, 2.45 GHz microwaves (10 microseconds, 100 pps) at average power densities of 0.2, 1, 5, 10, or 15 mW/cm2 4 h a day for 3 consecutive days (respective SARs were 0.052, 0.26, 1.3, 2.6, and 3.9 W/kg). Immediately before microwave exposure, one or both eyes were treated topically with one drop of 0.5% timolol maleate or of 2% pilocarpine. Following administration of a drug, we observed a significant reduction in the power-density threshold (from 10 to 1 mW/cm2) for induction of corneal endothelial lesions and for increased vascular permeability of the iris. Diagnostic procedures (in vivo specular microscopy and fluorescein iris angiography) were performed following each exposure protocol. In addition, increased vascular permeability was confirmed with horseradish peroxidase tracer techniques. Although we did not measure intraocular temperatures in experimental animals, the results suggest that a mechanism other than significant heating of the eye is involved. Our data indicate that pulsed microwaves at an average SAR of 0.26 W/kg, if administered after pretreatment with ophthalmic drugs, can produce significant ocular effects in the anesthetized primate.

**Kues HA, D'Anna SA, Osiander R, Green WR, Monahan JC, Absence of ocular effects after either single or repeated exposure to 10 mW/cm(2) from a 60 GHz CW source. Bioelectromagnetics 20(8):463-473, 1999.**

This study was designed to examine ocular effects associated with exposure to millimeter waves (60 GHz). Rabbits served as the primary experimental subjects. To confirm the results of the rabbit experiments in a higher species, the second phase of the study used nonhuman primates (Macaca mulatta). First, this study used time-resolved infrared radiometry to assess the field distribution patterns produced by different antennas operating at 60 GHz. These results allowed us to select an antenna that produced a uniform energy distribution and the best distance at which to expose our experimental

subjects. The study then examined ocular changes after exposure at an incident power density of 10 mW/cm(2). Acute exposure of both rabbits and nonhuman primates consisted of a single 8 h exposure, and the repeated exposure protocol consisted of five separate 4 h exposures on consecutive days. One eye in each animal was exposed and the contralateral eye served as the sham-exposed control. After postexposure diagnostic examinations, animals were euthanized and the eyes were removed. Ocular tissue was examined by both light and transmission electron microscopy. Neither microscopic examinations nor the diagnostic procedures performed on the eyes of acute and repeatedly exposed rabbits found any ocular changes that could be attributed to millimeter-wave exposure at 10 mW/cm(2). Examination of the primates after comparable exposures also failed to detect any ocular changes due to exposure. On the basis of our results, we conclude that single or repeated exposure to 60 GHz CW radiation at 10 mW/cm(2) does not result in any detectable ocular damage.

**Kühn S, Jennings W, Christ A, Kuster N. Assessment of induced radio-frequency electromagnetic fields in various anatomical human body models. Phys Med Biol. 54(4):875-890, 2009.**

The reference levels for testing compliance of human exposure with radio-frequency (RF) safety limits have been derived from very simplified models of the human. In order to validate these findings for anatomical models, we investigated the absorption characteristics for various anatomies ranging from 6 year old child to large adult male by numerical modeling. We address the exposure to plane-waves incident from all major six sides of the humans with two orthogonal polarizations each. Worst-case scattered field exposure scenarios have been constructed in order to test the implemented procedures of current in situ compliance measurement standards (spatial averaging versus peak search). Our findings suggest that the reference levels of current electromagnetic (EM) safety guidelines for demonstrating compliance as well as some of the current measurement standards are not consistent with the basic restrictions and need to be revised.

**Kulaber A, Kerimoğlu G, Ersöz Ş, Çolakoğlu S, Odacı E. Alterations of thymic morphology and antioxidant biomarkers in 60-day-old male rats following exposure to a continuous 900 MHz electromagnetic field during adolescence. Biotech Histochem. 92(5):331-337, 2017.**

We investigated changes in thymic tissue of male rats exposed to a 900 megahertz (MHz) electromagnetic field (EMF) on postnatal days 22-59. Three groups of six 21-day-old male Sprague-Dawley rats were allocated as: control (CG), sham (SG) and EMF (EMFG) groups. No procedure was performed on the CG rats. SG rats were placed in a Plexiglas cage for 1 h every day between postnatal days 22 and 59 without exposure to EMF. EMFG rats were placed in the same cage for the same periods as the SG rats and were exposed to 900 MHz EMF. Rats were sacrificed on postnatal day 60. Sections of thymus were stained for histological assessment. Oxidant/antioxidant parameters were investigated biochemically. Malondialdehyde (MDA) levels in EMFG increased compared to the other groups. Extravascular erythrocytes were observed in the medullary/corticomedullary regions in EMFG sections. We found that 900 MHz EMF

applied for 1 h/day on postnatal days 22-59 can increase tissue MDA and histopathological changes in male rat thymic tissue.

**Kulkybaev GA, Pospelov NI, [Changes in gastric electric activity and serum catecholamine level under the influence of electromagnetic microwaves]. Med Tr Prom Ekol (5):8-11, 2000.** (Article in Russian)

Chronic experiments on 17 dogs revealed that ultrahigh-frequency electromagnetic waves applied on epigastric area and head induce a double-phase response: depressed electric activity of gaster and increased total catecholamines level during exposure, but higher gastric activity and lower levels of epinephrine and norepinephrine in 24 hours after each of 10 procedures and during 7 days after 10 procedures. Double-phase changes in electric activity of gaster could be explained by double-phase fluctuations of humoral division in chromaffin system.

**Kumar A, Singh HP, Batish DR, Kaur S, Kohli RK. EMF radiations (1800 MHz)-inhibited early seedling growth of maize (Zea mays) involves alterations in starch and sucrose metabolism. Protoplasma. 2015 Aug 16. [Epub ahead of print]**

The present study investigated the impact of 1800-MHz electromagnetic field radiations (EMF-r), widely used in mobile communication, on the growth and activity of starch-, sucrose-, and phosphate-hydrolyzing enzymes in Zea mays seedlings. We exposed Z. mays to modulated continuous wave homogenous EMF-r at specific absorption rate (SAR) of 0.169 watts per kilogram for ½, 1, 2, and 4 hours. The analysis of seedlings after 7 days revealed that short-term exposure did not induce any significant change, while longer exposure of 4 h caused significant growth and biochemical alterations. There was a reduction in the root and coleoptile length with more pronounced effect on coleoptile growth (23% reduction on 4-h exposure). The contents of photosynthetic pigments and total carbohydrates declined by 13 and 18%, respectively, in 4-h exposure treatments compared to unexposed control. The activity of starch-hydrolyzing enzymes-α- and β-amylases-increased by ~92 and 94%, respectively, at an exposure duration of 4 h, over that in the control. In response to 4-h exposure treatment, the activity of sucrolytic enzymes-acid invertases and alkaline invertases-was increased by 88 and 266%, whereas the specific activities of phosphohydrolytic enzymes (acid phosphatases and alkaline phosphatases) showed initial increase up to ≤2 h duration and then declined at >2 h exposure duration. The study concludes that EMF-r-inhibited seedling growth of Z. mays involves interference with starch and sucrose metabolism.

**Kumar G, McIntosh RL, Anderson V, McKenzie RJ, Wood AW. A Genotoxic Analysis on Hematopoietic system after Mobile Phone Type Radiation Exposure in Rats. Int J Radiat Biol. 91(8):664-672, 2015.**

PURPOSE: In our earlier study we reported that 900 MHz continuous wave (CW) radiofrequency radiation (RFR) exposure (2 W/kg specific absorption rate (SAR)) had no significant effect on the hematopoietic system of rats. In this paper we extend the scope of the previous study by testing for possible effects at: i) different SAR levels; ii) both 900 and 1800 MHz, and; iii) both CW and pulse modulated (PM) RFR. MATERIALS AND

METHODS: Excised long bones from rats were placed in medium and RFR exposed in i) a Transverse Electromagnetic (TEM) cell or ii) a waveguide. Finite-difference time-domain (FDTD) numerical analyses were used to estimate forward power needed to produce nominal SAR levels of 2/10 and 2.5/12.4 W/kg in the bone marrow. After exposure, the lymphoblasts were extracted and assayed for proliferation rate, and genotoxicity. RESULTS: Our data did not indicate any significant change in these end points for any combination of CW/PM exposure at 900/1800 MHz at SAR levels of nominally 2/10 W/kg or 2.5/12.4 W/kg. CONCLUSIONS: No significant changes were observed in the hematopoietic system of rats after the exposure of CW/PM wave 900 MHz/1800 MHz RF radiations at different SAR values.

**Kumar NR, Sangwan S, Badotra P. Exposure to cell phone radiations produces biochemical changes in worker honey bees. Toxicol Int. 18(1):70-72, 2011.**

The present study was carried out to find the effect of cell phone radiations on various biomolecules in the adult workers of Apis mellifera L. The results of the treated adults were analyzed and compared with the control. Radiation from the cell phone influences honey bees' behavior and physiology. There was reduced motor activity of the worker bees on the comb initially, followed by en masse migration and movement toward "talk mode" cell phone. The initial quiet period was characterized by rise in concentration of biomolecules including proteins, carbohydrates and lipids, perhaps due to stimulation of body mechanism to fight the stressful condition created by the radiations. At later stages of exposure, there was a slight decline in the concentration of biomolecules probably because the body had adapted to the stimulus.

**Kumar RS, Sareesh NN, Nayak S, Mailankot M. Hypoactivity of Wistar rats exposed to mobile phone on elevated plus maze. Indian J Physiol Pharmacol. 53(3):283-286, 2009.**

No abstract available. From discussion section: “In conclusion, our preliminary results indicate mobile phone exposure induced behavioral changes in rats, expressed as deficit in open arm exploration on elevated plus-maze.”

**Kumar S, Kesari KK, Behari J. Influence of microwave exposure on fertility of male rats. Fertil Steril.95(4):1500-1502, 2011.**

The present study investigates the effect of 10-GHz microwave radiation on the fertility pattern of 70-day-old male rats (sham exposed and exposed), which were exposed for 2 h/d for 45 days continuously at a specific absorption rate of 0.014 W/kg and a power density of 0.21 mW/cm(2). Results show a significant change in the level of reactive oxygen species, histone kinase, apoptotic cells, and percentage of G(2)/M transition phase of cell cycle in the exposed group compared with the sham-exposed group. The study concludes that there is a significant effect of microwave radiations on the reproductive pattern in male rats, which is a causative factor of male infertility.

**Kumar S, Kesari KK, Behari J. Evaluation of genotoxic effects in male Wistar rats following microwave exposure. Indian J Exp Biol. 48(6):586-592, 2010.**

Wistar rats (70 days old) were exposed for 2 h a day for 45 days continuously at 10 GHz [power density 0.214 mW/cm2, specific absorption rate (SAR) 0.014 W/kg] and 50 GHz (power density 0.86 microW/cm2, SAR 8.0 x10(-4) W/kg). Micronuclei (MN), reactive oxygen species (ROS), and antioxidant enzymes activity were estimated in the blood cells and serum. These radiations induce micronuclei formation and significant increase in ROS production. Significant changes in the level of serum glutathione peroxidase, superoxide dismutase and catalase were observed in exposed group as compared with control group. It is concluded that microwave exposure can be affective at genetic level. This may be an indication of tumor promotion, which comes through the overproduction of reactive oxygen species.

**Kumar S, Kesari KK, Behari J. The therapeutic effect of a pulsed electromagnetic field on the reproductive patterns of male Wistar rats exposed to a 2.45-GHz microwave field. Clinics (Sao Paulo). 66(7):1237-1245, 2011.**

INTRODUCTION: Environmental exposure to man-made electromagnetic fields has been steadily increasing with the growing demand for electronic items that are operational at various frequencies. Testicular function is particularly susceptible to radiation emitted by electromagnetic fields. OBJECTIVES: This study aimed to examine the therapeutic effects of a pulsed electromagnetic field (100 Hz) on the reproductive systems of male Wistar rats (70 days old). METHODS: The experiments were divided into five groups: microwave sham, microwave exposure (2.45 GHz), pulsed electromagnetic field sham, pulsed electromagnetic field (100 Hz) exposure, and microwave/pulsed electromagnetic field exposure. The animals were exposed for 2 hours/day for 60 days. After exposure, the animals were sacrificed, their sperm was used for creatine and caspase assays, and their serum was used for melatonin and testosterone assays. RESULTS: The results showed significant increases in caspase and creatine kinase and significant decreases in testosterone and melatonin in the exposed groups. This finding emphasizes that reactive oxygen species (a potential inducer of cancer) are the primary cause of DNA damage. However, pulsed electromagnetic field exposure relieves the effect of microwave exposure by inducing Faraday currents. CONCLUSIONS: Electromagnetic fields are recognized as hazards that affect testicular function by generating reactive oxygen species and reduce the bioavailability of androgen to maturing spermatozoa. Thus, microwave exposure adversely affects male fertility, whereas pulsed electromagnetic field therapy is a non-invasive, simple technique that can be used as a scavenger agent to combat oxidative stress.

**Kumar S, Behari J, Sisodia R. Impact of microwave at X-band in the aetiology of male infertility. Electromagn Biol Med. 31(3):223-232, 2012.**

Reports of declining male fertility have renewed interest in assessing the role of environmental and occupational exposures to electromagnetic fields (EMFs) in the aetiology of human infertility. Testicular functions are particularly susceptible to electromagnetic fields. The aim of the present work was to investigate the effect of 10-GHz EMF on male albino rat's reproductive system and to investigate the possible causative factor for such effect of exposure. The study was carried out in two groups of 70-day old adult male albino rats: a sham-exposed and a 10-GHz-exposed group

(2 h a day for 45 days). Immediately after completion of the exposure, animals were sacrificed and sperms were extracted from the cauda and caput part of testis for the analysis of MDA, melatonin, and creatine kinase. Creatine kinase results revealed an increased level of phosphorylation that converts creatine to creatine phosphate in sperms after EMF exposure. EMF exposure also reduced the level of melatonin and MDA. It is concluded that microwaveexposure could adversely affect male fertility by reducing availability of the above parameters. These results are indications of deleterious effects of these radiations on reproductive pattern of male rats.

**Kumar S, Behari J, Sisodia R. Influence of electromagnetic Fields on reproductive system of male rats.Int J Radiat Biol. 2012 Oct 19. [Epub ahead of print]**

Purpose: Reports of declining male fertility have renewed interest in the role of environmental and occupational exposures in the etiology of human infertility. The aim of the present work is to investigate the effect of 10 GHz exposure on male Wistar rat's reproductive system and to find out the possible causative factors. Materials and methods: The study was divided into sham exposed and exposed groups. Seventy days old rats were exposed to 10 GHz microwave radiation for two hours per day for 45 days at power density 0.21mW/cm(2) and specific absorption rate (SAR) of 0.014W/kg. After the end of the experiment, blood samples were collected for the estimation of in vivo chromosomal aberration damage and micronucleus test. Spermatozoa were taken out for estimation of caspase3, comet assay, testosterone and electron microscopy and compared with sham exposed. Results: The study of scanning electron microscopic revealed shrinkage of the lumen of the seminiferous tubules. Apoptotic bodies were found in exposed group. A flow cytometry examination showed formation of micronuclei body in lymphocytes of exposed group. Comet assay confirmed DNA (deoxyribonucleic acid) strand break. Testosterone level was found significantly decreased with the shrinkage of testicular size. Conclusions: 10 GHz field has an injurious effect on fertility potential of male exposed animals.

**Kumar V, Vats RP, Pathak PP. Harmful effects of 41 and 202 MHz radiations on some body parts and tissues. Indian J Biochem Biophys. 45(4):269-274, 2008.**

Many types of invisible electromagnetic waves are produced in our atmosphere. When these radiations penetrate our body, electric fields are induced inside the body, resulting in the absorption of power, which is different for different body parts and also depends on the frequency of radiations. Higher power absorption may result into health problems. In this communication, effects of electromagnetic waves (EMW) of 41 and 202 MHz frequencies transmitted by the TV tower have been studied on skin, muscles, bone and fat of human. Using international standards for safe exposure limits of specific absorption rate (SAR), we have found the safe distance from TV transmission towers for two frequencies. It is suggested that transmission towers should be located away from the thickly populated areas and people should keep away from the transmission towers, as they radiate electromagnetic radiations that are harmful to some parts/tissues of body.

**Kumari K, Koivisto H, Viluksela M, Paldanius KMA, Marttinen M, Hiltunen M, Naarala J, Tanila H, Juutilainen J. Behavioral testing of mice exposed to**

**intermediate frequency magnetic fields indicates mild memory impairment. PLoS One. 2017 Dec 4;12(12):e0188880.**

Human exposure to intermediate frequency magnetic fields (MF) is increasing due to applications like electronic article surveillance systems and induction heating cooking hobs. However, limited data is available on their possible health effects. The present study assessed behavioral and histopathological consequences of exposing mice to 7.5 kHz MF at 12 or 120 μT for 5 weeks. No effects were observed on body weight, spontaneous activity, motor coordination, level of anxiety or aggression. In the Morris swim task, mice in the 120 μT group showed less steep learning curve than the other groups, but did not differ from controls in their search bias in the probe test. The passive avoidance task indicated a clear impairment of memory over 48 h in the 120 μT group. No effects on astroglial activation or neurogenesis were observed in the hippocampus. The mRNA expression of brain-derived neurotrophic factor did not change but expression of the proinflammatory cytokine tumor necrosis factor alpha mRNA was significantly increased in the 120 μT group. These findings suggest that 7.5 kHz MF exposure may lead to mild learning and memory impairment, possibly through an inflammatory reaction in the hippocampus.

**Kumlin T, Iivonen H, Miettinen P, Juvonen A, van Groen T, Puranen L, Pitkäaho R, Juutilainen J, Tanila H. Mobile phone radiation and the developing brain: behavioral and morphological effects in juvenile rats. Radiat Res. 168(4):471-479, 2007.**

The increasing use of mobile phones by children and teenagers has raised concerns about their safety. Addressing such concerns is difficult, because no data are available on possible effects from long-term exposure to radiofrequency (RF) fields during the development of the nervous system. Possible morphological and functional changes were evaluated in the central nervous system of young male Wistar rats exposed to 900 MHz mobile phone signal for 2 h/day on 5 days/week. After 5 weeks of exposure at whole-body average specific energy absorption rates of 0.3 or 3.0 W/kg or sham exposure, six rats per group were examined histologically, and the remaining 18 rats per group were subjected to behavioral tests. No degenerative changes, dying neurons, or effects on the leakage of the blood-brain barrier were detected. No group differences were observed in the open-field test, plus maze test or acoustic startle response tests. In the water maze test, however, significantly improved learning ($P = 0.012$) and memory ($P = 0.01$) were detected in rats exposed to RF fields. The results do not indicate a serious threat to the developing brain from mobile phone radiation at intensities relevant to human exposure. However, the interesting finding of improved learning and memory warrants further studies.

**Kundi M. The controversy about a possible relationship between mobile phone use and cancer. Cien Saude Colet. 15(5):2415-2430, 2010.**

Over the last decade, mobile phone use increased to almost 100% prevalence in many countries. Evidence for potential health hazards accumulated in parallel by epidemiologic investigations has raised controversies about the appropriate interpretation and the

degree of bias and confounding responsible for reduced or increased risk estimates. Overall, 33 epidemiologic studies were identified in the peer-reviewed literature, mostly (25) about brain tumors. Methodologic considerations revealed that three important conditions for epidemiologic studies to detect an increased risk are not met:no evidence-based exposure metric is available; the observed duration of mobile phone use is generally still too low; no evidence-based selection of end points among the grossly different types of neoplasias is possible because of lack of etiologic hypotheses. The overall evidence speaks in favor of an increased risk, but its magnitude cannot be assessed at present because of insufficient information on long-term use.

**Kundi M, Hutter HP.Mobile phone base stations-Effects on wellbeing and health.Pathophysiology. 16(2-3):123-135, 2009.**

Studying effects of mobile phone base station signals on health have been discouraged by authoritative bodies like WHO International EMF Project and COST 281. WHO recommended studies around base stations in 2003 but again stated in 2006 that studies on cancer in relation to base station exposure are of low priority. As a result only few investigations of effects of base station exposure on health and wellbeing exist. Cross-sectional investigations of subjective health as a function of distance or measured field strength, despite differences in methods and robustness of study design, found indications for an effect of exposure that is likely independent of concerns and attributions. Experimental studies applying short-term exposure to base station signals gave various results, but there is weak evidence that UMTS and to a lesser degree GSM signals reduce wellbeing in persons that report to be sensitive to such exposures. Two ecological studies of cancer in the vicinity of base stations report both a strong increase of incidence within a radius of 350 and 400m respectively. Due to the limitations inherent in this design no firm conclusions can be drawn, but the results underline the urgent need for a comprehensive investigation of this issue. Animal and in vitro studies are inconclusive to date. An increased incidence of DMBA induced mammary tumors in rats at a SAR of 1.4W/kg in one experiment could not be replicated in a second trial. Indications of oxidative stress after low-level in vivo exposure of rats could not be supported by in vitro studies of human fibroblasts and glioblastoma cells. From available evidence it is impossible to delineate a threshold below which no effect occurs, however, given the fact that studies reporting low exposure were invariably negative it is suggested that power densities around 0.5-1mW/m(2) must be exceeded in order to observe an effect. The meager data base must be extended in the coming years. The difficulties of investigating long-term effects of base station exposure have been exaggerated, considering that base station and handset exposure have almost nothing in common both needs to be studied independently. It cannot be accepted that studying base stations is postponed until there is firm evidence for mobile phones.

**Kunjilwar KK, Behari J Effect of amplitude-modulated radio frequency radiation on cholinergic system of developing rats. Brain Res 601(1-2):321-324, 1993.**

We examined the effect of long-term exposure to radio frequency radiation 147 MHz and its sub-harmonics 73.5 and 36.75 MHz amplitude modulated at 16 and 76 Hz (30-35

days, 3 h per day) on cholinergic systems in developing rat brain. A significant decrease in acetylcholine esterase activity was found in exposed rats as compared to the control. Decrease in acetylcholine esterase (AChE) activity was independent of carrier wave frequencies. A short-term exposure did not have any significant effect on AChE activity.

**Kuribayashi M, Wang J, Fujiwara O, Doi Y, Nabae K, Tamano S, Ogiso T, Asamoto M, Shirai T. Lack of effects of 1439 MHz electromagnetic near field exposure on the blood-brain barrier in immature and young rats. Bioelectromagnetics. 26(7):578-88, 2005.**

Possible effects of 1439 MHz electromagnetic near field (EMF) exposure on the blood-brain barrier (BBB) were investigated using immature (4 weeks old) and young (10 weeks old) rats, equivalent in age to the time when the BBB development is completed and the young adult, respectively. Alteration of BBB related genes, such as those encoding p-glycoprotein, aquaporin-4, and claudin-5, was assessed at the protein and mRNA levels in the brain after local exposure of the head to EMF at 0, 2, and 6 W/kg specific energy absorption rates (SARs) for 90 min/day for 1 or 2 weeks. Although expression of the 3 genes was clearly decreased after administration of 1,3-dinitrobenzene (DNB) as a positive control, when compared with the control values, there were no pathologically relevant differences with the EMF at any exposure levels at either age. Vascular permeability, monitored with reference to transfer of FITC-dextran, FD20, was not affected by EMF exposure. Thus, these findings suggest that local exposure of the head to 1439 MHz EMF exerts no adverse effects on the BBB in immature and young rats.

**Kuybulu AE, Öktem F, Çiriş İM, Sutcu R, Örmeci AR, Çömlekçi S, Uz E. Effects of long-term pre- and post-natal exposure to 2.45 GHz wireless devices on developing male rat kidney. Ren Fail. 2016 Feb 24:1-10. [Epub ahead of print]**

Purpose The aim of the present study was to investigate oxidative stress and apoptosis in kidney tissues of male Wistar rats that pre- and postnatally exposed to wireless electromagnetic field (EMF) with an internet frequency of 2.45 GHz for a long time. Methods The study was conducted in three groups of rats which were pre-natal, post-natal. and sham exposed groups. Oxidative stress markers and histological evaluation of kidney tissues were studied. Results Renal tissue malondialdehyde (MDA) and total oxidant (TOS) levels of pre-natal group were high and total antioxidant (TAS) and superoxide dismutase (SOD) levels were low. Spot urine NAG/creatinine ratio was significantly higher in pre- and post-natal groups ($p < 0.001$). Tubular injury was detected in most of the specimens in post-natal groups. Immunohistochemical analysis showed low-intensity staining with Bax in cortex, high-intensity staining with Bcl-2 in cortical and medullar areas of pre-natal group (p values, 0.000, 0.002, 0.000, respectively) when compared with sham group. Bcl2/Bax staining intensity ratios of medullar and cortical area was higher in pre-natal group than sham group ($p = 0.018$, $p = 0.011$). Conclusion Based on this study, it is thought that chronic pre- and post-natal period exposure to wireless internet frequency of EMF may cause chronic kidney damages; staying away from EMF source in especially pregnancy and early childhood period may reduce negative effects of exposure on kidney.

**Kwee S, Raskmark P, Changes in cell proliferation due to environmental non-ionizing radiation 2. Microwave radiation. Bioelectrochem Bioenerg 44(2) 251-255, 1998.**

Due to the use of mobile telephones, there is an increased exposure of the environment to weak radiofrequency (RF) electromagnetic fields, emitted by these devices. This study was undertaken to investigate if the microwave radiation from these fields will have a similar effect on cell proliferation as weak electromagnetic (ELF) fields. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) values for each cell well were calculated for this exposure system. Experiments were performed on cell cultures of transformed human epithelial amnion cells (AMA), which were exposed to 960 MHz microwave fields at three different power levels and three different exposure times, respectively. It was found that cell growth in the exposed cells was decreased in comparison to that in the control and sham exposed cells. Cell proliferation during the period following exposure varied not only with the various SAR levels, but also with the length of exposure time. On the other hand, repeated periods of exposure did not seem to change the effects. There was a general linear correlation between power level and growth change. However, the exposure time required to obtain the maximum effect was not the same for the various power levels. It turned out that at low power level, a maximum effect was first reached after a longer exposure time than at higher power level. A similar phenomenon was registered in the studies on ELF electromagnetic fields. Here, it was found that there was a linear correlation between the length of exposure time to obtain maximum effect and field strength.

**Kwee S, Raskmark P, Velizarov P. Changes in cellular proteins due to environmental non-ionizing radiation. i. Heat-shock proteins. Electro- and Magnetobiology 20: 141-152, 2001.**

This paper describes the effect of weak microwave fields on the amounts of heat-shock proteins in cell cultures at various temperatures. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 Mhz, used in portable phones. Transformed human epithelial amnion (AMA) cells, growing on glass coverslips, were exposed in a transverse electromagnetic (TEM) cell to a microwave field, generating a specific absorption rate (SAR) of 2.1 $mW.kg^{-1}$ in the cells. Exposure temperatures were 35, 37, and 40 ± 0.1°C, respectively, and the exposure time was 20 min. The heat-shock proteins Hsp-70 and Hsp-27 were detected by immuno-fluorescence. Higher amounts of Hsp-70 were present in the cells exposed at 35 and 37°C than in the sham-exposed cells. These effects can be considered to be athermal, since the field strength was much lower than the safety standard for absence of heat generation by microwave fields. There was no significant response in the case of Hsp-27.

**Kwon MK, Nam KC, Lee da S, Jang KH, Kim DW. Effects of RF fields emitted from**

**smart phones on cardio-respiratory parameters: a preliminary provocation study. Conf Proc IEEE Eng Med Biol Soc. 2011:1961-1964, 2011.**

This paper describes an experimental setup for evaluating the physiological effects of radiofrequency (RF) emitted from a Wideband Code Division Multiple Access (WCDMA) module with a 24 dBm at 1950 MHz for specific absorption rate (SAR(1g)) of 1.57 W/kg. This provocation study was executed in a double-blind study of two volunteer groups of 10 self-reported electromagnetic hypersensitivity (EHS) and 10 non-EHS subjects under both sham and real exposures in a randomly assigned and counter-balanced order. In the preliminary results, WCDMA RF exposure of 30 min did not have any effects on physiological changes in either group.

**Kwon MK, Choi JY, Kim SK, Yoo TK, Kim DW. Effects of radiation emitted by WCDMA mobile phones on electromagnetic hypersensitive subjects. Environ Health. 11(1):69, 2012.**

BACKGROUND: With the use of the third generation (3 G) mobile phones on the rise, social concerns have arisen concerning the possible health effects of radio frequency-electromagnetic fields (RF-EMFs) emitted by wideband code division multiple access (WCDMA) mobile phones in humans. The number of people with self-reported electromagnetic hypersensitivity (EHS), who complain of various subjective symptoms such as headache, dizziness and fatigue, has also increased. However, the origins of EHS remain unclear. METHODS: In this double-blind study, two volunteer groups of 17 EHS and 20 non-EHS subjects were simultaneously investigated for physiological changes (heart rate, heart rate variability, and respiration rate), eight subjective symptoms, and perception of RF-EMFs during real and sham exposure sessions. Experiments were conducted using a dummy phone containing a WCDMA module (average power, 24 dBm at 1950 MHz; specific absorption rate, 1.57 W/kg) within a headset placed on the head for 32 min. RESULTS: WCDMA RF-EMFs generated no physiological changes or subjective symptoms in either group. There was no evidence that EHS subjects perceived RF-EMFs better than non-EHS subjects. CONCLUSIONS: Considering the analyzed physiological data, the subjective symptoms surveyed, and the percentages of those who believed they were being exposed, 32 min of RF radiation emitted by WCDMA mobile phones demonstrated no effects in either EHS or non-EHS subjects.

**Kwon MK, Kim SK, Koo JM, Choi JY, Kim DW. EHS subjects do not perceive RF EMF emitted from smart phones better than non-EHS subjects. Conf Proc IEEE Eng Med Biol Soc. 2012:2190-193, 2012.**

As the use of smart phones increases, social concerns have arisen concerning the possible effects of radio frequency-electromagnetic fields (RF-EMFs) emitted from wideband code division multiple access (WCDMA) mobile phones on human health. The number of people with self-reported electromagnetic hypersensitivity (EHS) who complain of various subjective symptoms, such as headache, insomnia, etc., has also recently increased. However, it is unclear whether EHS subjects can detect RF-EMFs exposure or

not. In this double-blind study, two volunteer groups of 17 EHS and 20 non-EHS subjects were investigated in regards to their perception of RF-EMFs with real and sham exposure sessions. Experiments were conducted using a WCDMA module inside a dummy phone with an average power of 24 dBm at 1950 MHz and a specific absorption rate of 1.57 W/kg using a dummy headphone for 32 min. In conclusion, there was no indication that EHS subjects perceive RF-EMFs better than non-EHS subjects.

**Kwon MS, Kujala T, Huotilainen M, Shestakova A, Näätänen R, Hämäläinen H. Preattentive auditory information processing under exposure to the 902 MHz GSM mobile phone electromagnetic field: A mismatch negativity (MMN) study. Bioelectromagnetics.30(3):241-248, 2009.**

Previous studies on the effects of the mobile phone electromagnetic field (EMF) on various event-related potential (ERP) components have yielded inconsistent and even contradictory results, and often failed in replication. The mismatch negativity (MMN) is an auditory ERP component elicited by infrequent (deviant) stimuli differing in some physical features from the repetitive frequent (standard) stimuli in a sound sequence. The MMN provides a sensitive measure for cortical auditory stimulus feature discrimination, regardless of attention and other contaminating factors. In this study, MMN responses to duration, intensity, frequency, and gap changes were recorded in healthy young adults (n = 17), using a multifeature paradigm including several types of auditory change in the same stimulus sequence, while a GSM mobile phone was placed on either ear with the EMF (902 MHz pulsed at 217 Hz; SAR(1g) = 1.14 W/kg, SAR(10g) = 0.82 W/kg, peak value = 1.21 W/kg, measured with an SAM phantom) on or off. An MMN was elicited by all deviant types, while its amplitude and latency showed no significant differences due to EMF exposure for any deviant types. In the present study, we found no conclusive evidence that acute exposure to GSM mobile phone EMF affects cortical auditory change detection processing reflected by the MMN.

**Kwon MS, Jääskeläinen SK, Toivo T, Hämäläinen H. No effects of mobile phone electromagnetic field on auditory brainstem response. Bioelectromagnetics. 31(1):48-55, 2010.**

The present study investigated the possible effects of the electromagnetic field (EMF) emitted by an ordinary GSM mobile phone (902.4 MHz pulsed at 217 Hz) on brainstem auditory processing. Auditory brainstem responses (ABR) were recorded in 17 healthy young adults, without a mobile phone at baseline, and then with a mobile phone on the ear under EMF-off and EMF-on conditions. The amplitudes, latencies, and interwave intervals of the main ABR components (waves I, III, V) were compared among the three conditions. ABR waveforms showed no significant differences due to exposure, suggesting that short-term exposure to mobile phone EMF did not affect the transmission of sensory stimuli from the cochlea up to the midbrain along the auditory nerve and brainstem auditory pathways.

**Kwon MS**, **Huotilainen M**, **Shestakova A**, **Kujala T**, **Näätänen R**, **Hämäläinen H**. **No effects of mobile phone use on cortical auditory change-detection in children: An ERP study. Bioelectromagnetics.31(3):191-199, 2010.**

We investigated the effect of mobile phone use on the auditory sensory memory in

children. Auditory event-related potentials (ERPs), P1, N2, mismatch negativity (MMN), and P3a, were recorded from 17 children, aged 11-12 years, in the recently developed multi-feature paradigm. This paradigm allows one to determine the neural change-detection profile consisting of several different types of acoustic changes. During the recording, an ordinary GSM (Global System for Mobile Communications) mobile phone emitting 902 MHz (pulsed at 217 Hz) electromagnetic field (EMF) was placed on the ear, over the left or right temporal area (SAR(1g) = 1.14 W/kg, SAR(10g) = 0.82 W/kg, peak value = 1.21 W/kg). The EMF was either on or off in a single-blind manner. We found that a short exposure (two 6 min blocks for each side) to mobile phone EMF has no statistically significant effects on the neural change-detection profile measured with the MMN. Furthermore, the multi-feature paradigm was shown to be well suited for studies of perception accuracy and sensory memory in children. However, it should be noted that the present study only had sufficient statistical power to detect a large effect size.

**Kwon MS, Vorobyev V, Kännälä S, Laine M, Rinne JO, Toivonen T, Johansson J, Teräs M, Lindholm H, Alanko T, Hämäläinen H. GSM mobile phone radiation suppresses brain glucosemetabolism. J Cereb Blood Flow Metab. 31(12):2293-2301, 2011.**

We investigated the effects of mobile phone radiation on cerebral glucosemetabolism using high-resolution positron emission tomography (PET) with the (18)F-deoxyglucose (FDG) tracer. A long half-life (109 minutes) of the (18)F isotope allowed a long, natural exposure condition outside the PET scanner. Thirteen young right-handed male subjects were exposed to a pulse-modulated 902.4 MHz Global System for Mobile Communications signal for 33 minutes, while performing a simple visual vigilance task. Temperature was also measured in the head region (forehead, eyes, cheeks, ear canals) during exposure. (18)F-deoxyglucose PET images acquired after the exposure showed that relative cerebral metabolic rate of glucose was significantly reduced in the temporoparietal junction and anterior temporal lobe of the right hemisphere ipsilateral to the exposure. Temperature rise was also observed on the exposed side of the head, but the magnitude was very small. The exposure did not affect task performance (reaction time, error rate). Our results show that short-term mobile phone exposure can locally suppress brain energy metabolism in humans.

**Kwon MS, Vorobyev V, Kännälä S, Laine M, Rinne JO, Toivonen T, Johansson J, Teräs M, Joutsa J, Tuominen L, Lindholm H, Alanko T, Hämäläinen H. No effects of short-term GSM mobile phone radiation on cerebral blood flow measured using positron emission tomography. Bioelectromagnetics. 33(3):247-256, 2012.**

The present study investigated the effects of 902.4 MHz global system for mobile communications (GSM) mobile phone radiation on cerebral blood flow using positron emission tomography (PET) with the (15) O-water tracer. Fifteen young, healthy, right-handed male subjects were exposed to phone radiation from three different locations (left ear, right ear, forehead) and to sham exposure to test for possible exposure effects on brain regions close to the exposure source. Whole-brain [$^{15}$O]$H_2O$-PET images were acquired 12 times, 3 for each condition, in a counterbalanced order. Subjects were exposed for 5 min in each scan while performing a simple visual vigilance task.

Temperature was also measured in the head region (forehead, eyes, cheeks, ear canals) during exposure. The exposure induced a slight temperature rise in the ear canals but did not affect brain hemodynamics and task performance.The results provided no evidence for acute effects of short-term mobile phone radiation on cerebral blood flow.

**L'Abbate N, Pranzo S, Martucci V, Rella C, Vitucci L, Salamanna S. [Evaluation of the levels of radiofrequency electromagnetic fields in the territory of the city of Bari in outside and inside environments] G Ital Med Lav Ergon. 26(1):19-27, 2004.** [Article in Italian]

In this study we measured the levels of the high frequency field in the proximity of non-ionizing radiation sources (wireless transmitting stations for mobile telephones and radio and television transmitters) in nine districts of the city of Bari. The measurements were taken both inside and outside closed environments. For the indoor measurements we took into account electromagnetic field generating equipment (VDT, electric domestic appliances, mobile telephones) in working and non-working order and with the windows open and shut respectively. We carried out these measurements according to the methods laid down in the Italian regulation CEI ENV 50166-2 of May 1995, as shown in the enclosure to the Ministerial Decree of 10.9.98 n.381. The electromagnetic field levels near wireless transmitting stations for mobile telephones are certainly modest when we consider that they never exceeded the limits established by the aforesaid Ministerial Decree. On the contrary radio and television equipment creates a much greater source of exposure. The electromagnetic field levels are certainly superior to those of the wireless transmitting stations although they never exceed, except in one isolated case, the values established by the Ministerial Decree 381/98.

**La Regina M, Moros EG, Pickard WF, Straube WL, Baty J, Roti Roti JL. The effect of chronic exposure to 835.62 MHz FDMA or 847.74 MHz CDMA radiofrequency radiation on the incidence of spontaneous tumors in rats. Radiat Res. 160(2):143-151, 2003.**

This study was designed to determine whether chronic exposure to radiofrequency (RF) radiation from cellular phones increased the incidence of spontaneous tumors in F344 rats. Eighty male and 80 female rats were randomly placed in each of three irradiation groups. The sham group received no irradiation; the Frequency Division Multiple Access (FDMA) group was exposed to 835.62 MHz FDMA RF radiation; and the Code Division Multiple Access (CDMA) group was exposed to 847.74 MHz CDMA RF radiation. Rats were irradiated 4 h per day, 5 days per week over 2 years. The nominal time-averaged specific absorption rate (SAR) in the brain for the irradiated animals was 0.85 +/- 0.34 W/kg (mean +/- SD) per time-averaged watt of antenna power. Antennas were driven with a time-averaged power of 1.50 +/- 0.25 W (range). That is, the nominal time-averaged brain SAR was 1.3 +/- 0.5 W/kg (mean +/- SD). This number was an average from several measurement locations inside the brain, and it takes into account changes in animal weight and head position during irradiation. All major organs were evaluated grossly and histologically. The number of

tumors, tumor types and incidence of hyperplasia for each organ were recorded. There were no significant differences among final body weights or survival days for either males or females in any group. No significant differences were found between treated and sham-exposed animals for any tumor in any organ. We conclude that chronic exposure to 835.62 MHz FDMA or 847.74 MHz CDMA RF radiation had no significant effect on the incidence of spontaneous tumors in F344 rats.

**Laberge-Nadeau C, Maag U, Bellavance F, Lapierre SD, Desjardins D, Messier S, Sai;di A. Wireless telephones and the risk of road crashes. Accid Anal Prev. 35(5):649-660, 2003.**

In light of the rapidly increasing development of the cell phone market, the use of such equipment while driving raises the question of whether it is associated with an increased accident risk; and if so, what is its magnitude. This research is an epidemiological study on two large cohorts, namely users and non-users of cell phones, with the objective of verifying whether an association exists between cell phone use and road crashes, separating those with injuries.The Societe de l'Assurance Automobile du Quebec (SAAQ) mailed a questionnaire and letter of consent to 175000 licence holders for passenger vehicles. The questionnaire asked about exposure to risk, driving habits, opinions about activities likely to be detrimental to driving and accidents within the last 24 months. For cell phone users, questions pertaining to the use of the telephone were added. We received 36078 completed questionnaires, with a signed letter of consent. Four wireless phone companies provided the files on cell phone activity, and the SAAQ the files for 4 years of drivers' records and police reports. The three data sources were merged using an anonymized identification number. The statistical methods include logistic-normal regression models to estimate the strength of the links between the explanatory variables and crashes.The relative risk of all accidents and of accidents with injuries is higher for users of cell phones than for non-users. The relative risks (RR) for injury collisions and also for all collisions is 38% higher for men and women cell phone users. These risks diminish to 1.1 for men and 1.2 for women if other variables, such as the kilometres driven and driving habits are incorporated into the models. Similar results hold for several sub-groups. The most significant finding is a dose-response relationship between the frequency of cell phone use, and crash risks. The adjusted relative risks for heavy users are at least two compared to those making minimal use of cell phones; the latter show similar collision rates as do the non-users.

**Lagorio S, Rossi S, Vecchia P, De Santis M, Bastianini L, Fusilli M, Ferrucci A, Desideri E, Comba P, Mortality of plastic-ware workers exposed to radiofrequencies. Bioelectromagnetics 18(6):418-421, 1997.**

The mortality experience of a cohort of Italian plastic-ware workers exposed to radiofrequency (RF)-electromagnetic fields generated by dielectric heat sealers was investigated. Follow-up extended from 1962 to 1992. The standardised mortality ratio (SMR) analysis was restricted to 481 women workers, representing 78% of the total person-years at risk. Mortality from malignant neoplasms was slightly elevated, and increased risks of leukemia and accidents were detected. The all-cancer SMR was higher

among women employed in the sealing department, where exposure to RF occurred, than in the whole cohort. This study raises interest in a possible association between exposure to RF radiation and cancer risk. However, the study power was very small, and the possible confounding effects of exposure to solvents and vinyl chloride monomer (VCM) could not be ruled out. The hypothesis of an increased risk of cancer after radiofrequency exposure should be further explored by means of analytical studies characterised by adequate power and more accurate exposure assessment.

**Lagroye I, Anane R, Wettring BA, Moros EG, Straube WL, Laregina M, Niehoff M, Pickard WF, Baty J, Roti JL. Measurement of DNA damage after acute exposure to pulsed-wave 2450 MHz microwaves in rat brain cells by two alkaline comet assay methods. Int J Radiat Biol. 80(1):11-20, 2004.**

Purpose: To investigate the effect of 2450 MHz pulsed-wave microwaves on the induction of DNA damage in brain cells of exposed rats and to discover whether proteinase K is needed to detect DNA damage in the brain cells of rats exposed to 2450 MHz microwaves. Materials and methods: Sprague-Dawley rats were exposed to 2450 MHz pulsed-wave microwaves and sacrificed 4 h after a 2-h exposure. Rats irradiated whole-body with 1 Gy (137)Cs were included as positive controls. DNA damage was assayed by two variants of the alkaline comet assay on separate aliquots of the same cell preparation. Results: Significant DNA damage was observed in the rat brain cells of rats exposed to gamma-rays using both versions of the alkaline comet assay independent of the presence or absence of proteinase K. However, neither version of the assay could detect any difference in comet length and/or normalized comet moment between sham- and 2450 MHz pulsed-wave microwave-exposed rats, regardless of the inclusion or omission of proteinase K in the comet assay. Conclusions: No DNA damage in brain cells was detected following exposure of rats to 2450 MHz microwaves pulsed-wave at a specific absorption rate of 1.2 W kg(-1) regardless of whether or not proteinase K was included in the assay. Thus, the results support the conclusion that low-level 2450 MHz pulsed-wave microwave exposures do not induce DNA damage detectable by the alkaline comet assay.

**Lagroye I, Hook GJ, Wettring BA, Baty JD, Moros EG, Straube WL, Roti Roti JL. Measurements of alkali-labile DNA damage and protein-DNA crosslinks after 2450 MHz microwave and low-dose gamma irradiation In vitro. Radiat Res. 161(2): 201-214, 2004.**

In vitro experiments were performed to determine whether 2450 MHz microwave radiation induces alkali-labile DNA damage and/or DNA-protein or DNA-DNA crosslinks in C3H 10T(1/2) cells. After a 2-h exposure to either 2450 MHz continuous-wave (CW) microwaves at an SAR of 1.9 W/kg or 1 mM cisplatinum (CDDP, a positive control for DNA crosslinks), C3H 10T(1/2) cells were irradiated with 4 Gy of gamma rays ((137)Cs). Immediately after gamma irradiation, the single-cell gel electrophoresis assay was performed to detect DNA damage. For each exposure condition, one set of samples was treated with proteinase K (1 mg/ml) to remove any possible DNA-protein crosslinks. To measure DNA-protein crosslinks independent of DNA-DNA crosslinks, we quantified the proteins that were recovered with DNA after microwave exposure, using CDDP and gamma irradiation, positive controls for DNA-protein crosslinks. Ionizing radiation (4 Gy)

induced significant DNA damage. However, no DNA damage could be detected after exposure to 2450 MHz CW microwaves alone. The crosslinking agent CDDP significantly reduced both the comet length and the normalized comet moment in C3H 10T(1/2) cells irradiated with 4 Gy gamma rays. In contrast, 2450 MHz microwaves did not impede the DNA migration induced by gamma rays. When control cells were treated with proteinase K, both parameters increased in the absence of any DNA damage. However, no additional effect of proteinase K was seen in samples exposed to 2450 MHz microwaves or in samples treated with the combination of microwaves and radiation. On the other hand, proteinase K treatment was ineffective in restoring any migration of the DNA in cells pretreated with CDDP and irradiated with gamma rays. When DNA-protein crosslinks were specifically measured, we found no evidence for the induction of DNA-protein crosslinks or changes in amount of the protein associated with DNA by 2450 MHz CW microwave exposure. Thus 2-h exposures to 1.9 W/ kg of 2450 MHz CW microwaves did not induce measurable alkali-labile DNA damage or DNA-DNA or DNA-protein crosslinks.

**Lahham A, Hammash A. Outdoor radiofrequency radiation levels in the West Bank-Palestine. Radiat Prot Dosimetry. 149(4):399-402, 2012.**

This work presents the results of exposure levels to radio frequency (RF) emission from different sources in the environment of the West Bank-Palestine. These RF emitters include FM and TV broadcasting stations and mobile phone base stations. Power densities were measured at 65 locations distributed over the West Bank area. These locations include mainly centres of the major cities. Also a 24 h activity level was investigated for a mobile phone base station to determine the maximum activity level for this kind of RF emitters. All measurements were conducted at a height of 1.7 m above ground level using hand held Narda SRM 3000 spectrum analyzer with isotropic antenna capable of collecting RF signals in the frequency band from 75 MHz to 3 GHz. The average value of power density resulted from FM radio broadcasting in all investigated locations was 0.148 μW cm(-2), from TV broadcasting was 0.007 μW cm(-2) and from mobile phone base station was 0.089 μW cm(-2). The maximum total exposure evaluated at any location was 3.86 μW cm(-2). The corresponding exposure quotient calculated for this site was 0.02. This value is well below unity indicating compliance with the International Commission on non-ionising Radiation protection guidelines. Contributions from all relevant RF sources to the total exposure were evaluated and found to be ~62 % from FM radio, 3 % for TV broadcasting and 35 % from mobile phone base stations. The average total exposure from all investigated RF sources was 0.37 μW cm(-2).

**Lahham A, Sharabati A, ALMasri H. Assessment of Public Exposure From WLANs in the West Bank-Palestine. Radiat Prot Dosimetry. 2017 Mar 3:1-5. doi: 10.1093/rpd/ncx028.**

A total of 271 measurements were conducted at 69 different sites including homes, hospitals, educational institutions and other public places to assess the exposure to radiofrequency emission from wireless local area networks (WLANs). Measurements were conducted at different distances from 40 to 10 m from the access points (APs) in real life conditions using Narda SRM-3000 selective radiation meter. Three measurements modes were considered at 1 m distance from the AP which are transmit

mode, idle mode, and from the client card (laptop computer). All measurements were conducted indoor in the West Bank environment. Power density levels from WLAN systems were found to vary from 0.001 to ~1.9 μW cm-2 with an average of 0.12 μW cm-2. Maximum value found was in university environment, while the minimum was found in schools. For one measurement case where the AP was 20 cm far while transmitting large files, the measured power density reached a value of ~4.5 μW cm-2. This value is however 221 times below the general public exposure limit recommended by the International Commission on Non-Ionizing Radiation Protection, which was not exceeded in any case. Measurements of power density at 1 m around the laptop resulted in less exposure than the AP in both transmit and idle modes as well. Specific absorption rate for the head of the laptop user was estimated and found to vary from 0.1 to 2 mW/kg. The frequency distribution of measured power densities follows a log-normal distribution which is generally typical in the assessment of exposure resulting from sources of radiofrequency emissions.

**Lahkola A, Salminen T, Auvinen A. Selection bias due to differential participation in a case-control study of mobile phone use and brain tumors. Ann Epidemiol. 15(5):321-325, 2005.**

PURPOSE: To evaluate the possible selection bias related to the differential participation of mobile phone users and non-users in a Finnish case-control study on mobile phone use and brain tumors. METHODS: Mobile phone use was investigated among 777 controls and 726 cases participating in the full personal interview (full participants), and 321 controls and 103 cases giving only a brief phone interview (incomplete participants). To assess selection bias, the Mantel-Haenszel estimate of odds ratio was calculated for three different groups: full study participants, incomplete participants, and a combined group consisting of both full and incomplete participants. RESULTS: Among controls, 83% of the full participants and 73% of the incomplete participants had regularly used a mobile phone. Among cases, the figures were 76% and 64%, respectively. The odds ratio for brain tumor based on the combined group of full and incomplete participants was slightly closer to unity than that based only on the full participants. CONCLUSIONS: Selection bias tends to distort the effect estimates below unity, while analyses based on more comprehensive material gave results close to unity.

**Lahkola A, Tokola K, Auvinen A. Meta-analysis of mobile phone use and intracranial tumors. Scand J Work Environ Health. 32(3):171-177, 2006.**

OBJECTIVES: A summary of epidemiologic evidence regarding the effect of mobile phone use on intracranial tumor risk was obtained by means of a meta-analysis. METHODS: Reports of published studies on mobile phone use and intracranial tumors were sought. Altogether 12 relevant publications were identified from the PubMed database and reference lists of articles. Fixed or random effects analysis was carried out depending on the presence of heterogeneity between studies. Risk estimates were obtained for people who had used mobile phones for the longest periods of time (>5 years in most reports). A pooled estimate was calculated for all intracranial tumors combined and also separately for different histological tumor types. Separate analyses were conducted also based on the tumor location and type of mobile telephone network

(NMT or GSM). Results Twelve studies with 2780 cases gave a pooled odds ratio (OR) of 0.98 [95% confidence interval (95% CI) 0.83-1.16] for all intracranial tumors related to mobile phone use. For gliomas, the pooled OR was 0.96 (95% CI 0.78-1.18), for meningiomas it was 0.87 (95% CI 0.72-1.05), and for acoustic neuromas it was 1.07 (95% CI 0.89-1.30). Little indication was found for increased risks of analogue or digital phone use or temporal or occipital tumors. Conclusions The totality of evidence does not indicate a substantially increased risk of intracranial tumors from mobile phone use for a period of at least 5 years.

**Lahkola A, Auvinen A, Raitanen J, Schoemaker MJ, Christensen HC, Feychting M, Johansen C, Klaeboe L, Lonn S, Swerdlow AJ, Tynes T, Salminen T. Mobile phone use and risk of glioma in 5 North European countries. Int J Cancer. 120(8):1769-1775, 2007.**

Public concern has been expressed about the possible adverse health effects of mobile telephones, mainly related to intracranial tumors. We conducted a population-based case-control study to investigate the relationship between mobile phone use and risk of glioma among 1,522 glioma patients and 3,301 controls. We found no evidence of increased risk of glioma related to regular mobile phone use (odds ratio, OR = 0.78, 95% confidence interval, CI: 0.68, 0.91). No significant association was found across categories with duration of use, years since first use, cumulative number of calls or cumulative hours of use. When the linear trend was examined, the OR for cumulative hours of mobile phone use was 1.006 (1.002, 1.010) per 100 hr, but no such relationship was found for the years of use or the number of calls. We found no increased risks when analogue and digital phones were analyzed separately. For more than 10 years of mobile phone use reported on the side of the head where the tumor was located, an increased OR of borderline statistical significance (OR = 1.39, 95% CI 1.01, 1.92, p trend 0.04) was found, whereas similar use on the opposite side of the head resulted in an OR of 0.98 (95% CI 0.71, 1.37). Although our results overall do not indicate an increased risk of glioma in relation to mobile phone use, the possible risk in the most heavily exposed part of the brain with long-term use needs to be explored further before firm conclusions can be drawn.

**Lahkola A, Salminen T, Raitanen J, Heinävaara S, Schoemaker M, Christensen HC, Feychting M, Johansen C, Klæboe L, Lönn S, Swerdlow A, Tynes T, Auvinen A. Meningioma and mobile phone use--a collaborative case-control study in five North European countries. Int J Epidemiol.37(6):1304-1313, 2008.**

BACKGROUND: Use of mobile telephones has been suggested as a possible risk factor for intracranial tumours. To evaluate the effect of mobile phones on risk of meningioma, we carried out an international, collaborative case-control study of 1209 meningioma cases and 3299 population-based controls. METHODS: Population-based cases were identified, mostly from hospitals, and controls from national population registers and general practitioners' patient lists. Detailed history of mobile phone use was obtained by personal interview. Regular mobile phone use (at least once a week for at least 6 months), duration of use, cumulative number and hours of use, and several other indicators of mobile phone use were assessed in relation to meningioma risk using conditional logistic regression with strata defined by age, sex,

country and region. RESULTS: Risk of meningioma among regular users of mobile phones was apparently lower than among never or non-regular users (odds ratio, OR = 0.76, 95% confidence interval, CI 0.65, 0.89). The risk was not increased in relation to years since first use, lifetime years of use, cumulative hours of use or cumulative number of calls. The findings were similar regardless of telephone network type (analogue/digital), age or sex. CONCLUSIONS: Our results do not provide support for an association between mobile phone use and risk of meningioma.

**Lai H. Interaction of microwaves and a temporally incoherent magnetic field on spatial learning in the rat. Physiol Behav. 82(5):785-789, 2004.**

The effect of a temporally incoherent magnetic field ('noise') on microwave-induced spatial learning deficit in the rat was investigated. Rats were trained in six sessions to locate a submerged platform in a circular water maze. Four treatment groups of rats were studied: microwave-exposure (2450-MHz continuous-wave microwaves, power density 2 mW/cm(2), average whole-body specific absorption rate 1.2 W/kg), 'noise' exposure (60 mG), 'microwave+noise' exposure, and sham exposure. Animals were exposed to these conditions for 1 h immediately before each training session. One hour after the last training session, animals were tested in a 2-min probe trial in the maze during which the platform was removed. The time spent during the 2 min in the quadrant of the maze in which the platform had been located was scored. Results show that microwave-exposed rats had significant deficit in learning to locate the submerged platform when compared with the performance of the sham-exposed animals. Exposure to 'noise' alone did not significantly affect the performance of the animals (i.e., it was similar to that of the sham-exposed rats). However, simultaneous exposure to 'noise' significantly attenuated the microwave-induced spatial learning deficit (i.e. 'microwave+noise'-exposed rats learned significantly better than the microwave-exposed rats). During the probe trial, microwave-exposed animals spent significantly less time in the quadrant where the platform was located. However, response of the 'microwave+noise'-exposed animals was similar to that of the sham-exposed animals during the probe trial. Thus, simultaneous exposure to a temporally incoherent magnetic field blocks microwave-induced spatial learning and memory deficits in the rat.

**Lai H, Singh NP, Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics 16(3):207-210, 1995.**

Levels of DNA single-strand break were assayed in brain cells from rats acutely exposed to low-intensity 2450 MHz microwaves using an alkaline microgel electrophoresis method. Immediately after 2 h of exposure to pulsed (2 microseconds width, 500 pulses/s) microwaves, no significant effect was observed, whereas a dose rate-dependent [0.6 and 1.2 W/kg whole body specific absorption rate (SAR)] increase in DNA single-strand breaks was found in brain cells of rats at 4 h postexposure. Furthermore, in rats exposed for 2 h to continuous-wave 2450 MHz microwaves (SAR 1.2 W/kg), increases in brain cell DNA single-strand breaks were observed immediately as well as at 4 h postexposure.

**Lai H, Singh NP, Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. Int J Radiat Biol 69(4):513-521, 1996.**

We investigated the effects of acute (2-h) exposure to pulsed (2-micros pulse width, 500 pulses s(-1)) and continuous wave 2450-MHz radiofrequency electromagnetic radiation on DNA strand breaks in brain cells of rat. The spatial averaged power density of the radiation was 2mW/cm2, which produced a whole-body average-specific absorption rate of 1.2W/kg. Single- and double-strand DNA breaks in individual brain cells were measured at 4h post-exposure using a microgel electrophoresis assay. An increase in both types of DNA strand breaks was observed after exposure to either the pulsed or continuous-wave radiation, No significant difference was observed between the effects of the two forms of radiation. We speculate that these effects could result from a direct effect of radiofrequency electromagnetic energy on DNA molecules and/or impairment of DNA-damage repair mechanisms in brain cells. Our data further support the results of earlier in vitro and in vivo studies showing effects of radiofrequency electromagnetic radiation on DNA.

**Lai, H, Singh, NP, Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. Bioelectromagnetics 18(6):446-454, 1997.**

Effects of in vivo microwave exposure on DNA strand breaks, a form of DNA damage, were investigated in rat brain cells. In previous research, we have found that acute (2 hours) exposure to pulsed (2 microseconds pulses, 500 pps) 2450-MHz radiofrequency electromagnetic radiation (RFR) (power density 2 mW/cm2, average whole body specific absorption rate 1.2 W/kg) caused an increase in DNA single- and double-strand breaks in brain cells of the rat when assayed 4 hours post exposure using a microgel electrophoresis assay. In the present study, we found that treatment of rats immediately before and after RFR exposure with either melatonin (1 mg/kg/injection, SC) or the spin-trap compound N-tert-butyl-alpha-phenylnitrone (PBN) (100 mg/kg/injection, i.p.) blocks this effects of RFR. Since both melatonin and PBN are efficient free radical scavengers it is hypothesized that free radicals are involved in RFR-induced DNA damage in the brain cells of rats. Since cumulated DNA strand breaks in brain cells can lead to neurodegenerative diseases and cancer and an excess of free radicals in cells has been suggested to be the cause of various human diseases, data from this study could have important implications for the health effects of RFR exposure.

**Lai H, Singh NP, Interaction of Microwaves and a Temporally Incoherent Magnetic Field on Single and Double DNA Strand Breaks in Rat Brain Cells. Electromag Biol Med 24:23-29, 2005.**

The effect of a temporally incoherent magnetic field ('noise') on microwave-induced DNA single and double strand breaks in rat brain cells was investigated. Four treatment groups of rats were studied: microwave-exposure (continuous-wave 2450-MHz microwaves, power density 1 mW/cm$^2$, average whole body specific absorption rate of 0.6 W/kg), 'noise'-exposure (45 mG), 'microwave + noise'-exposure, and sham-exposure. Animals were exposed to these conditions for 2 hrs. DNA single and double strand breaks in brain cells of these animals were assayed 4 hrs later using a microgel electrophoresis assay. Results show that brain cells of microwave-exposed rats had significantly higher levels of DNA single and double strand breaks when compared with sham-exposed animals. Exposure to 'noise' alone did not significantly affect the levels

(i.e., they were similar to those of the sham-exposed rats). However, simultaneous 'noise' exposure blocked microwave-induced increases in DNA strand breaks. These data indicate that simultaneous exposure to a temporally incoherent magnetic field could block microwave-induced DNA damage in brain cells of the rat.

**Lai, H, Carino, MA, Singh, NP, Naltrexone blocks RFR-induced DNA double strand breaks in rat brain cells. Wireless Networks 3:471-476, 1997.**

Previous research in our laboratory has shown that various effects of radiofrequency electromagnetic radiation (RFR) exposure on the nervous system are mediated by endogenous opioids in the brain. We have also found that acute exposure to RFR induced DNA strand breaks in brain cells of the rat. The present experiment was carried out to investigate whether endogenous opioids are also involved in RFR-induced DNA strand breaks. Rats were treated with the opioid antagonist naltrexone (1 mg/kg, IP) immediately before and after exposure to 2450-MHz pulsed (2 μs pulses, 500 pps) RFR at a power density of 2 mW/cm2 (average whole body specific absorption rate of 1.2 W/kg) for 2 hours. DNA double strand breaks were assayed in brain cells at 4 hours after exposure using a microgel electrophoresis assay. Results showed that the RFR exposure significantly increased DNA double strand breaks in brain cells of the rat, and the effect was partially blocked by treatment with naltrexone. Thus, these data indicate that endogenous opioids play a mediating role in RFR-induced DNA strand breaks in brain cells of the rat.

**Lai H, Horita A, Guy AW, Microwave irradiation affects radial-arm maze performance in the rat. Bioelectromagnetics 15(2):95-104, 1994.**

After 45 min of exposure to pulsed 2450 MHz microwaves (2 microseconds pulses, 500 pps, 1 mW/cm2, average whole body SAR 0.6 W/kg), rats showed retarded learning while performing in the radial-arm maze to obtain food rewards, indicating a deficit in spatial "working memory" function. This behavioral deficit was reversed by pretreatment before exposure with the cholinergic agonist physostigmine or the opiate antagonist naltrexone, whereas pretreatment with the peripheral opiate antagonist naloxone methiodide showed no reversal of effect. These data indicate that both cholinergic and endogenous opioid neurotransmitter systems in the brain are involved in the microwave-induced spatial memory deficit.

**Lai H, Carino MA, Wen YF, Horita A, Guy AW, Naltrexone pretreatment blocks microwave-induced changes in central cholinergic receptors. Bioelectromagnetics 12(1):27-33, 1991.**

Repeated exposure of rats to pulsed, circularly polarized microwaves (2,450-MHz, 2-microseconds pulses at 500 pps, power density 1 mW/cm2, at an averaged, whole-body SAR of 0.6 W/kg) induced biphasic changes in the concentration of muscarinic cholinergic receptors in the central nervous system. An increase in receptor concentration occurred in the hippocampus of rats subjected to ten 45-min sessions of microwave exposure, whereas a decrease in concentration was observed in the frontal cortex and hippocampus of rats exposed to ten 20-min sessions. These findings, which confirm earlier work in the authors' laboratory, were extended to include pretreatment of rats with the narcotic antagonist naltrexone (1 mg/kg, IP) before each session of exposure. The

drug treatment blocked the microwave-induced changes in cholinergic receptors in the brain. These data further support the authors' hypothesis that endogenous opioids play a role in the effects of microwaves on central cholinergic systems.

**Lai H, Carino MA, Horita A, Guy AW, Opioid receptor subtypes that mediate a microwave-induced decrease in central cholinergic activity in the rat. Bioelectromagnetics 13(3):237-246, 1992.**

We performed experiments to investigate subtypes of opioid receptors in the brain involved in the effect of acute (45 min) pulsed microwave exposure (2,450-MHz, 2-microseconds pulses, 500 pps, average power density 1 mW/cm2, peak-power density, 1 W/cm2, average whole body SAR 0.6 W/kg) on cholinergic activity in the rat brain. Rats were pretreated by microinjection of specific antagonists of mu, delta, and kappa opioid-receptors into the lateral cerebroventricle before exposure to microwaves. The data showed that all three subtypes of opioid receptors are involved in the microwave-induced decrease in cholinergic activity in the hippocampus. However, the microwave-induced decrease in cholinergic activity in the frontal cortex was not significantly affected by any of the drug treatments, confirming our previous conclusion that the effect of microwaves on the frontal cortex is not mediated by endogenous opioids.

**Lai H, Carino MA, Horita A, Guy AW, Single vs. repeated microwave exposure: effects on benzodiazepine receptors in the brain of the rat. Bioelectromagnetics 13(1):57-66, 1992.**

We studied the effects of single (45 min) and repeated (ten daily 45-min sessions) microwave exposures (2450-MHz, 1 mW/cm2, average whole-body SAR of 0.6 W/kg, pulsed at 500 pps with pulse width of 2 microseconds) on the concentration and affinity of benzodiazepine receptors in the cerebral cortex, hippocampus, and cerebellum of the rat. We used a receptor-binding assay with 3H-flunitrazepam as ligand. Immediately after a single exposure, an increase in the concentration of receptor was observed in the cerebral cortex, but no significant effect was observed in the hippocampus or cerebellum. No significant change in binding affinity of the receptors was observed in any of the brain-regions studied. In rats subjected to repeated exposures, no significant change in receptor concentration was found in the cerebral cortex immediately after the last exposure, which may indicate an adaptation to repeated exposures. Our data also show that handling and exposure procedures in our experiments did not significantly affect benzodiazepine receptors in the brain. Because benzodiazepine receptors in the brain are responsive to anxiety and stress, our data support the hypothesis that low-intensity microwave irradiation can be a source of stress.

**Lai H, Carino MA, Horita A, Guy AW, Intraseptal microinjection of beta-funaltrexamine blocked a microwave-induced decrease of hippocampal cholinergic activity in the rat. Pharmacol Biochem Behav 53(3):613-616, 1994.**

Acute (45 min) exposure to pulsed (2 microseconds pulse width, 500 pulses per second) 2450-MHz microwaves at a power density of 1 mW/cm2 (whole body specific absorption rate 0.6 W/kg) microwaves caused a decrease in cholinergic activity in the hippocampus of the rat as measured by the sodium-dependent high-affinity choline uptake. Microinjection of beta-funaltrexamine (1 microgram) into the septum before microwave

exposure blocked this effect. These data indicate that mu-opioid receptors in the septum mediate a microwave-induced decrease in cholinergic activity in the hippocampus and support our hypothesis that microwaves at a whole body SAR of 0.6 W/kg can activate endogenous opioids in the brain.

**Lakshmi NK, Tiwari R, BhargavaSC, Ahuja YRInvestigations on DNA damage and frequency of micronuclei in occupational exposure to electromagnetic fields (EMFs) emitted from video display terminals (VDTs). Gen Mol Biol 33(1): 154-158, 2010.**

The potential effect of electromagnetic fields (EMFs) emitted from video display terminals (VDTs) to elicit biological response is a major concern for the public. The software professionals are subjected to cumulative EMFs in their occupational environments. This study was undertaken to evaluate DNA damage and incidences of micronuclei in such professionals. To the best of our knowledge, the present study is the first attempt to carry out cytogenetic investigations on assessing bioeffects in personal computer users. The study subjects (n = 138) included software professionals using VDTs for more than 2 years with age, gender, socioeconomic status matched controls (n = 151). DNA damage and frequency of micronuclei were evaluated using alkaline comet assay and cytochalasin blocked micronucleus assay respectively. Overall DNA damage and incidence of micronuclei showed no significant differences between the exposed and control subjects. With exposure characteristics, such as total duration (years) and frequency of use (minutes/day) sub-groups were assessed for such parameters. Although cumulative frequency of use showed no significant changes in the DNA integrity of the classified sub-groups, the long-term users (> 10 years) showed higher induction of DNA damage and increased frequency of micronuclei and micro nucleated cells.

**Lalic H, Lekic A, Radosevic-Stasic B. Comparison of chromosome aberrations in peripheral blood lymphocytes from people occupationally exposed to ionizing and radiofrequency radiation. Acta Med Okayama 55(2):117-127, 2001.**

The genotoxic effects of occupational exposure to ionizing and non-ionizing radiation were investigated in 25 physicians and nurses working in hospitals and in 20 individuals working at radio-relay stations. Examination was conducted by chromosome aberration analysis of peripheral blood lymphocytes. The data showed that total number of chromosome aberrations in people exposed to ionizing and radio-frequency radiation (4.08 +/- 0.37 and 4.35 +/- 0.5 on 200 scored metaphases, respectively) were almost equally higher than those of non-irradiated subjects. The increase was in proportion to the number of individuals having more that 5-aberration/200 metaphases. Acentric fragments comprised the most frequently seen type of aberration. The average numbers in examined groups (11.8 x 10(-3) and 14.8 x 10(-3) per cell, respectively), were significantly higher than 4.2 x 10(-3), which was observed in controls, unexposed individuals. Dicentric fragments were also frequent (4.8 x 10(-3) and 6.25 x 10(-3), respectively, vs. 0.52 x 10(-3) in control). In contrast, the frequency of chromatid breaks increased only after ionizing radiation (3.8 x 10(-3) vs. 0.26 x 10(-3) in control). A positive correlation between the total number of chromosome aberrations and cumulative 6-years dosage was also found. The data emphasized the dangerous effects of prolonged exposure to both types of radiation

and indicated that chromosomal aberration analysis should be obligatory for individuals working at radio-relay stations.

**Lam LT. Distractions and the risk of car crash injury: the effect of drivers' age. J Safety Res 33(3):411-419, 2002.**

PROBLEM: Motor-vehicle accidents are one of the major causes of injury in most motorized countries. Driver distractions have been suggested as a contributor to traffic accidents. Moreover, age of the driver seems to have a role in the relationship between distractions and car crashes. But very few studies have investigated the effect of driver's age on this relationship. This exploratory study investigated the association between distractions, both inside and outside the vehicle, and the increased risk of car crash injury among drivers across different ages. METHOD: This study used a case series design to analyze data routinely collected by the NSW police in Australia. A special focus of this study was on how drivers' age affects the risk of car crash injury, which was determined by using a well-documented risk estimation methodology. RESULTS: The results obtained indicated that drivers of all ages, on the whole, are more susceptible to distractions inside the vehicle than distractions coming from outside. Age was shown to affect the relationship between in-vehicle distraction and the risk of car crash injury. A separate analysis was also conducted on hand-held phone usage while driving with results supplementing previous findings reported in the literature. IMPACT TO INDUSTRY: Safety strategies to countermeasure in-vehicle distractions have been suggested and discussed.

**Lamble D, Kauranen T, Laakso M, Summala H, Cognitive load and detection thresholds in car following situations: safety implications for using mobile (cellular) telephones while driving. Accid Anal Pre 31(6):617-623, 1999.**

This study was aimed at investigating drivers' ability to detect a car ahead decelerating, while doing mobile phone related tasks. Nineteen participants aged between 20 and 29 years, (2000-125000 km driving experience) drove at 80 km/h, 50 m behind a lead car, on a 30 km section of motorway in normal traffic. During each trial the lead car started to decelerate at an average of 0.47 m/s2 while the participant either looked at the car in front (control), continuously dialed series of three random integers on a numeric keypad (divided visual attention), or performed a memory and addition task (non-visual attention). The results indicated that drivers' detection ability was impaired by about 0.5 s in terms of brake reaction time and almost 1 s in terms of time-to-collision, when they were doing the non-visual task whilst driving. This impairment was similar to when the drivers were dividing their visual attention between the road ahead and dialing numbers on the keypad. It was concluded that neither a hands-free option nor a voice controlled interface removes the safety problems associated with the use of mobile phones in a car.

**Lameth J, Gervais A, Colin C, Lévêque P, Jay TM, Edeline JM, Mallat M. Acute Neuroinflammation Promotes Cell Responses to 1800 MHz GSM Electromagnetic Fields in the Rat Cerebral Cortex. Neurotox Res. 2017 Jun 3. doi: 10.1007/s12640-017-9756-3. [Epub ahead of print]**

**Erratum in** Erratum to: Acute Neuroinflammation Promotes Cell Responses to 1800 MHz GSM Electromagnetic Fields in the rat Cerebral Cortex. [Neurotox Res. 2017]

Mobile phone communications are conveyed by radiofrequency (RF) electromagnetic fields, including pulse-modulated global system for mobile communications (GSM)-1800 MHz, whose effects on the CNS affected by pathological states remain to be specified. Here, we investigated whether a 2-h head-only exposure to GSM-1800 MHz could impact on a neuroinflammatory reaction triggered by lipopolysaccharide (LPS) in 2-week-old or adult rats. We focused on the cerebral cortex in which the specific absorption rate (SAR) of RF averaged 2.9 W/kg. In developing rats, 24 h after GSM exposure, the levels of cortical interleukin-1ß (IL1ß) or NOX2 NADPH oxidase transcripts were reduced by 50 to 60%, in comparison with sham-exposed animals (SAR = 0), as assessed by RT-qPCR. Adult rats exposed to GSM also showed a 50% reduction in the level of IL1ß mRNA, but they differed from developing rats by the lack of NOX2 gene suppression and by displaying a significant growth response of microglial cell processes imaged in anti-Iba1-stained cortical sections. As neuroinflammation is often associated with changes in excitatory neurotransmission, we evaluated changes in expression and phosphorylation of α-amino-3-hydroxy-5-methyl-4-isoxazolepropionic acid (AMPA) receptors in the adult cerebral cortex by Western blot analyses. We found that GSM exposure decreased phosphorylation at two residues on the GluA1 AMPAR subunit (serine 831 and 845). The GSM-induced changes in gene expressions, microglia, and GluA1 phosphorylation did not persist 72 h after RF exposure and were not observed in the absence of LPS pretreatment. Together, our data provide evidence that GSM-1800 MHz can modulate CNS cell responses triggered by an acute neuroinflammatory state.

**Landgrebe M, Hauser S, Langguth B, Frick U, Hajak G, Eichhammer P. Altered cortical excitability in subjectively electrosensitive patients: results of a pilot study. J Psychosom Res. 62(3):283-288, 2007.**

OBJECTIVE: Hypersensitivity to electromagnetic fields is frequently claimed to be linked to a variety of unspecific somatic and/or neuropsychological complaints. Whereas provocation studies often failed to demonstrate a causal relationship between electromagnetic field exposure and symptom formation, neurophysiological examinations highlight baseline deviations in people claiming to be electrosensitive. METHODS: To elucidate a potential role of dysfunctional cortical regulations in mediating hypersensitivity to electromagnetic fields, cortical excitability parameters were measured by transcranial magnetic stimulation in subjectively electrosensitive patients (n=23) and two control groups (n=49) differing in their level of unspecific health complaints. RESULTS: Electrosensitive patients showed reduced intracortical facilitation as compared to both control groups, while motor thresholds and intracortical inhibition were unaffected. CONCLUSIONS: This pilot study gives additional evidence that altered central nervous system function may account for symptom manifestation in subjectively electrosensitive patients as has been postulated for several chronic multisymptom illnesses sharing a similar clustering of symptoms.

**Landgrebe M, Frick U, Hauser S, Langguth B, Rosner R, Hajak G, Eichhammer P. Cognitive and neurobiological alterations in electromagnetic hypersensitive patients: results of a case-control study. Psychol Med. 38(12):1781-1791, 2008.**

BACKGROUND: Hypersensitivity to electromagnetic fields (EMF) is frequently claimed to be linked to a variety of non-specific somatic and neuropsychological complaints. Whereas provocation studies often failed to demonstrate a causal relationship between EMF exposure and symptom formation, recent studies point to a complex interplay of neurophysiological and cognitive alterations contributing to symptom manifestation in electromagnetic hypersensitive patients (EHS). However, these studies have examined only small sample sizes or have focused on selected aspects. Therefore this study examined in the largest sample of EHS EMF-specific cognitive correlates, discrimination ability and neurobiological parameters in order to get further insight into the pathophysiology of electromagnetic hypersensitivity. METHOD: In a case-control design 89 EHS and 107 age- and gender-matched controls were included in the study. Health status and EMF-specific cognitions were evaluated using standardized questionnaires. Perception thresholds following single transcranial magnetic stimulation (TMS) pulses to the dorsolateral prefrontal cortex were determined using a standardized blinded measurement protocol. Cortical excitability parameters were measured by TMS. RESULTS: Discrimination ability was significantly reduced in EHS (only 40% of the EHS but 60% of the controls felt no sensation under sham stimulation during the complete series), whereas the perception thresholds for real magnetic pulses were comparable in both groups (median 21% versus 24% of maximum pulse intensity). Intra-cortical facilitation was decreased in younger and increased in older EHS. In addition, typical EMF-related cognitions (aspects of rumination, symptom intolerance, vulnerability and stabilizing self-esteem) specifically differentiated EHS from their controls. CONCLUSIONS: These results demonstrate significant cognitive and neurobiological alterations pointing to a higher genuine individual vulnerability of electromagnetic hypersensitive patients.

**Landgrebe M, Frick U, Hauser S, Hajak G, Langguth B. Association of tinnitus and electromagnetic hypersensitivity: hints for a shared pathophysiology? PLoS One.4(3):e5026, 2009.**

BACKGROUND: Tinnitus is a frequent condition with high morbidity and impairment in quality of life. The pathophysiology is still incompletely understood. Electromagnetic fields are discussed to be involved in the multi-factorial pathogenesis of tinnitus, but data proofing this relationship are very limited. Potential health hazards of electromagnetic fields (EMF) have been under discussion for long. Especially, individuals claiming themselves to be electromagnetic hypersensitive suffer from a variety of unspecific symptoms, which they attribute to EMF-exposure. The aim of the study was to elucidate the relationship between EMF-exposure, electromagnetic hypersensitivity and tinnitus using a case-control design. METHODOLOGY: Tinnitus occurrence and tinnitus severity were assessed by questionnaires in 89 electromagnetic hypersensitive patients and 107 controls matched for age-, gender, living surroundings and workplace. Using a logistic regression approach, potential risk factors for the development of tinnitus were evaluated. FINDINGS: Tinnitus was significantly more frequent in the electromagnetic hypersensitive group (50.72% vs. 17.5%) whereas tinnitus duration and severity did not differ between groups. Electromagnetic hypersensitivity and tinnitus were independent risk factors for sleep disturbances. However, measures of individual EMF-exposure like e.g. cell phone use did not show any association with tinnitus. CONCLUSIONS: Our data indicate that

tinnitus is associated with subjective electromagnetic hypersensitivity. An individual vulnerability probably due to an over activated cortical distress network seems to be responsible for, both, electromagnetic hypersensitivity and tinnitus. Hence, therapeutic efforts should focus on treatment strategies (e.g. cognitive behavioral therapy) aiming at normalizing this dysfunctional distress network.

**Landler L, Painter MS, Youmans PW, Hopkins WA, Phillips JB. Spontaneous magnetic alignment by yearling snapping turtles: rapid association of radio frequency dependent pattern of magnetic input with novel surroundings. PLoS One. 10(5):e0124728, 2015.**

We investigated spontaneous magnetic alignment (SMA) by juvenile snapping turtles using exposure to low-level radio frequency (RF) fields at the Larmor frequency to help characterize the underlying sensory mechanism. Turtles, first introduced to the testing environment without the presence of RF aligned consistently towards magnetic north when subsequent magnetic testing conditions were also free of RF ('RF off → RF off'), but were disoriented when subsequently exposed to RF ('RF off → RF on'). In contrast, animals initially introduced to the testing environment with RF present were disoriented when tested without RF ('RF on → RF off'), but aligned towards magnetic south when tested with RF ('RF on → RF on'). Sensitivity of the SMA response of yearling turtles to RF is consistent with the involvement of a radical pair mechanism. Furthermore, the effect of RF appears to result from a change in the pattern of magnetic input, rather than elimination of magnetic input altogether, as proposed to explain similar effects in other systems/organisms. The findings show that turtles first exposed to a novel environment form a lasting association between the pattern of magnetic input and their surroundings. However, under natural conditions turtles would never experience a change in the pattern of magnetic input. Therefore, if turtles form a similar association of magnetic cues with the surroundings each time they encounter unfamiliar habitat, as seems likely, the same pattern of magnetic input would be associated with multiple sites/localities. This would be expected from a sensory input that functions as a global reference frame, helping to place multiple locales (i.e., multiple local landmark arrays) into register to form a global map of familiar space.

**Lange DG, Sedmak J, Japanese encephalitis virus (JEV): potentiation of lethality in mice by microwave radiation. Bioelectromagnetics 12(6):335-348, 1991.**

The expression of Japanese Encephalitis Virus (JEV) lethality in mice requires entry of the virus into the central nervous system. This entry is presumably through the capillary endothelial cells (CEC), because entry between CECs is inhibited by bands of circumferential tight-junctions. A viremic stage occurs during the first 4 to 5 days after JEV administration in mice, and both microwave radiation (2.45-GHz, continuous wave, 10-min exposure) and hypercarbia were employed to increase CEC permeability to JEV. Exposure to microwaves at power densities of 10-50 mW/cm2 resulted in a dose-dependent increase in JEV-induced lethality. Mice did not become tolerant or sensitized to microwave potentiation of JEV-induced mortality because 4 daily exposures at 10 or 50

mW/cm2 (SARS, approximately 24-98 W/kg) did not alter the lethality pattern to subsequent microwave radiation of JEV-exposed animals. Similarly, hypercarbia (5, 10, and 20% CO2) was observed to produce a dose-dependent increase in JEV-induced lethality. Both microwave radiation and hypercarbia are thought to promote pinocytosis in CNS capillary endothelial cells. This may be one mechanism by which they enhance JEV-induced lethality in adult Swiss-Cox mice.

**Lange DG, D'Antuono ME, Timm RR, Ishii TK, Fujimoto JM. Differential response of the permeability of the rat liver canalicular membrane to sucrose and mannitol following in vivo acute single and multiple exposures to microwave radiation (2.45 GHz) and radiant-energy thermal stress. Radiat Res 134(1):54-62, 1993.**

Both acute and chronic exposures to microwave radiation altered the function of the rat canalicular membrane. A single acute exposure to microwave radiation [80 mW/cm2, 2.45 GHz, continuous wave, 30 min exposure (SAR approximately equal to 72 W/kg)] or a matched radiant-energy thermal load, both designed to raise core body temperature approximately 3 degrees C, decreased the permeability of the canalicular membrane of male Sprague-Dawley rats to sucrose. The change in canalicular membrane permeability was demonstrated by a significant increase in the percentage of [3H]sucrose recovered in bile following its administration by a segmented retrograde intrabiliary injection. Similar acute exposures to microwave and radiant-energy thermal sources produced no significant alterations in canalicular membrane permeability to [14C]mannitol. In both acute exposure protocols, a rapidly reversible increase in bile flow rate was observed. Four exposures (30 min/day x 4 days) to either microwave radiation (80 mW/cm2) or a matched radiant-energy thermal load resulted in a significant depression in bile flow rate at normothermic temperatures. Animals receiving multiple exposures to microwave radiation had significant decreases in canalicular membrane permeability to both [3H]sucrose and [14C]mannitol, while similar exposure to radiant-energy thermal load alone altered canalicular membrane permeability to [3H]sucrose. An examination of the hepatic clearance of sucrose and mannitol following acute microwave exposure demonstrated no significant differences. Thus acute single exposure to microwave and radiant-energy thermal loads produced similar alterations in canalicular membrane permeability. Conversely, multiple exposures produced nonreversible changes in bile flow rate and canalicular membrane permeability, with microwave exposure producing greater alterations in the function of the canalicular membrane than an equivalent radiant-energy thermal load.

**Langer P, Holzner B, Magnet W, Kopp M. Hands-free mobile phone conversation impairs the peripheral visual system to an extent comparable to an alcohol level of 4-5 g 100 ml. Hum Psychopharmacol. 20(1):65-66, 2005. Letter.**

**Lantow M, Schuderer J, Hartwig C, Simko M. Free radical release and HSP70 expression in two human immune-relevant cell lines after exposure to 1800 MHz Radiofrequency Radiation. Radiat Res. 165(1):88-94, 2006.**

The goal of this study was to investigate whether radiofrequency (RF) electromagnetic-field (EMF) exposure at 1800 MHz causes production of free radicals and/or expression of heat-shock proteins (HSP70) in human immune-relevant cell systems. Human Mono

Mac 6 and K562 cells were used to examine free radical release after exposure to incubator control, sham, RF EMFs, PMA, LPS, heat (40 degrees C) or co-exposure conditions. Several signals were used: continuous-wave, several typical modulations of the Global System for Mobile Communications (GSM): GSM-non DTX (speaking only), GSM-DTX (hearing only), GSM-Talk (34% speaking and 66% hearing) at specific absorption rates (SARs) of 0.5, 1.0, 1.5 and 2.0 W/kg. Heat and PMA treatment induced a significant increase in superoxide radical anions and in ROS production in the Mono Mac 6 cells when compared to sham and/ or incubator conditions. No significant differences in free radical production were detected after RF EMF exposure or in the respective controls, and no additional effects on superoxide radical anion production were detected after co-exposure to RF EMFs+PMA or RF EMFs+LPS. The GSM-DTX signal at 2 W/kg produced a significant difference in free radical production when the data were compared to sham because of the decreasing sham value. This difference disappeared when data were compared to the incubator controls. To determine the involvement of heat-shock proteins as a possible inhibitor of free radical production, we investigated the HSP70 expression level after different RF EMF exposures; no significant effects were detected.

**Lantow M, Lupke M, Frahm J, Mattsson MO, Kuster N, Simko M. ROS release and Hsp70 expression after exposure to 1,800 MHz radiofrequency electromagnetic fields in primary human monocytes and lymphocytes. Radiat Environ Biophys.45(1):55-62, 2006.**

The aim of this study is to investigate if 1,800 MHz radiofrequency electromagnetic fields (RF-EMF) can induce reactive oxygen species (ROS) release and/or changes in heat shock protein 70 (Hsp70) expression in human blood cells, using different exposure and co-exposure conditions. Human umbilical cord blood-derived monocytes and lymphocytes were used to examine ROS release after exposure to continuous wave or different GSM signals (GSM-DTX and GSM-Talk) at 2 W/kg for 30 or 45 min of continuous or intermittent (5 min ON/5 min OFF) exposure. The cells were exposed to incubator conditions, to sham, to RF-EMF, or to chemicals in parallel. Cell stimulation with the phorbol ester phorbol-12-myristate-13-acetate (PMA; 1 muM) was used as positive control for ROS release. To investigate the effects on Hsp70 expression, the human monocytes were exposed to the GSM-DTX signal at 2 W/kg for 45 min, or to heat treatment (42 degrees C) as positive control. ROS production and Hsp70 expression were determined by flow cytometric analysis. The data were compared to sham and/or to control values and the statistical analysis was performed by the Student's t-test ($P<0.05$). The PMA treatment induced a significant increase in ROS production in human monocytes and lymphocytes when the data were compared to sham or to incubator controls. After continuous or intermittent GSM-DTX signal exposure (2 W/kg), a significantly different ROS production was detected in human monocytes if the data were compared to sham. However, this significant difference appeared due to the lowered value of ROS release during sham exposure. In human lymphocytes, no differences could be detected if data were compared either to sham or to incubator control. The Hsp70 expression level after 0, 1, and 2 h post-exposure to GSM-DTX signal at 2 W/kg for 1 h did not show any differences compared to the incubator or to sham control.

**Lantow M, Viergutz T, Weiss DG, Simko M. Comparative study of cell cycle kinetics**

**and induction of apoptosis or necrosis after exposure of human mono mac 6 cells to radiofrequency radiation. Radiat Res. 166(3):539-543, 2006.**

The possible harmful effects of radiofrequency electromagnetic fields (RF EMFs) are controversial. We have used human Mono Mac 6 cells to investigate the influence of RF EMFs in vitro on cell cycle alterations and BrdU uptake, as well as the induction of apoptosis and necrosis in human Mono Mac 6 cells, using flow cytometry after exposure to a 1800 MHz, 2 W/kg specific absorption rate (SAR), GSM-DTX signal for 12 h. No statistically significant differences in the induction of apoptosis or necrosis, cell cycle kinetics, or BrdU uptake were detected after RF EMF exposure compared to sham or incubator controls. However, in the positive control cells treated with gliotoxin and PMA (phorbol 12 myristate-13 acetate), a significant increase in apoptotic and necrotic cells was seen. Cell cycle analysis or BrdU incorporation for 72 h showed no differences between RF EMF- or sham-exposed cells, whereas PMA treatment induced a significant accumulation of cells in G(0)/G(1)-phase and a reduction in S-phase cells. RF EMF radiation did not induce cell cycle alterations or changes in BrdU incorporation or induce apoptosis and necrosis in Mono Mac 6 cells under the exposure conditions used.

**Larsen AI, Olsen J, Svane O, Gender-specific reproductive outcome and exposure to high-frequency electromagnetic radiation among physiotherapists. Scand J Work Environ Health 17(5):324-329, 1991.**

The aim of this case-referent study was to investigate reproductive hazards other than congenital malformations after exposure to high-frequency electromagnetic radiation. Cases and referents were sampled from a cohort of pregnancies of members of the Union of Danish Physiotherapists through linkage of the union file with national medical registers. Case groups were spontaneous abortions and children with low birth-weight prematurity, and stillbirth/death within one year. Exposure to high-frequency electromagnetic radiation before and during pregnancy was assessed through telephone interviews. As referents to the 270 cases, 316 pregnancies were randomly sampled. A total of 8.4% did not participate. Only 23.5% of the children born by the highly exposed mothers were boys. This value is a statistically significantly altered gender ratio showing a dose-response pattern. High-frequency electromagnetic radiation was furthermore associated with low birthweight, but only for male newborns. The other outcomes were not statistically significantly associated with exposure to high-frequency electromagnetic radiation.

**Larsen AI, Congenital malformations and exposure to high-frequency electromagnetic radiation among Danish physiotherapists. Scand J Work Environ Health 17(5):318-323, 1991.**

A cluster initiated the present case-referent study to assess the relation between exposure to high-frequency electromagnetic radiation and congenital malformations. Through the linkage of a cohort formed from a union file of Danish physiotherapists with complete national registers of pregnancy outcome, cases (pregnancies terminated by the birth of a malformed child) and referents were identified. From responses in a blinded telephone interview without knowledge of case status, exposure to high-frequency electromagnetic radiation in the first month of pregnancy was assessed. Indices reflecting

duration of exposure ("time") and maximum level of exposure ("peak") were composed. After a 7% dropout 54 cases and 247 referents were interviewed. No statistically significant associations between pregnancy outcome and high-frequency electromagnetic radiation were found (odds ratio 1.7, 95% confidence interval 0.6-4.3).

**Lass L, Tuulik V, Ferenets CR, Riisalo R, Hinrikus H. Effects of 7 Hz-modulated 450 MHz electromagnetic radiation on human performance in visual memory tasks. Int. J. Rad. Biol. 78: 937-944, 2002.**

**Abstract:** Purpose: The aim was to examine low-level 7 Hz-modulated 450 MHz radiation effects on human performance in visually presented neuropsychological tasks associated with attention and short-term memory. Materials and methods: A homogeneous group of 100 subjects (37 female, 63 male) were randomly assigned to either the exposed (10-20 min, 0.158mW $cm^{-2}$) or the sham-exposed group. A battery of three different tests measured attention and shortterm memory. Task 1 involved alternately selecting black digits from 1 to 25 in ascending order and white digits from 24 to 1 in descending order. The time spent on the task and the number of errors were recorded and analysed. Task 2 involved viewing a picture of 12 objects during 3 s, followed by a list of 24 words. The subject was required to select words representing previously presented objects. In task 3, an array of letters in 10 rows (60 in each row) was presented, and the subject was required to identify all examples of a particular two-letter combination. Results: The results of tasks 1 and 3 showed a significant increase in variances of errors ($p < 0.05$) in the exposed versus the shamexposed group. The results of task 2 indicated a significant decrease in errors ($p < 0.05$) in the exposed group. Conclusions: The data provide additional evidence that acute lowlevel exposure to microwaves modulated at 7 Hz can affect cognitive processes such as attention and short-term memory.

**Laszlo, A., Moros, E. G., Davidson, T., Bradbury, M., Straube, W. and Roti Roti, J. The Heat-Shock Factor is not Activated in Mammalian Cells Exposed to Cellular Phone Frequency Microwaves. Radiat. Res. 164, 163-172, 2005.**

There has been considerable interest in the biological effects of exposure to radiofrequency electromagnetic radiation, given the explosive growth of cellular telephone use, with the possible induction of malignancy being a significant concern. Thus the determination of whether nonthermal effects of radiofrequency electromagnetic radiation contribute to the process leading to malignancy is an important task. One proposed pathway to malignancy involves the induction of the stress response by exposures to cell phone frequency microwaves. The first step in the induction of the stress response is the activation of the DNA-binding activity of the specific transcription factor involved in this response, the heat-shock factor (HSF). The DNA-binding activity of HSF in hamster, mouse and human cells was determined after acute and continuous exposures to frequency domain multiple access (FDMA)- or code domain multiple access (CDMA)-modulated microwaves at low (0.6 W/kg) or high ( approximately 5 W/kg) SARs at frequencies used for mobile communication. The DNA-binding activity of HSF was monitored using a gel shift assay; the calibration of this assay indicated that an increase of approximately 10% in the activation of the DNA-binding activity of HSF after a 1 degrees C increase in temperature could be detected. We failed to detect any increase in

the DNA-binding ability of HSF in cultured mammalian cells as a consequence of any exposure tested, within the sensitivity of our assay. Our results do not support the notion that the stress response is activated as a consequence of exposure to microwaves of frequencies associated with mobile communication devices.

**Laudisi F, Sambucci M, Nasta F, Pinto R, Lodato R, Altavista P, Lovisolo GA, Marino C, Pioli C. Prenatal exposure to radiofrequencies: Effects of WiFi signals on thymocyte development and peripheral T cell compartment in an animal model.Bioelectromagnetics. 33(8):652-661, 2012.**

Wireless local area networks are an increasing alternative to wired data networks in workplaces, homes, and public areas. Concerns about possible health effects of this type of signal, especially when exposure occurs early in life, have been raised. We examined the effects of prenatal (in utero) exposure to wireless fidelity (WiFi) signal-associated electromagnetic fields (2450 MHz center-frequency band) on T cell development and function. Pregnant mice were exposed whole body to a specific absorption rate of 4 W/kg, 2 h per day, starting 5 days after mating and ending 1 day before the expected delivery. Sham-exposed and cage control groups were used as controls. No effects on cell count, phenotype, and proliferation of thymocytes were observed. Also, spleen cell count, CD4/CD8 cell frequencies, T cell proliferation, and cytokine production were not affected by the exposure. These findings were consistently observed in the male and female offspring at early (5 weeks of age) and late (26 weeks of age) time points. Nevertheless, the expected differences associated with aging and/or gender were confirmed. In conclusion, our results do not support the hypothesis that the exposure to WiFi signals during prenatal life results in detrimental effects on the immune T cell compartment.

**Lauer O, Frei P, Gosselin MC, Joseph W, Röösli M, Fröhlich J. Combining near- and far-field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: A reference case. Bioelectromagnetics. 2013 Feb 15. doi: 10.1002/bem.21782. [Epub ahead of print]**

**A** framework for the combination of near-field (NF) and far-field (FF) radio frequency electromagnetic exposure sources to the average organ and whole-body specific absorption rates (SARs) is presented. As a reference case, values based on numerically derived SARs for whole-body and individual organs and tissues are combined with realistic exposure data, which have been collected using personal exposure meters during the Swiss Qualifex study. The framework presented can be applied to any study region where exposure data is collected by appropriate measurement equipment. Based on results derived from the data for the region of Basel, Switzerland, the relative importance of NF and FF sources to the personal exposure is examined for three different study groups. The results show that a 24-h whole-body averaged exposure of a typical mobile phone user is dominated by the use of his or her own mobile phone when a Global System for Mobile Communications (GSM) 900 or GSM 1800 phone is used. If only Universal Mobile Telecommunications System (UMTS) phones are used, the user would experience a lower exposure level on average caused by the lower average output power of UMTS phones. Data presented clearly indicate the necessity of collecting band-selective exposure data in epidemiological studies related to electromagnetic fields.

**Laurence JA, French PW, Lindner RA, Mckenzie DR, Biological Effects of Electromagnetic Fields-Mechanisms for the Effects of Pulsed Microwave Radiation on Protein Conformation. J Theor Biol 206(2):291-298, 2000.**

Microwave exposure under "athermal" conditions occurs when no temperature rise can be measured by conventional thermometry. The existence of biological effects arising from the athermal exposure is still controversial, partly because of a lack of the linear dose response relation. We propose a model in which pulsed microwave radiation causes a triggering of the heat shock or stress response by altering the conformation of proteins through a transient heating of the protein and its close environment. We support this by modelling using the heat diffusion equation and show that pulsed exposure even when athermal can lead to transient temperature excursions outside the normal range. We propose that the power window phenomenon in which biological effects are observed at low power levels may be caused by an incomplete triggering of the heat shock response.

**Le Quément C, Nicolaz CN, Habauzit D, Zhadobov M, Sauleau R, Le Dréan Y. Impact of 60-GHz millimeter waves and corresponding heat effect on endoplasmic reticulum stress sensor gene expression. Bioelectromagnetics. 35(6):444-451, 2014.**

Emerging high data rate wireless communication systems, currently under development, will operate at millimeter waves (MMW) and specifically in the 60 GHz band for broadband short-range communications. The aim of this study was to investigate potential effects of MMW radiation on the cellular endoplasmic reticulum (ER) stress. Human skin cell lines were exposed at 60.4 GHz, with incident power densities (IPD) ranging between 1 and 20 mW/cm(2) . The upper IPD limits correspond to the ICNIRP local exposure limit for the general public. The expression of ER-stress sensors, namely BIP and ORP150, was then examined by real-time RT-PCR. Our experimental data demonstrated that MMW radiations do not change BIP or ORP150 mRNA basal levels, whatever the cell line, the exposure duration or the IPD level. Co-exposure to the well-known ER-stress inducer thapsigargin (TG) and MMW were then assessed. Our results show that MMW exposure at 20 mW/cm(2) inhibits TG-induced BIP and ORP150 over expression. Experimental controls showed that this inhibition is linked to the thermal effect resulting from the MMW exposure.

**Lebedeva NN, Sulimov AV, Sulimova OP, Kotrovskaya TI, Gailus T. Cellular phone electromagnetic field effects on bioelectric activity of human brain. Crit Rev Biomed Eng 28(1-2):323-337, 2000.**

24 volunteers participated in the experiments. The investigation of EEG reactions to cellular phone (EMF frequency 902.4 MHz and intensity 0.06 mW/cm2) was conducted. Two experiments were performed with each subject--cellular phone exposure and Placebo Duration of the experiment was 60 min: 15 min--background; 15 min--EMF exposure or Placebo; 30 min--afterexposure. EEG was recorded in 16 standard leads with "eyes open" and "eyes closed". Special software with non-linear dynamics was developed for EEG analyses. One parameter, multichannel (global) correlation dimension, was calculated. The changes of these parameters can be evidence of brain functional state changes. As a result of EEG record processing, a

significant increase of global correlation dimension during the exposure and afterexposure period was discovered, more pronounced in the case of "eyes closed". That can be viewed as the manifestation of cortex activation under phone EMF exposure.

**Lebedeva NN, Sulimov AV, Sulimova OP, Korotkovskaya TI, Gailus T, Investigation of brain potentials in sleeping humans exposed to the electromagnetic field of mobile phones. Crit Rev Biomed Eng 29(1):125-133, 2001.**

An investigation was made of 8-hour EEG tracings of sleeping humans exposed to the electromagnetic field of a GSM-standard mobile phone. To analyze the EEG-patterns, manual scoring, nonlinear dynamics, and spectral analysis were employed. It was found that, when human beings were exposed to the electromagnetic field of a cellular phone, their cerebral cortex biopotentials revealed an increase in the alpha-range power density as compared to the placebo experiment. It was also found that the dimension of EEG correlation dynamics and the relation of sleep stages changed under the influence of the electromagnetic field of a mobile phone.

**Lee AK, Hong SE, Kwon JH, Choi HD, Cardis E. Mobile phone types and SAR characteristics of the human brain. Phys Med Biol. 62(7):2741-2761, 2017.**

Mobile phones differ in terms of their operating frequency, outer shape, and form and location of the antennae, all of which affect the spatial distributions of their electromagnetic field and the level of electromagnetic absorption in the human head or brain. For this paper, the specific absorption rate (SAR) was calculated for four anatomical head models at different ages using 11 numerical phone models of different shapes and antenna configurations. The 11 models represent phone types accounting for around 86% of the approximately 1400 commercial phone models released into the Korean market since 2002. Seven of the phone models selected have an internal dual-band antenna, and the remaining four possess an external antenna. Each model was intended to generate an average absorption level equivalent to that of the same type of commercial phone model operating at the maximum available output power. The 1 g peak spatial SAR and ipsilateral and contralateral brain-averaged SARs were reported for all 11 phone models. The effects of the phone type, phone position, operating frequency, and age of head models on the brain SAR were comprehensively determined.

**Lee D, Lee J, Lee I. Cell Phone Generated Radio Frequency Electromagnetic Field Effects on the Locomotor Behaviors of the Fishes** Poecilia reticulata **and Danio rerio. Int J Radiat Biol. 2015 Jun 15:1-20. [Epub ahead of print]**
PURPOSE: The locomotor behavior of small fish was characterized under a cell phone generated radio frequency electromagnetic field (RF EMF). MATERIALS AND METHODS: The trajectory of movement of 10 pairs of poecilia reticulata and 15 pairs of danio rerio in a fish tank was recorded and tracked under the presence of a cell phone generated RF EMF. The measures were based on spatial and temporal distributions. A time-series trajectory was utilized to emphasis the dynamic nature of locomotor behavior. Fish movement was recorded in real-time. Their spatial, velocity, turning angle and sinuosity distribution were analyzed in terms of F(v,x), P[n(x,t)], P(v), F (Θ) and F(s), respectively. In addition, potential temperature elevation caused by a cellular phone was

also examined. RESULTS: We demonstrated that a cellular phone induced temperature elevation was not relevant, and that our measurements reflected RF EMF-induced effects on the locomotor behavior of poecilia reticulata and danio rerio. Fish locomotion was observed under normal conditions, in the visual presence of a cell phone, after feeding, and under starvation. Fish locomotor behavior was random both in normal conditions and in the presence of an off-signaled cell phone. However, there were significant changes in the locomotion of the fish after feeding under the RF EMF. CONCLUSIONS: The locomotion of the fed fish was affected in terms of changes in population and velocity distributions under the presence of the RF EMF emitted by the cell phone. There was, however, no significant difference in angular distribution.

**Lee HJ, Lee JS, Pack JK, Choi HD, Kim N, Kim SH, Lee YS. Lack of teratogenicity after combined exposure of pregnant mice to CDMA and WCDMA radiofrequency electromagnetic fields. Radiat Res. 172(5):648-652, 2009.**

Concern about the possible adverse effects of radiofrequency (RF)-field exposure on public health has increased because of the extensive use of wireless mobile phones and other telecommunication devices in daily life. The murine fetus is a very sensitive indicator of the effects of stress or stimuli in the environment. Therefore, we investigated the teratogenic effects of multi-signal radiofrequency electromagnetic fields (RF EMFs) on mouse fetuses. Pregnant mice were simultaneously exposed to two types of RF signals, single code division multiple access (CDMA) and wideband code division multiple access (WCDMA). Mice received two 45-min RF-field exposures, separated by a 15-min interval, daily throughout the entire gestation period. The whole-body average specific absorption rate (SAR) of CDMA or WCDMA was 2.0 W/kg. The animals were killed humanely on the 18th day of gestation and fetuses were examined for mortality, growth retardation, changes in head size and other morphological abnormalities. From the results, we report for the first time that simultaneous experimental exposure to CDMA and WCDMA RF EMFs did not cause any observable adverse effects on mouse fetuses.

**Lee HJ, Pack JK, Kim TH, Kim N, Choi SY, Lee JS, Kim SH, Lee YS. The lack of histological changes of CDMA cellular phone-based radio frequency on rat testis. Bioelectromagnetics.31(7):528-534, 2010.**

We examined the histological changes by radiofrequency (RF) fields on rat testis, specifically with respect to sensitive processes such as spermatogenesis. Male rats were exposed to 848.5 MHz RF for 12 weeks. The RF exposure schedule consisted of two 45-min RF exposure periods, separated by a 15-min interval. The whole-body average specific absorption rate (SAR) of RF was 2.0 W/kg. We then investigated correlates of testicular function such as sperm counts in the cauda epididymis, malondialdehyde concentrations in the testes and epididymis, frequency of spermatogenesis stages, germ cell counts, and appearance of apoptotic cells in the testes. We also performed p53, bcl-2, caspase 3, p21, and PARP immunoblotting of the testes in sham- and RF-exposed animals. Based on these results, we concluded that subchronic exposure to 848.5 MHz with 2.0 W/kg SAR RF did not have any observable adverse effects on rat spermatogenesis.

**Lee HJ, Jin YB, Lee JS, Choi SY, Kim TH, Pack JK, Choi HD, Kim N, Lee YS. Lymphoma development of simultaneously combined exposure to two radiofrequency signals in AKR/J mice.Bioelectromagnetics. 32(6):485-492, 2011.**

There are public concerns regarding possible carcinogenic or cancer-promoting effects of radiofrequency electromagnetic fields (RF-EMFs) because of the extensive use of wireless mobile phones and other telecommunication devices in daily life. However, so far it is unclear if non-thermal exposure of single EMF exposure in animal studies has a direct influence on carcinogenesis. Here, carcinogenic effects of combined signal RF-EMFs on AKR/J mice, which were used for the lymphoma animal model, were investigated. Six-week-old AKR/J mice were simultaneously exposed to two types of RF signals: single code division multiple access (CDMA) and wideband code division multiple access (WCDMA). AKR/J mice were exposed to combined RF-EMFs for 45 min/day, 5 days/week, for a total of 42 weeks. The whole-body average specific absorption rate (SAR) of CDMA and WCDMA fields was 2.0 W/kg each, 4.0 W/kg in total. When we examined final survival, lymphoma incidence, and splenomegaly incidence, no differences were found between sham- and RF-exposed mice. However, occurrence of metastasis infiltration to the brain in lymphoma-bearing mice was significantly different in RF-exposed mice when compared to sham-exposed mice, even though no consistent correlation (increase or decrease) was observed between male and female mice. However, infiltration occurrence to liver, lung, and spleen was not different between the groups. From the results, we suggested that simultaneous exposure to CDMA and WCDMA RF-EMFs did not affect lymphoma development in AKR/J mice.

**Lee HJ, Jin YB, Kim TH, Pack JK, Kim N, Choi HD, Lee JS, Lee YS. The effects of simultaneous combined exposure to CDMA and WCDMA electromagnetic fields on rat testicular function.Bioelectromagnetics. 2011 Oct 19. doi: 10.1002/bem.20715. [Epub ahead of print]**

Wireless mobile phones and other telecommunication devices are used extensively in daily life. We therefore examined the effects of combined exposure to radiofrequency electromagnetic fields (RF-EMF) on rat testicular function, specifically with respect to sensitive processes such as spermatogenesis. Male rats were exposed to single code division multiple access (CDMA) and wideband code division multiple access (WCDMA) RF signals for 12 weeks. The RF exposure schedule comprised 45 min/day, 5 days/week for a total of 12 weeks. The whole-body average specific absorption rate (SAR) of CDMA and WCDMA was 2.0 W/kg each or 4.0 W/kg in total. We then investigated the correlates of testicular function such as sperm count in the cauda epididymis, testosterone concentration in the blood serum, malondialdehyde concentrations in the testes and epididymis, frequency of spermatogenesis stages, and appearance of apoptotic cells in the testes. We also immunoblotted for p53, bcl2, GADD45, cyclin G, and HSP70 in the testes of sham- and combined RF-exposed animals. Based on the results, we concluded that simultaneous exposure to CDMA and WCDMA RF-EMFs at 4.0 W/kg SAR did not have any observable adverse effects on rat spermatogenesis.

**Lee JJ, Kwak HJ, Lee YM, Lee JW, Park MJ, Ko YG, Choi HD, Kim N, Pack JK, Hong**

**SI, Lee JS. Acute radio frequency irradiation does not affect cell cycle, cellular migration, and invasion. Bioelectromagnetics. 29(8):615-625, 2008.**

Although in vitro studies have been previously conducted to determine the biological effects of radio frequency (RF) radiation, it has not yet been determined whether or not RF radiation poses a potential hazard. This study was conducted to determine whether RF radiation exposure exerts detectable effects on cell cycle distribution, cellular invasion, and migration. NIH3T3 mouse fibroblasts were exposed to 849 MHz of RF radiation at average SAR values of 2 or 10 W/kg for either 1 h, or for 1 h per day for 3 days. During the exposure period, the temperature in the exposure chamber was maintained isothermally by circulating water throughout the cavity. Cell cycle distribution was analyzed at 24 and 48 h after exposure, by flow cytometry. We detected no statistically significant differences between the sham-exposed and RF radiation-exposed cells. Cellular invasion and migration were assessed by in vitro Matrigel invasion and Transwell migration assays. The RF radiation-exposed groups evidenced no significant changes in motility and invasiveness compared to the sham-exposed group. However, the ionizing radiation-exposed cells, used as a positive control group, manifested dramatic alterations in their cell cycle distribution, cellular invasiveness, and migration characteristics. Our results show that 849 MHz RF radiation exposure exerts no detectable effects on cell cycle distribution, cellular migration, or invasion at average SAR values of 2 or 10 W/kg.

**Lee JS, Huang TQ, Lee JJ, Pack JK, Jang JJ, Seo JS. Subchronic exposure of hsp70.1-deficient mice to radiofrequency radiation. Int J Radiat Biol. 81(10):781-792, 2005.**

Purpose: Heat shock protein 70 (HSP70) is one of the most inducible proteins to play a cytoprotective role under stressful conditions. Previously we generated hsp70.1-deficient mice to elucidate the in vivo function of HSP70 in detail. The renal tissues and embryonic fibroblasts of these mice were shown to be more vulnerable to hyperosmotic stress. Since RF (radiofrequency) energy has been suggested to be an environmental stressor, we carried out a study to determine whether sub-chronic RF exposure can cause constitutive induction of a stress response at a cellular and/or molecular level in hsp70.1-deficient mice due to repeated stimulation.Materials and methods: Eight-week-old hsp70.1-deficient mice were exposed twice daily for 45 min, with a 15 min interval, 5 days a week for 10 weeks. Whole-body average specific absorption rate was 0.4 W/Kg for fields of both 849 MHz and 1763 MHz. Major tissues were histopathologically analysed, and immunocytochemically evaluated for cell proliferative activity. Apoptosis was investigated by TdT-mediated dUTP nick-end labeling (TUNEL) assay. To determine whether RF radiation elicits a stress response, the expression level of heat shock proteins (HSP) and phosphorylation of the stress-activated kinases were also observed by western blots.Results: No difference was observed in the histopathological analysis between sham- and RF-exposed mice. There was no evidence of increased proliferative and apoptotic activities. The levels of HSP90, HSP70, and HSP25 showed no obvious changes. RF exposure did not affect the phosphorylation status of the major stress-activated kinase (MAPK); extracellular signal-regulated kinase 1/2 (ERK1/2), C-Jun N-terminal kinase 1/2 (JNK1/2) or p38 MAPK.Conclusion: The hsp70.1-deficient mice did

not show any significant changes in terms of cell proliferation, apoptosis, or stress response due to exposure of 849 or 1,763 MHz RF fields.

**Lee JS, Huang TQ, Kim TH, Kim JY, Kim HJ, Pack JK, Seo JS. Radiofrequency radiation does not induce stress response in human T-lymphocytes and rat primary astrocytes. Bioelectromagnetics. 27(7):578-588, 2006.**

Heat shock proteins (HSPs) are rapidly induced by a variety of stressors, including heat shock, ethanol, heavy metals, UV, and gamma-radiation. Mitogen-activated protein kinases (MAPKs) are also involved in the stress transduction pathways in all eukaryotes. In this study, we attempted to determine whether radiofrequency (RF) radiation is able to induce a non-thermal stress response. Human T-lymphocyte Jurkat cells and rat primary astrocytes were exposed to 1763 MHz of RF radiation at an average specific absorption rate (SAR) of either 2 W/kg or 20 W/kg, for 30 min or 1 h. Temperature was completely controlled at 37 +/- 0.2 degrees C throughout the exposure period. The sham exposures were performed under exactly identical experimental conditions without exposure to RF radiation. We assessed alterations in the expression of HSPs and the activation of MAPKs in the RF-exposed cells. No detectable difference was observed in the expression levels of HSP90, HSP70, and HSP27. The phosphorylation status of MAPKs, extracellular signal-regulated kinases (ERK1/2), c-Jun N-terminal protein kinases (JNK1/2), or p38, did not change significantly. In order to determine whether RF radiation can promote the effects of 12-O-tetradecanoylphorbol 13-acetate (TPA) on stress response, cells were exposed to RF radiation coupled with TPA treatment. When TPA alone was applied, the MAPKs were found to be phosphorylated in a dose-dependent manner. However, RF radiation did not result in any enhancement of TPA-induced MAPK phosphorylation. Neither TPA nor RF radiation exerted any detectable effect on the induction of HSPs. These results indicate that 1763 MHz RF radiation alone did not elicit any stress response, nor did it have any effect on TPA-induced MAPK phosphorylation, under our experimental conditions.

**Lee JW, Kim MS, Kim YJ, Choi YJ, Lee Y, Chung HW. Genotoxic effects of 3 T magnetic resonance imaging in cultured human lymphocytes.Bioelectromagnetics. 32(7):535-542, 2011.**

The clinical and preclinical use of high-field intensity (HF, 3 T and above) magnetic resonance imaging (MRI) scanners have significantly increased in the past few years. However, potential health risks are implied in the MRI and especially HF MRI environment due to high-static magnetic fields, fast gradient magnetic fields, and strong radiofrequency electromagnetic fields. In this study, the genotoxic potential of 3 T clinical MRI scans in cultured human lymphocytes in vitro was investigated by analyzing chromosome aberrations (CA), micronuclei (MN), and single-cell gel electrophoresis. Human lymphocytes were exposed to electromagnetic fields generated during MRI scanning (clinical routine brain examination protocols: three-channel head coil) for 22, 45, 67, and 89 min. We observed a significant increase in the frequency of single-strand DNA breaks following exposure to a 3 T MRI. In addition, the frequency of both CAs and MN in exposed cells increased in a time-dependent manner. The frequencies of MN in lymphocytes exposed to complex electromagnetic fields for 0, 22, 45, 67, and 89 min

were 9.67, 11.67, 14.67, 18.00, and 20.33 per 1000 cells, respectively. Similarly, the frequencies of CAs in lymphocytes exposed for 0, 45, 67, and 89 min were 1.33, 2.33, 3.67, and 4.67 per 200 cells, respectively. These results suggest that exposure to 3 T MRI induces genotoxic effects in human lymphocytes. 1

**Lee KS, Choi JS, Hong SY, Son TH, Yu K. Mobile phone electromagnetic radiation activates MAPK signaling and regulates viability in Drosophila. Bioelectromagnetics.29(5):371-379, 2008.**

Mobile phones are widely used in the modern world. However, biological effects of electromagnetic radiation produced by mobile phones are largely unknown. In this report, we show biological effects of the mobile phone 835 MHz electromagnetic field (EMF) in the Drosophila model system. When flies were exposed to the specific absorption rate (SAR) 1.6 W/kg, which is the proposed exposure limit by the American National Standards Institute (ANSI), more than 90% of the flies were viable even after the 30 h exposure. However, in the SAR 4.0 W/kg strong EMF exposure, viability dropped from the 12 h exposure. These EMF exposures triggered stress response and increased the production of reactive oxygen species. The EMF exposures also activated extracellular signal regulated kinase (ERK) and c-Jun N-terminal kinase (JNK) signaling, but not p38 kinase signaling. Interestingly, SAR 1.6 W/kg activated mainly ERK signaling and expression of an anti-apoptotic gene, whereas SAR 4.0 W/kg strongly activated JNK signaling and expression of apoptotic genes. In addition, SAR 4.0 W/kg amplified the number of apoptotic cells in the fly brain. These findings demonstrate that the exposure limit on electromagnetic radiation proposed by ANSI triggered ERK-survival signaling but the strong electromagnetic radiation activated JNK-apoptotic signaling in Drosophila.

**Lee S, Johnson D, Dunbar K, Dong H, Ge X, Kim YC, Wing C, Jayathilaka N, Emmanuel N, Zhou CQ, Gerber HL, Tseng CC, Wang SM2.45GHz radiofrequency fields alter gene expression in cultured human cells. FEBS Lett. 579(21):4829-4836, 2005.**

The biological effect of radiofrequency (RF) fields remains controversial. We address this issue by examining whether RF fields can cause changes in gene expression. We used the pulsed RF fields at a frequency of 2.45GHz that is commonly used in telecommunication to expose cultured human HL-60 cells. We used the serial analysis of gene expression (SAGE) method to measure the RF effect on gene expression at the genome level. We observed that 221 genes altered their expression after a 2-h exposure. The number of affected genes increased to 759 after a 6-h exposure. Functional classification of the affected genes reveals that apoptosis-related genes were among the upregulated ones and the cell cycle genes among the downregulated ones. We observed no significant increase in the expression of heat shock genes. These results indicate that the RF fields at 2.45GHz can alter gene expression in cultured human cells through non-thermal mechanism.

**Lee SS, Kim HR, Kim MS, Park S, Yoon ES, Park SH, Kim DW. Influence of Smartphone Wi-Fi Signals on Adipose-Derived Stem Cells. J Craniofac Surg. 2014**

**Aug 5. [Epub ahead of print].**

The use of smartphones is expanding rapidly around the world, thus raising the concern of possible harmful effects of radiofrequency generated by smartphones. We hypothesized that Wi-Fi signals from smartphones may have harmful influence on adipose-derived stem cells (ASCs). An in vitro study was performed to assess the influence of Wi-Fi signals from smartphones. The ASCs were incubated under a smartphone connected to a Wi-Fi network, which was uploading files at a speed of 4.8 Mbps for 10 hours a day, for a total of 5 days. We constructed 2 kinds of control cells, one grown in 37°C and the other grown in 39°C. After 5 days of Wi-Fi exposure from the smartphone, the cells underwent cell proliferation assay, apoptosis assay, and flow cytometry analysis. Three growth factors, vascular endothelial growth factor, hepatocyte growth factor, and transforming growth factor-β, were measured from ASC-conditioned media. Cell proliferation rate was higher in Wi-Fi-exposed cells and 39°C control cells compared with 37°C control cells. Apoptosis assay, flow cytometry analysis, and growth factor concentrations showed no remarkable differences among the 3 groups. We could not find any harmful effects of Wi-Fi electromagnetic signals from smartphones. The increased proliferation of ASCs under the smartphone, however, might be attributable to the thermal effect.

**LeeTMC, HoSMY, Tsang LYH, Yang SYC, LiLSW, ChanCCH, Effect on human attention of exposure to the electromagnetic field emitted by mobile phones. NeuroReport 12:729-731, 2001.**

This study examined the effect of exposure to the electromagnetic field emitted by mobile phones on human attention. Three measures of attention were administered to 72 teenagers, 37 of whom were mobile phone users. The results showed that the mobile phone users performed better on one of the three measures of attention than did the non-mobile phone users. The results suggest that exposure to the electro- magnetic field emitted by mobile phones may have a mild facilitating effect on attention functions, which is consistent with previous observations that exposure to the electromagnetic field has a facilitating effect on cognitive processing. The possibility that mobile phone users may be naturally better at multiple tasking tasks was discussed.

**Lee TM, Lam PK, Yee LT, Chan CC. The effect of the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. Neuroreport. 14(10):1361-1364, 2003.**

Previous findings suggested the facilitating effect of the electromagnetic field emitted by mobile phones on human attention. This study aimed to examine the relationship between the facilitating effect and the duration of exposure to the electromagnetic field emitted by mobile phones on human attention. Seventy-eight university students were randomly assigned to either an experimental or a control group. Their performance in the administered attention tasks was compared. Participants in the experimental group performed better on one of the two measures of attention only after they had been exposed to the electromagnetic field emitted by the mobile phone for some time. The results seem to suggest that attention functions may be differentially enhanced after

exposing to the electromagnetic field emitted by mobile phones. Furthermore, this transient facilitation effect might be dose dependent.

**Lee W, Yang KL. Using medaka embryos as a model system to study biological effects of the electromagnetic fields on development and behavior. Ecotoxicol Environ Saf. 2014 Jul 29;108C:187-194. doi: 10.1016/j.ecoenv.2014.06.035. [Epub ahead of print].**

The electromagnetic fields (EMFs) of anthropogenic origin are ubiquitous in our environments. The health hazard of extremely low frequency and radiofrequency EMFs has been investigated for decades, but evidence remains inconclusive, and animal studies are urgently needed to resolve the controversies regarding developmental toxicity of EMFs. Furthermore, as undersea cables and technological devices are increasingly used, the lack of information regarding the health risk of EMFs to aquatic organisms needs to be addressed. Medaka embryos (Oryzias latipes) have been a useful tool to study developmental toxicity in vivo due to their optical transparency. Here we explored the feasibility of using medaka embryos as a model system to study biological effects of EMFs on development. We also used a white preference test to investigate behavioral consequences of the EMF developmental toxicity. Newly fertilized embryos were randomly assigned to four groups that were exposed to an EMF with 3.2 kHz at the intensity of 0.12, 15, 25, or 60μT. The group exposed to the background 0.12μT served as the control. The embryos were exposed continually until hatch. They were observed daily, and the images were recorded for analysis of several developmental endpoints. Four days after hatching, the hatchlings were tested with the white preference test for their anxiety-like behavior. The results showed that embryos exposed to all three levels of the EMF developed significantly faster. The endpoints affected included the number of somites, eye width and length, eye pigmentation density, midbrain width, head growth, and the day to hatch. In addition, the group exposed to the EMF at 60μT exhibited significantly higher levels of anxiety-like behavior than the other groups did. In conclusion, the EMF tested in this study accelerated embryonic development and heightened anxiety-like behavior. Our results also demonstrate that the medaka embryo is a sensitive and cost-efficient in vivo model system to study developmental toxicity of EMFs.

**Leena K, Tomi L, Arja RR. Intensity of mobile phone use and health compromising behaviours-how is information and communication technology connected to health-related lifestyle in adolescence? J Adolesc. 28(1):35-47, 2005.**

The association of mobile phone use with health compromising behaviours (smoking, snuffing, alcohol) was studied in a survey comprising a representative sample of 14-16-year-olds ( [Formula: see text] ) in 2001. Mobile phone was used by 89% of respondents and by 13% for at least 1h daily. The intensity of use was positively associated with health compromising behaviours. The associations remained, although somewhat reduced, after including weekly spending money in the models. This study concludes that, at least in the present developmental level of communication technologies, intensive mobile phone use seems to be part of the same health-related lifestyle as health compromising behaviours.

**Leitgeb N, Tropper K, [Eye heating caused by microwave ovens]. Biomed Tech**

**(Berl) 38(1-2):17-20, 1993.** [Article in German].

To clarify the question as to whether microwave ovens represent a risk for the eyes, a worst-case situation was investigated in which it was assumed that a child observes the internal heating process with its eyes as close to the door of a microwave oven as it is possible to get. As expected, heating of the eyes was observed, which, however, was caused mainly by the conventional heating process rather than by microwave radiation. Significant microwave heating was observed only when increased scattered radiation was simulated by inactivating the safety contacts and opening the door of the microwave oven. When the door is opened to a clearly visible gap width (2.3 cm), the contribution of the microwave component to the overall temperature increase of 5 degrees C after one hour of continuous exposure did not exceed 16%. Even at the maximum possible door gap width which just did not cause the oven to switch off automatically (2.6 cm), 15 minutes of continuous exposure contributed only 50% to the 2 degrees C temperature increase. On the basis of these results, damage to the eye through the use of microwave ovens can be excluded.

**Leng L, Zhang Y. Etiology of Pituitary Tumors: A Case Control Study. Turk Neurosurg. 2016;26(2):195-9. doi: 10.5137/1019-5149.JTN.5985-12.1.**

AIM: Pituitary tumors are generally benign, but may be associated with some morbidities. The aim of this study was to identify the risk factors for pituitary tumors. MATERIAL AND METHODS: A population-based case-control study on the potential risk factors of pituitary tumors was conducted in China. The personal interview technique was used to gather information on medical and reproductive history, taste, and cigarette smoking from 204 pituitary tumor cases and 246 controls aged between 6 and 82 years. RESULTS: The risk of tumor was reduced when the interviewee was a worker. The risk was raised with spicy taste, mobile phone use, duration of use, characteristics, and taking vitamins. No significant association was observed with gender, age, education, marriage, speed of eating, fat intake, other tastes (salt, sour, sweet), medical and reproductive history, female sex hormones, cigarette smoking, tea drinking, wine drinking, menses, and oral contraceptive use, whether the interviewee was a farmer. CONCLUSION: Increased risk for pituitary tumors is related with spicy taste, mobile phone use, duration of use, characteristics, taking vitamins and possibly a reduced risk is related with the interviewee being a worker. Further investigations are needed to clarify the causes of these associations.

**Lepp A, Barkley JE, Sanders GJ, Rebold M, Gates P. The relationship between cell phone use, physical and sedentary activity, and cardiorespiratory fitness in a sample of U.S. college students. Int J Behav Nutr Phys Act. 2013 Jun 21;10:79. doi: 10.1186/1479-5868-10-79.**

BACKGROUND: Today's cell phones increase opportunities for activities traditionally defined as sedentary behaviors (e.g., surfing the internet, playing video games). People who participate in large amounts of sedentary behaviors, relative to those who do not, tend to be less physically active, less physically fit, and at greater risk for health problems.

However, cell phone use does not have to be a sedentary behavior as these devices are portable. It can occur while standing or during mild-to-moderate intensity physical activity. Thus, the relationship between cell phone use, physical and sedentary activity, and physical fitness is unclear. The purpose of this study was to investigate these relationships among a sample of healthy college students. METHODS: Participants were first interviewed about their physical activity behavior and cell phone use. Then body composition was assessed and the validated self-efficacy survey for exercise behaviors completed. This was followed by a progressive exercise test on a treadmill to exhaustion. Peak oxygen consumption (VO2 peak) during exercise was used to measure cardiorespiratory fitness. Hierarchical regression was used to assess the relationship between cell phone use and cardiorespiratory fitness after controlling for sex, self-efficacy, and percent body fat. Interview data was transcribed, coded, and Chi-square analysis was used to compare the responses of low and high frequency cell phone users. RESULTS: Cell phone use was significantly ($p = 0.047$) and negatively ($\beta = -0.25$) related to cardio respiratory fitness independent of sex, self-efficacy, and percent fat which were also significant predictors ($p < 0.05$). Interview data offered several possible explanations for this relationship. First, high frequency users were more likely than low frequency users to report forgoing opportunities for physical activity in order to use their cell phones for sedentary behaviors. Second, low frequency users were more likely to report being connected to active peer groups through their cell phones and to cite this as a motivation for physical activity. Third, high levels of cell phone use indicated a broader pattern of sedentary behaviors apart from cell phone use, such as watching television. CONCLUSION: Cell phone use, like traditional sedentary behaviors, may disrupt physical activity and reduce cardiorespiratory fitness.

**Lerchl A, Krüger H, Niehaus M, Streckert JR, Bitz AK, Hansen V. Effects of mobile phone electromagnetic fields at nonthermal SAR values on melatonin and body weight of Djungarian hamsters (Phodopus sungorus). J Pineal Res. 44(3):267-272, 2008.**

In three experiments, adult male Djungarian hamsters (Phodopus sungorus) were exposed 24 hr/day for 60 days to radio frequency electromagnetic fields (RF-EMF) at 383, 900, and 1800 MHz, modulated according to the TETRA (383 MHz) and GSM standards (900 and 1800 MHz), respectively. A radial waveguide system ensured a well defined and uniform exposure at whole-body averaged specific absorption rates of 80 mW/kg, which is equal to the upper limit of whole-body exposure of the general population in Germany and other countries. For each experiment, using two identical waveguides, hamsters were exposed (n = 120) and sham-exposed (n = 120) in a blind fashion. In all experiments, pineal and serum melatonin levels as well as the weights of testes, brain, kidneys, and liver were not affected. At 383 MHz, exposure resulted in a significant transient increase in body weight up to 4%, while at 900 MHz this body weight increase was more pronounced (up to 6%) and not transient. At 1800 MHz, no effect on body weight was seen. The results corroborate earlier findings which have shown no effects of RF-EMF on melatonin levels in vivo and in vitro. The data are in accordance with the hypothesis that absorbed RF energy may result in metabolic changes which eventually cause body weight increases in exposed animals. The data support the notion that metabolic effects of RF-EMFs need to be investigated in more detail in future studies.

**Lerchl A, Klose M, Grote K, Wilhelm AF, Spathmann O, Fiedler T, Streckert J, Hansen V, Clemens M. Tumor promotion by exposure to radiofrequency electromagnetic fields below exposure limits for humans. Biochem Biophys Res Commun. 2015 Mar 6. pii: S0006-291X(15)00398-8. doi: 10.1016/j.bbrc.2015.02.151. [Epub ahead of print]**

The vast majority of in vitro and in vivo studies did not find cancerogenic effects of exposure to electromagnetic fields (RF-EMF), i.e. emitted by mobile phones and base stations. Previously published results from a pilot study with carcinogen-treated mice, however, suggested tumor-promoting effects of RF-EMF (Tillmann et al., 2010). We have performed a replication study using higher numbers of animals per group and including two additional exposure levels (0 (sham), 0.04, 0.4 and 2 W/kg SAR). We could confirm and extend the originally reported findings. Numbers of tumors of the lungs and livers in exposed animals were significantly higher than in sham-exposed controls. In addition, lymphomas were also found to be significantly elevated by exposure. A clear dose-response effect is absent. We hypothesize that these tumor-promoting effects may be caused by metabolic changes due to exposure. Since many of the tumor-promoting effects in our study were seen at low to moderate exposure levels (0.04 and 0.4 W/kg SAR), thus well below exposure limits for the users of mobile phones, further studies are warranted to investigate the underlying mechanisms. Our findings may help to understand the repeatedly reported increased incidences of brain tumors in heavy users of mobile phones.

**Lesch MF, Hancock PA. Driving performance during concurrent cell-phone use: are drivers aware of their performance decrements? Accid Anal Prev. 36(3):471-480, 2004.**

Prior research has documented the manner in which a variety of driving performance measures are impacted by concurrent cell-phone use as well as the influence of age and gender of the driver. This current study examined the extent to which different driver groups are aware of their associated performance decrements. Subjects' confidence in dealing with distractors while driving and their ratings of task performance and demand were compared with their actual driving performance in the presence of a cell-phone task. While high confidence ratings appeared to be predictive of better driving performance for male drivers (as confidence increased, the size of the distraction effects decreased), this relationship did not hold for females; in fact, for older females, as confidence increased, performance decreased. Additionally, when drivers were matched in terms of confidence level, brake responses of older females were slowed to a much greater extent (0.38s) than were brake responses of any other group (0.10s for younger males and females and 0.07s for older males). Finally, females also rated the driving task as less demanding than males, even though their performance was more greatly affected by distraction. These results suggest that many drivers may not be aware of their decreased performance while using cell-phones and that it may be particularly important to target educational campaigns on driver distraction towards female drivers for whom there tended to be a greater discrepancy between driver perceptions and actual performance.

**Leshin VV, [Changes of neurocytes in CNS under general exposure to UHF field**

**with local protection applied]. Med Tr Prom Ekol (5):5-8, 2000.** [Article in Russian]

Experiments on white rats were performed to study influence of UHF field on cortical sensomotor area under general exposure or with the head shielded. The changes in CNS caused by UHF field were not prevented completely by means of the shield. That is probably due to pathologic reflex impulses from the body receptors.

**Leszczynski D, Joenväärä S, Reivinen J, Kuokka R, Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: Molecular mechanism for cancer- and blood-brain barrier-related effects. Differentiation 70:120–129, 2002.**

**Abstract** We have examined whether non-thermal exposures of cultures of the human endothelial cell line EA.hy926 to 900 MHz GSM mobile phone microwave radiation could activate stress response. Results obtained demonstrate that 1-hour non-thermal exposure of EA.hy926 cells changes the phosphorylation status of numerous, yet largely unidentified, proteins. One of the affected proteins was identified as heat shock protein-27 (hsp27). Mobile phone exposure caused a transient increase in phosphorylation of hsp27, an effect which was prevented by SB203580, a specific inhibitor of p38 mitogen-activated protein kinase (p38MAPK). Also, mobile phone exposure caused transient changes in the protein expression levels of hsp27 and p38MAPK. All these changes were non-thermal effects because, as determined using temperature probes, irradiation did not alter the temperature of cell cultures, which remained throughout the irradiation period at 37±0.3 °C. Changes in the overall pattern of protein phosphorylation suggest that mobile phone radiation activates a variety of cellular signal transduction pathways, among them the hsp27/p38MAPK stress response pathway. Based on the known functions of hsp27, we put forward the hypothesis that mobile phone radiation-induced activation of hsp27 may (i) facilitate the development of brain cancer by inhibiting the cytochrome c/caspase-3 apoptotic pathway and (ii) cause an increase in blood-brain barrier permeability through stabilization of endothelial cell stress fibers. We postulate that these events, when occurring repeatedly over a long period of time, might become a health hazard because of the possible accumulation of brain tissue damage. Furthermore, our hypothesis suggests that other brain damaging factors may co-participate in mobile phone radiation-induced effects.

**Leszczynski D, Nylund R, Joenvaara S, Reivinen J. Applicability of discovery science approach to determine biological effects of mobile phone radiation. Proteomics. 4(2):426-431, 2004.**

We argue that the use of high-throughput screening techniques, although expensive and laborious, is justified and necessary in studies that examine biological effects of mobile phone radiation. The "case of hsp27 protein" presented here suggests that even proteins with only modestly altered (by exposure to mobile phone radiation) expression and activity might have an impact on cell physiology. However, this short communication does not attempt to present the full scientific evidence that is far too large to be presented in a single article and that is being prepared for publication in three separate research articles. Examples of the experimental evidence presented here were designed to show the flow of experimental process demonstrating that the use of high-throughput screening techniques might help in rapid identification of the responding proteins. This, in turn, can

help in speeding up of the process of determining whether these changes might affect human health.

**Leung S, Croft RJ, McKenzie RJ, Iskra S, Silber B, Cooper NR, O'Neill B, Cropley V, Diaz-Trujillo A, Hamblin D, Simpson D. Effects of 2G and 3G mobile phones on performance and electrophysiology in adolescents, young adults and older adults. Clin Neurophysiol. 122(11):2203-2216, 2011.**

**OBJECTIVE:** This study examined sensory and cognitive processing in adolescents, young adults and older adults, when exposed to 2nd (2G) and 3rd (3G) generation mobile phone signals. **METHODS:** Tests employed were the auditory 3-stimulus oddball and the N-back. Forty-one 13-15 year olds, forty-two 19-40 year olds and twenty 55-70 year olds were tested using a double-blind cross-over design, where each participant received Sham, 2G and 3G exposures, separated by at least 4 days. **RESULTS:** 3-Stimulus oddball task: Behavioural: accuracy and reaction time of responses to targets were not affected by exposure. Electrophysiological: augmented N1 was found in the 2G condition (independent of age group). N-back task: Behavioural: the combined groups performed less accurately during the 3G exposure (compared to Sham), with post hoc tests finding this effect separately in the adolescents only. Electrophysiological: delayed ERD/ERS responses of the alpha power were found in both 3G and 2G conditions (compared to Sham; independent of age group). **CONCLUSION:** Employing tasks tailored to each individual's ability level, this study provides support for an effect of acute 2G and 3G exposure on human cognitive function. **SIGNIFICANCE:** The subtlety of mobile phone effect on cognition in our study suggests that it is important to account for individual differences in future mobile phone research.

**Leung S, Diao Y, Chan K, Siu Y, Wu Y. Specific Absorption Rate Evaluation for Passengers Using Wireless Communication Devices inside Vehicles with Different Handedness, Passenger Counts, and Seating Locations. IEEE Trans Biomed Eng. 2012 Aug 8. [Epub ahead of print]**

Radiation from mobile phones inside vehicles, which are semi open metallic enclosures with irregular shapes and apertures, has been a major concern and has warranted investigation in past years. In this paper, the specific absorption rate (SAR) induced in mobile phone users inside a vehicle was evaluated using different scenarios, including handedness, passenger counts, and seating locations. A computer simulation for SAR distributions in a human body was performed based on the Finite-difference Time-domain method (FDTD). The SAR values in mobile phone users in free space were also compared to those inside a vehicle; results illustrated that the maximum SAR induced for mobile phone users in a vehicle is 5% higher than those in free space, but the SAR results showed no significant difference for the handedness. By comparing the SAR values between mobile phone users and non-users inside a vehicle with a passenger count and seating locations, it was observed that the SAR values around the non-users body varied much in different situations, and were higher than those in free space, in some circumstances.

**Levis AG, Minicuci N, Ricci P, Gennaro V, Garbisa S. Mobile phones and head**

**tumours. The discrepancies in cause-effect relationships in the epidemiological studies - how do they arise?Environ Health. 10:59, 2011.**

**BACKGROUND:** Whether or not there is a relationship between use of mobile phones (analogue and digital cellulars, and cordless) and head tumour risk (brain tumours, acousticneuromas, and salivary gland tumours) is still a matter of debate; progress requires a critical analysis of the methodological elements necessary for an impartial evaluation of contradictory studies. **METHODS:** A close examination of the protocols and results from all case-control and cohort studies, pooled- and meta-analyses on head tumour risk for mobile phone users was carried out, and for each study the elements necessary for evaluating its reliability were identified. In addition, new meta-analyses of the literature data were undertaken. These were limited to subjects with mobile phone latency time compatible with the progression of the examined tumours, and with analysis of the laterality of head tumour localisation corresponding to the habitual laterality of mobile phone use. **RESULTS:** Blind protocols, free from errors, bias, and financial conditioning factors, give positive results that reveal a cause-effect relationship between long-term mobile phone use or latency and statistically significant increase of ipsilateral head tumour risk, with biological plausibility. Non-blind protocols, which instead are affected by errors, bias, and financial conditioning factors, give negative results with systematic underestimate of such risk. However, also in these studies a statistically significant increase in risk of ipsilateral head tumours is quite common after more than 10 years of mobile phone use or latency. The meta-analyses, our included, examining only data on ipsilateral tumours in subjects using mobile phones since or for at least 10 years, show large and statistically significant increases in risk of ipsilateral brain gliomas and acoustic neuromas. **CONCLUSIONS:** Our analysis of the literature studies and of the results from meta-analyses of the significant data alone shows an almost doubling of the risk of head tumours induced by long-term mobile phone use or latency.

**Lewicka M, Henrykowska GA, Pacholski K, Szczęsny A, Dziedziczak-Buczyńska M, Buczyński A. The Impact of Electromagnetic Radiation of Different Parameters on Platelet Oxygen Metabolism - In Vitro Studies. Adv Clin Exp Med. 24(1):31-35, 2015.**

BACKGROUND: Electromagnetic radiation emitted by a variety of devices, e.g. cell phones, computers and microwaves, interacts with the human body in many ways. Research studies carried out in the last few decades have not yet resolved the issue of the effect of this factor on the human body and many questions are left without an unequivocal answer. Various biological and health-related effects have not been fully recognized. Thus further studies in this area are justified. OBJECTIVES: A comparison of changes within catalase enzymatic activity and malondialdehyde concentration arising under the influence of the electromagnetic radiation emitted by car electronics, equipment used in physiotherapy and LCD monitors. MATERIAL AND METHODS: The suspension of human blood platelets at a concentration of 1 × 109/0.001 dm 3, obtained from whole blood by manual apheresis, was the study material. Blood platelets were exposed to an electromagnetic field for 30 min in a laboratory stand designed for the reconstruction of the electromagnetic radiation generated by car electronics, physiotherapy equipment and LCD monitors. The changes in catalase activity and malondialdehyde concentration were

investigated after the exposure and compared to the control values (unexposed material). RESULTS: An increase in catalase activity and malondialdehyde concentration was observed after 30 min exposure of platelets to EMF regardless of the radiation source. The most significant changes determining the degree of oxidative stress were observed after exposure to the EMF generated by car electronics. CONCLUSIONS: The low frequency electromagnetic fields generated by car electronics, physiotherapy equipment and LCD monitors may be a cause of oxidative stress in the human body and may lead to free radical diseases.

**Lewis RC, Mínguez-Alarcón L, Meeker JD, Williams PL, Mezei G, Ford JB, Hauser R; EARTH Study Team. Self-reported mobile phone use and semen parameters among men from a fertility clinic. Reprod Toxicol. 2016 Nov 9. pii: S0890-6238(16)30408-7. doi: 10.1016/j.reprotox.2016.11.008. [Epub ahead of print]**

There is increasing concern that use of mobile phones, a source of low-level radio-frequency electromagnetic fields, may be associated with poor semen quality, but the epidemiologic evidence is limited and conflicting. The relationship between mobile phone use patterns and markers of semen quality was explored in a longitudinal cohort study of 153 men that attended an academic fertility clinic in Boston, Massachusetts. Information on mobile phone use duration, headset or earpiece use, and the body location in which the mobile phone was carried was ascertained via nurse-administered questionnaire. Semen samples (n=350) were collected and analyzed onsite. To account for multiple semen samples per man, linear mixed models with random intercepts were used to investigate the association between mobile phone use and semen parameters. Overall, there was no evidence for a relationship between mobile phone use and semen quality.

**Li BF, Guo GZ, Ren DQ, Zhang RB. Electromagnetic pulses induce fluctuations in blood pressure in rats. Int J Radiat Biol.83(6):421-429, 2007.**

Purpose: To investigate the effects of exposure to electromagnetic pulses (EMP) on functional indices of the cardiovascular system in male Sprague-Dawley rats. Materials and methods: A tapered parallel plate Gigahertz Transverse Electromagnetic cell (GTEM cell) with a flared rectangular coaxial transmission line was used to expose the rats to EMP (0.5 pps, total 200 pulses and whole-body averaged specific absorption rate 50 mW/kg at 200 kV/m or 75 mW/kg at 400 kV/m). Concurrent sham-exposed animals were used as controls. Cardiovascular functions, namely, heart rate, and systolic, mean and diastolic blood pressures were measured immediately and up to 4 weeks post-exposure using a non-invasive tail-cuff photoelectric sensor sphygmomanometer. Results: The heart rates in sham- and EMP-exposed rats were not significantly changed. In the exposed rats, increased systolic blood pressure (SBP) occurred at 0 h and decreased SBP occurred at 1 day and 3 days after exposure. Significantly higher diastolic blood pressure (DBP) was found at 0 h and significantly lower DBP was found at 12 h, 1 day, and 1 month after exposure. Significantly higher mean arterial pressure (MAP) was noted at 0 h and significantly lower MAP was noted at 1 day. Conclusions: Significant alterations in arterial blood pressure were observed in rats exposed to EMP exposure while heart

rate was not altered.

**Li C, Chen Z, Yang L, Lv B, Liu J, Varsier N, Hadjem A, Wiart J, Xie Y, Ma L, Wu T. Generation of infant anatomical models for evaluating electromagnetic field exposures. Bioelectromagnetics. 2015 Jan;36(1):10-26, 2015.**

Realistic anatomical modeling is essential in analyzing human exposure to electromagnetic fields. Infants have significant physical and anatomical differences compared with other age groups. However, few realistic infant models are available. In this work, we developed one 12-month-old male whole body model and one 17-month-old male head model from magnetic resonance images. The whole body and head models contained 28 and 30 tissues, respectively, at spatial resolution of 1 mm × 1 mm × 1 mm. Fewer identified tissues in the whole body model were a result of the low original image quality induced by the fast imaging sequence. The anatomical and physical parameters of the models were validated against findings in published literature (e.g., a maximum deviation as 18% in tissue mass was observed compared with the data from International Commission on Radiological Protection). Several typical exposure scenarios were realized for numerical simulation. Dosimetric comparison with various adult and child anatomical models was conducted. Significant differences in the physical and anatomical features between adult and child models demonstrated the importance of creating realistic infant models. Current safety guidelines for infant exposure to radiofrequency electromagnetic fields may not be conservative.

**Li C, Zhan C, Long Y, Gu H, Deng Y, Jiang Y, Tang M, Tang C, Luo S, [Some biochemical indexes in white rabbit's blood affected by acute high intensity microwave]. Hua Hsi I Ko Ta Hsueh Hsueh Pao ;26(2):206-209, 1995.** [Article in Chinese]

Irradiation of white rabbits by 10, 50, 100 and 200 mW/cm2 microwave respectively can cause the disorder of protein metabolism, the abnormality of blood sugar, and the change of the activity of serum alpha-hydroxybutyrate dehydrogenase, lactate dehydrogenase, glutamic oxalacetic transaminase, glutamic pyruvic transaminase, acid phosphatase ect. These changes can be used as indexes in the evaluation of the effect of acute high intensity microwave exposure. The effect on the organism mainly depends on the intensity of exposure provided the dose of microwave remains the same.

**Li C, Wu T. Dosimetry for infant exposures to electronic article surveillance system: Posture, physical dimension and anatomy. Bioelectromagnetics. 2015 Mar 10. doi: 10.1002/bem.21901. [Epub ahead of print]**

The use of electronic article surveillance (EAS) systems has become popular in many public sites. As a consequence, concern has risen about infant exposure to magnetic fields (MFs) from this kind of device. To evaluate infant exposure to MFs of an EAS system (operating at 125 kHz and 13.56 MHz), we numerically compared dosimetric results among adult, child and infant models. Results revealed that postures insignificantly influenced dosimetric results if there was a similar cross-sectional area

under exposure. Although safety limits are unlikely to be exceeded, the infant has higher SAR values for brain and central nervous system tissues compared with adult (1.5x at 125 kHz and 112x at 13.56 MHz), which deserve further investigation. Infant's specific anatomy (e.g., non-proportionally large head and high fat content) did not induce higher SAR values. The numerical models developed in the study (stroller and postured infant models) could be freely used for nonprofit academic research.

**Li CY, Liu CC, Chang YH, Chou LP, Ko MC. A population-based case-control study of radiofrequency exposure in relation to childhood neoplasm. Sci Total Environ. 435-436:472-478, 2012.**

This population-based case-control study in Taiwan considered incident cases aged 15 years or less and admitted in 2003 to 2007 for all neoplasm (ICD-9-CM: 140-239) (n=2606), including 939 leukemia and 394 brain neoplasm cases. Controls were randomly selected, with a case/control ratio of 1:30 and matched on year of birth, from all non-neoplasm children insured in the same year when the index case was admitted. Annual summarized power (ASP, watt-year) was calculated for each of the 71,185 mobile phone base stations (MPBS) in service between 1998 and 2007. Then, the annual power density (APD, watt-year/km(2)) of each township (n=367) was computed as a ratio of the total ASP of all MPBS in a township to the area of that particular township. Exposure of each study subject to radio frequency (RF) was indicated by the averaged APD within 5 years prior to the neoplasm diagnosis (cases) or July 1st of the year when the index case was admitted (controls) in the township where the subject lived. Unconditional logistic regression model with generalized estimation equation was employed to calculate the covariate-adjusted odds ratio [AOR] of childhood neoplasm in relation to RF exposure. A higher than median averaged APD (approximately 168 WYs/km(2)) was significantly associated with an increased AOR for all neoplasms (1.13; 1.01 to 1.28), but not for leukemia (1.23; 0.99 to 1.52) or brain neoplasm (1.14, 0.83 to 1.55). This study noted a significantly increased risk of all neoplasms in children with higher-than-median RF exposure to MPBS. The slightly elevated risk was seen for leukemia and brain neoplasm, but was not statistically significant. These results may occur due to several methodological limitations.

**Li CY, Liao MH, Lin CW, Tsai WS, Huang CC, Tang TK. Inhibitory Effects of Microwave Radiation on LPS-Induced NFκB Expression in THP-1 Monocytes. Chin J Physiol. 55(6):421-427, 2012.**

Microwave radiations can be encountered regularly in daily lives. When WHO announced that microwave radiations were a kind of environmental energy which interfere with the physiological functions of the human body, great concerns have been raised over the damages microwave frequencies can do to human physiology. The immunological performance and the activities of the cellular inflammatory factor NFκB have been closely related in monocyte. Due to the effect of phorbol 12-myristate 13-acetate (PMA) on THP-1 monocytes, THP-1 monocytes would differentiate into macrophages and would then react with lipopolysaccharides (LPS), and the amount of NFκB increased in the THP-1 monocytes. Expression of cytokine is affected when cells are exposed to a frequency of

2450 MHz and at 900 W. Thus, in our experiments, an observation was made when THP-1 monocytes were stimulated with PMA and LPS to differentiate into macrophage, the amount of NFκB in cells increased exponentially, and the levels of NFκB expression were decreased by the exposure of microwave radiation. In conclusion, microwave radiations were found to inhibit the activity functions of THP-1 monocytes stimulated with PMA and LPS.

**Li H, Peng R, Wang C, Qiao S, Yong-Zou, Gao Y, Xu X, Wang S, Dong J, Zuo H, Li-Zhao, Zhou H, Wang L, Hu X. Alterations of cognitive function and 5-HT system in rats after long term microwave exposure. Physiol Behav. 2014 Dec 24. pii: S0031-9384(14)00663-5. doi: 10.1016/j.physbeh.2014.12.039. [Epub ahead of print]**

The increased use of microwaves raises concerns about its impact on health including cognitive function in which neurotransmitter system plays an important role. In this study, we focused on the serotonergic system and evaluated the long term effects of chronic microwave radiation on cognition and correlated items. Wistar rats were exposed or sham exposed to 2.856GHz microwaves with the average power density of 5, 10, 20 or 30mW/cm$^2$ respectively for 6min three times a week up to 6weeks. At different time points after the last exposure, spatial learning and memory function, morphology structure of the hippocampus, electroencephalogram (EEG) and neurotransmitter content (amino acid and monoamine) of rats were tested. Above results raised our interest in serotonin system. Tryptophan hydroxylase 1 (TPH1) and monoamine oxidase (MAO), two important rate-limiting enzymes in serotonin synthesis and metabolic process respectively, were detected. Expressions of serotonin receptors including 5-HT$_{1A, 2A, 2C}$ receptors were measured. We demonstrated that chronic exposure to microwave (2.856GHz, with the average power density of 5, 10, 20 and 30mW/cm$^2$) could induce dose-dependent deficit of spatial learning and memory in rats accompanied with inhibition of brain electrical activity, the degeneration of hippocampus neurons, and the disturbance of neurotransmitters, among which the increase of 5-HT occurred as the main long-term change that the decrease of its metabolism partly contributed to. Besides, the variations of 5-HT$_{1A}$R and 5-HT$_{2C}$R expressions were also indicated. The results suggested that in the long-term way, chronic microwave exposure could induce cognitive deficit and 5-HT system may be involved in it.

**Li, JR, Chou, CK, McDougall, JA, Dasgupta, G, Wu, HH, Ren, RL, Lee, A, Han, J, Momand J TP53 tumor suppressor protein in normal human fibroblasts does not respond to 837 MHz microwave exposure. Radiat Res 151(6):710-716, 1999.**

The TP53 tumor suppressor protein (formerly known as p53) responds to a wide variety of environmental insults. To evaluate the safety of cellular telephones, TP53 responses in human fibroblast cells were studied after exposure to 837 MHz microwaves. Cells were exposed in a temperature-controlled transverse electromagnetic (TEM) chamber to a specific absorption rate (SAR) of 0.9 or 9.0 W/kg at 837 MHz continuous-wave (CW) microwave irradiation for 2 h. The TP53 protein levels were measured by Western blot at 2, 8, 24 and 48 h after treatment. The TP53 protein levels in microwave-treated cells, sham-treated cells, and untreated cells remained unchanged relative to each other at all

times tested (Fisher test and Student-Newman-Keuls test, P > 0.05). No morphological alterations were observed in microwave-treated cells compared to sham-treated cells. We conclude that TP53 protein expression levels in cultured human fibroblast cells do not change significantly during a 48-h period after exposure to 837 MHz continuous microwaves for 2 h at SAR levels of 0.9 or 9.0 W/kg.

**Li L, Bisht KS, LaGroye I, Zhang P, Straube WL, Moros EG, Roti Roti JL.Measurement of DNA damage in mammalian cells exposed in vitro to radiofrequency fields at sars of 3-5 w/kg. Radiat Res 156:328-332, 2001.**

In the present study, we determined whether exposure of mammalian cells to 3.2-5.1 W/kg specific absorption rate (SAR) radiofrequency fields could induce DNA damage in murine C3H 10T(1/2) fibroblasts. Cell cultures were exposed to 847.74 MHz code-division multiple access (CDMA) and 835.62 frequency-division multiple access (FDMA) modulated radiations in radial transmission line (RTL) irradiators in which the temperature was regulated to 37.0 +/- 0.3 degrees C. Using the alkaline comet assay to measure DNA damage, we found no statistically significant differences in either comet moment or comet length between sham-exposed cells and those exposed for 2, 4 or 24 h to CDMA or FDMA radiations in either exponentially growing or plateau-phase cells. Further, a 4-h incubation after the 2-h exposure resulted in no significant changes in comet moment or comet length. Our results show that exposure of cultured C3H 10T(1/2) cells at 37 degrees C CDMA or FDMA at SAR values of up to 5.1 W/kg did not induce measurable DNA damage.

**Li WH, Li YZ, Song DD, Wang XR, Liu M, Wu XD, Liu XH. Calreticulin Protects Rat Microvascular Endothelial Cells against Microwave Radiation-induced Injury by Attenuating Endoplasmic Reticulum Stress. Microcirculation. 2014 Mar 3. doi: 10.1111/micc.12126. [Epub ahead of print]**

OBJECTIVE: The present study was designed to evaluate whether exogenous calreticulin (CRT) was beneficial for alleviating microwave radiation (MR)-induced injury by suppressing endoplasmic reticulum (ER) stress in rat myocardial microvascular endothelial cells (MMECs). METHODS: MMECs were pretreated with CRT (25 pg/mL) for 12 h, followed by the exposure to 2.856 GHz radiation at a mean power density of 30 $mW/cm^2$ for 6 min. MR-induced injury in MMECs was evaluated by lactate dehydrogenase (LDH) leakage, apoptosis and cell viability analysis. The expression of glucose-regulating protein 78 (GRP78), CRT, C/EBP homologous protein (CHOP), Bcl-2 and Bax were examined by Western blot analysis to reflect ER-stress response and ER stress-related apoptosis. RESULTS: MR induced marked MMECs injury, as shown by increased LDH leakage and apoptosis rate and decreased cell viability. MR also induced excessive ER stress, characterized by increased expression of GRP78 and CRT, and ER stress-related apoptotic signaling as well, as shown by the up-regulation of CHOP and Bax and the down-regulation of Bcl-2. Exogenous CRT pretreatment remarkably attenuated MR-induced cell apoptosis and LDH leakage, ER stress and activation of the ER stress-related apoptotic signaling. CONCLUSIONS: Exogenous CRT attenuates MR-induced ER stress-related apoptosis by suppressing CHOP-mediated apoptotic signaling pathways in MMECs.

**Li X, Hu XJ, Peng RY, Gao YB, Wang SM, Wang LF, Xu XP, Su ZT, Yang GS. [A aquaporin 4 expression and effects in rat hippocampus after microwave radiation.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):534-538, 2009.** [Article in Chinese]

OBJECTIVE: To investigate the expression of aquaporin 4 (AQP4) after microwave exposure and the correlation with the brain injury by radiation. METHODS: 70 male rats were exposed to microwave whose average power density was 0, 10, 30 and 100 mW/cm(2) respectively. Rats were sacrificed at 6 h, 1 d, 3 d and 7 d after exposure. Immunohistochemistry and Western blot were used to detect the expression of AQP4 in protein level in rat hippocampus, and the expression of AQP4 in gene level was measured by in situ hybridization and RT-PCR. RESULTS: The expression of AQP4 in rat hippocampus was abnormal after 10, 30, 100 mW/cm(2) microwave exposure. The protein level showed increased at first and then recovered at 10 and 30 mW/cm(2) groups, while increased progressively in 100 mW/cm(2) group within 14 d ($P < 0.01$). The gene expression of AQP4 was increased (0.51 +/- 0.02) at the beginning (6 h) and then regained after 10 mW/cm(2) microwave exposure, while in 30 and 100 mW/cm(2) groups, it rose to the peak at 7 d (0.46 +/- 0.02 and 0.43 +/- 0.08) and didn't get back ($P = 0.004$; $P = 0.012$). CONCLUSION: Microwave radiation can increase the expression of AQP4 in rat hippocampus. The change might participate in the process of increasing permeability of blood-brain barrier and lead to the brain edema after microwave radiation.

**Lian HY, Lin KW, Yang C, Cai P. Generation and propagation of yeast prion [URE3] are elevated under electromagnetic field. Cell Stress Chaperones. 2017 Dec 6. doi: 10.1007/s12192-017-0867-9.**

In this study, we studied the effect of 2.0 GHz radio frequency electromagnetic field (RF-EMF) and 50 Hz extremely low frequency electromagnetic field (ELF-EMF) exposure on prion generation and propagation using two budding yeast strains, NT64C and SB34, as model organisms. Under exposure to RF-EMF or ELF-EMF, the de novo generation and propagation of yeast prions [URE3] were elevated in both strains. The elevation increased over time, and the effects of ELF-EMF occurred in a dose-dependent manner. The transcription and expression levels of the molecular chaperones Hsp104, Hsp70-Ssa1/2, and Hsp40-Ydj1 were not statistically significantly changed after exposure. Furthermore, the levels of ROS, as well as the activities of superoxide dismutase (SOD) and catalase (CAT), were significantly elevated after short-term, but not long-term exposure. This work demonstrated for the first time that EMF exposure could elevate the de novo generation and propagation of yeast prions and supports the hypothesis that ROS may play a role in the effects of EMF on protein misfolding. The effects of EMF on protein folding and ROS levels may mediate the broad effects of EMF on cell function.

**Libertin CR, Panozzo J, Groh KR, Chang-Liu CM, Schreck S, Woloschak GE. Effects of gamma rays, ultraviolet radiation, sunlight, microwaves and electromagnetic fields on gene expression mediated by human immunodeficiency virus promoter. Radiat Res. 140(1):91-96, 1994.**

Previous work by our group and others has shown the modulation of human immunodeficiency virus (HIV) promoter or long terminal repeat (LTR) after exposure to neutrons and ultraviolet radiations. Using HeLa cells stably transfected with a construct containing the chloramphenicol acetyl transferase (CAT) gene, the transcription of which is mediated by the HIV-LTR, we designed experiments to examine the effects of exposure to different types of radiation (such as gamma rays, ultraviolet and sunlight irradiations, electromagnetic fields and microwaves) on HIV-LTR-driven expression of CAT. These results demonstrated ultraviolet-light-induced transcription from the HIV promoter, as has been shown by others. Exposure to other DNA-damaging agents such as gamma rays and sunlight (with limited exposures) had no significant effect on transcription mediated by HIV-LTR, suggesting that induction of HIV is not mediated by just any type of DNA damage but rather may require specific types of DNA damage. Microwaves did not cause cell killing when cells in culture were exposed in high volumes of medium, and the same cells showed no changes in expression. When microwave exposure was carried out in low volumes of medium (so that excessive heat was generated) induction of HIV-LTR transcription (as assayed by CAT activity) was evident. Electromagnetic field exposures had no effect on expression of HIV-LTR. These results demonstrate that not all types of radiation and not all DNA-damaging agents are capable of inducing HIV. We hypothesize that induction of HIV transcription may be mediated by several different signals after exposure to radiation.

**Liddle CG, Putnam JP, Huey OP, Alteration of life span of mice chronically exposed to 2.45 GHz CW microwaves. Bioelectromagnetics 15(3):177-181, 1994.**

Female CD1 mice were exposed from the thirty-fifth day of age for the remainder of their lives to 2.45 GHz, CW-microwave radiation at a power density of 3 or 10 mW/cm2 (SAR = 2.0 or 6.8 W/kg). Exposures took place 1 h/day, 5 day/week in an anechoic chamber at an ambient temperature of 22 degrees C and a relative humidity of 50%. There were 25 animals in each exposure group, and an equal number of controls were concurrently sham exposed. The average life span of animals exposed at 10 mW/cm2 was significantly shorter than that of sham-exposed controls (572 days vs. 706 days; P = .049; truncation > 20%). In contrast, the average lifespan of the animals exposed at 3 mW/cm2 was slightly, but not significantly, longer (738 days) than that of controls (706 days).

**Liljestrand B, Sandström M, Hansson Mild K. RF exposure during use of electrosurgical units  Electromag. Biol. Med. 22:129-132, 2003.**

Electrosurgical units (ESUs) commonly used in operating suites employ radiofrequency (RF) energy for cutting and coagulation, and operate at different frequencies in the range 0.3–5 MHz. Around the electrode and cables, electric and magnetic fields at similar frequencies will be generated, and the surgeon using the ESU will therefore be exposed to these electromagnetic fields. In this study we have measured the levels of RF fields near the lead wires of two electrosurgical units, BARD 3000 operating at a fixed frequency of 0.5 MHz, and ERBE ICC 350 with a frequency range from 0.3 to 1 MHz. Electric fields were measured at distances from 5–30 cm from the lead wire. Measurements were done with the ESU both cutting and coagulating, and power levels ranging from 10–100 W. The magnetic field outside the

lead wire was calculated from the measured current through the leads using standard theory. Using those measurements as a base, the calculated local exposure of the surgeon's hand was estimated to exceed 15 kV/m for the electric field and the corresponding value for the magnetic field was 16 µT. These calculations exceed the suggested international reference levels at 0.5 MHz (610 V/m and 4 µT, respectively).

**Lim HB, Cook GG, Barker AT, Coulton LA. Effect of 900 MHz electromagnetic fields on nonthermal induction of heat-shock proteins in human leukocytes. Radiat Res. 163(1):45-52, 2005.**

Despite many studies, the evidence as to whether radiofrequency fields are detrimental to health remains controversial, and the debate continues. Cells respond to some abnormal physiological conditions by producing cytoprotective heat-shock (or stress) proteins. The aim of this study was to determine whether exposure to mobile phone-type radiation causes a nonthermal stress response in human leukocytes. Human peripheral blood was sham-exposed or exposed to 900 MHz fields (continuous-wave or GSM-modulated signal) at three average specific absorption rates (0.4, 2.0 and 3.6 W/kg) for different durations (20 min, 1 h and 4 h) in a calibrated TEM cell placed in an incubator to give well-controlled atmospheric conditions at 37 degrees C and 95% air/5% CO(2). Positive (heat-stressed at 42 degrees C) and negative (kept at 37 degrees C) control groups were incubated simultaneously in the same incubator. Heat caused an increase in the number of cells expressing stress proteins (HSP70, HSP27), measured using flow cytometry, and this increase was dependent on time. However, no statistically significant difference was detected in the number of cells expressing stress proteins after RF-field exposure. These results suggest that mobile phone-type radiation is not a stressor of normal human lymphocytes and monocytes, in contrast to mild heating.

**Lim JI, Fine SL, Kues HA, Johnson MA. Visual abnormalities associated with high-energy microwave exposure. Retina 13(3):230-233, 1993**.

A 44-year-old man was accidentally exposed to high-energy microwave irradiation. After resolution of facial erythema and iritis, he noted a foreign body sensation and blurring of vision. Ophthalmoscopic examination showed bilateral, small hard drusen. Ancillary tests were consistent with abnormal cone function. Electroretinogram testing revealed a marked decrease in the flicker electroretinogram. Results of D15 and Farnsworth Munsel Hue 100 color tests were abnormal. Two years later, the patient's visual acuity was stable at 20/25 in both eyes; however, results of flicker electroretinogram test remain markedly decreased. (comment by: Appleton B, Osepchuk J, Cohen J. A case of color vision abnormality and reduced amplitude of the 30 Hz flicker dark-adapted electroretinographic (ERG) Retina 15(2):170-172, 1995.)

**Lin WT, Chang CH, Cheng CY, Chen MC, Wen YR, Lin CT, Lin CW. Effects of low amplitude pulsed radiofrequency stimulation with different waveform in rats for neuropathic pain. Conf Proc IEEE Eng Med Biol Soc. 2013 Jul;2013:3590-3593.**

Pulsed-radiofrequency (PRF) electrical stimulation has been widely used for chronic pain treatment. It has been demonstrated with advantages of low temperature over traditional continuous radiofrequency (CRF) lesions with higher amplitude and mono polar electrode to treat pain in clinics (frequency 500 KHz, Pulse duration 20 msec,

Amplitude 45 V, Treatment 2 min). We compare the effects of different pulse waveforms and PRF parameters (Pulse duration 25 ms, Treatment duration 5 min, low amplitude of 2.5/1.25 V) with a miniature bi-polar electrode on Dorsal root ganglion (DRG). The pain relief effect due to PRF is evaluated by using Von Frey method for the pain threshold index based on behavior response to mechanical stimulus of various strengths. Experimental results of Von Frey Score show that the sinusoidal group has higher responses than the square wave one. Both fast and secondary expressed proteins of c-fos and pp38 are measured from spinal cord tissue sectioning slides to characterize the pain associated inflammatory responses and their responses due to PRF stimulation.

**Lindholm H, Alanko T, Rintamäki H, Kännälä S, Toivonen T, Sistonen H, Tiikkaja M, Halonen J, Mäkinen T, Hietanen M. Thermal effects of mobile phone RF fields on children: a provocation study. Prog Biophys Mol Biol. 107(3):399-403, 2011.**

The aim of this study was to examine thermal and local blood flow responses in the head area of the preadolescent boys during exposure to radiofrequency (RF) electromagnetic fields produced by a GSM mobile phone. The design was a double-blinded sham-controlled study of 26 boys, aged 14-15 years. The SAR distribution was calculated and modelled in detail. The duration of the sham periods and exposures with GSM 900 phone was 15 min each, and the tests were carried out in a climatic chamber in controlled thermoneutral conditions. The ear canal temperatures were registered from both ear canals, and the skin temperatures at several sites of the head, trunk and extremities. The local cerebral blood flow was monitored by a near-infrared spectroscopy (NIRS), and the autonomic nervous system function by recordings of ECG and continuous blood pressure. During the short-term RF exposure, local cerebral blood flow did not change, the ear canal temperature did not increase significantly and autonomic nervous system was not interfered. The strengths of this study were the age of the population, multifactorial physiological monitoring and strictly controlled thermal environment. The limitations of the study were large inter-individual variation in the physiological responses, and short duration of the exposure. Longer provocation protocols, however, might cause in children distress related confounding physiological responses.

**Linet MS, Taggart T, Severson RK, Cerhan JR, Cozen W, Hartge P, Colt J. Cellular telephones and non-Hodgkin lymphoma. Int J Cancer.119(10):2382-8, 2006.**

Dramatic increase in hand-held cellular telephone use since the 1980s and excess risk of lymphoproliferative malignancies associated with radio-frequency radiation (RFR) exposures in epidemiological and experimental studies motivated assessment of cellular telephones within a comprehensive US case-control investigation of non-Hodgkin lymphoma (NHL). A questionnaire ascertained cellular telephone use in 551 NHL cases and 462 frequency-matched population controls. Compared to persons who had never used cellular telephones, risks were not increased among individuals whose lifetime use was fewer than 10 (odds ratio (OR) = 0.9, 95% confidence intervals (CI): 0.6, 1.3), 10-100 (OR = 1.0, 95 % CI: 0.7, 1.5) or more than 100 times (e.g., regular users, OR = 0.9, 95% CI: 0.6, 1.4). Among regular users compared to those who had never used hand-held

cellular telephones, risks of NHL were not significantly associated with minutes per week, duration, cumulative lifetime or year of first use, although NHL was non-significantly higher in men who used cellular telephones for more than 8 years. Little evidence linked use of cellular telephones with total, diffuse large B-cell lymphoma or follicular NHL. These findings must be interpreted in the context of less than 5% of the population reporting duration of use of 6 or more years or lifetime cumulative use of 200 or more hours.

**Linet MS, Taggart T, Severson RK, Cerhan JR, Cozen W, Hartge P, Colt J. Cellular telephones and non-Hodgkin lymphoma. Int J Cancer. 119(10):2382-2388, 2006.**

Dramatic increase in hand-held cellular telephone use since the 1980s and excess risk of lymphoproliferative malignancies associated with radio-frequency radiation (RFR) exposures in epidemiological and experimental studies motivated assessment of cellular telephones within a comprehensive US case-control investigation of non-Hodgkin lymphoma (NHL). A questionnaire ascertained cellular telephone use in 551 NHL cases and 462 frequency-matched population controls. Compared to persons who had never used cellular telephones, risks were not increased among individuals whose lifetime use was fewer than 10 (odds ratio (OR) = 0.9, 95% confidence intervals (CI): 0.6, 1.3), 10-100 (OR = 1.0, 95 % CI: 0.7, 1.5) or more than 100 times (e.g., regular users, OR = 0.9, 95% CI: 0.6, 1.4). Among regular users compared to those who had never used hand-held cellular telephones, risks of NHL were not significantly associated with minutes per week, duration, cumulative lifetime or year of first use, although NHL was non-significantly higher in men who used cellular telephones for more than 8 years. Little evidence linked use of cellular telephones with total, diffuse large B-cell lymphoma or follicular NHL. These findings must be interpreted in the context of less than 5% of the population reporting duration of use of 6 or more years or lifetime cumulative use of 200 or more hours.

**Linz, KW, von Westphalen, C, Streckert, J, Hansen, V, Meyer, R, Membrane potential and currents of isolated heart muscle cells exposed to pulsed radio frequency fields. Bioelectromagnetics 20(8):497-511, 1999.**

The influence of radio frequency (RF) fields of 180, 900, and 1800 MHz on the membrane potential, action potential, L-type Ca(2+) current and potassium currents of isolated ventricular myocytes was tested. The study is based on 90 guinea-pig myocytes and 20 rat myocytes. The fields were applied in rectangular waveguides (1800 MHz at 80, 480, 600, 720, or 880 mW/kg and 900 MHz, 250 mW/kg) or in a TEM-cell (180 MHz, 80 mW/kg and 900 MHz, 15 mW/kg). Fields of 1800 and 900 MHz were pulsed according to the GSM-standard of cellular phones. The specific absorption rates were determined from computer simulations of the electromagnetic fields inside the exposure devices by considering the structure of the physiological test arrangement. The electrical membrane parameters were measured by whole cell patch-clamp. None of the tested electrophysiological parameters was changed significantly by exposure to RF fields. Another physical stimulus, lowering the temperature from 36 degrees C to 24 degrees C, decreased the current amplitude almost 50% and shifted the voltage dependence of the

steady state activation parameter d(infinity) and inactivation parameter f(infinity) of L-type Ca(2+) current by about 5 mV. However, at this lower temperature RF effects (900 MHz, 250 mW/kg; 1800 MHz, 480 mW/kg) on L-type Ca(2+) current were also not detected.

**Lippi G, Danese E, Brocco G, Gelati M, Salvagno GL, Montagnana M. Acute effects of 30 minutes of exposure to a smartphone call on in vitro platelet function. Blood Transfus. 15(3):249-253, 2017.**

BACKGROUND: Significant concerns are now regularly raised about the safety of excessive mobile phone use. This study was aimed to assess the acute effects of radiofrequency waves emitted by a commercial smartphone on platelet function. MATERIALS AND METHODS: Two sequential citrated blood samples were collected from 16 healthy volunteers recruited from laboratory staff. The first sample was placed in a plastic rack, 1 cm distant from a commercial smartphone receiving a 30-min call and emitting 900 MHz radiofrequency waves. The second sample was placed in another plastic rack, isolated from radiofrequency wave sources, for the same period. The platelet count and the mean platelet volume were then assessed in all blood samples, whereas platelet function was evaluated using the platelet function analyser-100 (PFA-100). RESULTS: A 30-min exposure of citrated blood to smartphone radiofrequency waves induced significant prolongation of collagen-epinephrine aggregation (median increase, 10%) and a considerable increase of mean platelet volume (median increase, 5%), whereas collagen-adenosine diphosphate aggregation and platelet count remained unchanged. DISCUSSION: This study demonstrates that smartphone radiofrequency waves induce significant perturbation of platelet structure and function, thus providing further support to concerns regarding excessive use of mobile phones. Caution should also be taken with regards to blood products containing platelets, which should be kept far away from mobile phones and smartphones throughout the production pipeline and storage period.

**Lipping T, Rorarius M, Jantti V, Annala K, Mennander A, Ferenets R, Toivonen T, Toivo T, Varri A, Korpinen L. Using the nonlinear control of anesthesia-induced hypersensitivity of EEG at burst suppression level to test the effects of radiofrequency radiation on brain function. Nonlinear Biomed Phys.3(1):5, 2009.**

ABSTRACT: BACKGROUND: In this study, investigating the effects of mobile phone radiation on test animals, eleven pigs were anaesthetised to the level where burst-suppression pattern appears in the electroencephalogram (EEG). At this level of anaesthesia both human subjects and animals show high sensitivity to external stimuli which produce EEG bursts during suppression. The burst-suppression phenomenon represents a nonlinear control system, where low-amplitude EEG abruptly switches to very high amplitude bursts. This switching can be triggered by very minor stimuli and the phenomenon has been described as hypersensitivity. To test if also radio frequency (RF) stimulation can trigger this nonlinear control, the animals were exposed to pulse modulated signal of a GSM mobile phone at 890 MHz. In the first phase of the experiment electromagnetic field (EMF) stimulation was randomly switched on and off

and the relation between EEG bursts and EMF stimulation onsets and endpoints were studied. In the second phase a continuous RF stimulation at 31 W/kg was applied for 10 minutes. The ECG, the EEG, and the subcutaneous temperature were recorded. RESULTS: No correlation between the exposure and the EEG burst occurrences was observed in phase I measurements. No significant changes were observed in the EEG activity of the pigs during phase II measurements although several EEG signal analysis methods were applied. The temperature measured subcutaneously from the pigs' head increased by 1.6 degrees Celsius and the heart rate by 14.2 bpm on the average during the 10 min exposure periods. CONCLUSIONS: The hypothesis that RF radiation would produce sensory stimulation of somatosensory, auditory or visual system or directly affect the brain so as to produce EEG bursts during suppression was not confirmed.

**Litovitz TA, Krause D, Penafiel M, Elson EC, Mullins JM, The role of coherence time in the effect of microwaves on ornithine decarboxylase activity. Bioelectromagnetics 14(5):395-403, 1993.**

Previously, we demonstrated the requirements for a minimum coherence time of an applied, small amplitude (10 microT) ELF magnetic field if the field were to produce an enhancement of ornithine decarboxylase activity in L929 fibroblasts. Further investigation has revealed a remarkably similar coherence time phenomenon for enhancement of ornithine decarboxylase activity by amplitude-modulated 915 MHz microwaves of large amplitude (SAR 2.5 W/kg). Microwave fields modulated at 55, 60, or 65 Hz approximately doubled ornithine decarboxylase activity after 8 h. Switching modulation frequencies from 55 to 65 Hz at coherence times of 1.0 s or less abolished enhancement, while times of 10 s or longer provided full enhancement. Our results show that the microwave coherence effects are remarkably similar to those observed with ELF fields.

**Litovitz, TA, Penafiel, LM, Farrel, JM, Krause, D, Meister, R, Mullins, JM Bioeffects induced by exposure to microwaves are mitigated by superposition of ELF noise. Bioelectromagnetics 18(6):422-430, 1997.**

We have previously demonstrated that microwave fields, amplitude modulated (AM) by an extremely low-frequency (ELF) sine wave, can induce a nearly twofold enhancement in the activity of ornithine decarboxylase (ODC) in L929 cells at SAR levels of the order of 2.5 W/kg. Similar, although less pronounced, effects were also observed from exposure to a typical digital cellular phone test signal of the same power level, burst modulated at 50 Hz. We have also shown that ODC enhancement in L929 cells produced by exposure to ELF fields can be inhibited by superposition of ELF noise. In the present study, we explore the possibility that similar inhibition techniques can be used to suppress the microwave response. We concurrently exposed L929 cells to 60 Hz AM microwave fields or a 50 Hz burst-modulated DAMPS (Digital Advanced Mobile Phone System) digital cellular phone field at levels known to produce ODC enhancement, together with band-limited 30-100 Hz ELF noise with root mean square amplitude of up to 10 microT. All exposures were carried out for 8 h, which was previously found to yield the peak microwave response. In both cases, the ODC enhancement was found to decrease exponentially as a function of the noise root mean square amplitude. With 60 Hz AM

microwaves, complete inhibition was obtained with noise levels at or above 2 microT. With the DAMPS digital cellular phone signal, complete inhibition occurred with noise levels at or above 5 microT. These results suggest a possible practical means to inhibit biological effects from exposure to both ELF and microwave fields.

**Little MP, Rajaraman P, Curtis RE, Devesa SS, Inskip PD, Check DP, Linet MS. Mobile phone use and glioma risk: comparison of epidemiological study results with incidence trends in the United States. BMJ.344:e1147, 2012. doi: 10.1136/bmj.e1147.**

OBJECTIVE: In view of mobile phone exposure being classified as a possible human carcinogen by the International Agency for Research on Cancer (IARC), we determined the compatibility of two recent reports of glioma risk (forming the basis of the IARC's classification) with observed incidence trends in the United States.DESIGN: Comparison of observed rates with projected rates of glioma incidence for 1997-2008. We estimated projected rates by combining relative risks reported in the 2010 Interphone study and a 2011 Swedish study by Hardell and colleagues with rates adjusted for age, registry, and sex; data for mobile phone use; and various latency periods.SETTING: US population based data for glioma incidence in 1992-2008, from 12 registries in the Surveillance, Epidemiology, and End Results (SEER) programme (Atlanta, Detroit, Los Angeles, San Francisco, San Jose-Monterey, Seattle, rural Georgia, Connecticut, Hawaii, Iowa, New Mexico, and Utah).PARTICIPANTS: Data for 24 813 non-Hispanic white people diagnosed with glioma at age 18 years or older.RESULTS: Age specific incidence rates of glioma remained generally constant in 1992-2008 (-0.02% change per year, 95% confidence interval -0.28% to 0.25%), a period coinciding with a substantial increase in mobile phone use from close to 0% to almost 100% of the US population. If phone use was associated with glioma risk, we expected glioma incidence rates to be higher than those observed, even with a latency period of 10 years and low relative risks (1.5). Based on relative risks of glioma by tumour latency and cumulative hours of phone use in the Swedish study, predicted rates should have been at least 40% higher than observed rates in 2008. However, predicted glioma rates based on the small proportion of highly exposed people in the Interphone study could be consistent with the observed data. Results remained valid if we used either non-regular users or low users of mobile phones as the baseline category, and if we constrained relative risks to be more than 1.CONCLUSIONS: Raised risks of glioma with mobile phone use, as reported by one (Swedish) study forming the basis of the IARC's re-evaluation of mobile phone exposure, are not consistent with observed incidence trends in US population data, although the US data could be consistent with the modest excess risks in the Interphone study.

**Liu C, Duan W, Xu S, Chen C, He M, Zhang L, Yu Z, Zhou Z. Exposure to 1800 MHz radiofrequency electromagnetic radiation induces oxidative DNA base damage in a mouse spermatocyte-derived cell line. Toxicol Lett 218(1): 2-9, 2013.**

Whether exposure to radiofrequency electromagnetic radiation (RF-EMR) emitted from mobile phones can induce DNA damage in male germ cells remains unclear. In this study, we conducted a 24 h intermittent exposure (5 min on and 10 min off) of a mouse spermatocyte-derived GC-2 cell line to 1800 MHz Global System for Mobile

Communication (GSM) signals in GSM-Talk mode at specific absorption rates (SAR) of 1 W/kg, 2 W/kg or 4 W/kg. Subsequently, through the use of formamidopyrimidine DNA glycosylase (FPG) in a modified comet assay, we determined that the extent of DNA migration was significantly increased at a SAR of 4 W/kg. Flow cytometry analysis demonstrated that levels of the DNA adduct 8-oxoguanine (8-oxoG) were also increased at a SAR of 4 W/kg. These increases were concomitant with similar increases in the generation of reactive oxygen species (ROS); these phenomena were mitigated by co-treatment with the antioxidant α-tocopherol. However, no detectable DNA strand breakage was observed by the alkaline comet assay. Taking together, these findings may imply the novel possibility that RF-EMR with insufficient energy for the direct induction of DNA strand breaks may produce genotoxicity through oxidative DNA base damage in male germ cells.

**Liu C, Gao P, Xu SC, Wang Y, Chen CH, He MD, Yu ZP, Zhang L, Zhou Z. Mobile phone radiation induces mode-dependent DNA damage in a mouse spermatocyte-derived cell line: a protective role of melatonin. Int J Radiat Biol. 2013 Aug 19. [Epub ahead of print]**

Purpose: To evaluate whether exposure to mobile phone radiation (MPR) can induce DNA damage in male germ cells. Materials and methods: A mouse spermatocyte-derived GC-2 cell line was exposed to a commercial mobile phone handset once every 20 minutes in standby, listen, dialed or dialing modes for 24 h. DNA damage was determined using an alkaline comet assay. Results: The levels of DNA damage were significantly increased following exposure to MPR in the listen, dialed and dialing modes. Moreover, there were significantly higher increases in the dialed and dialing modes than in the listen mode. Interestingly, these results were consistent with the radiation intensities of these modes. However, the DNA damage effects of MPR in the dialing mode were efficiently attenuated by melatonin pretreatment. Conclusions: These results regarding mode-dependent DNA damage have important implications for the safety of inappropriate mobile phone use by males of reproductive age and also suggest a simple preventive measure, keeping our body from mobile phones as far away as possible, not only during conversations but during "dialed" and "dialing" operation modes as well. Since the "dialed" mode is actually part of the standby mode, mobile phones should be kept at a safe distance from our body even during standby operation. Furthermore, the protective role of melatonin suggests that it may be a promising pharmacological candidate for preventing mobile phone use-related reproductive impairments.

**Liu H, Chen G, Pan Y, Chen Z, Jin W, Sun C, Chen C, Dong X, Chen K, Xu Z, Zhang S, Yu Y. (2014) Occupational Electromagnetic Field Exposures Associated with Sleep Quality: A Cross-Sectional Study. PLoS ONE 9(10): e110825. doi:10.1371/journal.pone.0110825.**

BACKGROUND: Exposure to electromagnetic field (EMF) emitted by mobile phone and other machineries concerns half the world's population and raises the problem of their impact on human health. The present study aims to explore the effects of electromagnetic

field exposures on sleep quality and sleep duration among workers from electric power plant. METHODS: A cross-sectional study was conducted in an electric power plant of Zhejiang Province, China. A total of 854 participants were included in the final analysis. The detailed information of participants was obtained by trained investigators using a structured questionnaire, which including socio-demographic characteristics, lifestyle variables, sleep variables and electromagnetic exposures. Physical examination and venous blood collection were also carried out for every study subject. RESULTS: After grouping daily occupational electromagnetic exposure into three categories, subjects with long daily exposure time had a significantly higher risk of poor sleep quality in comparison to those with short daily exposure time. The adjusted odds ratios were 1.68 (95%CI: 1.18, 2.39) and 1.57 (95%CI: 1.10, 2.24) across tertiles. Additionally, among the subjects with long-term occupational exposure, the longer daily occupational time apparently increased the risk of poor sleep quality (OR (95%CI): 2.12 (1.23~3.66) in the second tertile; 1.83 (1.07~3.15) in the third tertile). There was no significant association of long-term occupational exposure duration, monthly electric fee or years of mobile-phone use with sleep quality or sleep duration. CONCLUSIONS: The findings showed that daily occupational EMF exposure was positively associated with poor sleep quality. It implies EMF exposure may damage human sleep quality rather than sleep duration.

**Liu K, Zhang G, Wang Z, Liu Y, Dong J, Dong X, Liu J, Cao J, Ao L, Zhang S. The protective effect of autophagy on mouse spermatocyte derived cells exposure to 1800MHz radiofrequency electromagnetic radiation. Toxicol Lett. 2014 May 8. pii: S0378-4274(14)00195-7. doi: 10.1016/j.toxlet.2014.05.004. [Epub ahead of print]**

The increasing exposure to radiofrequency (RF) radiation emitted from mobile phone use has raised public concern regarding the biological effects of RF exposure on the male reproductive system. Autophagy contributes to maintaining intracellular homeostasis under environmental stress. To clarify whether RF exposure could induce autophagy in the spermatocyte, mouse spermatocyte-derived cells (GC-2) were exposed to 1800MHz Global System for Mobile Communication (GSM) signals in GSM-Talk mode at specific absorption rate (SAR) values of 1 w/kg, 2w/kg or 4w/kg for 24h, respectively. The results indicated that the expression of LC3-II increased in a dose- and time-dependent manner with RF exposure, and showed a significant change at the SAR value of 4w/kg. The autophagosome formation and the occurrence of autophagy were further confirmed by GFP-LC3 transient transfection assay and transmission electron microscopy (TEM) analysis. Furthermore, the conversion of LC3-I to LC3-II was enhanced by co-treatment with Chloroqrine (CQ), indicating autophagic flux could be enhanced by RF exposure. Intracellular ROS levels significantly increased in a dose- and time-dependent manner after cells were exposed to RF. Pretreatment with anti-oxidative NAC obviously decreased the conversion of LC3-I to LC3-II and attenuated the degradation of p62 induced by RF exposure. Meanwhile, phosphorylated extracellular-signal-regulated kinase (ERK) significantly increased after RF exposure at the SAR value of 2w/kg and 4w/kg. Moreover, we observed that RF exposure did not increase the percentage of apoptotic cells, but inhibition of autophagy could increase the percentage of apoptotic cells. These findings suggested that autophagy flux could be enhanced by 1800MHz

GSM exposure (4w/kg), which is mediated by ROS generation. Autophagy may play an important role in preventing cells from apoptotic cell death under RF exposure stress.

**Liu ML, Wen JQ, Fan YB. Potential protection of green tea polyphenols against 1800 MHz electromagnetic radiation-induced injury on rat cortical neurons. Neurotox Res. 20(3):270-276, 2011.**

Radiofrequency electromagnetic fields (EMF) are harmful to public health, but the certain anti-irradiation mechanism is not clear yet. The present study was performed to investigate the possible protective effects of green tea polyphenols against electromagnetic radiation-induced injury in the cultured rat cortical neurons. In this study, green tea polyphenols were used in the cultured cortical neurons exposed to 1800 MHz EMFs by the mobile phone. We found that the mobile phone irradiation for 24 h induced marked neuronal cell death in the MTT (3-(4,5-dimethylthiazole-2-yl)-2,5-diphenyl-tetrazolium bromide) and TUNEL (TdT mediated biotin-dUTP nicked-end labeling) assay, and protective effects of green tea polyphenols on the injured cortical neurons were demonstrated by testing the content of Bcl-2 Assaciated X protein (Bax) in the immunoprecipitation assay and Western blot assay. In our study results, the mobile phone irradiation-induced increases in the content of active Bax were inhibited significantly by green tea polyphenols, while the contents of total Bax had no marked changes after the treatment of green tea polyphenols. Our results suggested a neuroprotective effect of green tea polyphenols against the mobile phone irradiation-induced injury on the cultured rat cortical neurons.

**Liu X, Shen H, Shi Y, Chen J, Chen Y, Ji A. The microarray study on the stress gene transcription profile in human retina pigment epithelial cells exposed to microwave radiation. Zhonghua Yu Fang Yi Xue Za Zhi 36(5):291-294, 2002.**

OBJECTIVE: To study the difference in stress and apoptosis related genes transcription between hTERT-RPE1 cells exposed to simulated microwave radiation and the cells with heat water bath, and the effects of microwave on gene transcription in cultured human retina pigment epithelial cells. METHODS: cDNA microarray technique was used to detect the mRNA isolated from hTERT-RPE1 cells exposed to 2 450 MHz simulated microwave radiation and with heat water bath, respectively. RESULTS: Among the 97 related aim genes, there were seven genes up-regulating its transcription, i.e., M31166 (2.52fold), L24123 (2.66fold), AF039704 (2.22fold), U67156 (2.07fold), AF040958 (2.13fold), NM-001423 (2.63fold) and NM-005346 (3.68fold). But, no notably down-regulating gene in transcription was detected. CONCLUSIONS: Microwave could induce up-regulating in multiple stress and apoptosis related genes transcription in cultured human retina pigment epithelial cells, hTERT-RPE1 cells. Microwave radiation has unique effect itself in addition to its heat effect.

**Liu XY, Bian XM, Han JX, Cao ZJ, Fan GS, Zhang C, Zhang WL, Zhang SZ, Sun XG. [Risk factors in the living environment of early spontaneous abortion pregnant women] Zhongguo Yi Xue Ke Xue Yuan Xue Bao. 29(5):661-664, 2007.**[Article in Chinese]

OBJECTIVE: To study the relationship between early spontaneous abortion and

living environment, and explore the risk factors of spontaneous abortion. METHODS: We conducted analysis based on the interview of 200 spontaneous abortion cases and the matched control (age +/- 2 years) by using multifactor Logistic regression analysis. RESULTS: The proportions of watching TV > or =10 hours/week, operating computer > or =45 hours/week, using copycat, microwave oven and mobile phone, electromagnetism equipment near the dwell or work place, e. g. switch room < or =50 m and launching tower < or =500 m in the cases are significantly higher than those in the controls in single factor analysis (all P < 0.05). After adjusted the effect of other risk factors by multifactor analysis, using microwave oven and mobile phone, contacting abnormal smell of fitment material > or =3 months, having emotional stress during the first term of pregnancy and spontaneous abortion history were significantly associated with risk of spontaneous abortion. The odds ratios of these risk factors were 2.23 and 4.63, respectively. CONCLUSION: Using microwave oven and mobile phone, contacting abnormal smell of fitment material > or =3 months, having emotional stress during the first term of pregnancy, and spontaneous abortion history are risk factors of early spontaneous abortion.

**Liu Y, Wang ML, Zhong RG, Ma XM, Wang Q, Zeng Y. The Induction of Epstein-Barr Virus Early Antigen Expression in Raji Cells by GSM Mobile Phone Radiation. Biomed Environ Sci. 26(1):76-78, 2013.**

No abstract available.

**Liu YQ, Gao YB, Dong J, Yao BW, Zhao L, Peng RY. Pathological changes in the sinoatrial node tissues of rats caused by pulsed microwave exposure. Biomed Environ Sci. 28(1):72-75, 2015.**

To observe microwave induced dynamic pathological changes in the sinus nodes, wistar rats were exposed to 0, 5, 10, 50 mW/cm2 microwave. In 10 and 50 mW/cm2 groups, disorganized sinoatrial node cells, cell swelling, cytoplasmic condensation, nuclear pyknosis, and anachromasis, swollen, and empty mitochondria, and blurred and focally dissolved myofibrils could be detected from 1 to 28 d, while reduced parenchymal cells, increased collagen fibers, and extracellular matrix remodeling of interstitial cells were observed from 6 to 12 months. In conclusion, 10 and 50 mW/cm2 microwave could cause structural damages in the sinoatrial node and extracellular matrix remodeling in rats.

**Liu YX, Tai JL, Li GQ, Zhang ZW, Xue JH, Liu HS, Zhu H, Cheng JD, Liu YL, Li AM, Zhang Y. Exposure to 1950-MHz TD-SCDMA Electromagnetic Fields Affects the Apoptosis of Astrocytes via Caspase-3-Dependent Pathway. PLoS One. 7(8):e42332, 2012.**

The usage of mobile phone increases globally. However, there is still a paucity of data about the impact of electromagnetic fields (EMF) on human health. This study investigated whether EMF radiation would alter the biology of glial cells and act as a tumor-promoting agent. We exposed rat astrocytes and C6 glioma cells to 1950-MHz TD-SCDMA for 12, 24 and 48 h respectively, and found that EMF exposure had differential

effects on rat astroctyes and C6 glioma cells. A 48 h of exposure damaged the mitochondria and induced significant apoptosis of astrocytes. Moreover, caspase-3, a hallmark of apoptosis, was highlighted in astrocytes after 48 h of EMF exposure, accompanied by a significantly increased expression of bax and reduced level of bcl-2. The tumorigenicity assays demonstrated that astrocytes did not form tumors in both control and exposure groups. In contrast, the unexposed and exposed C6 glioma cells show no significant differences in both biological feature and tumor formation ability. Therefore, our results implied that exposure to the EMF of 1950-MHz TD-SCDMA may not promote the tumor formation, but continuous exposure damaged the mitochondria of astrocytes and induce apoptosis through a caspase-3-dependent pathway with the involvement of bax and bcl-2.

**Liu YX, Li GQ, Fu XP, Xue JH, Ji SP, Zhang ZW, Zhang Y, Li AM. Exposure to 3G mobile phone signals does not affect the biological features of brain tumor cells.BMC Public Health. 15(1):764, 2015.**

BACKGROUND: The increase in mobile phone use has generated concerns about possible risks to human health, especially the development of brain tumors. Whether tumor patients should continue to use mobile telephones has remained unclear because of a paucity of information. Herein, we investigated whether electromagnetic fields from mobile phones could alter the biological features of human tumor cells and act as a tumor-promoting agent. METHODS: Human glioblastoma cell lines, U251-MG and U87-MG, were exposed to 1950-MHz time division-synchronous code division multiple access (TD-SCDMA) at a specific absorption rate (maximum SAR = 5.0 W/kg) for 12, 24, and 48 h. Cell morphologies and ultra-structures were observed by microscopy and the rates of apoptosis and cell cycle progression were monitored by flow cytometry. Additionally, cell growth was determined using the CKK-8 assay, and the expression levels of tumor and apoptosis-related genes and proteins were analyzed by real-time PCR and western blotting, respectively. Tumor formation and invasiveness were measured using a tumorigenicity assay in vivo and migration assays in vitro. RESULTS: No significant differences in either biological features or tumor formation ability were observed between unexposed and exposed glioblastoma cells. Our data showed that exposure to 1950-MHz TD-SCDMA electromagnetic fields for up to 48 h did not act as a cytotoxic or tumor-promoting agent to affect the proliferation or gene expression profile of glioblastoma cells. CONCLUSIONS: Our findings implied that exposing brain tumor cells in vitro for up to 48 h to 1950-MHz continuous TD-SCDMA electromagnetic fields did not elicit a general cell stress response.

**Lixia S, Yao K, Kaijun W, Deqiang L, Huajun H, Xiangwei G, Baohong W, Wei Z, Jianling L, Wei W. Effects of 1.8GHz radiofrequency field on DNA damage and expression of heat shock protein 70 in human lens epithelial cells. Mutat Res.602(1-2):135-142, 2006.**

To investigate the DNA damage, expression of heat shock protein 70 (Hsp70) and cell proliferation of human lens epithelial cells (hLEC) after exposure to the 1.8GHz

radiofrequency field (RF) of a global system for mobile communications (GSM). An Xc-1800 RF exposure system was used to employ a GSM signal at 1.8GHz (217Hz amplitude-modulated) with the output power in the specific absorption rate (SAR) of 1, 2 and 3W/kg. After 2h exposure to RF, the DNA damage of hLEC was accessed by comet assay at five different incubation times: 0, 30, 60, 120 and 240min, respectively. Western blot and RT-PCR were used to determine the expression of Hsp70 in hLECs after RF exposure. The proliferation rate of cells was evaluated by bromodeoxyuridine incorporation on days 0, 1 and 4 after exposure. The results show that the difference of DNA-breaks between the exposed and sham-exposed (control) groups induced by 1 and 2W/kg irradiation were not significant at any incubation time point ($P>0.05$). The DNA damage caused by 3W/kg irradiation was significantly increased at the times of 0 and 30min after exposure ($P<0.05$), a phenomenon that could not be seen at the time points of 60, 120 or 240min ($P>0.05$). Detectable mRNA as well as protein expression of Hsp70 was found in all groups. Exposure at SARs of 2 and 3W/kg for 2h exhibited significantly increased Hsp70 protein expression ($P<0.05$), while no change in Hsp70 mRNA expression could be found in any of the groups ($P>0.05$). No difference of the cell proliferation rate between the sham-exposed and exposed cells was found at any exposure dose tested ($P>0.05$). The results indicate that exposure to non-thermal dosages of RF for wireless communications can induce no or repairable DNA damage and the increased Hsp70 protein expression in hLECs occurred without change in the cell proliferation rate. The non-thermal stress response of Hsp70 protein increase to RF exposure might be involved in protecting hLEC from DNA damage and maintaining the cellular capacity for proliferation.

**Logani MK, Agelan A, Ziskin MC. Effect of millimeter wave radiation on catalase activity. Electromag Biol Med 21:303-308, 2002.**

Millimeter wave therapy has been reported to reduce the toxic side effects of chemo- and radiation therapy in the treatment of cancer. In order to understand the mechanisms involved in this reduction, the effect of millimeter electromagnetic waves (MWs) on catalase activity was examined in mouse blood. SKH-1 hairless mice were irradiated on their midbacks with 42.2±0.2 GHz millimeter waves. The incident power density used was 31±5 mW/cm$^2$ and the peak SAR was 622±100 W/kg as measured using infrared thermography. The animals were irradiated before or after administration of cyclophosphamide (CPA), an anticancer drug. The sham control groups were treated in a similar manner, but not irradiated. MW irradiation, before or after administration of CPA did not significantly reduce the toxic effect of CPA on catalase activity in mouse blood.

**Lokhmatova SA, [The effect of low-intensity prolonged impulse electromagnetic irradiation in the UHF range on the testes and the appendages of the testis in rats]. Radiats Biol Radioecol 34(2):279-285, 1994.** [Article in Russian]

The influence of the long (4 months, 2 hr/day) impulsive electromagnetic irradiation with the power density of 0.25 mW/cm2 on the testes and epididymides was studied. The results demonstrate the high sensitivity of the rat testes and epididymides to electromagnetic field of 3 GHz. Some destructive changes both in the seminiferous tubules and testicular tissue were found. The full recovery has not been observed even 4

months after irradiation was finished.

**Lonappan A, Rajasekharan C, Thomas V, Bindu G, Mathew KT. Dielectric properties of human colostrum at microwave frequencies. J Microw Power Electromagn Energy. 41(2):33-38, 2007.**

This article communicates the study of both the dielectric properties of human colostrums and breast milk at microwave frequencies. The colostrum samples were taken immediately after child birth and breast milk samples were collected at weekly intervals following the delivery. Rectangular cavity perturbation technique is used for the measurements of dielectric properties at the S-band of microwave frequency. The dielectric constants of the colostrums samples and breast milk samples are found to increase as weeks elapse, which is attributed to the reduced fat content and increased lactose concentration. The conductivity of these samples is similarly found to increase due to the increased dilution.

**Lonn S, Klaeboe L, Hall P, Mathiesen T, Auvinen A, Christensen HC, Johansen C, Salminen T, Tynes T, Feychting M. Incidence trends of adult primary intracerebral tumors in four Nordic countries. Int J Cancer. 108(3):450-455, 2004.**

Brain tumors are some of the most lethal adult cancers and there is a concern that the incidence is increasing. It has been suggested that the reported increased incidence can be explained by improvements in diagnostic procedures, although this has not been totally resolved. The aim of our study was to describe the incidence trends of adult primary intracerebral tumors in four Nordic countries during a period with introduction of new diagnostic procedures and increasing prevalence of mobile phone users. Information about benign and malignant primary intracerebral tumor cases 20-79 years of age was obtained from the national cancer registries in Denmark, Finland, Norway and Sweden for the years 1969-98 and estimates of person-years at risk were calculated from the information obtained from national population registries. Annual age standardized incidence rates per 100,000 person-years were calculated and time trends analyses were carried out using Poisson regression. The overall incidence of all intracerebral tumors ranged from 8.4-11.8 for men and 5.8-9.3 for women, corresponding to an average annual increase of 0.6% for men (95% confidence interval [CI] = 0.4, 0.7) and 0.9% for women (95% CI = 0.7, 1.0). The increase in the incidence was confined to the late 1970s and early 1980s and coinciding with introduction of improved diagnostic methods. This increase was largely confined to the oldest age group. After 1983 and during the period with increasing prevalence of mobile phone users, the incidence has remained relatively stable for both men and women.

**Lonn S, Forssen U, Vecchia P, Ahlbom A, Feychting M. Output power levels from mobile phones in different geographical areas; implications for exposure assessment. Occup Environ Med. 61(9):769-772, 2004.**

BACKGROUND: The power level used by the mobile phone is one of the most important factors determining the intensity of the radiofrequency exposure during a call. Mobile phone calls made in areas where base stations are densely situated (normally urban areas) should theoretically on average use lower output power levels than mobile phone

calls made in areas with larger distances between base stations (rural areas). AIMS: To analyse the distribution of power levels from mobile phones in four geographical areas with different population densities. METHODS: The output power for all mobile phone calls managed by the GSM operator Telia Mobile was recorded during one week in four defined areas (rural, small urban, suburban, and city area) in Sweden. The recording included output power for the 900 MHz and the 1800 MHz frequency band. RESULTS: In the rural area, the highest power level was used about 50% of the time, while the lowest power was used only 3% of the time. The corresponding numbers for the city area were approximately 25% and 22%. The output power distribution in all defined urban areas was similar. CONCLUSION: In rural areas where base stations are sparse, the output power level used by mobile phones are on average considerably higher than in more densely populated areas. A quantitative assessment of individual exposure to radiofrequency fields is important for epidemiological studies of possible health effects for many reasons. Degree of urbanisation may be an important parameter to consider in the assessment of radiofrequency exposure from mobile phone use.

**Lonn S, Ahlbom A, Hall P, Feychting M. Mobile phone use and the risk of acoustic neuroma. Epidemiology. 15(6):653-659, 2004.**

BACKGROUND:: Radiofrequency exposure from mobile phones is concentrated to the tissue closest to the handset, which includes the auditory nerve. If this type of exposure increases tumor risk, acoustic neuroma would be a potential concern. METHODS:: In this population-based case-control study we identified all cases age 20 to 69 years diagnosed with acoustic neuroma during 1999 to 2002 in certain parts of Sweden. Controls were randomly selected from the study base, stratified on age, sex, and residential area. Detailed information about mobile phone use and other environmental exposures was collected from 148 (93%) cases and 604 (72%) controls. RESULTS:: The overall odds ratio for acoustic neuroma associated with regular mobile phone use was 1.0 (95% confidence interval = 0.6-1.5). Ten years after the start of mobile phone use the estimates relative risk increased to 1.9 (0.9-4.1); when restricting to tumors on the same side of the head as the phone was normally used, the relative risk was 3.9 (1.6-9.5). CONCLUSIONS:: Our findings do not indicate an increased risk of acoustic neuroma related to short-term mobile phone use after a short latency period. However, our data suggest an increased risk of acoustic neuroma associated with mobile phone use of at least 10 years' duration.

**Lonn S, Ahlbom A, Hall P, Feychting M. Long-term mobile phone use and brain tumor risk. Am J Epidemiol. 161(6):526-535, 2005.**

Handheld mobile phones were introduced in Sweden during the late 1980s. The purpose of this population-based, case-control study was to test the hypothesis that long-term mobile phone use increases the risk of brain tumors. The authors identified all cases aged 20-69 years who were diagnosed with glioma or meningioma during 2000-2002 in certain parts of Sweden. Randomly selected controls were stratified on age, gender, and residential area. Detailed information about mobile phone use was collected from 371 (74%) glioma and 273 (85%) meningioma cases and 674 (71%) controls. For regular mobile phone use, the odds ratio was 0.8 (95% confidence interval: 0.6, 1.0) for glioma and 0.7 (95% confidence interval: 0.5, 0.9) for meningioma. Similar results were found for

more than 10 years' duration of mobile phone use. No risk increase was found for ipsilateral phone use for tumors located in the temporal and parietal lobes. Furthermore, the odds ratio did not increase, regardless of tumor histology, type of phone, and amount of use. This study includes a large number of long-term mobile phone users, and the authors conclude that the data do not support the hypothesis that mobile phone use is related to an increased risk of glioma or meningioma.

**Lonn S, Ahlbom A, Christensen HC, Johansen C, Schuz J, Edstrom S, Henriksson G, Lundgren J, Wennerberg J, Feychting M. Mobile phone use and risk of parotid gland tumor. Am J Epidemiol. 164(7):637-643, 2006.**

Handheld mobile phones were introduced in Denmark and Sweden during the late 1980s. This makes the Danish and Swedish populations suitable for a study aimed at testing the hypothesis that long-term mobile phone use increases the risk of parotid gland tumors. In this population-based case-control study, the authors identified all cases aged 20-69 years diagnosed with parotid gland tumor during 2000-2002 in Denmark and certain parts of Sweden. Controls were randomly selected from the study population base. Detailed information about mobile phone use was collected from 60 cases of malignant parotid gland tumors (85% response rate), 112 benign pleomorphic adenomas (88% response rate), and 681 controls (70% response rate). For regular mobile phone use, regardless of duration, the risk estimates for malignant and benign tumors were 0.7 (95% confidence interval: 0.4, 1.3) and 0.9 (95% confidence interval: 0.5, 1.5), respectively. Similar results were found for more than 10 years' duration of mobile phone use. The risk estimate did not increase, regardless of type of phone and amount of use. The authors conclude that the data do not support the hypothesis that mobile phone use is related to an increased risk of parotid gland tumors.

**Loos N, György T, Ghosn R, Brenet-Dufour V, Liabeuf S, Selmaoui B, Jean-Pierre L, Bach V, Diouf M, de Seze R. Is the effect of mobile phone radiofrequency waves on human skin perfusion non-thermal? Microcirculation. 2013 Apr 17. doi: 10.1111/micc.12062. [Epub ahead of print]**

OBJECTIVE: to establish whether skin micro blood flow can be modified by exposure to the radiofrequency waves emitted by a mobile phone when the latter is held against the jaw and ear. METHODS: Variations in skin micro blood flow and skin temperature in adult volunteers were simultaneously recorded with a thermostatic laser Doppler system during a 20-minute "radiofrequency" exposure session and a 20-minute "sham" session. The skin microvessels' vasodilatory reserve was assessed with a heat challenge at the end of the protocol. RESULTS: During the radiofrequency exposure session, skin micro blood flow increased (vs. baseline) more than during the sham exposure session. The sessions did not differ significant in terms of the skin temperature time-course response. The skin microvessels' vasodilatory ability was found to be greater during radiofrequency exposure than during sham exposure. CONCLUSIONS: Our results reveal the existence of a specific vasodilatory effect of mobile phone radiofrequency emission from mobile phones.

**López-Furelos A, Leiro-Vidal JM, Salas-Sánchez AÁ, Ares-Pena FJ, López-Martín ME. Evidence of cellular stress and caspase-3 resulting from a combined two-**

**frequency signal in the cerebrum and cerebellum of sprague-dawley rats. Oncotarget. 7(40):64674-64689, 2016.**

Multiple simultaneous exposures to electromagnetic signals induced adjustments in mammal nervous systems. In this study, we investigated the non-thermal SAR (Specific Absorption Rate) in the cerebral or cerebellar hemispheres of rats exposed in vivo to combined electromagnetic field (EMF) signals at 900 and 2450 MHz.Forty rats divided into four groups of 10 were individually exposed or not exposed to radiation in a GTEM chamber for one or two hours. After radiation, we used the Chemiluminescent Enzyme-Linked Immunosorbent Assay (ChELISA) technique to measure cellular stress levels, indicated by the presence of heat shock proteins (HSP) 90 and 70, as well as caspase-3-dependent pre-apoptotic activity in left and right cerebral and cerebellar hemispheres of Sprague Dawley rats.Twenty-four hours after exposure to combined or single radiation, significant differences were evident in HSP 90 and 70 but not in caspase 3 levels between the hemispheres of the cerebral cortex at high SAR levels. In the cerebellar hemispheres, groups exposed to a single radiofrequency (RF) and high SAR showed significant differences in HSP 90, 70 and caspase-3 levels compared to control animals. The absorbed energy and/or biological effects of combined signals were not additive, suggesting that multiple signals act on nervous tissue by a different mechanism.

**Lopez-Martin E, Relova-Quinteiro JL, Gallego-Gomez R, Peleteiro-Fernandez M, Jorge-Barreiro FJ, Ares-Pena FJ. GSM radiation triggers seizures and increases cerebral c-Fos positivity in rats pretreated with subconvulsive doses of picrotoxin. Neurosci Lett.398(1-2):139-144,2006.**

This study investigated the effects of mobile-phone-type radiation on the cerebral activity of seizure-prone animals. When rats transformed into an experimental model of seizure-proneness by acute subconvulsive doses of picrotoxin were exposed to 2h GSM-modulated 900MHz radiation at an intensity similar to that emitted by mobile phones, they suffered seizures and the levels of the neuronal activity marker c-Fos in neocortex, paleocortex, hippocampus and thalamus increased markedly. Non-irradiated picrotoxin-treated rats did not suffer seizures, and their cerebral c-Fos counts were significantly lower. Radiation caused no such differences in rats that had not been pretreated with picrotoxin. We conclude that GSM-type radiation can induce seizures in rats following their facilitation by subconvulsive doses of picrotoxin, and that research should be pursued into the possibility that this kind of radiation may similarly affect brain function in human subjects with epileptic disorders.

**López-Martín E, Bregains J, Relova-Quinteiro JL, Cadarso-Suárez C, Jorge-Barreiro FJ, Ares-Pena FJ.The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness. J Neurosci Res.87(6):1484-1499, 2009.**

The action of the pulse-modulated GSM radiofrequency of mobile phones has been suggested as a physical phenomenon that might have biological effects on the mammalian central nervous system. In the present study, GSM-exposed picrotoxin-pretreated rats showed differences in clinical and EEG signs, and in c-Fos expression in

the brain, with respect to picrotoxin-treated rats exposed to an equivalent dose of unmodulated radiation. Neither radiation treatment caused tissue heating, so thermal effects can be ruled out. The most marked effects of GSM radiation on c-Fos expression in picrotoxin-treated rats were observed in limbic structures, olfactory cortex areas and subcortical areas, the dentate gyrus, and the central lateral nucleus of the thalamic intralaminar nucleus group. Nonpicrotoxin-treated animals exposed to unmodulated radiation showed the highest levels of neuronal c-Fos expression in cortical areas. These results suggest a specific effect of the pulse modulation of GSM radiation on brain activity of a picrotoxin-induced seizure-proneness rat model and indicate that this mobile-phone-type radiation might induce regional changes in previous preexcitability conditions of neuronal activation.

**López-Martín E, Bregains J, Relova-Quinteiro JL, Cadarso-Suárez C, Jorge-Barreiro FJ, Ares-Pena FJ. The action of pulse-modulated GSM radiation increases regional changes in brain activity and c-Fos expression in cortical and subcortical areas in a rat model of picrotoxin-induced seizure proneness. J Neurosci Res. 87(6):1484-1499, 2009.**

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**Loscher W, Kas G, Extraordinary behavior disorders in cows in proximity to transmission stations. Der Praktische Tierarz 79:437-444, 1998.** (Article in German)

In addition to reduction of milk yield and increased health problems, behavioral abnormalities were observed over a period of two years in a herd of diary cows maintained in close proximity to a TV and cell phone transmitting antenna. Evaluation of possible factors which could explain the abnormalities in the live stock did not disclose any factors other than the high-frequency electromagnetic fields. An experiment in which a cow with abnormal behavior was brought to a stable 20 km away from the antenna resulted in a complete normalization of the cow within five days, whereas symptoms returned when the cow was brought back to the stable nearby the antenna. In view of the previous described effects of electromagnetic fields, it might be possible that the observed abnormalities in cows are related to electromagnetic field exposure. (power densities measured 0.02-7 mW/m2).

**Loughran SP, Wood AW, Barton JM, Croft RJ, Thompson B, Stough C. The effect of electromagnetic fields emitted by mobile phones on human sleep. Neuroreport. 16(17):1973-1976, 2005.**

Previous research has suggested that exposure to radiofrequency electromagnetic fields increases electroencephalogram spectral power in non-rapid eye movement sleep. Other sleep parameters have also been affected following exposure. We examined whether aspects of sleep architecture show sensitivity to electromagnetic fields emitted by digital mobile phone handsets. Fifty participants were exposed to electromagnetic fields for 30 min prior to sleep. Results showed a decrease in rapid eye movement sleep latency and increased electroencephalogram spectral power in the 11.5-12.25 Hz frequency range during the initial part of sleep following exposure. These results are evidence that mobile phone exposure prior to sleep may promote rapid eye movement sleep and modify the sleep electroencephalogram in the first non-rapid eye movement sleep period.

**Loughran SP, McKenzie RJ, Jackson ML, Howard ME, Croft RJ. Individual differences in the effects of mobile phone exposure on human sleep: rethinking the problem.Bioelectromagnetics. 33(1):86-93, 2012.**

Mobile phone exposure-related effects on the human electroencephalogram (EEG) have been shown during both waking and sleep states, albeit with slight differences in the frequency affected. This discrepancy, combined with studies that failed to find effects, has led many to conclude that no consistent effects exist. We hypothesised that these differences might partly be due to individual variability in response, and that mobile phone emissions may in fact have large but differential effects on human brain activity. Twenty volunteers from our previous study underwent an adaptation night followed by two experimental nights in which they were randomly exposed to two conditions (Active and Sham), followed by a full-night sleep episode. The EEG spectral power was increased in the sleep spindle frequency range in the first 30 min of non-rapid eye movement (non-REM) sleep following Active exposure. This increase was more prominent in the participants that showed an increase in the original study. These results confirm previous findings of mobile phone-like emissions affecting the EEG during non-REM sleep. Importantly, this low-level effect was also shown to be sensitive to individual variability. Furthermore, this indicates that previous negative results are not strong evidence for a lack of an effect and, given the far-reaching implications of mobile phone research, we may need to rethink the interpretation of results and the manner in which research is conducted in this field.

**Loughran SP, Benz DC, Schmid MR, Murbach M, Kuster N, Achermann P. No increased sensitivity in brain activity of adolescents exposed to mobile phone-like emissions. Clin Neurophysiol. 2013 Feb 18. pii: S1388-2457(13)00051-5. doi: 10.1016/j.clinph.2013.01.010. [Epub ahead of print]**

OBJECTIVE: To examine the potential sensitivity of adolescents to radiofrequency electromagnetic field (RF EMF) exposures, such as those emitted by mobile phones. METHODS: In a double-blind, randomized, crossover design, 22 adolescents aged 11-13years (12 males) underwent three experimental sessions in which they were exposed

to mobile phone-like RF EMF signals at two different intensities, and a sham session. During exposure cognitive tasks were performed and waking EEG was recorded at three time-points subsequent to exposure (0, 30 and 60min). RESULTS: No clear significant effects of RF EMF exposure were found on the waking EEG or cognitive performance. CONCLUSIONS: Overall, the current study was unable to demonstrate exposure-related effects previously observed on the waking EEG in adults, and also provides further support for a lack of an influence of mobile phone-like exposure on cognitive performance. SIGNIFICANCE: Adolescents do not appear to be more sensitive than adults to mobile phone RF EMF emissions.

**Lourencini da Silva R , Albano F, Lopes dos Santos LR , Tavares AD, Felzenszwalb I, The effect of electromagnetic field exposure on the formation of DNA lesions. Redox Rep 5(5):299-301, 2000.**

In an attempt to determine whether electromagnetic field (EMF) exposure might lead to DNA damage, we exposed SnCl2-treated pBR322 plasmids to EMF and analysed the resulting conformational changes using agarose gel electrophoresis. An EMF-dependent potentiation of DNA scission (i.e. the appearance of relaxed plasmids) was observed. In confirmation of this, plasmids pre-exposed to EMF also were less capable of transforming Escherichia coli. The results indicate that EMF, in the presence of a transition metal, is capable of causing DNA damage. These observations support the idea that EMF, probably through secondary generation of reactive oxygen species, can be clastogenic and provide a possible explanation for the observed correlation between EMF exposure and the frequency of certain types of cancers in humans.

**Lowden A, Akerstedt T, Ingre M, Wiholm C, Hillert L, Kuster N, Nilsson JP, Arnetz B. Sleep after mobile phone exposure in subjects with mobile phone-related symptoms. Bioelectromagnetics. 32(1):4-14, 2011.**

Several studies show increases in activity for certain frequency bands (10-14 Hz) and visually scored parameters during sleep after exposure to radiofrequency electromagnetic fields. A shortened REM latency has also been reported. We investigated the effects of a double-blind radiofrequency exposure (884 MHz, GSM signaling standard including non-DTX and DTX mode, time-averaged 10 g psSAR of 1.4 W/kg) on self-evaluated sleepiness and objective EEG measures during sleep. Forty-eight subjects (mean age 28 years) underwent 3 h of controlled exposure (7:30-10:30 PM; active or sham) prior to sleep, followed by a full-night polysomnographic recording in a sleep laboratory. The results demonstrated that following exposure, time in Stages 3 and 4 sleep (SWS, slow-wave sleep) decreased by 9.5 min (12%) out of a total of 78.6 min, and time in Stage 2 sleep increased by 8.3 min (4%) out of a total of 196.3 min compared to sham. The latency to Stage 3 sleep was also prolonged by 4.8 min after exposure. Power density analysis indicated an enhanced activation in the frequency ranges 0.5-1.5 and 5.75-10.5 Hz during the first 30 min of Stage 2 sleep, with 7.5-11.75 Hz being elevated within the first hour of Stage 2 sleep, and bands 4.75-8.25 Hz elevated during the second hour of Stage 2 sleep. No pronounced power changes were observed in SWS or for the third hour of scored Stage 2 sleep. No differences were found between controls and subjects with prior complaints of mobile phone-related symptoms. The results confirm previous findings

that RF exposure increased the EEG alpha range in the sleep EEG, and indicated moderate impairment of SWS. Furthermore, reported differences in sensitivity to mobile phone use were not reflected in sleep parameters.

**Lu L, Xu H, Wang X, Guo G.Increased nitric oxide synthase activity is essential for electromagnetic-pulse-induced blood-retinal barrier breakdown in vivo.Brain Res. 1264:104-10, 2009.**

**PURPOSE:** To examine whether electromagnetic pulses (EMPs) affected the permeability of the blood-retinal barrier (BRB), gene expression of occludin and activity of nitric oxide synthase (NOS).**METHODS:** Sprague-Dawley (SD) rats were used and randomized into EMP and control groups. Retinas were removed immediately, and 2 h or 24 h after EMP radiation. BRB permeability was analyzed by transmission electron microscopy and Evans Blue staining. Retinal NOS activity and concentrations of nitrite and nitrate were measured. Occludin mRNA and protein levels were detected by RT-PCR and Western blotting.**RESULTS:** Exposure of SD rats to EMP resulted in increased BRB permeability, with the greatest decrease in occludin at 24 h. Moreover, this permeability defect was also correlated with significant increases in the formation of NO and induction of NOS activity in SD rats. Furthermore, we found that treatment with NOS inhibitor N-nitro-L-arginine methyl ester (L-NAME) blocked BRB breakdown and prevented the increase in NO formation and induction of NOS activity, as well as the decrease in occluding expression.**CONCLUSION:** Taken together, these results support the view that NOS-dependent NO production is an important factor that contributes to EMP-induced BRB dysfunction, and suggests that NOS induction may play an important role in BRB breakdown.

**Lu ST, Mathur SP, Akyel Y, Lee JC, Ultrawide-band electromagnetic pulses induced hypotension in rats. Physiol Behav 65(4-5):753-761, 1999; Corrected and republished in Physiol Behav;67(3):753-761, 1999.**

The ultrawide-band (UWB) electromagnetic pulses are used as a new modality in radar technology. Biological effects of extremely high peak E-field, fast rise time, ultrashort pulse width, and ultrawide band have not been investigated heretofore due to the lack of animal exposure facilities. A new biological effects database is needed to establish personnel protection guidelines for these new type of radiofrequency radiation. Functional indices of the cardiovascular system (heart rate, systolic, mean, and diastolic pressures) were selected to represent biological end points that may be susceptible to the UWB radiation. A noninvasive tail-cuff photoelectric sensor sphygmomanometer was used. Male Wistar-Kyoto rats were subjected to sham exposure, 0.5-kHz (93 kV/m, 180 ps rise time, 1.00 ns pulse width, whole-body averaged specific absorption rate, SAR = 70 mW/kg) or a 1-kHz (85 kV/m, 200 ps rise time, 1.03 ns pulse width, SAR = 121 mW/kg) UWB fields in a tapered parallel plate GTEM cell for 6 min. Cardiovascular functions were evaluated from 45 min to 4 weeks after exposures. Significant decrease in arterial blood pressures (hypotension) was found. In contrast, heart rate was not altered by these exposures. The UWB radiation-induced hypotension was a robust, consistent, and persistent effect.

**Lu ST, Mathur SP, Stuck B, Zwick H, D'Andrea JA, Ziriax JM, Merritt JH, Lutty G, McLeod DS, Johnson M, Effects of high peak power microwaves on the retina of the rhesus monkey. Bioelectromagnetics 21(6):439-454, 2000.**

We studied the retinal effects of 1.25 GHz high peak power microwaves in Rhesus monkeys. Preexposure fundus photographs, retinal angiograms, and electroretinograms (ERG) were obtained to screen for normal ocular structure and function and, after exposure, as endpoints of the study. Histopathology of the retina was an additional endpoint. Seventeen monkeys were randomly assigned to receive sham exposure or pulsed microwave exposures. Microwaves were delivered anteriorly to the face at 0, 4.3, 8.4, or 20.2 W/kg spatially and temporally averaged retinal specific absorption rates (R-SAR). The pulse characteristics were 1.04 MW (approximately 1.30 MW/kg temporal peak R-SAR), 5.59 &mgr;s pulse length at 0, 0.59, 1. 18, and 2.79 Hz pulse repetition rates. Exposure was 4 h per day and 3 days per week for 3 weeks, for a total of nine exposures. The preexposure and postexposure fundus pictures and angiograms were all within normal limits. The response of cone photoreceptors to light flash was enhanced in monkeys exposed at 8.4 or 20.2 W/kg R-SAR, but not in monkeys exposed at 4.3 W/kg R-SAR. Scotopic (rod) response, maximum (combined cone and rod) response, and Naka-Rushton R(max) and log K of scotopic b-waves were all within normal range. Retinal histopathology revealed the presence of enhanced glycogen storage in photoreceptors among sham (2/5), 8.4 W/kg (3/3), and 20.2 W/kg (2/5) exposed monkeys, while enhanced glycogen storage was not observed in the 4.3 W/kg (0/4) exposed group. Supranormal cone photoreceptor b-wave was R-SAR dependent and may be an early indicator of mild injury. However no evidence of degenerative changes and ERG depression was seen. We concluded that retinal injury is very unlikely at 4 W/kg. Functional changes that occur at higher R-SAR are probably reversible since we saw no evidence of histopathologic correlation with ERG changes.

**Lu ST, D'Andrea J, Chalfin S, Crane C, Marchello D, Garay R, Hatcher D, Ziriax J. Absence of corneal endothelium injury in non-human primates treated with and without ophthalmologic drugs and exposed to 2.8 GHz pulsed microwaves. Bioelectromagnetics.31(4):324-333,2010.**

Microwave-induced corneal endothelial damage was reported to have a low threshold (2.6 W/kg), and vasoactive ophthalmologic medications lowered the threshold by a factor of 10-0.26 W/kg. In an attempt to confirm these observations, four adult male Rhesus monkeys (Macaca mulatta) under propofol anesthesia were exposed to pulsed microwaves in the far field of a 2.8 GHz signal (1.43 +/- 0.06 micros pulse width, 34 Hz pulse repetition frequency, 13.0 mW/cm(2) spatial and temporal average, and 464 W/cm(2) spatial and temporal peak (291 W/cm(2) square wave equivalent) power densities). Corneal-specific absorption rate was 5.07 W/kg (0.39 W/kg/mW/cm(2)). The exposure resulted in a 1.0-1.2 degrees C increase in eyelid temperature. In Experiment I, exposures were 4 h/day, 3 days/week for 3 weeks (nine exposures and 36 h total). In Experiment II, these subjects were pretreated with 0.5% Timolol maleate and 0.005% Xalatan(R) followed by 3 or 7 4-h pulsed microwave exposures. Under ketamine-xylazine anesthesia, a non-contact specular microscope was used to obtain corneal endothelium images, corneal endothelial cell density, and

pachymetry at the center and four peripheral areas of the cornea. Ophthalmologic measurements were done before and 7, 30, 90, and 180 days after exposures. Pulsed microwave exposure did not cause alterations in corneal endothelial cell density and corneal thickness with or without ophthalmologic drugs. Therefore, previously reported changes in the cornea exposed to pulsed microwaves were not confirmed at exposure levels that are more than an order of magnitude higher.

**Lu X, Oda M, Ohba T, Mitsubuchi H, Masuda S, Katoh T. Association of excessive mobile phone use during pregnancy with birth weight: an adjunct study in Kumamoto of Japan Environment and Children's Study. Environ Health Prev Med. 22(1):52, 2017.**

BACKGROUND: Low birth weight has been shown to be closely associated with neonatal mortality and morbidity, inhibited growth, poor cognitive development, and chronic diseases later in life. Some studies have also shown that excessive mobile phone use in the postnatal period may lead to behavioral complications in the children during their growing years; however, the relationship between mobile phone use during pregnancy and neonatal birth weight is not clear. The aim of the present study was to determine the associations of excessive mobile phone use with neonatal birth weight and infant health status. METHODS: A sample of 461 mother and child pairs participated in a survey on maternal characteristics, infant characteristics, and maternal mobile phone usage information during pregnancy. RESULTS: Our results showed that pregnant women tend to excessively use mobile phones in Japan. The mean infant birth weight was lower in the excessive use group than in the ordinary use group, and the frequency of infant emergency transport was significantly higher in the excessive use group than in the ordinary use group. CONCLUSIONS: Excessive mobile phone use during pregnancy may be a risk factor for lower birth weight and a high rate of infant emergency transport.

**Lu Y, Xu S, He M, Chen C, Zhang L, Liu C, Chu F, Yu Z, Zhou Z, Zhong M. Glucose administration attenuates spatial memory deficits induced by chronic low-power-density microwave exposure. Physiol Behav. 106(5):631-637, 2012.**

Extensive evidence indicates that glucose administration attenuates memory deficits in rodents and humans, and cognitive impairment has been associated with reduced glucose metabolism and uptake in certain brain regions including the hippocampus. In the present study, we investigated whether glucose treatment attenuated memory deficits caused by chronic low-power-density microwave (MW) exposure, and the effect of MW exposure on hippocampal glucose uptake. We exposed Wistar rats to 2.45 GHz pulsed MW irradiation at a power density of 1 mW/cm(2) for 3 h/day, for up to 30 days. MW exposure induced spatial learning and memory impairments in rats. Hippocampal glucose uptake was also reduced by MW exposure in the absence or presence of insulin, but the levels of blood glucose and insulin were not affected. However, these spatial memory deficits were reversed by systemic glucose treatment. Our results indicate that glucose administration attenuates the spatial memory deficits induced by chronic low-power-density MW exposure, and reduced

hippocampal glucose uptake may be associated with cognitive impairment caused by MW exposure.

**Lu Y, Yu J, Ren Y, Dielectric properties of human red blood cells in suspension at radio frequencies. Bioelectromagnetics 15(6):589-591, 1994.**

Dielectric properties of human red blood cells (RBCs) in suspension (hematocrit 50%) from 243 healthy persons (120 males, 123 females) were measured at 25 degrees C in a frequency range of 1-500 MHz, with a coaxial transmission line reflection method (one-side measurement). The measuring system, controlled by an IBM-PC computer, was composed of a network analyzer (HP4195A), an impedance test adapter (HP41951-61001), a coaxial line sensor, and a temperature-controlling set. The data measured revealed a statistically significant age dependence, with a critical age of about 49 years, above which permittivity and conductivity of human RBCs in suspension decreased significantly.

**Lu Y, He M, Zhang Y, Xu S, Zhang L, He Y, Chen C, Liu C, Pi H, Yu Z, Zhou Z. Differential Pro-Inflammatory Responses of Astrocytes and Microglia Involve STAT3 Activation in Response to 1800 MHz Radiofrequency Fields. PLoS One. 2014 Oct 2;9(9):e108318. doi: 10.1371/journal.pone.0108318.**

Microglia and astrocytes play important role in maintaining the homeostasis of central nervous system (CNS). Several CNS impacts have been postulated to be associated with radiofrequency (RF) electromagnetic fields exposure. Given the important role of inflammation in neural physiopathologic processes, we investigated the pro-inflammatory responses of microglia and astrocytes and the involved mechanism in response to RF fields. Microglial N9 and astroglial C8-D1A cells were exposed to 1800 MHz RF for different time with or without pretreatment with STAT3 inhibitor. Microglia and astrocytes were activated by RF exposure indicated by up-regulated CD11b and glial fibrillary acidic protein (GFAP). However, RF exposure induced differential pro-inflammatory responses in astrocytes and microglia, characterized by different expression and release profiles of IL-1β, TNF-α, IL-6, PGE2, nitric oxide (NO), inducible nitric oxide synthase (iNOS) and cyclooxygenase 2 (COX2). Moreover, the RF exposure activated STAT3 in microglia but not in astrocytes. Furthermore, the STAT3 inhibitor Stattic ameliorated the RF-induced release of pro-inflammatory cytokines in microglia but not in astrocytes. Our results demonstrated that RF exposure differentially induced pro-inflammatory responses in microglia and astrocytes, which involved differential activation of STAT3 in microglia and astrocytes. Our data provide novel insights into the potential mechanisms of the reported CNS impacts associated with mobile phone use and present STAT3 as a promising target to protect humans against increasing RF exposure.

**Lu YS, Huang BT, Huang YX.Reactive oxygen species formation and apoptosis in human peripheral blood mononuclear cell induced by 900MHz mobile phone radiation.Oxid Med Cell Longev. 2012:740280, 2012.**

We demonstrate that reactive oxygen species (ROS) plays an important role in the

process of apoptosis in human peripheral blood mononuclear cell (PBMC) which is induced by the radiation of 900MHz radiofrequency electromagnetic field (RFEMF) at a specific absorption rate (SAR) of ~0.4 W/kg when the exposure lasts longer than two hours. The apoptosis is induced through the mitochondrial pathway and mediated by activating ROS and caspase-3, and decreasing the mitochondrial potential. The activation of ROS is triggered by the conformation disturbance of lipids, protein, and DNA induced by the exposure of GSM RFEMF. Although human PBMC was found to have a self-protection mechanism of releasing carotenoid in response to oxidative stress to lessen the further increase of ROS, the imbalance between the antioxidant defenses and ROS formation still results in an increase of cell death with the exposure time and can cause about 37% human PBMC death in eight hours.

**Lukac N, Massanyi P, Roychoudhury S, Capcarova M, Tvrda E, Knazicka Z, Kolesarova A, Danko J. In vitro effects of radiofrequency electromagnetic waves on bovine spermatozoa motility. J Environ Sci Health A Tox Hazard Subst Environ Eng. 46(12):1417-1423, 2011.**

In this study the effects of 1800 MHz GSM-like radiofrequency electromagnetic waves (RF-EMW) exposure on bovine semen was monitored. The experimental samples were analyzed in vitro in four time periods (0, 30, 120 and 420 min) and compared with unexposed samples (control). Spermatozoa motility was determined by computer assisted semen analyzer (CASA). Evaluation of the percentage of motile spermatozoa showed significant ($P < 0.001$) decrease in experimental groups after 120 and 420 min of culture when exposed to microwaves, in comparison to control. Similar spermatozoa motility inhibition was detected for the percentage of progressively motile spermatozoa, too. Average path distance decreased significantly ($p < 0.001$) in experimental groups after 30 and 420 min of culture. Path velocity increased in the experimental groups exposed to RF-EMW after 30 minutes of culture, but subsequently decreased after 420 min of culture, in comparison to control. This indicates a possible initial stimulation and subsequent velocity inhibition of bovine spermatozoa under RF-EMW exposure. Changes in spermatozoa motility were also detected for some fine parameters, too. A significant decrease ($P < 0.001$) was noted for amplitude of lateral head displacement in the experimental group after 420 minutes of culture. Detailed in vitro motility analysis of bovine spermatozoa exposed to microwave radiation suggested that the parameters of path and velocity at the beginning of the culture significantly increase, but after longer culture (420 minutes) a significant decrease occur in the experimental group as compared to control. In general, results of this experiment indicate a negative time-dependent effect of 1800 MHz RF-EMW radiation on bovine spermatozoa motility.

**Luo Q, Jiang Y, Jin M, Xu J, Huang HF. Proteomic Analysis on the Alteration of Protein Expression in the Early-Stage Placental Villous Tissue of Electromagnetic Fields Associated With Cell Phone Exposure. Reprod Sci. 2013 Feb 18. [Epub ahead of print]**

Background:To explore the possible adverse effects and search for cell phone electromagnetic field (EMF)-responsive proteins in human early reproduction, a proteomics approach was employed to investigate the changes in protein expression profile induced by cell phone EMF in human chorionic tissues of early pregnancy in vivo.Methods:Volunteer women about 50 days pregnant were exposed to EMF at the average absorption rate of 1.6 to 8.8 W/kg for 1 hour with the irradiation device placed 10 cm away from the umbilicus at the midline of the abdomen. The changes in protein profile were examined using 2-dimensional electrophoresis (2-DE).Results:Up to 15 spots have yielded significant change at least 2- to 2.5-folds up or down compared to sham-exposed group. Twelve proteins were identified- procollagen-proline, eukaryotic translation elongation factor 1 delta, chain D crystal structure of human vitamin D-binding protein, thioredoxin-like 3, capping protein, isocitrate dehydrogenase 3 alpha, calumenin, Catechol-O-methyltransferase protein, proteinase inhibitor 6 (PI-6; SerpinB6) protein, 3,2-trans-enoyl-CoA isomerase protein, chain B human erythrocyte 2,3-bisphosphoglycerate mutase, and nucleoprotein.Conclusion:Cell phone EMF might alter the protein profile of chorionic tissue of early pregnancy, during the most sensitive stage of the embryos. The exposure to EMF may cause adverse effects on cell proliferation and development of nervous system in early embryos. Furthermore, 2-DE coupled with mass spectrometry is a promising approach to elucidate the effects and search for new biomarkers for environmental toxic effects.

**Luo YP, Ma HR, Chen JW, Li JJ, Li CX. [Effect of American Ginseng Capsule on the liver oxidative injury and the Nrf2 protein expression in rats exposed by electromagnetic radiation of frequency of cell phone.] [Article in Chinese]. Zhongguo Zhong Xi Yi Jie He Za Zhi. 34(5):575-580, 2014. (In Chinese)**

OBJECTIVE: To observe the effect of American Ginseng Capsule (AGC) on the liver oxidative injury and the Nrf2 protein expression in the liver tissue of rats exposed by 900 MHz cell phone electromagnetic radiation. METHODS: Totally 40 male SD rats were randomly divided into the normal control group, the model group, the Shuifei Jibin Capsule (SJC) group, and the AGC group,10 in each group. Rats in the normal control group were not irradiated. Rats in the rest three groups were exposed by imitated 900 MHz cellular phone for 4 h in 12 consecutive days. Meanwhile, rats in the SJC group and the AGC group were intragastrically administrated with suspension of SJC and AGC (1 mL/200 g body weight) respectively. Normal saline was administered to rats in the normal control group and the model group. The histolomorphological changes of the liver tissue were observed by HE staining. Contents of malonic dialdehyde (MDA), superoxide dismutase (SOD), glutathione (GSH), and glutathione peroxidase (GSH-PX)were detected by colorimetry. The Nrf2 protein expression of hepatocytes was detected by immunohistochemical assay and Western blot. RESULTS: Compared with the normal control group, hepatocyte nucleus was atrophied or partially disappeared, the contents of liver MDA and Nrf2 protein obviously increased (P <0. 05, P <0. 01); contents of liver SOD and GSH decreased (P <0. 05) in the model group. Compared with the model group, karyopyknosis was obviously attenuated and approached to the normal level in the SJC group and the AGC group. The contents of liver MDA and Nrf2 protein expression decreased (P <0. 05), and the contents of liver SOD, GSH, and GSH-PX obviously

increased (P < 0.05) in the SJC group. The contents of liver MDA and the Nrf2 protein expression decreased (P < 0.05), and contents of SOD and GSH obviously increased in the AGC group (P <0.01, P <0.05). CONCLUSIONS: The electromagnetic radiation induced by 900 MHz cell phone could affect the expression of Nrf2 protein, induce oxidative injury, and induce abnormal morphology of liver cells. SJC and AGC could promote the morphological recovery of the liver cells. Its mechanism might be related to affecting the expression of Nrf2 protein and attenuating oxidative damage of liver cells.

**Luria R, Eliyahu I, Hareuveny R, Margaliot M, Meiran N. Cognitive effects of radiation emitted by cellular phones: the influence of exposure side and time.Bioelectromagnetics. 30(3):198-204, 2009.**

This study examined the time dependence effects of exposure to radiofrequency radiation (RFR) emitted by standard GSM cellular phones on the cognitive functions of humans. A total of 48 healthy right-handed male subjects performed a spatial working memory task (that required either a left-hand or a right-hand response) while being exposed to one of two GSM phones placed at both sides of the head. The subjects were randomly divided into three groups. Each group was exposed to one of three exposure conditions: left-side of the head, right-side, or sham-exposure. The experiment consisted of 12 blocks of trials. Response times (RTs) and accuracy of the responses were recorded. It was found that the average RT of the right-hand responses under left-side exposure condition was significantly longer than those of the right-side and sham-exposure groups averaged together during the first two time blocks.These results confirmed the existence of an effect of exposure on RT, as well as the fact that exposure duration (together with the responding hand and the side of exposure) may play an important role in producing detectable RFR effects on performance. Differences in these parameters might be the reason for the failure of certain studies to detect or replicate RFR effects.

**Lushnikov KV, Gapeev AB, Sadovnikov VB, Cheremis NK. [Effect of extremely high frequency electromagnetic radiation of low intensity on parameters of humoral immunity in healthy mice.] Biofizika 46(4):753-760, 2001.** [Article in Russian]

The modification of indices of the humoral immune response to thymus-dependent antigen (sheep erythrocytes) after a whole-body exposure of healthy mice to low-intensity extremely-high-frequency electromagnetic radiation was studied. Male NMRI mice were exposed in the far-field zone of horn antenna at a frequency of 42.0 GHz and energy flux density of 0.15 mW/cm2 under different regimes: once for 20 min, for 20 min daily during 5 and 20 successive days before immunization, and for 20 min daily during 5 successive days after immunization throughout the development of the humoral immune response. The intensity of the humoral immune response was estimated on day 5 after immunization by the number of antibody-forming cells of the spleen and antibody titers. Changes in cellularity of the spleen, thymus and red bone marrow were also assessed. The indices of humoral immunity and cellularity of lymphoid organs changed insignificantly after acute exposure and series of 5 exposures before and after immunization of the animals. However, after repeated exposures for 20 days before immunization, a statistically significant reduction of thymic cellularity by 17.5% (p < 0.05)

and a decrease in cellularity of the spleen by 14.5% ($p < 0.05$) were revealed. The results show that low-intensity extremely-high-frequency electromagnetic radiation with the frequency and energy flux density used does not influence the humoral immune response intensity in healthy mice but influences immunogenesis under multiple repeated exposures.

**Lustenberger C, Murbach M, Dürr R, Schmid MR, Kuster N, Achermann P, Huber R. Stimulation of the brain with radiofrequency electromagnetic field pulses affects sleep-dependent performance improvement. Brain Stimul. 6(5):805-811, 2013.**

BACKGROUND: Sleep-dependent performance improvements seem to be closely related to sleep spindles (12-15 Hz) and sleep slow-wave activity (SWA, 0.75-4.5 Hz). Pulse-modulated radiofrequency electromagnetic fields (RF EMF, carrier frequency 900 MHz) are capable to modulate these electroencephalographic (EEG) characteristics of sleep. OBJECTIVE: The aim of our study was to explore possible mechanisms how RF EMF affect cortical activity during sleep and to test whether such effects on cortical activity during sleep interact with sleep-dependent performance changes. METHODS: Sixteen male subjects underwent 2 experimental nights, one of them with all-night 0.25-0.8 Hz pulsed RF EMF exposure. All-night EEG was recorded. To investigate RF EMF induced changes in overnight performance improvement, subjects were trained for both nights on a motor task in the evening and the morning. RESULTS: We obtained good sleep quality in all subjects under both conditions (mean sleep efficiency > 90%). After pulsed RF EMF we found increased SWA during exposure to pulse-modulated RF EMF compared to sham exposure ($P < 0.05$) toward the end of the sleep period. Spindle activity was not affected. Moreover, subjects showed an increased RF EMF burst-related response in the SWA range, indicated by an increase in event-related EEG spectral power and phase changes in the SWA range. Notably, during exposure, sleep-dependent performance improvement in the motor sequence task was reduced compared to the sham condition (-20.1%, $P = 0.03$). CONCLUSION: The changes in the time course of SWA during the exposure night may reflect an interaction of RF EMF with the renormalization of cortical excitability during sleep, with a negative impact on sleep-dependent performance improvement.

**Lustenberger, C., Murbach, M., Tüshaus, L., Wehrle, F., Kuster, N., Achermann, P. and Huber, R. (2015), Inter-individual and intra-individual variation of the effects of pulsed RF EMF exposure on the human sleep EEG. Bioelectromagnetics. doi: 10.1002/bem.21893. First published online Feb 17, 2015.**

Pulse-modulated radiofrequency electromagnetic fields (RF EMF) can alter brain activity during sleep; increases of electroencephalographic (EEG) power in the sleep spindle (13.75–15.25 Hz) and delta-theta (1.25–9 Hz) frequency range have been reported. These field effects show striking inter-individual differences. However, it is still unknown whether individual subjects react in a similar way when repeatedly exposed. Thus, our study aimed to investigate inter-individual variation and intra-individual stability of field effects. To do so, we exposed 20 young male subjects twice for 30 min prior to sleep to the same amplitude modulated 900 MHz (2 Hz pulse, 20 Hz Gaussian low-pass filter and a ratio of peak-to-average of 4) RF EMF (spatial peak absorption of 2 W/kg averaged

over 10 g) 2 weeks apart. The topographical analysis of EEG power during all-night non-rapid eye movement sleep revealed: (1) exposure-related increases in delta-theta frequency range in several fronto-central electrodes; and (2) no differences in spindle frequency range. We did not observe reproducible within-subject RF EMF effects on sleep spindle and delta-theta activity in the sleep EEG and it remains unclear whether a biological trait of how the subjects' brains react to RF EMF exists.

**Luukkonen J, Hakulinen P, Mäki-Paakkanen J, Juutilainen J, Naarala J. Enhancement of chemically induced reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells by 872MHz radiofrequency radiation. Mutat Res. 662(1-2):54-58, 2009.**

The objective of the study was to investigate effects of 872MHz radiofrequency (RF) radiation on intracellular reactive oxygen species (ROS) production and DNA damage at a relatively high SAR value (5W/kg). The experiments also involved combined exposure to RF radiation and menadione, a chemical inducing intracellular ROS production and DNA damage. The production of ROS was measured using the fluorescent probe dichlorofluorescein and DNA damage was evaluated by the Comet assay. Human SH-SY5Y neuroblastoma cells were exposed to RF radiation for 1h with or without menadione. Control cultures were sham exposed. Both continuous waves (CW) and a pulsed signal similar to that used in global system for mobile communications (GSM) mobile phones were used. Exposure to the CW RF radiation increased DNA breakage ($p<0.01$) in comparison to the cells exposed only to menadione. Comparison of the same groups also showed that ROS level was higher in cells exposed to CW RF radiation at 30 and 60min after the end of exposure ($p<0.05$ and $p<0.01$, respectively). No effects of the GSM signal were seen on either ROS production or DNA damage. The results of the present study suggest that 872MHz CW RF radiation at 5W/kg might enhance chemically induced ROS production and thus cause secondary DNA damage. However, there is no known mechanism that would explain such effects from CW RF radiation but not from GSM modulated RF radiation at identical SAR.

**Luukkonen J, Juutilainen J, Naarala J. Combined effects of 872 MHz radiofrequency radiation and ferrous chloride on reactive oxygen species production and DNA damage in human SH-SY5Y neuroblastoma cells. Bioelectromagnetics. 31(6):417-424, 2010.**

The aim of the present study was to investigate possible cooperative effects of radiofrequency (RF) radiation and ferrous chloride (FeCl(2)) on reactive oxygen species (ROS) production and DNA damage. In order to test intracellular ROS production as a possible underlying mechanism of DNA damage, we applied the fluorescent probe DCFH-DA. Integrity of DNA was quantified by alkaline comet assay. The exposures to 872 MHz RF radiation were conducted at a specific absorption rate (SAR) of 5 W/kg using continuous waves (CW) or a modulated signal similar to that used in Global System for Mobile Communications (GSM) phones. Four groups were included: (1) Sham exposure (control), (2) RF radiation, (3) Chemical treatment, (4) Chemical treatment, and RF radiation. In the ROS production experiments, human neuroblastoma (SH-SY5Y) cells were exposed to RF radiation and 10 microg/ml FeCl(2) for 1 h. In the comet assay experiments, the exposure time

was 3 h and an additional chemical (0.015% diethyl maleate) was used to make DNA damage level observable. The chemical treatments resulted in statistically significant responses, but no effects from either CW or modulated RF radiation were observed on ROS production, DNA damage or cell viability.

**Lv B, Chen Z, Wu T, Shao Q, Yan D, Ma L, Lu K, Xie Y. The alteration of spontaneous low frequency oscillations caused by acute electromagnetic fields exposure. Clin Neurophysiol. 2013 Sep 4. pii: S1388-2457(13)00976-0. doi: 10.1016/j.clinph.2013.07.018. [Epub ahead of print]**

OBJECTIVE: The motivation of this study is to evaluate the possible alteration of regional resting state brain activity induced by the acute radiofrequency electromagnetic field (RF-EMF) exposure (30min) of Long Term Evolution (LTE) signal. METHODS: We designed a controllable near-field LTE RF-EMF exposure environment. Eighteen subjects participated in a double-blind, crossover, randomized and counterbalanced experiment including two sessions (real and sham exposure). The radiation source was close to the right ear. Then the resting state fMRI signals of human brain were collected before and after the exposure in both sessions. We measured the amplitude of low frequency fluctuation (ALFF) and fractional ALFF (fALFF) to characterize the spontaneous brain activity. RESULTS: We found the decreased ALFF value around in left superior temporal gyrus, left middle temporal gyrus, right superior temporal gyrus, right medial frontal gyrus and right paracentral lobule after the real exposure. And the decreased fALFF value was also detected in right medial frontal gyrus and right paracentral lobule. CONCLUSIONS: The study provided the evidences that 30min LTE RF-EMF exposure modulated the spontaneous low frequency fluctuations in some brain regions. SIGNIFICANCE: With resting state fMRI, we found the alteration of spontaneous low frequency fluctuations induced by the acute LTE RF-EMF exposure.

**Lv B, Su C, Yang L, Xie Y, Wu T. Whole brain EEG synchronization likelihood modulated by long term evolution electromagnetic fields exposure. Conf Proc IEEE Eng Med Biol Soc. 2014:986-989, 2014.**

In this paper, we aimed to investigate the possible interactions between human brain and radiofrequency electromagnetic fields (EMF) with electroencephalogram (EEG) technique. Unlike the previous studies which mainly focused on EMF effect on local brain activities, we attempted to evaluate whether the EMF emitted from Long Term Evolution (LTE) devices can modulate the functional connectivity of brain electrical activities. Ten subjects were recruited to participate in a crossover, double-blind exposure experiment which included two sessions (real and sham exposure). In each session, LTE EMF exposure (power on or off) lasted for 30 min and the EEG signals were collected with 32 channels throughout the experiment. Then we applied the synchronization likelihood method to quantify the neural synchronization over the whole brain in different frequency bands and in different EEG record periods. Our results illustrated that the short-term LTE EMF exposure would modulate the synchronization patterns of EEG activation across the whole brain.

**Ma HR, Ma ZH, Wang GY, Song CM, Ma XL, Cao XH, Zhang GH. Impacts of exposure to 900 MHz mobile phone radiation on liver function in rats. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 31(6):567-571, 2015.**

OBJECTIVE: To study the impacts of exposure to electromagnetic radiation (EMR) on liver function in rats. METHODS: Twenty adult male Sprague-Dawley rats were randomly divided into normal group and radiated group. The rats in normal group were not radiated, those in radiated group were exposed to EMR 4 h/ d for 18 consecutive days. Rats were sacrificed immediately after the end of the experiment. The serum levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST), and those of malondialdehyde (MDA) and glutathione (GSH) in liver tissue were evaluated by colorimetric method. The liver histopathological changes were observed by hematoxylin and eosin staining and the protein expression of bax and bcl- 2 in liver tissue were detected by immunohistochemical method. Terminal-deoxynucleotidyl transferase mediated nick and labelling (TUNEL) method was used for analysis of apoptosis in liver. RESULTS: Compared with the normal rats, the serum levels of ALT and AST in the radiated group had no obvious changes ($P>0.05$), while the contents of MDA increased ($P < 0.01$) and those of GSH decreased ($P < 0.01$) in liver tissues. The histopathology examination showed diffuse hepatocyte swelling and vacuolation, small pieces and focal necrosis. The immunohistochemical results displayed that the expression of the bax protein was higher and that of bcl-2 protein was lower in radiated group. The hepatocyte apoptosis rates in radiated group was higher than that in normal group (all $P < 0.01$). CONCLUSION: The exposure to 900 MHz mobile phone 4 h/d for 18 days could induce the liver histological changes, which may be partly due to the apoptosis and oxidative stress induced in liver tissue by electromagnetic radiation.

**Maaroufi K, Save E, Poucet B, Sakly M, Abdelmelek H, Had-Aissouni L. Oxidative stress and prevention of the adaptive response to chronic iron overload in the brain of young adult rats exposed to a 150 kilohertz electromagnetic field. Neuroscience. 186:39-47, 2011.**

Iron surcharge may induce an oxidative stress-based decline in several neurological functions. In addition, electromagnetic fields (EMF) of frequencies up to about 100 kHz, emitted by electric/electronic devices, have been suggested to enhance free radical production through an iron dependent pathway. The purpose of this study was therefore to determine a possible relationship between iron status, exposure to EMF, and brain oxidative stress in young adult rats. Samples were micro-dissected from prefrontal cortex, hippocampus, striatum, and cerebellum after chronic saline or iron overload (IO) as well as after chronic sham exposure or exposure to a 150 kHz EMF or after combining EMF exposure with IO. The brain samples were used to monitor oxidative stress-induced lipid peroxidation and activity of the antioxidant enzymes superoxide dismutase and catalase. While IO did not induce any oxidative stress in young adult rats, it stimulated antioxidant defenses in the cerebellum and prefrontal cortex in particular. On the contrary, EMF exposure stimulated lipid peroxidation mainly in the cerebellum, without affecting antioxidant defenses. When EMF was coapplied with IO, lipid peroxidation was further increased as compared to EMF alone while the increase in antioxidant defenses triggered by the sole IO was abolished.

These data suggest that EMF exposure may be harmful in young adults by impairing the antioxidant defenses directed at preventing iron-induced oxidative stress.

**Maaroufi K, Had-Aissouni L, Melon C, Sakly M, Abdelmelek H, Poucet B, Save E. Spatial learning, monoamines and oxidative stress in rats exposed to 900MHz electromagnetic field in combination with iron overload. Behav Brain Res. 2013 Oct 18. pii: S0166-4328(13)00624-4. doi: 10.1016/j.bbr.2013.10.016. [Epub ahead of print]**

The increasing use of mobile phone technology over the last decade raises concerns about the impact of high frequency electromagnetic fields (EMF) on health. More recently, a link between EMF, iron overload in the brain and neurodegenerative disorders including Parkinson's and Alzheimer's diseases has been suggested. Co-exposure to EMF and brain iron overload may have a greater impact on brain tissues and cognitive processes than each treatment by itself. To examine this hypothesis, Long-Evans rats submitted to 900MHz exposure or combined 900MHz EMF and iron overload treatments were tested in various spatial learning tasks (navigation task in the Morris water maze, working memory task in the radial-arm maze, and object exploration task involving spatial and non spatial processing). Biogenic monoamines and metabolites (dopamine, serotonin) and oxidative stress were measured. Rats exposed to EMF were impaired in the object exploration task but not in the navigation and working memory tasks. They also showed alterations of monoamine content in several brain areas but mainly in the hippocampus. Rats that received combined treatment did not show greater behavioral and neurochemical deficits than EMF-exposed rats. None of the two treatments produced global oxidative stress. These results show that there is an impact of EMF on the brain and cognitive processes but this impact is revealed only in a task exploiting spontaneous exploratory activity. In contrast, there are no synergistic effects between EMF and a high content of iron in the brain.

**Maby E, Le Bouquin Jeannes R, Liegeois-Chauvel C, Gourevitch B, Faucon G.Analysis of auditory evoked potential parameters in the presence of radiofrequency fields using a support vector machines method. Med Biol Eng Comput. 42(4):562-568, 2004.**

The paper presents a study of global system for mobile (GSM) phone radiofrequency effects on human cerebral activity. The work was based on the study of auditory evoked potentials (AEPs) recorded from healthy humans and epileptic patients. The protocol allowed the comparison of AEPs recorded with or without exposure to electrical fields. Ten variables measured from AEPs were employed in the design of a supervised support vector machines classifier. The classification performance measured the classifier's ability to discriminate features performed with or without radiofrequency exposure. Most significant features were chosen by a backward sequential selection that ranked the variables according to their pertinence for the discrimination. Finally, the most discriminating features were analysed statistically by a Wilcoxon signed rank test. For both populations, the N100 amplitudes were reduced under the influence of GSM radiofrequency (mean attenuation of -0.36 microV for healthy subjects and -0.60 microV for epileptic patients). Healthy subjects showed a N100 latency decrease (-5.23 ms in

mean), which could be consistent with mild, localised heating. The auditory cortical activity in humans was modified by GSM phone radiofrequencies, but an effect on brain functionality has not been proven.

**Maby E, Jeannes RL, Faucon G, Liegeois-Chauvel C, De Seze R. Effects of GSM signals on auditory evoked responses. Bioelectromagnetics. 26(5):341-350, 2005.**

The article presents a study of the influence of radio frequency (RF) fields emitted by mobile phones on human cerebral activity. Our work was based on the study of Auditory Evoked Potentials (AEPs) recorded on the scalp of healthy humans and epileptic patients. The protocol allowed us to compare AEPs recorded with or without exposure to RFs. To get a reference, a control session was also introduced. In this study, the correlation coefficients computed between AEPs, as well as the correlation coefficients between spectra of AEPs were investigated to detect a possible difference due to RFs. A difference in the correlation coefficients computed in control and experimental sessions was observed, but it was difficult to deduce the effect of RFs on human health.

**Maby E, Jeannes Rle B, Faucon G. Scalp localization of human auditory cortical activity modified by GSM electromagnetic fields. Int J Radiat Biol. 82(7):465-472, 2006.**

Purpose: This study attempted to determine whether there is a localized effect of GSM (Global System for Mobile communications) microwaves by studying the Auditory Evoked Potentials (AEP) recorded at the scalp of nine healthy subjects and six epileptic patients.Materials and methods: We determined the influence of GSM RadioFrequency (RF) on parameters characterizing the AEP in time or/and frequency domains. A parameter selection method using SVM (Support Vector Machines)-based criteria allowed us to estimate those most altered by the radiofrequencies. The topography of the parameter modifications was computed to determine the localization of the radiofrequency influence. A statistical test was conducted for selected scalp areas, in order to determine whether there were significant localized alterations due to the RF.Results: The epileptic patients showed a lengthening of the scalp component N100 (100 ms latency) in the frontal area contralateral to the radiation, which may be due to an afferent tract alteration. For the healthy subjects, an amplitude increase of the P200 wave (200 ms latency) was identified in the frontal area.Conclusions: The present study suggests that radiofrequency fields emitted by mobile phones modify the AEP. Nevertheless, no direct link between these findings and RF-induced damages in brain function was established.

**Maby E, Le Bouquin Jeannes R, Faucon G. Short-term effects of GSM mobiles phones on spectral components of the human electroencephalogram. Conf Proc IEEE Eng Med Biol Soc. 1:3751-3754, 2006.**

The aim of the study was to investigate whether the GSM (global system for mobile) signals affect the electrical activity of the human brain. Nine healthy subjects and six temporal epileptic patients were exposed to radiofrequencies emitted by a GSM mobile phone signals. Electroencephalographic (EEG) signals were recorded using surface electrodes with and without radiofrequency. In order to obtain a reference, a control session was also carried out. The spectral attributes of the EEG signals recorded by

surface electrodes were analyzed. The significant decrease of spectral correlation coefficients under radiofrequency influence showed that the GSM signal altered the spectral arrangement of the EEG activity for healthy subjects as well as epileptic patients. For the healthy subjects, the EEG spectral energy decreased on the studied frequency band [0-40 Hz] and more precisely on occipital electrodes for the alpha-band. For the epileptic patients, these modifications were demonstrated by an increase of the power spectral density of the EEG signal. Nevertheless, these biological effects on the EEG are not sufficient to put forward some electrophysiological hypothesis.

**Maccà I, Scapellato ML, Carrieri M, Pasqua di Bisceglie A, Saia B, Bartolucci GB. Occupational exposure to electromagnetic fields in physiotherapy departments. Radiat Prot Dosimetry. 128(2):180-190, 2008.**

To assess occupational exposure to electromagnetic fields, 11 microwave (MW), 4 short-wave diathermy and 15 magneto therapy devices were analysed in eight physiotherapy departments. Measurements taken at consoles and environmental mapping showed values above European Directive 2004/40/EC and ACGIH exposure limits at approximately 50 cm from MW applicators (2.45 GHz) and above the Directive magnetic field limit near the diathermy unit (27.12 MHz). Levels in front of MW therapy applicators decreased rapidly with distance and reduction in power; this may not always occur in work environments where nearby metal structures (chairs, couches, etc.) may reflect or perturb electromagnetic fields. Large differences in stray field intensities were found for various MW applicators. Measurements of power density strength around MW electrodes confirmed radiation fields between 30 degrees and 150 degrees , with a peak at 90 degrees , in front of the cylindrical applicator and maximum values between 30 degrees and 150 degrees over the whole range of 180 degrees for the rectangular parabolic applicator. Our results reveal that although most areas show substantially low levels of occupational exposure to electromagnetic fields in physiotherapy units, certain cases of over-occupational exposure limits do exist.

**Maes A, Verschaeve L, Arroyo A, De Wagter C, Vercruyssen L, In vitro cytogenetic effects of 2450 MHz waves on human peripheral blood lymphocytes. Bioelectromagnetics 14(6):495-501, 1993.**

Cytogenetic analyses were performed on human peripheral blood lymphocytes exposed to 2450 MHz microwaves during 30 and 120 min at a constant temperature of 36.1 degrees C (body temperature). The temperature was kept constant by means of a temperature probe put in the blood sample which gives feedback to a microcomputer that controls the microwave supply. We found a marked increase in the frequency of chromosome aberrations (including dicentric chromosomes and acentric fragments) and micronuclei. On the other hand the microwave exposure did not influence the cell kinetics nor the sister chromatid exchange (SCE) frequency.

**Maes A, Collier M, Slaets D, Verschaeve L, 954 MHz microwaves enhance the mutagenic properties of mitomycin C. Environ Mol Mutagen 28(1):26-30, 1996.**

This paper focuses on the combined effects of microwaves from mobile communication frequencies and a chemical DNA damaging agent mitomycin C (MMC). The investigation was performed in vitro by exposing whole blood samples to a 954 MHz emitting antenna

from a GSM (Global System for Mobile Communication) base station, followed by lymphocyte cultivation in the presence of MMC. A highly reproducible synergistic effect was observed as based on the frequencies of sister chromatid exchanges in metaphase figures.

**Maes A, Collier M, Van Gorp U, Vandoninck S, Verschaeve L, Cytogenetic effects of 935.2-MHz (GSM) microwaves alone and in combination with mitomycin C. Mutat Res 393(1-2):151-156, 1997.**

This paper focuses on the genetic effects of microwaves from mobile communication frequencies (935.2 MHz) alone and in combination with a chemical DNA-damaging agent (mitomycin C). Three cytogenetic endpoints were investigated after in vitro exposure of human whole blood cells. These endpoints were the 'classical' chromosome aberration test, the sister chromatid exchange test and the alkaline comet assay. No direct cytogenetic effect was found. The combined exposure of the cells to the radiofrequency fields followed by their cultivation in the presence of mitomycin C revealed a very weak effect when compared to cells exposed to mitomycin C alone.

**Maes A, Collier M, Verschaeve L Cytogenetic investigations on microwavesemitted by a 455.7 MHz car phone. Folia Biol (Praha) 46(5):175-180, 2000.**

The chromosome aberration or sister chromatid exchange frequency was determined in 455.7 MHz microwave-exposed human lymphocytes and in lymphocytes that were subsequently exposed to MMC or X-rays. The exposure was performed by placing the cells at 5 cm from the antenna of a car phone. In this way the specific absorption ratio was approximately 6.5 W/kg. The temperature and humidity was kept constant during the experiments. No statistically significant difference was found between microwave-exposed and unexposed control samples. When the microwave exposure was followed by exposure to MMC, some differences were found between the combined treatments and the MMC treatments alone. However, there was no consistency in the results. Combined treatments with X-rays did not provide any indication of a synergistic action between the RF fields and X-rays, either. Our data therefore do not support the hypothesis that RF fields act synergistically with chemical or physical mutagens.

**Maes A, Collier M, Verschaeve L Cytogenetic effects of 900 MHz (GSM) microwaves on human lymphocytes. Bioelectromagnetics 22(2):91-96, 2001**

The cytogenetic effects of 900 MHz radiofrequency fields were investigated with the chromosome aberration and sister chromatid exchange frequency methods. Three different modes of exposure (continuous, pseudo-random and dummy burst) were studied for different power outputs (0, 2, 8, 15, 25, 50 W). The specific absorption rates varied between 0 and 10 W/kg. We investigated the possible effects of the 900 MHz radiation alone as well as of combined exposure to the chemical or physical mutagens mitomycin C and X-rays. Overall, no indication was found of a mutagenic, and/or co-mutagenic/synergistic effect of this kind of nonionizing radiation.

**Maes A, Van Gorp U, Verschaeve L. Cytogenetic investigation of subjects professionally exposed to radiofrequency radiation. Mutagenesis. 21(2):139-142, 2006.**

Nowadays, virtually everybody is exposed to radiofrequency radiation (RFR) from mobile phone base station antennas or other sources. At least according to some scientists, this exposure can have detrimental health effects. We investigated cytogenetic effects in peripheral blood lymphocytes from subjects who were professionally exposed to mobile phone electromagnetic fields in an attempt to demonstrate possible RFR-induced genetic effects. These subjects can be considered well suited for this purpose as their RFR exposure is 'normal' though rather high, and definitely higher than that of the 'general population'. The alkaline comet assay, sister chromatid exchange (SCE) and chromosome aberration tests revealed no evidence of RFR-induced genetic effects. Blood cells were also exposed to the well known chemical mutagen mitomycin C in order to investigate possible combined effects of RFR and the chemical. No cooperative action was found between the electromagnetic field exposure and the mutagen using either the comet assay or SCE test.

**Maganioti AE, Hountala CD, Papageorgiou CC, Kyprianou MA, Rabavilas AD, Capsalis CN. Principal component analysis of the P600 waveform: RF and gender effects.Neurosci Lett. 478(1):19-23, 2010.**

The aim of the present study was to examine the patterns of activation of the P600 waveform of the event-related potentials (ERP), applying principal component analysis (PCA) and repeated measures ANOVA, and whether these patterns are RF and gender dependent. The ERPs of thirty-nine healthy subjects (20 male and 19 female) were recorded during an auditory memory task in the presence and absence of RF, similar to that emitted by mobile phones. Both PCA and ANOVA produced congruent results, showing that activation of the P600 component occurs early and more intensely in the region of the posterior electrodes and in a less intense manner in the central electrodes. Conversely, the activation at the anterior electrodes arises later with a considerably reduced intensity. In the absence of RF female subjects exhibited significantly lower amplitudes at anterior electrodes and earlier latencies at central electrodes than male subjects. These differences disappear in the presence of RF. Consequently, the P600 component follows distinct patterns of activation in the anterior, central and posterior brain areas and gender differences are observed simultaneously at several electrodes within these areas. Finally, the gender-related functional architecture with regard the P600 component appears to be RF sensitive. In conclusion, the application of the PCA procedure provides an adequate model of the spatially distributed event-related dynamics that correspond to the P600 waveform.

**Magras, IN, Xenos, TD, RF radiation-induced changes in the prenatal development of mice. Bioelectromagnetics 18(6):455-461, 1997.**

The possible effects of radiofrequency (RF) radiation on prenatal development has been investigated in mice. This study consisted of RF level measurements and in vivo experiments at several places around an "antenna park." At these locations RF power densities between 168 nW/cm2 and 1053 nW/cm2 were measured. Twelve pairs of mice, divided in two groups, were placed in locations of different power densities and were repeatedly mated five times. One hundred eighteen newborns were collected. They were measured, weighed, and examined macro- and microscopically. A progressive decrease

in the number of newborns per dam was observed, which ended in irreversible infertility. The prenatal development of the newborns, however, evaluated by the crown-rump length, the body weight, and the number of the lumbar, sacral, and coccygeal vertebrae, was improved.

**Mahfouz Z, Gati A, Lautru D, Wong MF, Wiart J, Hanna VF. Influence of traffic variations on exposure to wireless signals in realistic environments.Bioelectromagnetics. 2011 Sep 29. doi: 10.1002/bem.20705. [Epub ahead of print]**

In this article, the general public daily exposure to broadcast signals and Global System for Mobile Communications (GSM) or Universal Mobile Telecommunications System (UMTS) mobile telephone signals in indoor areas is investigated. Temporal variations and traffic distributions during a day at different indoor sites in urban and rural zones are presented. The goal is to analyze the real exposure compared to the maximum assessment imposed by radio protection standards and to characterize the ratio between daily and maximum theoretical values. Hence, a realistic maximum is proposed based on the statistical analysis performed using measurements. Broadcast signals remain constant over the day so they are best fitted with a Normal distribution while the mobile telephone signals depend on the traffic demand during the day so they fit a three-Gaussian distribution model. A general mask is also constructed for underlining the maximum equivalent active traffic for different periods in the day. Also, relations between the mean values over 24 h, the realistic maximal values (at 99%) and the maximal theoretical values are presented. The realistic maximum is also presented with a sliding time average of 6 min applied to the measurements in accordance with international standards. An extrapolation factor is given for the different systems to easily assess the maximum values starting from an instantaneous measurement. The extrapolation factor is also given for a broadband measurement to estimate the maximum potential exposure during the day.

**Mahmoudabadi FS, Ziaei S, Firoozabadi M, Kazemnejad A. Use of mobile phone during pregnancy and the risk of spontaneous abortion. J Environ Health Sci Eng. 13:34, 2015.**

BACKGROUND: Exposure to electromagnetic fields of cell phones increasingly occurs, but the potential influence on spontaneous abortion has not been thoroughly investigated. METHODS: In a case-control study, 292 women who had an unexplained spontaneous abortion at < 14 weeks gestation and 308 pregnant women > 14 weeks gestation were enrolled. Two data collection forms were completed; one was used to collect data about socioeconomic and obstetric characteristics, medical and reproductive history, and lifestyles. Another was used to collect data about the use of cell phones during pregnancy. For the consideration of cell phone effects, we measured the average calling time per day, the location of the cell phones when not in use, use of hands-free equipment, use of phones for other applications, the specific absorption rate (SAR) reported by the manufacturer and the average of the effective SAR (average duration of calling time per day × SAR). Analyses were carried out with statistical package state software(SPSS)v.16. RESULTS: All the data pertaining to mobile phones were different

between the two groups except the use of hands free devices ($p < 0.001$).
CONCLUSION: Our result suggests that use of mobile phones can be related to the early spontaneous abortions.

**Maier R, Greter SE, Maier N. Effects of pulsed electromagnetic fields on cognitive processes - a pilot study on pulsed field interference with cognitive regeneration. Acta Neurol Scand. 110(1):46-52, 2004**.

BACKGROUND: Due to the ubiquitous use of cellular phones much has been speculated on secondary effects of electromagnetic irradiation emitted by those. Additionally, several studies have reported vegetative alterations as well as effects on the neuronal and molecular levels in humans. Here, using a psycho-physiological test paradigm, we examined effects of exposure to pulsed electromagnetic fields on cognitive performance. MATERIALS AND METHODS: In 11 volunteers, we tested cognitive processing under field exposure (GSM standard) and under field-free conditions. To examine the hypothesized effect of pulsed fields, we applied an auditory discrimination task and determined the participant's current 'Order Threshold' value. Following a first test cycle, the volunteers had to relax for 50 min while being, or not, exposed to pulsed electromagnetic fields. Subsequently, the test was repeated. Data acquired before and after the resting phase were compared from both experimental conditions. RESULTS: We found that nine of the 11 test participants (81.8%) showed worse results in their auditory discrimination performance upon field exposure as compared with control conditions. Group data comparison revealed a statistical significance of $P = 0.0105$. CONCLUSION: We could show that the participants' cognitive performance was impaired after exposure to pulsed electromagnetic fields. With regard to this finding, we recommend that the use of cellular phones should be restricted generally and in particular in respect of physical hazard of high-risk groups, e.g. elderly, children and ill people.

**Mailankot M, Kunnath AP, Jayalekshmi H, Koduru B, Valsalan R. Radio frequency electromagnetic radiation (RF-EMR) from GSM (0.9/1.8GHz) mobile phones induces oxidative stress and reduces sperm motility in rats. Clinics (Sao Paulo). 64(6):561-565, 2009.**

INTRODUCTION: Mobile phones have become indispensable in the daily lives of men and women around the globe. As cell phone use has become more widespread, concerns have mounted regarding the potentially harmful effects of RF-EMR from these devices. OBJECTIVE: The present study was designed to evaluate the effects of RF-EMR from mobile phones on free radical metabolism and sperm quality. MATERIALS AND METHODS: Male albino Wistar rats (10-12 weeks old) were exposed to RF-EMR from an active GSM (0.9/1.8 GHz) mobile phone for 1 hour continuously per day for 28 days. Controls were exposed to a mobile phone without a battery for the same period. The phone was kept in a cage with a wooden bottom in order to address concerns that the effects of exposure to the phone could be due to heat emitted by the phone rather than to RF-EMR alone. Animals were sacrificed 24 hours after the last exposure and tissues of interest were harvested. RESULTS: One hour of exposure to the phone did not significantly change facial temperature in either group of rats. No significant difference was observed in total sperm count between controls and RF-EMR exposed groups.

However, rats exposed to RF-EMR exhibited a significantly reduced percentage of motile sperm. Moreover, RF-EMR exposure resulted in a significant increase in lipid peroxidation and low GSH content in the testis and epididymis. CONCLUSION: Given the results of the present study, we speculate that RF-EMR from mobile phones negatively affects semen quality and may impair male fertility.

**Maillefer RH, Quock RM. Naltrexone-sensitive analgesia following exposure of mice to 2450-MHz radiofrequency radiation. Physiol Behav 52(3):511-514, 1992.**

To determine whether exposure to radiofrequency radiation (RFR) would induce sufficient thermal stress to activate endogenous opioid mechanisms, male Swiss Webster mice were exposed to 10, 15, and 20 mW/cm2 RFR in a 2450-MHz waveguide system for 10 min at specific absorption rates (SARs) of 23.7, 34.6, and 45.5 W/kg, respectively, then tested in the abdominal constriction paradigm. Confinement in the RFR exposure chamber alone did not appreciably alter body temperature but did appear to induce a stress-associated analgesia that was not blocked by naltrexone. Exposure of confined mice to RFR raised body temperature and further increased analgesia in an SAR-dependent manner. The high SAR-induced analgesia, but not the hyperthermia, was blocked by naltrexone. These findings suggest that 1) RFR produces SAR-dependent hyperthermia and analgesia, and 2) RFR-induced analgesia is mediated by opioid mechanisms while confinement-induced analgesia involves nonopioid mechanisms.

**Manta AK, Papadopoulou D, Polyzos AP, Fragopoulou AF, Skouroliakou AS, Thanos D, Stravopodis DJ, Margaritis LH. Mobile-phone radiation-induced perturbation of gene-expression profiling, redox equilibrium and sporadic-apoptosis control in the ovary of Drosophila melanogaster. Fly (Austin). 11(2):75-95, 2017.**

The daily use by people of wireless communication devices has increased exponentially in the last decade, begetting concerns regarding its potential health hazards. Drosophila melanogaster four days-old adult female flies were exposed for 30 min to radiation emitted by a commercial mobile phone at a SAR of 0.15 W/kg and a SAE of 270 J/kg. ROS levels and apoptotic follicles were assayed in parallel with a genome-wide microarrays analysis. ROS cellular contents were found to increase by 1.6-fold (x), immediately after the end of exposure, in follicles of pre-choriogenic stages (germarium - stage 10), while sporadically generated apoptotic follicles (germarium 2b and stages 7-9) presented with an averaged 2x upregulation in their sub-population mass, 4 h after fly's irradiation with mobile device. Microarray analysis revealed 168 genes being differentially expressed, 2 h post-exposure, in response to radiofrequency (RF) electromagnetic field-radiation exposure (≥1.25x, $P < 0.05$) and associated with multiple and critical biological processes, such as basic metabolism and cellular subroutines related to stress response and apoptotic death. Exposure of adult flies to mobile-phone radiation for 30 min has an immediate impact on ROS production in animal's ovary, which seems to cause a global, systemic and non-targeted transcriptional reprogramming of gene expression, 2 h post-exposure, being finally followed by induction of apoptosis 4 h after the end of exposure. Conclusively, this unique type of pulsed radiation, mainly being derived from daily used mobile phones, seems capable of mobilizing critical cytopathic mechanisms, and altering fundamental genetic programs and networks in D. melanogaster.

**Marjanovic Cermak AM, Pavicic I, Tariba Lovakovic B, Pizent A, Trosic I. In vitro non-thermal oxidative stress response after 1800 MHz radiofrequency radiation. Gen Physiol Biophys. 36(4):407-414, 2017.**

In this study possible connection between radiofrequency exposure (RF) and development of oxidative stress was investigated by measuring impairment in cellular oxidation-reduction balance immediately after RF exposure. Fibroblast cells V79 were exposed for 10, 30 and 60 minutes to 1800 MHz RF radiation. Electric field strength was 30 V/m and specific absorption rate (SAR) was calculated to be 1.6 W/kg. Electromagnetic field was generated within Gigahertz Transversal Electromagnetic Mode cell (GTEM) equipped by signal generator, amplifier and modulator. Cell viability was determined by CCK-8 colorimetric assay and level of reactive oxygen species (ROS) was detected by dihydroethidium staining. Reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) were used to assess cell antioxidant activity while lipid oxidative damage was evaluated measuring concentration of malondialdehyde. Viability of V79 cells remained within normal physiological values regardless of exposure time. Increased level of superoxide radicals was detected after 60-min exposure. Significantly higher GSH level was observed immediately after 10-min exposure with higher but insignificant activity of GSH-Px. Lipid oxidative damage in exposed cell samples was not observed. Short-term RF exposure revealed transient oxidation-reduction imbalance in fibroblast cells following adaptation to applied experimental conditions.

**Mokarram P, Sheikhi M, Mortazavi SMJ, Saeb S[4] Shokrpour N. Effect of Exposure to 900 MHz GSM** Mobile Phone **Radiofrequency Radiation on Estrogen Receptor Methylation Status in Colon Cells of Male Sprague Dawley Rats. J Biomed Phys Eng. 7(1):79-86, 2017.**

BACKGROUND: Over the past several years, the rapidly increasing use of **mobile phones** has raised global concerns about the biological effects of exposure to radiofrequency (RF) radiation. Numerous studies have shown that exposure to electromagnetic fields (EMFs) can be associated with effects on the nervous, endocrine, immune, cardiovascular, hematopoietic and ocular systems. In spite of genetic diversity, the onset and progression of cancer can be controlled by epigenetic mechanisms such as gene promoter methylation. There are extensive studies on the epigenetic changes of the tumor suppressor genes as well as the identification of methylation biomarkers in colorectal cancer. Some studies have revealed that genetic changes can be induced by exposure to RF radiation. However, whether or not RF radiation is capable of inducing epigenetic alteration has not been clarified yet. To date, no study has been conducted on the effect of radiation on epigenetic alterations in colorectal cancer (CRC). Several studies have also shown that methylation of estrogen receptor α (ERα), MYOD, MGMT, SFRP2 and P16 play an important role in CRC. It can be hypothesized that RF exposure can be a reason for the high incidence of CRC in Iran. This study aimed to investigate whether epigenetic pattern of ERα is susceptible to RF radiation and if RF radiation can induce radioadaptive response as epigenetic changes after receiving the challenge dose (γ-ray).MATERIAL AND METHOD: 40 male Sprague-Dawley rats were divided into 4 equal groups (Group I: exposure to RF radiation of a GSM **cell phone** for 4 hours and

sacrificed after 24 hours; Group II: RF exposure for 4 hours, exposure to Co-60 gamma radiation (3 Gy) after 24 hours and sacrificed after 72 hrs; Group III: only 3Gy gamma radiation; Group 4: control group). DNA from colon tissues was extracted to evaluate the methylation status by methylation specific PCR.RESULTS: Our finding showed that exposure to GSM **cell phone** RF radiation was capable of altering the pattern of ERα gene methylation compared to that of non-exposed controls. Furthermore, no adaptive response phenomenon was induced in the pattern of ERα gene methylation after exposure to the challenging dose of Co-60 γ-rays.CONCLUSION: It can be concluded that exposure to RF radiation emitted by GSM **mobile phones** can lead to epigenetic detrimental changes in ERα promoter methylation pattern.

**Malek F, Rani KA, Rahim HA, Omar MH. Effect of Short-Term Mobile Phone Base Station Exposure on Cognitive Performance, Body Temperature, Heart Rate and Blood Pressure of Malaysians. Sci Rep. 5:13206, 2015.**

Individuals who report their sensitivity to electromagnetic fields often undergo cognitive impairments that they believe are due to the exposure of mobile phone technology. The aim of this study is to clarify whether short-term exposure at 1 V/m to the typical Global System for Mobile Communication and Universal Mobile Telecommunications System (UMTS) affects cognitive performance and physiological parameters (body temperature, blood pressure and heart rate). This study applies counterbalanced randomizing single blind tests to determine if sensitive individuals experience more negative health effects when they are exposed to base station signals compared with sham (control) individuals. The sample size is 200 subjects with 50.0% Idiopathic Environmental Intolerance attributed to electromagnetic fields (IEI-EMF) also known as sensitive and 50.0% (non-IEI-EMF). The computer-administered Cambridge Neuropsychological Test Automated Battery (CANTAB eclipse(TM)) is used to examine cognitive performance. Four tests are chosen to evaluate Cognitive performance in CANTAB: Reaction Time (RTI), Rapid Visual Processing (RVP), Paired Associates Learning (PAL) and Spatial Span (SSP). Paired sample t-test on the other hand, is used to examine the physiological parameters. Generally, in both groups, there is no statistical significant difference between the exposure and sham exposure towards cognitive performance and physiological effects (P's > 0.05).

**Malka N. Halgamuge, See Kye Yak and Jacob L. Eberhardt. Reduced growth of soybean seedlings after exposure to weak microwave radiation from GSM 900 mobile phone and base station. Bioelectromagnetics. Article first published online: Jan 21, 2015. DOI: 10.1002/BEM.21890**

The aim of this work was to study possible effects of environmental radiation pollution on plants. The association between cellular telephone (short duration, higher amplitude) and base station (long duration, very low amplitude) radiation exposure and the growth rate of soybean (Glycine max) seedlings was investigated. Soybean seedlings, pre-grown for 4 days, were exposed in a gigahertz transverse electromagnetic cell for 2 hrs. to global

system for mobile communication (GSM) mobile phone pulsed radiation or continuous wave (CW) radiation at 900 MHz with amplitudes of 5.7 and 41 volts per meter, and outgrowth was studied one week after exposure. The exposure to higher amplitude (41 V m−1) GSM radiation resulted in diminished outgrowth of the epicotyl. The exposure to lower amplitude (5.7 V m−1) GSM radiation did not influence outgrowth of epicotyl, hypocotyls, or roots. The exposure to higher amplitude CW radiation resulted in reduced outgrowth of the roots whereas lower CW exposure resulted in a reduced outgrowth of the hypocotyl. Soybean seedlings were also exposed for 5 days to an extremely low level of radiation (GSM 900 MHz, 0.56 V m−1) and outgrowth was studied 2 days later. Growth of epicotyl and hypocotyl was found to be reduced, whereas the outgrowth of roots was stimulated. Our findings indicate that the observed effects were significantly dependent on field strength as well as amplitude modulation of the applied field.

**Malkemper EP, Eder SH, Begall S, Phillips JB, Winklhofer M, Hart V, Burda H. Magnetoreception in the wood mouse (Apodemus sylvaticus): influence of weak frequency-modulated radio frequency fields. Sci Rep. 2015 Apr 29;4:9917. doi: 10.1038/srep09917.**

The mammalian magnetic sense is predominantly studied in species with reduced vision such as mole-rats and bats. Far less is known about surface-dwelling (epigeic) rodents with well-developed eyes. Here, we tested the wood mouse Apodemus sylvaticus for magnetoreception using a simple behavioural assay in which mice are allowed to build nests overnight in a visually symmetrical, circular arena. The tests were performed in the ambient magnetic field or in a field rotated by 90°. When plotted with respect to magnetic north, the nests were bimodally clustered in the northern and southern sectors, clearly indicating that the animals used magnetic cues. Additionally, mice were tested in the ambient magnetic field with a superimposed radio frequency magnetic field of the order of 100 nT. Wood mice exposed to a 0.9 to 5 MHz frequency sweep changed their preference from north-south to east-west. In contrast to birds, however, a constant frequency field tuned to the Larmor frequency (1.33 MHz) had no effect on mouse orientation. In sum, we demonstrated magnetoreception in wood mice and provide first evidence for a radical-pair mechanism in a mammal.

**Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti Roti JL, Measurement of DNA damage after exposure to 2450 MHz electromagnetic radiation. Radiat Res 148(6):608-617, 1997.**

Recent reports suggest that exposure to 2450 MHz electromagnetic radiation causes DNA single-strand breaks (SSBs) and double-strand breaks (DSBs) in cells of rat brain irradiated in vivo (Lai and Singh, Bioelectromagnetics 16, 207-210, 1995; Int. J. Radiat. Biol. 69, 513-521, 1996). Therefore, we endeavored to determine if exposure of cultured mammalian cells in vitro to 2450 MHz radiation causes DNA damage. The alkaline comet assay (single-cell gel electrophoresis), which is reportedly the most sensitive method to assay DNA damage in individual cells, was used to measure DNA damage after in vitro 2450 MHz irradiation. Exponentially growing U87MG and C3H 10T1/2 cells were exposed to 2450 MHz continuous-wave (CW) radiation in specially designed radial transmission lines (RTLs) that provided relatively uniform microwave exposure. Specific

absorption rates (SARs) were calculated to be 0.7 and 1.9 W/kg. Temperatures in the RTLs were measured in real time and were maintained at 37 +/- 0.3 degrees C. Every experiment included sham exposure(s) in an RTL. Cells were irradiated for 2 h, 2 h followed by a 4-h incubation at 37 degrees C in an incubator, 4 h and 24 h. After these treatments samples were subjected to the alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-267, 1992). Images of comets were digitized and analyzed using a PC-based image analysis system, and the "normalized comet moment" and "comet length" were determined. No significant differences were observed between the test group and the controls after exposure to 2450 MHz CW irradiation. Thus 2450 MHz irradiation does not appear to cause DNA damage in cultured mammalian cells under these exposure conditions as measured by this assay.

**Malyapa RS, Ahern EW, Bi C, Straube WL, LaRegina M, Pickard WF, Roti RotiJL, DNA damage in rat brain cells after in vivo exposure to 2450 MHz electromagnetic radiation and various methods of euthanasia. Radiat Res 149(6):637-645, 1998.**

The present study was done to confirm the reported observation that low-intensity acute exposure to 2450 MHz radiation causes DNA single-strand breaks (Lai and Singh, Bioelectromagnetics 16, 207-210, 1995). Male Sprague-Dawley rats weighing approximately 250 g were irradiated with 2450 MHzcontinuous-wave (CW) microwaves for 2 h at a specific absorption rate of 1.2 W/kg in a cylindrical waveguide system (Guy et al., Radio Sci. 14, 63-74, 1979). There was no associated rise in the core body temperature of the rats. After the irradiation or sham treatments, rats were euthanized by either CO2 asphyxia or decapitation by guillotine (eight pairs of animals per euthanasia group). After euthanasia the brains were removed and immediately immersed in cold Ames medium and the cells of the cerebral cortex and the hippocampus were dissociated separately and subjected to the alkaline comet assay. Irrespective of whether the rats were euthanized by CO2 asphyxia or decapitated by guillotine, no significant differences were observed between either the comet length or the normalized comet moment of cells from either the cerebral cortex or the hippocampus of sham-treated rats and those from the irradiated rats. However, the data for the rats asphyxiated with CO2 showed more intrinsic DNA damage and more experiment-to-experiment variation than did the data for rats euthanized by guillotine. Therefore, the guillotine method of euthanasia is the most appropriate in studies relating to DNA damage. Furthermore, we did not confirm the observation that DNA damage is produced in cells of the rat cerebral cortex or the hippocampus after a 2-h exposure to 2450 MHz CW microwaves or at 4 h after the exposure.

**Malyapa RS, Ahern EW, Straube WL, Moros EG, Pickard WF, Roti Roti JL. Measurement of DNA damage after exposure to electromagnetic radiation in the cellular phone communication frequency band (835.62 and 847.74 MHz). Radiat Res 148(6):618-627, 1997.**

Mouse C3H 10T1/2 fibroblasts and human glioblastoma U87MG cells were exposed to cellular phone communication frequency radiations to investigate whether such exposure produces DNA damage in in vitro cultures. Two types of frequency modulations were studied: frequency-modulated continuous-wave (FMCW), with a carrier frequency of 835.62 MHz, and code-division multiple-access (CDMA) centered on 847.74 MHz.

Exponentially growing (U87MG and C3H 10T1/2 cells) and plateau-phase (C3H 10T1/2 cells) cultures were exposed to either FMCW or CDMA radiation for varying periods up to 24 h in specially designed radial transmission lines (RTLs) that provided relatively uniform exposure with a specific absorption rate (SAR) of 0.6 W/kg. Temperatures in the RTLs were monitored continuously and maintained at 37 +/- 0.3 degrees C. Sham exposure of cultures in an RTL (negative control) and 137Cs gamma-irradiated samples (positive control) were included with every experiment. The alkaline comet assay as described by Olive et al. (Exp. Cell Res. 198, 259-269, 1992) was used to measure DNA damage. No significant differences were observed between the test group exposed to FMCW or CDMA radiation and the sham-treated negative controls. Our results indicate that exposure of cultured mammalian cells to cellular phone communication frequencies under these conditions at an SAR of 0.6 W/kg does not cause DNA damage as measured by the alkaline comet assay.

**Mancinelli F, Caraglia M, Abbruzzese A, d'Ambrosio G, Massa R, Bismuto E.Non-thermal effects of electromagnetic fields at mobile phone frequency on the refolding of an intracellular protein: myoglobin. J Cell Biochem. 93(1):188-196, 2004.**

Non-thermal effects induced by exposure to microwave electromagnetic field (MW-EMF) at 1.95 MHz, a frequency used in mobile communication, have been observed on the refolding kinetics of the heme binding site in an intracellular protein: tuna myoglobin, starting from acidic conditions. We have selected myoglobin because it can be considered a good model to study protein interactions with MW-EMF for its well-known high-resolution crystallographic structure. Myoglobin solutions at pH 3.0 were subjected to 3 h exposure to microwave field (with a specific absorption rate of 51 +/- 1 mW/g); the heme site refolding has been followed by measuring the molecular absorption in the Soret spectral region and the data were fitted to a bi-exponential model. The kinetics of exposed samples appear to be slowered by MW-EMF action. Moreover, the tryptophanyl lifetime distribution of the exposed protein, as deduced by the analysis of the fluorescence emission decay from its single tryptophan, appears sharper if compared to non-exposed protein samples. This observation suggests that the presence of MW-EMF could affect the propensity of protein molecules to populate specific conformational substates among which myoglobin molecules fluctuate at acidic pH. Changes in the structural fluctuation caused by MW perturbation can affect differently the aggregation process that occurs competitively during the protein folding, so representing a potential risk for protein "misfolding." These data suggest that MW-EMF could have also biochemical and, consequently, biological effects on eukaryotic cells that are still under investigation.

**Mandalà M, Colletti V, Sacchetto L, Manganotti P, Ramat S, Marcocci A, Colletti L. Effect of Bluetooth headset and mobile phone electromagnetic fields on the human auditory nerve. Laryngoscope. 2013 Apr 25. doi: 10.1002/lary.24103. [Epub ahead of print]**

OBJECTIVES/HYPOTHESIS: The possibility that long-term mobile phone use increases the incidence of astrocytoma, glioma and acoustic neuroma has been investigated in several studies. Recently, our group showed that direct exposure (in a surgical setting) to

cell phone electromagnetic fields (EMFs) induces deterioration of auditory evoked cochlear nerve compound action potential (CNAP) in humans. To verify whether the use of Bluetooth devices reduces these effects, we conducted the present study with the same experimental protocol. STUDY DESIGN: Randomized trial. METHODS: Twelve patients underwent retrosigmoid vestibular neurectomy to treat definite unilateral Ménière's disease while being monitored with acoustically evoked CNAPs to assess direct mobile phone exposure or alternatively the EMF effects of Bluetooth headsets. RESULTS: We found no short-term effects of Bluetooth EMFs on the auditory nervous structures, whereas direct mobile phone EMF exposure confirmed a significant decrease in CNAPs amplitude and an increase in latency in all subjects. CONCLUSIONS: The outcomes of the present study show that, contrary to the finding that the latency and amplitude of CNAPs are very sensitive to EMFs produced by the tested mobile phone, the EMFs produced by a common Bluetooth device do not induce any significant change in cochlear nerve activity. The conditions of exposure, therefore, differ from those of everyday life, in which various biological tissues may reduce the EMF affecting the cochlear nerve. Nevertheless, these novel findings may have important safety implications.

**Mann, K, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on human sleep. Neuropsychobiology 33(1):41-47, 1996.**

In the present study we investigated the influence of pulsed high-frequency electromagnetic fields of digital mobile radio telephones on sleep in healthy humans. Besides a hypnotic effect with shortening of sleep onset latency, a REM suppressive effect with reduction of duration and percentage of REM sleep was found. Moreover, spectral analysis revealed qualitative alterations of the EEG signal during REM sleep with an increased spectral power density. Knowing the relevance of REM sleep for adequate information processing in the brain, especially concerning mnestic functions and learning processes, the results emphasize the necessity to carry out further investigations on the interaction of this type of electromagnetic fields and the human organism.

**Mann, K, Roschke, J, Connemann, B, Beta, H, No effects of pulsed high-frequency electromagnetic fields on heart rate variability during human sleep. Neuropsychobiology;38(4):251-256, 1998.**

The influence of pulsed high-frequency electromagnetic fields emitted by digital mobile radio telephones on heart rate during sleep in healthy humans was investigated. Beside mean RR interval and total variability of RR intervals based on calculation of the standard deviation, heart rate variability was assessed in the frequency domain by spectral power analysis providing information about the balance between the two branches of the autonomic nervous system. For most parameters, significant differences between different sleep stages were found. In particular, slow-wave sleep was characterized by a low ratio of low- and high-frequency components, indicating a predominance of the parasympathetic over the sympathetic tone. In contrast, during REM sleep the autonomic balance was shifted in favor of the sympathetic activity. For all heart rate parameters, no significant effects were detected under exposure to the field compared to placebo condition. Thus, under the given experimental conditions, autonomic control of heart rate was not affected by weak-pulsed high-frequency electromagnetic fields.

**Mann, K, Wagner, P, Brunn, G, Hassan, F, Hiemke, C, Roschke, J, Effects of pulsed high-frequency electromagnetic fields on the neuroendocrine system. Neuroendocrinology 67(2):139-144, 1998.**

The influence of pulsed high-frequency electromagnetic fields emitted from a circularly polarized antenna on the neuroendocrine system in healthy humans was investigated (900 MHz electromagnetic field, pulsed with 217 Hz, average power density 0.02 mW/cm2). Nocturnal hormone profiles of growth hormone (GH), cortisol, luteinizing hormone (LH) and melatonin were determined under polysomnographic control. An alteration in the hypothalamo-pituitary-adrenal axis activity was found with a slight, transient elevation in the cortisol serum level immediately after onset of field exposure which persisted for 1 h. For GH, LH and melatonin, no significant effects were found under exposure to the field compared to the placebo condition, regarding both total hormone production during the entire night and dynamic characteristics of the secretion pattern. Also the evaluation of the sleep EEG data revealed no significant alterations under field exposure, although there was a trend to an REM suppressive effect. The results indicate that weak high-frequency electromagnetic fields have no effects on nocturnal hormone secretion except for a slight elevation in cortisol production which is transient, pointing to an adaptation of the organism to the stimulus.

**Manta AK, Stravopodis DJ, Papassideri IS, Margaritis LH. Reactive oxygen species elevation and recovery in Drosophila bodies and ovaries following short-term and long-term exposure to DECT base EMF. Electromagn Biol Med. 2013 Jun 19. [Epub ahead of print]**

Abstract The objective of this study was to approach the basic mechanism(s) underlying reported ovarian apoptotic cell death and fecundity decrease induced by nonionizing radiation (NIR) in Drosophila melanogaster. ROS (Reactive Oxygen Species) levels were measured in the bodies and the ovaries of (sexually mature) 4-day-old flies, following exposure for 0.5, 1, 6, 24 and 96 h to a wireless DECT (Digital Enhanced Cordless Telephone) base radiation (1.88-1.90 GHz). Electrical field intensity was 2.7 V/m, measured within the fly vials and calculated SAR (Specific Absorption Rate) value = 0.009 W/Kg. Male and female bodies showed twofold increase in ROS levels ($p < 0.001$) after 6 h of exposure, slightly increasing with more irradiation (24 and 96 h). Ovaries of exposed females had a quick response in ROS increase after 0.5 h (1.5-fold, $p < 0.001$), reaching 2.5-fold after 1 h with no elevation thereafter at 6, 24 and 96 h. ROS levels returned to normal, in the male and the female bodies 24 h after 6 h of exposure of the flies ($p < 0.05$) and in the ovaries 4 h after 1 h exposure of the females ($p < 0.05$). It is postulated that the pulsed (at 100 Hz rate and 0.08 ms duration) idle state of the DECT base radiation is capable of inducing free radical formation albeit the very low SAR, leading rapidly to accumulation of ROS in a level-saturation manner under continuous exposure, or in a recovery manner after interruption of radiation, possibly due to activation of the antioxidant machinery of the organism.

**Manta AK, Papadopoulou D, Polyzos AP, Fragopoulou AF, Skouroliakou AS, Thanos D, Stravopodis DJ, Margaritis LH. Mobile-phone Radiation-induced**

**Perturbation of Gene-expression Profiling, Redox Equilibrium and Sporadic-apoptosis Control in the Ovary of Drosophila melanogaster. Fly (Austin). 2016 Dec 14:0. [Epub ahead of print]**

BACKGROUND: The daily use by people of wireless communication devices has increased exponentially in the last decade, begetting concerns regarding its potential health hazards. METHODS: Drosophila melanogaster four days-old adult female flies were exposed for 30 min to radiation emitted by a commercial mobile phone at a SAR of 0.15 W/kg and a SAE of 270 J/kg. ROS levels and apoptotic follicles were assayed in parallel with a genome-wide microarrays analysis. RESULTS: ROS cellular contents were found to increase by 1.6 fold (x), immediately after the end of exposure, in follicles of pre-choriogenic stages (germarium - stage 10), while sporadically generated apoptotic follicles (germarium 2b and stages 7-9) presented with an averaged 2x upregulation in their sub-population mass, 4 h after fly's irradiation with mobile device. Microarray analysis revealed 168 genes being differentially expressed, 2 h post-exposure, in response to radiofrequency (RF) electromagnetic field-radiation exposure (≥1.25x, $P<0.05$) and associated with multiple and critical biological processes, such as basic metabolism and cellular subroutines related to stress response and apoptotic death. CONCLUSION: Exposure of adult flies to mobile-phone radiation for 30 min has an immediate impact on ROS production in animal's ovary, which seems to cause a global, systemic and non-targeted transcriptional reprogramming of gene expression, 2 h post-exposure, being finally followed by induction of apoptosis 4 h after the end of exposure. Conclusively, this unique type of pulsed radiation, mainly being derived from daily used mobile phones, seems capable of mobilizing critical cytopathic mechanisms, and altering fundamental genetic programs and networks in D. melanogaster.

**Manti L, Braselmann H, Calabrese ML, Massa R, Pugliese M, Scampoli P, Sicignano G, Grossi G. Effects of modulated microwave radiation at cellular telephone frequency (1.95 GHz) on X-ray-induced chromosome aberrations in human lymphocytes in vitro. Radiat Res. 169(5):575-583, 2008.**

The case for a DNA-damaging action produced by radiofrequency (RF) signals remains controversial despite extensive research. With the advent of the Universal Mobile Telecommunication System (UMTS) the number of RF-radiation-exposed individuals is likely to escalate. Since the epigenetic effects of RF radiation are poorly understood and since the potential modifications of repair efficiency after exposure to known cytotoxic agents such as ionizing radiation have been investigated infrequently thus far, we studied the influence of UMTS exposure on the yield of chromosome aberrations induced by X rays. Human peripheral blood lymphocytes were exposed in vitro to a UMTS signal (frequency carrier of 1.95 GHz) for 24 h at 0.5 and 2.0 W/kg specific absorption rate (SAR) using a previously characterized waveguide system. The frequency of chromosome aberrations was measured on metaphase spreads from cells given 4 Gy of X rays immediately before RF radiation or sham exposures by fluorescence in situ hybridization. Unirradiated controls were RF-radiation- or sham-exposed. No significant variations due to the UMTS exposure were found in the fraction of aberrant cells. However, the frequency of exchanges per cell was affected by the SAR, showing a small

but statistically significant increase of 0.11 exchange per cell compared to 0 W/kg SAR. We conclude that, although the 1.95 GHz signal (UMTS modulated) does not exacerbate the yield of aberrant cells caused by ionizing radiation, the overall burden of X-ray-induced chromosomal damage per cell in first-mitosis lymphocytes may be enhanced at 2.0 W/kg SAR. Hence the SAR may either influence the repair of X-ray-induced DNA breaks or alter the cell death pathways of the damage response.

**Marconi A, Tasteyre A, de Seze R, Fogel P, Simoneau G, Conti M, Sarbach C, Young SS, Gilbert J-E, Thomas Y. Multivariate Entropy Analysis of Oxidative Stress Biomarkers Following Mobile Phone Exposure of Human Volunteers: A Pilot StudyJournal Scientific Exploration. 29 (3): 449-465, 2015.**

A multidisciplinary project was conducted to study the possible biological impact of mobile phone emissions. As part of that project, we conducted a pilot study on 18 human volunteers, with the treatment being GSM mobile phone exposure. The volunteers were randomized and the study was a double-blind, crossover design. Two categories of oxidative stress biomarkers were followed and measured in blood and exhaled air: those assessing oxidative attacks of cell membrane lipids (malondialdehyde, exhaled alkanes, aldehydes, and isoprene) and those accounting for the organism's antioxidant defense systems (superoxyde dismutase, glutathion Peroxydase, and exhaled halogenated alkanes).The overall entropy of the system with and without GSM exposure was then calculated for each volunteer, using a statistical approach based on the global entropie difference of raw data. A significant modulation of organization of the biomarkers after 30 minutes of mobile phone exposure was found, as evidenced by a decreased entropy of the dataset associated to the emitting mobile phone condition. While these results illustrate neither deleterious effects nor the innocuity of mobile phone use, they nonetheless constitute evidence of actual interactions of these wavelengths with complex biological systems. These results will need to be confirmed in larger, future studies.

**Margaritis LH, Manta AK, Kokkaliaris CD, Schiza D, Alimisis K, Barkas G, Georgiou E, Giannakopoulou O, Kollia I, Kontogianni G, Kourouzidou A, Myari A, Roumelioti F, Skouroliakou A, Sykioti V, Varda G, Xenos K, Ziomas K. Drosophila oogenesis as a bio-marker responding to EMF sources. Electromagn Biol Med. 2013 Aug 5. [Epub ahead of print]**

The model biological organisms Drosophila melanogaster and Drosophila virilis have been utilized to assess effects on apoptotic cell death of follicles during oogenesis and reproductive capacity (fecundity) decline. A total of 280 different experiments were performed using newly emerged flies exposed for short time daily for 3-7 d to various EMF sources including: GSM 900/1800 MHz mobile phone, 1880-1900 MHz DECT wireless base, DECT wireless handset, mobile phone-DECT handset combination, 2.44 GHz wireless network (Wi-Fi), 2.44 GHz blue tooth, 92.8 MHz FM generator, 27.15 MHz baby monitor, 900 MHz CW RF generator and microwave oven's 2.44 GHz RF and magnetic field components. Mobile phone was used as a reference exposure system for evaluating factors considered very important in dosimetry extending our published work with D. melanogaster to the insect D. virilis.

Distance from the emitting source, the exposure duration and the repeatability were examined. All EMF sources used created statistically significant effects regarding fecundity and cell death-apoptosis induction, even at very low intensity levels (0.3 V/m blue tooth radiation), well below ICNIRP's guidelines, suggesting that Drosophila oogenesis system is suitable to be used as a biomarker for exploring potential EMF bioactivity. Also, there is no linear cumulative effect when increasing the duration of exposure or using one EMF source after the other (i.e. mobile phone and DECT handset) at the specific conditions used. The role of the average versus the peak E-field values as measured by spectrum analyzers on the final effects is discussed.

**Marinelli F, La Sala D, Cicciotti G, Cattini L, Trimarchi C, Putti S, Zamparelli A, Giuliani L, Tomassetti G, Cinti C. Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukemia CCRF-CEM cells. J Cell Physiol. 198(2):324-332, 2004.**

It has been recently established that low-frequency electromagnetic field (EMFs) exposure induces biological changes and could be associated with increased incidence of cancer, while the issue remains unresolved as to whether high-frequency EMFs can have hazardous effect on health. Epidemiological studies on association between childhood cancers, particularly leukemia and brain cancer, and exposure to low- and high-frequency EMF suggested an etiological role of EMFs in inducing adverse health effects. To investigate whether exposure to high-frequency EMFs could affect in vitro cell survival, we cultured acute T-lymphoblastoid leukemia cells (CCRF-CEM) in the presence of unmodulated 900 MHz EMF, generated by a transverse electromagnetic (TEM) cell, at various exposure times. We evaluated the effects of high-frequency EMF on cell growth rate and apoptosis induction, by cell viability (MTT) test, FACS analysis and DNA ladder, and we investigated pro-apoptotic and pro-survival signaling pathways possibly involved as a function of exposure time by Western blot analysis. At short exposure times (2-12 h), unmodulated 900 MHz EMF induced DNA breaks and early activation of both p53-dependent and -independent apoptotic pathways while longer continuous exposure (24-48 h) determined silencing of pro-apoptotic signals and activation of genes involved in both intracellular (Bcl-2) and extracellular (Ras and Akt1) pro-survival signaling. Overall our results indicate that exposure to 900 MHz continuous wave, after inducing an early self-defense response triggered by DNA damage, could confer to the survivor CCRF-CEM cells a further advantage to survive and proliferate.

**Marino AA, Nilsen E, Frilot C. Nonlinear changes in brain electrical activity due to cell phone radiation. Bioelectromagnetics 24(5):339-346, 2003.**

We studied the effect of an electromagnetic field from a cellular telephone on brain electrical activity, using a novel analytical method based on a nonlinear model. The electroencephalogram (EEG) from rabbits was embedded in phase space and local recurrence plots were calculated and quantified using recurrence quantitation analysis to permit statistical comparisons between filtered segments of exposed and control epochs from individual rabbits. When the rabbits were exposed to the radiation from a standard cellular telephone (800 MHz band, 600 mW maximum radiated power) under conditions that simulated normal human use, the EEG was significantly affected in nine of ten

animals studied. The effect occurred beginning about 100 ms after initiation of application of the field and lasted approximately 300 ms. In each case, the fields increased the randomness in the EEG. A control procedure ruled out the possibility that the observations were a product of the method of analysis. No differences were found between exposed and control epochs in any animal when the experiment was repeated after the rabbits had been sacrificed, indicating that absorption of radiation by the EEG electrodes could not account for the observed effect. No effect was seen when deposition of energy in the brain was minimized by repositioning the radiating antenna from the head to the chest, showing that the type of tissue that absorbed the energy determined the observed changes in the EEG. We conclude that, in normal use, the fields from a standard cellular telephone can alter brain function as a consequence of absorption of energy by the brain.

**Marino AA, Carrubba S. The effects of mobile-phone electromagnetic fields on brain electrical activity: a critical analysis of the literature. Electromagn Biol Med. 28(3):250-274, 2009.**

We analyzed the reports in which human brain electrical activity was compared between the presence and absence of radio-frequency and low-frequency electromagnetic fields (EMFs) from mobile phones, or between pre- and post-exposure to the EMFs. Of 55 reports, 37 claimed and 18 denied an EMF-induced effect on either the baseline electro encephalogram (EEG), or on cognitive processing of visual or auditory stimuli as reflected in changes in event-related potentials. The positive reports did not adequately consider the family-wise error rate, the presence of spike artifacts in the EEG, or the confounding role of the two different EMFs. The negative reports contained neither positive controls nor power analyses. Almost all reports were based on the incorrect assumption that the brain was in equilibrium with its surroundings. Overall, the doubt regarding the existence of reproducible mobile-phone EMFs on brain activity created by the reports appeared to legitimate the knowledge claims of the mobile-phone industry. However, it funded, partly or wholly, at least 87% of the reports. From an analysis of their cognitive framework, the common use of disclaimers, the absence of information concerning conflicts of interest, and the industry's donations to the principal EMF journal, we inferred that the doubt was manufactured by the industry. The crucial scientific question of the pathophysiology of mobile-phone EMFs as reflected in measurements of brain electrical activity remains unanswered, and essentially unaddressed.

**Marino C, Cristalli G, Galloni P, Pasqualetti P, Piscitelli M, Lovisolo GA , Effects of microwaves (900 MHz) on the cochlear receptor: exposure systems and preliminary results. Radiat Environ Biophys 39(2):131-136, 2000.**

The purpose of this paper is to present the experimental device and the work in progress performed in search for objective organic correlation of damage to hearing, examining possible acoustic otofunctional effects on the cochlear epithelium of the rat due to exposure to microwaves (900 MHz). Two experiments using male Sprague-Dawley rats were carried out with a far-field exposure in a cubic chamber. No statistically significant evidence was obtained at both specific absorption rate (SAR) values. The exposure system and the diagnostic apparatus are extremely useful to investigate a potential effect

on the auditory system: however, with the parameters applied in these experiments, no evidence was observed.

**Marjanović AM, Pavičić I, Trošić IBiological indicators in response to radiofrequency/microwave exposure. Arh Hig Rada Toksikol. 2012 Sep 25;63(3):407-416, 2012.**

Over the years, due to rapid technological progress, radiation from man-made sources exceeded that of natural origin. There is a general concern regarding a growing number of appliances that use radiofrequency/ microwave (RF/MW) radiation with particular emphasis on mobile communication systems. Since nonthermal biological effects and mechanisms of RF/MW radiation are still uncertain, laboratory studies on animal models, tissues, cells, and cell free system are of extraordinary importance in bioelectromagnetic research. We believe that such investigations play a supporting role in public risk assessment. Cellular systems with the potential for a clear response to RF/MW exposures should be used in those studies. It is known that organism is a complex electrochemical system where processes of oxidation and reduction regularly occur. One of the plausible mechanisms is connected with generation of reactive oxygen species (ROS). Depending on concentration, ROS can have both benefi cial and deleterious effects. Positive effects are connected with cell signalling, defence against infectious agents, and proliferative cell ability. On the other hand, excessive production, which overloads antioxidant defence mechanism, leads to cellular damage with serious potential for disease development. ROS concentration increase within the cell caused by RF/MW radiation seems to be a biologically relevant hypothesis to give clear insight into the RF/MW action at non-thermal level of radiation. In order to better understand the exact mechanism of action and its consequences, further research is needed in the fi eld. We would like to present current knowledge on possible biological mechanisms of RF/MW actions.

**Marjanovic AM, Pavicic I, Trosic I. Cell oxidation-reduction imbalance after modulated radiofrequency radiation. Electromagn Biol Med. 2015 Aug 28:1-6. [Epub ahead of print]**

Aim of this study was to evaluate an influence of modulated radiofrequency field (RF) of 1800 MHz, strength of 30 V/m on oxidation-reduction processes within the cell. The assigned RF field was generated within Gigahertz Transversal Electromagnetic Mode cell equipped by signal generator, modulator, and amplifier. Cell line V79, was irradiated for 10, 30, and 60 min, specific absorption rate was calculated to be 1.6 W/kg. Cell metabolic activity and viability was determined by MTT assay. In order to define total protein content, colorimetric method was used. Concentration of oxidised proteins was evaluated by enzyme-linked immunosorbent assay. Reactive oxygen species (ROS) marked with fluorescent probe 2',7'-dichlorofluorescin diacetate were measured by means of plate reader device. In comparison with control cell samples, metabolic activity and total protein content in exposed cells did not differ significantly. Concentrations of carbonyl derivates, a product of protein oxidation, insignificantly but continuously increase with duration of exposure. In exposed samples, ROS level significantly ($p < 0.05$) increased after 10 min of exposure. Decrease in ROS level was observed after 30-min treatment indicating

antioxidant defence mechanism activation. In conclusion, under the given laboratory conditions, modulated RF radiation might cause impairment in cell oxidation-reduction equilibrium within the growing cells.

**Marjanovic Cermak AM, Pavicic I, Tariba Lovakovic B, Pizent A, Trosic I. In vitro non-thermal oxidative stress response after 1800 MHz radiofrequency radiation. Gen Physiol Biophys. 2017 Aug 24. doi: 10.4149/gpb_2017007. [Epub ahead of print]**

In this study possible connection between radiofrequency exposure (RF) and development of oxidative stress was investigated by measuring impairment in cellular oxidation-reduction balance immediately after RF exposure. Fibroblast cells V79 were exposed for 10, 30 and 60 minutes to 1800 MHz RF radiation. Electric field strength was 30 V/m and specific absorption rate (SAR) was calculated to be 1.6 W/kg. Electromagnetic field was generated within Gigahertz Transversal Electromagnetic Mode cell (GTEM) equipped by signal generator, amplifier and modulator. Cell viability was determined by CCK-8 colorimetric assay and level of reactive oxygen species (ROS) was detected by dihydroethidium staining. Reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) were used to assess cell antioxidant activity while lipid oxidative damage was evaluated measuring concentration of malondialdehyde. Viability of V79 cells remained within normal physiological values regardless of exposure time. Increased level of superoxide radicals was detected after 60-min exposure. Significantly higher GSH level was observed immediately after 10-min exposure with higher but insignificant activity of GSH-Px. Lipid oxidative damage in exposed cell samples was not observed. Short-term RF exposure revealed transient oxidation-reduction imbalance in fibroblast cells following adaptation to applied experimental conditions.

**Markakis I, Samaras T. Radiofrequency exposure in greek indoor environments. Health Phys. 104(3):293-301, 2013.**

This is the first measurement campaign that takes place in Greece in order to assess the exposure levels in different microenvironments (offices, bedrooms, living rooms, schools). Due to the exponential growth in the use of wireless network devices, the aim of this work was to perform indoor measurements with the use of personal dosimeters. The measurement period was 3 d in each of the 40 different locations that were selected, both in the urban and suburban area of Thessaloniki, the second largest city of Greece. The measurements took place from 23 July 2010 to 19 January 2012. After processing the obtained data with the robust regression on order statistics (ROS) method, various statistical exposure quantities were calculated. Compared to similar measurement campaigns across Europe, a larger proportion of measurement data above the detection limit for specific frequency bands (at most 56% for the DCS Rx frequency band) was found. Furthermore, mean exposure levels in the mobile downlink frequency bands were higher than those in other studies (GSM Rx: 0.259 V m, DCS Rx: 0.131 V m, UMTS Rx: 0.12 V m), yet many times below the ICNIRP guidelines. On the other hand, maximum exposures were found to be of the same magnitude (GSM Rx: 0.38 V m, DCS Rx: 0.3 V

m, UMTS Rx: 0.28 V m). These measurement results indicate that signals from mobile base stations are dominant in workplaces and schools, whereas wireless phones and computer networks play the leading role in home environments. While the former reach their maximum values during daytime, the latter have an observable increase in the evening after work hours.

**Markkanen A, Penttinen P, Naarala J, Pelkonen J, Sihvonen A-P, Juutilainen J.Apoptosis induced by ultraviolet radiation is enhanced by amplitude modulated radiofrequency radiation in mutant yeast cells Bioelectromagnetics 25:127-133, 2004**.

The aim of this study was to investigate whether radiofrequency (RF) electromagnetic field (EMF) exposure affects cell death processes of yeast cells. Saccharomyces cerevisiae yeast cells of the strains KFy417 (wild-type) and KFy437 (cdc48-mutant) were exposed to 900 or 872 MHz RF fields, with or without exposure to ultraviolet (UV) radiation, and incubated simultaneously with elevated temperature (+37°C) to induce apoptosis in the cdc48-mutated strain. The RF exposure was carried out in a special waveguide exposure chamber where the temperature of the cell cultures can be precisely controlled. Apoptosis was analyzed using the annexin V-FITC method utilizing flow cytometry. Amplitude modulated (217 pulses per second) RF exposure significantly enhanced UV induced apoptosis in cdc48-mutated cells, but no effect was observed in cells exposed to unmodulated fields at identical time-average specfic absorption rates (SAR, 0.4 or 3.0 W/kg). The findings suggest that amplitude modulated RF fields, together with known damaging agents, can affect the cell death process in mutated yeast cells.

**Markova E, Hillert L, Malmgren L, Persson BR, Belyaev IY. Microwaves from GSM Mobile Telephones Affect 53BP1 and gamma-H2AX Foci in Human Lymphocytes from Hypersensitive and Healthy Persons. Environ Health Perspect. 113(9):1172-1177, 2005.**

The data on biologic effects of nonthermal microwaves (MWs) from mobile telephones are diverse, and these effects are presently ignored by safety standards of the International Commission for Non-Ionizing Radiation Protection (ICNIRP). In the present study, we investigated effects of MWs of Global System for Mobile Communication (GSM) at different carrier frequencies on human lymphocytes from healthy persons and from persons reporting hypersensitivity to electromagnetic fields (EMFs). We measured the changes in chromatin conformation, which are indicative of stress response and genotoxic effects, by the method of anomalous viscosity time dependence, and we analyzed tumor suppressor p53-binding protein 1 (53BP1) and phosphorylated histone H2AX (gamma-H2AX), which have been shown to colocalize in distinct foci with DNA double-strand breaks (DSBs), using immunofluorescence confocal laser microscopy. We found that MWs from GSM mobile telephones affect chromatin conformation and 53BP1/gamma-H2AX foci similar to heat shock. For the first time, we report here that effects of MWs from mobile telephones on human lymphocytes are dependent on carrier frequency. On average, the same response was observed in lymphocytes from hypersensitive and healthy subjects. Key words: 53BP1 and gamma-H2AX foci, chromatin, DNA double-strand breaks, hypersensitivity to electromagnetic fields, stress

response.

**Marjanovic Cermak AM, Pavicic I, Trosic I. Oxidative stress response in SH-SY5Y cells exposed to short-term 1800 MHz radiofrequency radiation. J Environ Sci Health A Tox Hazard Subst Environ Eng. 2017 Nov 17:1-7. doi: 10.1080/10934529.2017.1383124.**

The exact mechanism that could explain the effects of radiofrequency (RF) radiation exposure at non-thermal level is still unknown. Increasing evidence suggests a possible involvement of reactive oxygen species (ROS) and development of oxidative stress. To test the proposed hypothesis, human neuroblastoma cells (SH-SY5Y) were exposed to 1800 MHz short-term RF exposure for 10, 30 and 60 minutes. Electric field strength within Gigahertz Transverse Electromagnetic cell (GTEM) was 30 V m-1 and specific absorption rate (SAR) was calculated to be 1.6 W kg-1. Cellular viability was measured by MTT assay and level of ROS was determined by fluorescent probe 2',7'-dichlorofluorescin diacetate. Concentrations of malondialdehyde and protein carbonyls were used to assess lipid and protein oxidative damage and antioxidant activity was evaluated by measuring concentrations of total glutathione (GSH). After radiation exposure, viability of irradiated cells remained within normal physiological values. Significantly higher ROS level was observed for every radiation exposure time. After 60 min of exposure, the applied radiation caused significant lipid and protein damage. The highest GSH concentration was detected after 10 minute-exposure. The results of our study showed enhanced susceptibility of SH-SY5Y cells for development of oxidative stress even after short-term RF exposure.

**Masuda H, Hirota S, Ushiyama A, Hirata A, Arima T, Watanabe H, Wake K, Watanabe S, Taki M, Nagai A, Ohkubo C. No Changes in Cerebral Microcirculatory Parameters in Rat During Local Cortex Exposure to Microwaves. In Vivo. 29(2):207-215, 2015.**

The aim of this study was to determine whether cerebral microcirculatory parameters in rats were modified during local cortex exposure to a radiofrequency electromagnetic field (RF) under non-thermal conditions. The cortex tissue targeted was locally exposed to 1439 MHz RF using a figure-8 loop antenna at an averaged specific absorption rate of 2.0 W/kg in the target area for 50 min. Three microcirculatory parameters related to cerebral inflammation were measured by the cranial window method in real-time under RF exposure. No extravasation of intravenously injected fluorescent dye was observed during RF exposure. There was no significant difference either in pial venule blood flow velocity or diameter between exposed and sham-exposed rats. Histological evaluation for the brain immediately after RF exposure did not reveal any serum albumin leakage sites or degenerate neurons. These findings suggest that no dynamic changes occurred in cerebral microcirculation even during local cortex exposure under these conditions.

**Martens AL, Slottje P, Timmermans DRM, Kromhout H, Reedijk M, Vermeulen RCH, Smid T. Modeled and Perceived Exposure to Radiofrequency Electromagnetic**

**Fields From Mobile-Phone Base Stations and the Development of Symptoms Over Time in a General Population Cohort. Am J Epidemiol. 186(2):210-219, 2017.**

We assessed associations between modeled and perceived exposure to radiofrequency electromagnetic fields (RF-EMF) from mobile-phone base stations and the development of nonspecific symptoms and sleep disturbances over time. A population-based Dutch cohort study, the Occupational and Environmental Health Cohort Study (AMIGO) (n = 14,829; ages 31-65 years), was established in 2011/2012 (T0), with follow-up of a subgroup (n = 3,992 invited) in 2013 (T1; n = 2,228) and 2014 (T2; n = 1,740). We modeled far-field RF-EMF exposure from mobile-phone base stations at the home addresses of the participants using a 3-dimensional geospatial model (NISMap). Perceived exposure (0 = not at all; 6 = very much), nonspecific symptoms, and sleep disturbances were assessed by questionnaire. We performed cross-sectional and longitudinal analyses, including fixed-effects regression. We found small correlations between modeled and perceived exposure in AMIGO participants at baseline (n = 14,309; rSpearman = 0.10). For 222 follow-up participants, modeled exposure increased substantially (>0.030 mW/m2) between T0 and T1. This increase in modeled exposure was associated with an increase in perceived exposure during the same time period. In contrast to modeled RF-EMF exposure from mobile-phone base stations, perceived exposure was associated with higher symptom reporting scores in both cross-sectional and longitudinal analyses, as well as with sleep disturbances in cross-sectional analyses.

**Martinez-Burdalo M, Martin A, Anguiano M, Villar R. Comparison of FDTD-calculated specific absorption rate in adults and children when using a mobile phone at 900 and 1800 MHz. Phys Med Biol. 49(2):345-354, 2004.**

In this paper, the specific absorption rate (SAR) in scaled human head models is analysed to study possible differences between SAR in the heads of adults and children and for assessment of compliance with the international safety guidelines, while using a mobile phone. The finite-difference time-domain method (FDTD) has been used for calculating SAR values for models of both children and adults, at 900 and 1800 MHz. Maximum 1 g averaged SAR (SAR1 g) and maximum 10 g averaged SAR (SAR10 g) have been calculated in adults and scaled head models for comparison and assessment of compliance with ANSI/IEEE and European guidelines. Results show that peak SAR1 g and peak SAR10 g all trend downwards with decreasing head size but as head size decreases, the percentage of energy absorbed in the brain increases. So, higher SAR in children's brains can be expected depending on whether the thickness of their skulls and surrounding tissues actually depends on age. The SAR in eyes of different sizes, as a critical organ, has also been studied and very similar distributions for the full size and the scaled models have been obtained. Standard limits can only be exceeded in the unpractical situation where the antenna is located at a very short distance in front of the eye.

**Martinez-Burdalo M, Martin A, Anguiano M, Villar R. On the safety assessment of human exposure in the proximity of cellular communications base-station**

**antennas at 900, 1800 and 2170 MHz. Phys Med Biol. 50(17):4125-4137, 2005.**

In this work, the procedures for safety assessment in the close proximity of cellular communications base-station antennas at three different frequencies (900, 1800 and 2170 MHz) are analysed. For each operating frequency, we have obtained and compared the distances to the antenna from the exposure places where electromagnetic fields are below reference levels and the distances where the specific absorption rate (SAR) values in an exposed person are below the basic restrictions, according to the European safety guidelines. A high-resolution human body model has been located, in front of each base-station antenna as a worst case, at different distances, to compute whole body averaged SAR and maximum 10 g averaged SAR inside the exposed body. The finite-difference time-domain method has been used for both electromagnetic fields and SAR calculations. This paper shows that, for antenna-body distances in the near zone of the antenna, the fact that averaged field values be below the reference levels could, at certain frequencies, not guarantee guidelines compliance based on basic restrictions.

**Marzook EA, Abd El Moneim AE, Elhadary AA. Prootective role of seame oil against mobile phone base station-induced oxidative stress. J Rad Res Appl Sci 7(1):1-6, 2014.**

The present study was undertaken to shed the light on the environmental threats associated with the wireless revolution and the health hazards associated with exposure to mobile base station (MBS). Besides, studying the possible protective role of sesame oil (SO) as an antioxidant against oxidative stress. Therefore, the present work was designed to study the effect of chronic exposure to electromagnetic radiations (EMR), produced by a cellular tower for mobile phone and the possible protective role of sesame oil on glutathione reductase (GSH-Rx), superoxide dismutase (SOD), catalase (CAT), total testosterone and lipid profile (total cholesterol (Tch), triglycerides (TG), low density lipoprotein cholesterol (LDL-c) and high density lipoprotein cholesterol (HDL-c) in male albino rats. Rats were arranged into four groups: the control unexposed, the exposed untreated and the exposed treated groups (1.5 and 3 ml oil). Exposed groups were subjected to electromagnetic field at frequency of 900 MHz, for 24 h/day for 8 weeks, at the same time both treated groups were supplied with oral injection of sesame oil three times per week. At the end of the experiment, blood samples were obtained for determination of the above mentioned variables in serum. The results obtained revealed that TG and testosterone were raised significantly over control in all groups and the significant increase in oil groups occurred in dose dependent manner. SOD and CAT activities were reduced significantly in exposed rats than control and increased significantly in sesame oil groups as the dose of oil increased. Total cholesterol only showed remarkable reduction in the group treated with 3 ml sesame oil. Also, in this latter group, significant elevation of GSH-Rx was recorded. Changes in serum HDL-c and LDL-c followed an opposite trend in exposed and sesame oil groups reflecting their affectation by EMR or sesame oil. In conclusion, all results of the current study proved that sesame oil can be used as an edible oil to attenuate the oxidative stress which could be yielded as a result of chronic exposure to EMR.

**Mashevich M, Folkman D, Kesar A, Barbul A, Korenstein R, Jerby E, Avivi**

**L,Exposure of human peripheral blood lymphocytes to electromagnetic fields associated with cellular phones leads to chromosomal instability. Bioelectromagnetics 24:82-90, 2003.**

Whether exposure to radiation emitted from cellular phones poses a health hazard is at the focus of current debate. We have examined whether in vitro exposure of human peripheral blood lymphocytes (PBL) to continuous 830 MHz electromagnetic fields causes losses and gains of chromosomes (aneuploidy), a major "somatic mutation" leading to genomic instability and thereby to cancer. PBL were irradiated at different average absorption rates (SAR) in the range of 1.6-8.8 W/kg for 72 hr in an exposure system based on a parallel plate resonator at temperatures ranging from 34.5-37.5 °C. The averaged SAR and its distribution in the exposed tissue culture flask were determined by combining measurements and numerical analysis based on a finite element simulation code. A linear increase in chromosome 17 aneuploidy was observed as a function of the SAR value, demonstrating that this radiation has a genotoxic effect. The SAR dependent aneuploidy was accompanied by an abnormal mode of replication of the chromosome 17 region engaged in segregation (repetitive DNA arrays associated with the centromere), suggesting that epigenetic alterations are involved in the SAR dependent genetic toxicity. Control experiments (i.e., without any RF radiation) carried out in the temperature range of 34.5-38.5 °C showed that elevated temperature is not associated with either the genetic or epigenetic alterations observed following RF radiation - the increased levels of aneuploidy and the modification in replication of the centromeric DNA arrays. These findings indicate that the genotoxic effect of the electromagnetic radiation is elicited via a non-thermal pathway. Moreover, the fact that aneuploidy is a phenomenon known to increase the risk for cancer, should be taken into consideration in future evaluation of exposure guidelines.

**Maskarinec G, Cooper J, Swygert L. Investigation of increased incidence in childhood leukemia near radio towers in Hawaii: preliminary observations. J Environ Pathol Toxicol Oncol. 13(1):33-37, 1994.**

Twelve children from the Waianae Coast, Hawaii, were diagnosed with acute leukemia from 1979 to 1990. The standardized incidence ratio (SIR) of 2.09 (95% confidence interval (CI) 1.08 to 3.65) indicates a significant increase. Seven cases occurred between 1982 and 1984 and were unusual in terms of sex, age, and type of leukemia. A case-control study (12 cases, 48 matched controls) explored risk factors, including parents' occupation, X-ray exposure, domestic smoking, family and medical histories, and distance of children's residence locations to low frequency radio towers. The odds ratio (OR) for having lived within 2.6 miles of the radio towers before diagnosis was 2.0 (95% CI 0.06 to 8.3). The clustering may have been a chance event, but because of its peculiar characteristics, we feel it should be noted.

**Maskey D, Kim M, Aryal B, Pradhan J, Choi IY, Park KS, Son T, Hong SY, Kim SB, Kim HG, Kim MJ. Effect of 835 MHz radiofrequency radiation exposure on calcium binding proteins in the hippocampus of the mouse brain. Brain Res.1313:232-241, 2010.**

Worldwide expansion of mobile phones and electromagnetic field (EMF) exposure

has raised question of their possible biological effects on the brain and nervous system. Radiofrequency (RF) radiation might alter intracellular signaling pathways through changes in calcium (Ca(2+)) permeability across cell membranes. Changes in the expression of calcium binding proteins (CaBP) like calbindin D28-k (CB) and calretinin (CR) could indicate impaired Ca(2+)homeostasis due to EMF exposure. CB and CR expression were measured with immunohistochemistry in the hippocampus of mice after EMF exposure at 835 MHz for different exposure times and absorption rates, 1 h/day for 5 days at a specific absorption rate (SAR)=1.6 W/kg, 1 h/day for 5 days at SAR=4.0 W/kg, 5 h/day for 1 day at SAR=1.6 W/kg, 5 h/day for 1 day at SAR=4.0 W/kg, daily exposure for 1 month at SAR=1.6 W/kg. Body weights did not change significantly. CB immunoreactivity (IR) displayed moderate staining of cells in the cornu ammonis (CA) areas and prominently stained granule cells. CR IR revealed prominently stained pyramidal cells with dendrites running perpendicularly in the CA area. Exposure for 1 month produced almost complete loss of pyramidal cells in the CA1 area. CaBP differences could cause changes in cellular Ca(2+)levels, which could have deleterious effect on normal hippocampal functions concerned with neuronal connectivity and integration..

**Maskey D, Pradhan J, Aryal B, Lee CM, Choi IY, Park KS, Kim SB, Kim HG, Kim MJ. Chronic 835 MHz radiofrequency exposure to mice hippocampus alters the distribution of calbindin and GFAP immunoreactivity. Brain Res 1346:237-246, 2010.**

Exponential interindividual handling in wireless communication system has raised possible doubts in the biological aspects of radiofrequency (RF) exposure on human brain owing to its close proximity to the mobile phone. In the nervous system, calcium (Ca(2+)) plays a critical role in releasing neurotransmitters, generating action potential and membrane integrity. Alterations in intracellular Ca(2+) concentration trigger aberrant synaptic action or cause neuronal apoptosis, which may exert an influence on the cellular pathology for learning and memory in the hippocampus. Calcium binding proteins like calbindin D28-K (CB) is responsible for the maintaining and controlling Ca(2+) homeostasis. Therefore, in the present study, we investigated the effect of RF exposure on rat hippocampus at 835MHz with low energy (Specific Absorption Rate: SAR=1.6W/kg) for 3months by using both CB and glial fibrillary acidic protein (GFAP) specific antibodies by immunohistochemical method. Decrease in CB immunoreactivity (IR) was noted in exposed (E1.6) group with loss of interneurons and pyramidal cells in CA1 area and loss of granule cells. Also, an overall increase in GFAP IR was observed in the hippocampus of E1.6. By TUNEL assay, apoptotic cells were detected in the CA1, CA3 areas and dentate gyrus of hippocampus, which reflects that chronic RF exposure may affect the cell viability. Additionally, the increase of GFAP IR due to RF exposure could be well suited with the feature of reactive astrocytosis, which is an abnormal increase in the number of astrocytes due to the loss of nearby neurons. Chronic RF exposure to the rat brain suggested that the decrease of CB IR accompanying apoptosis and increase of GFAP IR might be morphological parameters in the hippocampus damages.

**Maskey D, Kim HJ, Kim HG, Kim MJ. Calcium-binding proteins and GFAP immunoreactivity alterations in murine hippocampus after 1 month of exposure to**

**835MHz radiofrequency at SAR values of 1.6 and 4.0W/kg. Neurosci Lett. 506(2):292-296, 2012.**

Abstract. Widespread use of wireless mobile communication has raised concerns of adverse effect to the brain owing to the proximity during use due to the electromagnetic field emitted by mobile phones. Changes in calcium ion concentrations via binding proteins can disturb calcium homeostasis; however, the correlation between calcium-binding protein (CaBP) immunoreactivity (IR) and glial cells has not been determined with different SAR values. Different SAR values [1.6 (E1.6 group) and 4.0 (E4 group) W/kg] were applied to determine the distribution of calbindin D28-k (CB), calretinin (CR), and glial fibrillary acidic protein (GFAP) IR in murine hippocampus. Compared with sham control group, decreased CB and CR IRs, loss of CB and CR immunoreactive cells and increased GFAP IR exhibiting hypertrophic cytoplasmic processes were noted in both experimental groups. E4 group showed a prominent decrement in CB and CR IR than the E1.6 group due to down-regulation of CaBP proteins and neuronal loss. GFAP IR was more prominent in the E4 group than the E1.6 group. Decrement in the CaBPs can affect the calcium-buffering capacity leading to cell death, while increased GFAP IR and changes in astrocyte morphology, may mediate brain injury due to radiofrequency exposure.

**Maskey D, Kim MJ. Immunohistochemical Localization of Brain-derived Neurotrophic Factor and Glial Cell Line-derived Neurotrophic Factor in the Superior Olivary Complex of Mice after Radiofrequency Exposure. Neuroscience Letters. 564:78-82, 2014.**

Raising health concerns about the biological effects from radiofrequency exposure, even with conflicting results, has prompted calls for formulation of a guideline of the biological safety level. Given the close proximity between a mobile phone and the ear, it has been suggested that the central auditory system may be detrimentally influenced by radiofrequency exposure. In the auditory system, neurotrophins are important in the regulation of neuron survival, especially mammalian cochlear neurons. Neurotrophic factors like brain-derived neurotrophic factor (BDNF) and glial-derived neurotrophic factor (GDNF) present in the auditory system are responsible for the maintenance of auditory neurons. BDNF and GDNF may protect against acoustic trauma and prevent from hearing defect. The present study applied radiofrequency at a specific absorption rate (SAR) of 1.6 W/kg (E1.6) or 0 W/kg group to determine the distribution of BDNF and GDNF in the nuclei of superior olivary complex (SOC). In the E1.6 group, significant decrements of BDNF immunoreactivity (IR) were noted in the lateral superior olive, medial superior olive, superior paraolivary nucleus and medial nucleus of the trapezoid body. GDNF IR was also significantly decreased ($p < 0.001$) in all SOC nuclei of the E1.6 group. The decrease in the IR of these neurotrophic factors in the SOC of the E1.6 group suggests a detrimental effect of RF exposure in the auditory nuclei.

**Mason PA, Escarciga R, Doyle JM, Romano WF, Berger RE, Donnellan JP, Amino acid concentrations in hypothalamic and caudate nuclei during microwave-induced thermal stress: analysis by microdialysis. Bioelectromagnetics 18(3):277-283, 1997.**

Exposure to radiofrequency radiation (RFR) may produce thermal responses. Extracellular amino acid concentrations in the hypothalamus (Hyp) and caudate nucleus (CN) were measured by using in vivo microdialysis before and during exposure to RFR. Under urethane anesthetic, each rat was implanted stereotaxically with a nonmetallic microdialysis probe and temperature probe guides and then placed in the exposure chamber. The rat laid on its right side with its head and neck placed directly under the wave guide. Temperature probes were placed in the left brain, right brain, face (subcutaneously), left tympanum, and rectum. Each microdialysis sample was collected over a 20 min period. The microdialysis probe was perfused for 2 h before the rat was exposed to 5.02 GHz radiation (10 microseconds pulse width, 1000 pulses/s). The right and left sides of the brain were maintained at approximately 41.2 and 41.7 degrees C, respectively, throughout a 40 min exposure period. Initially when the brain was being heated to these temperatures, the time-averaged specific absorption rates (SARs) for the right and left sides of the brain were 29 and 40 W/kg, respectively. Concentrations of aspartic acid, glutamic acid, serine, glutamine, and glycine in dialysate were determined by using high-pressure liquid chromatography with electrochemical detection. In the Hyp and CN, the concentrations of aspartic acid, serine, and glycine increased significantly during RFR exposure ($P < .05$). These results indicate that RFR-induced thermal stress produces a general change in the amino acid concentrations that is not restricted to thermoregulatory centers. Changes in the concentrations of glutamic acid (Hyp, $P = .16$; CN, $P = .34$) and glutamine (Hyp, $P = .13$; CN, $P = .10$) were not statistically significant. Altered amino acid concentrations may reveal which brain regions are susceptible to damage in response to RFR-induced thermal stress.

**Mason PA, Walters TJ, DiGiovanni J, Beason CW, Jauchem JR, Dick EJ Jr, Mahajan K, Dusch SJ, Shields BA, Merritt JH, Murphy MR, Ryan KL. Lack of effect of 94 GHz radio frequency radiation exposure in an animal model of skin carcinogenesis. Carcinogenesis 22(10):1701-1708, 2001.**

Although there is no evidence that electromagnetic energy in the radio frequency radiation (RFR) band is mutagenic, there have been suggestions that RFR energy might serve as either a promoter or co-promoter in some animal models of carcinogenesis. Recent developments in electromagnetic technology have resulted in the manufacture of RFR sources capable of generating frequencies in the millimeter wavelength (MMW) range (30-300 GHz). Because absorption of MMW energy occurs in the skin, it is to be expected that long-term detrimental health effects, if any, would most likely be manifest in the skin. In this study we investigated whether a single (1.0 W/cm(2) for 10 s) or repeated (2 exposures/week for 12 weeks, 333 mW/cm(2) for 10 s) exposure to 94 GHz RFR serves as a promoter or co-promoter in the 7,12-dimethylbenz[a]anthracene (DMBA)-induced SENCAR mouse model of skin carcinogenesis. Neither paradigm of MMW exposure significantly affected papilloma development, as evidenced by a lack of effect on tumor incidence and multiplicity. There was also no evidence that MMW exposure served as a co-promoter in DMBA-induced animals repeatedly treated with 12-O-tetradecanoylphorbol 13-acetate. Therefore, we conclude that exposure to 94 GHz RFR under these conditions does not promote or co-promote papilloma development in this animal model of skin carcinogenesis.

**Masuda H, Sanchez S, Dulou PE, Haro E, Anane R, Billaudel B, Leveque P, Veyret**

**B. Effect of GSM-900 and -1800 signals on the skin of hairless rats. I: 2-hour acute exposures. Int J Radiat Biol. 82(9):669-674, 2006.**

Purpose: The acute influence on the skin of non-ionizing electromagnetic fields in the radiofrequency (RF) range used in mobile telephony has not been widely studied to date. The purpose of this work was to determine whether the cells of hairless rat skin are affected by acute local exposure to Global System for Mobile Communication: GSM-900 or -1800 RadioFrequency Radiation (RFR).Materials and methods: Hairless female rats were exposed or sham-exposed for 2 h to GSM-900 or -1800 signals, using a loop-antenna located on the right part of the rats' back. The local Specific Absorption rate (SAR) at skin level was ca. 5 W/kg (5.8+/-0.4 and 4.8+/-0.4 W/kg at 900 and 1800 MHz, respectively). A skin biopsy was done at the end of the experiment not only at the location of exposure, but also on the symmetrical part of the back.Results: Analysis of skin sections using Hematoxylin Eosin Saffron (HES) coloration showed no difference in skin thickness or apparent cell toxicity (with no sign of cellular necrosis) among the animal groups. Histological analysis of the epidermis showed that the ratio between cells expressing the antigen Ki-67 (cellular proliferation marker) and the total number of cells remained within the range of normal proliferation ratio for the exposed side of the animal. No Ki-67 labelling was observed at the dermis level. Results on filaggrin, collagen and elastin levels also showed an insignificant influence of RFR.Conclusions: These results do not demonstrate any major physical and histological variations at skin level induced by RFR used in mobile telephony.

**Masuda H, Ushiyama A, Hirota S, Wake K, Watanabe S, Yamanaka Y, Taki M, Ohkubo C. Effects of subchronic exposure to a 1439 MHz electromagnetic field on the microcirculatory parameters in rat brain. In Vivo. 21(4):563-570, 2007.**

THE AIM of this study was to investigate whether repeated exposure to radio frequency electromagnetic field (RF-EMF) of 1439 MHz affects the cerebral microcirculation, including blood-brain barrier function, in a rat brain. MATERIALS AND METHODS: The head of the rat was exposed for four weeks (60 min/day, 5 days/week) to RF-EMF at 2.4 W/kg of brain averaged specific absorption rate (BASAR). Three microcirculatory parameters: blood-brain barrier permeability, leukocyte behavior and plasma velocity were measured before and after RF-EMF exposure using a closed cranial window method. RESULTS: No extravasation of intravenously injected dyes from pial venules was found at any BASAR level. No significant changes in the number of endothelial-adhering leukocytes after exposure were found. The plasma velocity remained constant within the physiological range through each exposure. CONCLUSION: These findings suggest that there were no effects on the cerebral microcirculation under the given RF-EMF exposure conditions.

**Masuda H, Ushiyama A, Hirota S, Wake K, Watanabe S, Yamanaka Y, Taki M, Ohkubo C. Effects of acute exposure to a 1439 MHz electromagnetic field on the microcirculatory parameters in rat brain. In Vivo. 21(4):555-562, 2007.**

THE AIM of this study was to determine the potential of radio-frequency electromagnetic fields (RF-EMF) to affect cerebral microcirculation, including blood-brain barrier function, in rat brain. MATERIALS AND METHODS: The head of the rat

was exposed for 10 min to 1439 MHz RF-EMF having three intensity doses: 0.6, 2.4, 4.8 W/kg of brain averaged specific absorption rate (BASAR). Four microcirculatory parameters: blood-brain barrier permeability, leukocyte behavior, plasma velocity, and vessel diameter were measured before and after RF-EMF exposure using a closed cranial window method. RESULTS: No extravasation of intravenously injected dyes from pial venules was found at any BASAR level. No significant changes in the number of endothelial-adhering leukocytes after exposure were found. The hemodynamics indicated that the plasma velocities and vessel diameters remained constant within the physiological range throughout each exposure. CONCLUSION: These findings suggest that there were no effects on the cerebral microcirculation under the given RF-EMF exposure conditions.

**Masuda H, Hirata A, Kawai H, Wake K, Watanabe S, Arima T, Poulletier de Gannes F, Lagroye I, Veyret B. Local exposure of the rat cortex to radiofrequency electromagnetic fields increases local cerebral blood flow along with temperature. J Appl Physiol. 110(1):142-148, 2011.**

Few studies have shown that local exposure to radiofrequency electromagnetic fields (RF) induces intensity-dependent physiological changes, especially in the brain. The aim of the present study was to detect reproducible responses to local RF exposure in the parietal cortex of anesthetized rats and to determine their dependence on RF intensity. The target cortex tissue was locally exposed to 2-GHz RF using a figure-eight loop antenna within a range of averaged specific absorption rates (10.5, 40.3, 130, and 263 W/kg averaged over 4.04 mg) in the target area. Local cerebral blood flow (CBF) and temperatures in three regions (target area, rectum, and calf hypodermis) were measured using optical fiber blood flow meters and thermometers during RF exposure. All parameters except for the calf hypodermis temperature increased significantly in exposed animals compared with sham-exposed ones during 18-min exposures. Dependence of parameter values on exposure intensity was analyzed using linear regression models. The elevation of local CBF was correlated with temperature rise in both target and rectum at the end of RF exposure. However, the local CBF elevation seemed to be elevated by the rise in target temperature, but not by that of the rectal temperature, in the early part of RF exposure or at low-intensity RF exposure. These findings suggest that local RF exposure of the rat cortex drives a regulation of CBF accompanied by a local temperature rise, and our findings may be helpful for discussing physiological changes in the local cortex region, which is locally exposed to RF.

**Mathur R. Effect of chronic intermittent exposure to AM radiofrequency field on responses to various types of noxious stimuli in growing rats. Electromagn Biol Med. 27(3):266-276, 2008.**

There are several reports of altered pain sensation after exposure (from a few minutes to hours in single or repeated doses for 2-3 weeks) to electromagnetic fields (EMF) in adults. The commonly utilized noxious stimulus is radiant heat. The nociceptive responses are known to be influenced by characteristics of stimulus, organism, and environment. We studied the pattern of nociceptive responses to various noxious stimuli

in growing rats exposed to radiofrequency field (73.5 MHz amplitude modulated, 16 Hz power density 1.33 mw/cm(2), SAR = 0.4 w/kg) for 45 d (2 h/d). Threshold current for stimulation of nociceptive afferents to mediate motor response of tail (TF), vocalization during stimulus (VD), and vocalization after discharge (VA); the withdrawal latency of tail (TFL) and hind paw (HPL) to thermal noxious stimulus and tonic pain responses were recorded in every rat. The TFL was not affected, HPL was decreased ($p < 0.01$), and the thresholds of TF and VD were not affected, while, that of VA was significantly decreased. The tonic pain rating was decreased ($p < 0.01$). A decrease in the threshold of VA ($p < 0.01$) is indicative of an increase in the emotional component of the response to the phasic pain, whereas a decrease in the pain rating indicates analgesia in response to the tonic pain. The results of our study suggest that chronic (45 d), intermittent (2 h/d) amplitude modulated RF field exposure to the peripubertal rat increases the emotional component of phasic pain over a basal eaualgesic state, while late response to tonic pain is decreased. The data suggest that amplitude modulated RF field differentially affects the mechanisms involved in the processing of various noxious stimuli.

**Mattei E, Censi F, Triventi M, Calcagnini G. Electromagnetic Immunity of Implantable Pacemakers Exposed to Wi-Fi Devices. Health Phys. 107(4):318-325, 2014.**

The purpose of this study is to evaluate the potential for electromagnetic interference (EMI) and to assess the immunity level of implantable pacemakers (PM) when exposed to the radiofrequency (RF) field generated by Wi-Fi devices. Ten PM from five manufacturers, representative of what today is implanted in patients, have been tested in vitro and exposed to the signal generated by a Wi-Fi transmitter. An exposure setup that reproduces the actual IEEE 802.11b/g protocol has been designed and used during the tests. The system is able to amplify the Wi-Fi signal and transmits at power levels higher than those allowed by current international regulation. Such approach allows one to obtain, in case of no EMI, a safety margin for PM exposed to Wi-Fi signals, which otherwise cannot be derived if using commercial Wi-Fi equipment. The results of this study mitigate concerns about using Wi-Fi devices close to PM: none of the PM tested exhibit any degradation of their performance, even when exposed to RF field levels five times higher than those allowed by current international regulation (20 W EIRP). In conclusion, Wi-Fi devices do not pose risks of EMI to implantable PM. The immunity level of modern PM is much higher than the transmitting power of RF devices operating at 2.4 GHz.

**Matthews R, Legg S, Charlton S. The effect of cell phone type on drivers subjective workload during concurrent driving and conversing. Accid Anal Prev 35(4):451-457, 2003.**

The effect of three types of cell phones (hand held, hands free with an external speaker and personal hands free) on total subjective workload (including its constituent components; mental demand, physical demand, temporal demand, performance, effort and frustration) and intelligibility was measured using the NASA-task load index (TLX)

and the modified rhyme test (MRT), respectively in 13 experienced drivers (nine male, four female, age range 28-65 years), whilst driving on a rural highway. The drivers rated all components of workload for each type of cell phone to be significantly higher than for a control condition in which no cell phone was used. The mean (standard deviation) total workload was lowest for the personal hands free cell phone (7.1(3.65)) and highest for the hands free speaker phone (10.8 (3.63)) (P<0.001). The mean (standard deviation) intelligibility score was highest for the personal hands free cell phone (74.1 (7.9)) and lowest for the hands free speaker phone (55.0 (10.4)) (P<0.001). Frustration was significantly correlated with total workload (0.60, P<0.001) and intelligibility was significantly correlated with frustration (-0.35, P<0.05). Physical demand was not a high contributor to total workload. It is concluded that a personal hands free cell phone would interfere least with the cognitive demands of driving.

**Mausset A, de Seze R, Montpeyroux F, Privat A. Effects of radiofrequency exposure on the GABAergic system in the rat cerebellum: clues from semi-quantitative immunohistochemistry. Brain Res 912(1):33-46, 2001.**

The widespread use of cellular phones raises the problem of interaction of electromagnetic fields with the central nervous system (CNS). In order to measure these effects on neurotransmitter content in the CNS, we developed a protocol of neurotransmitter detection based on immunohistochemistry and image analysis. Gamma-vinyl-GABA (GVG), an inhibitor of the GABA-transaminase was injected in rats to increase GABA concentration in the CNS. The cellular GABA contents were then revealed by immunohistochemistry and semi-quantified by image analysis thanks to three parameters: optical density (O.D.), staining area, and number of positive cells. The increase in cerebellar GABA content induced by GVG 1200 mg/kg was reflected in these three parameters in the molecular and the granular layers. Therefore, control of immunohistochemistry parameters, together with appropriate image analysis, allowed both the location and the detection of variations in cellular neurotransmitter content. This protocol was used to investigate the effects of exposure to 900 MHz radiofrequencies on cerebellar GABA content. Both pulsed emission with a specific absorption rate (SAR) of 4 W/kg and continuous emission with high SAR (32 W/kg) were tested. We observed a selective diminution of the stained processes area in the Purkinje cell layer after exposure to pulsed radiofrequency and, in addition, a decrease in O.D. in the three cell layers after exposure to continuous waves. Whether this effect is, at least partly, due to a local heating of the tissues is not known. Overall, it appears that high energetic radiofrequency exposure induces a diminution in cellular GABA content in the cerebellum.

**Mausset-Bonnefont AL, Hirbec H, Bonnefont X, Privat A, Vignon J, de Seze R.Acute exposure to GSM 900-MHz electromagnetic fields induces glial reactivity and biochemical modifications in the rat brain. Neurobiol Dis. 17(3):445-454, 2004.**

The worldwide proliferation of mobile phones raises the question of the effects of 900-MHz electromagnetic fields (EMF) on the brain. Using a head-only exposure device in the rat, we showed that a 15-min exposure to 900-MHz pulsed microwaves at a high brain-averaged power of 6 W/kg induced a strong glial reaction in the brain. This effect, which suggests neuronal damage, was particularly pronounced in the striatum. Moreover, we observed significant and immediate effects on the K(d) and B(max) values of N-methyl-d-

aspartate (NMDA) and GABA(A) receptors as well as on dopamine transporters. Decrease of the amount of NMDA receptors at the postsynaptic membrane is also reported. Although we showed that the rat general locomotor behavior was not significantly altered on the short term, our results provide the first evidence for rapid cellular and molecular alterations in the rat brain after an acute exposure to high power GSM (Global System for Mobile communication) 900-MHz microwaves.

**Mazor R, Korenstein-Ilan A, Barbul A, Eshet Y, Shahadi A, Jerby E, Korenstein R. Increased levels of numerical chromosome aberrations after in vitro exposure of human peripheral blood lymphocytes to radiofrequency electromagnetic fields for 72 hours. Radiat Res 169(1):28-37, 2008.**

We investigated the effects of 72 h in vitro exposure of 10 human lymphocyte samples to radiofrequency electromagnetic fields (800 MHz, continuous wave) on genomic instability. The lymphyocytes were exposed in a specially designed waveguide resonator at specific absorption rates (SARs) of 2.9 and 4.1 W/kg in a temperature range of 36-37 degrees C. The induced aneuploidy of chromosomes 1, 10, 11 and 17 was determined by interphase FISH using semi-automated image analysis. We observed increased levels of aneuploidy depending on the chromosome studied as well as on the level of exposure. In chromosomes 1 and 10, there was increased aneuploidy at the higher SAR, while for chromosomes 11 and 17, the increases were observed only for the lower SAR. Multisomy (chromosomal gains) appeared to be the primary contributor to the increased aneuploidy. The effect of temperature on the level of aneuploidy was examined over the range of 33.5-40 degrees C for 72 h with no statistically significant difference in the level of aneuploidy compared to 37 degrees C. These findings suggest the possible existence of an athermal effect of RF radiation that causes increased levels of aneuploidy. These results contribute to the assessment of potential health risks after continuous chronic exposure to RF radiation at SARs close to the current levels set by ICNIRP guidelines.

**McEvoy SP, Stevenson MR, McCartt AT, Woodward M, Haworth C, Palamara P, Cercarelli R. Role of mobile phones in motor vehicle crashes resulting in hospital attendance: a case-crossover study. BMJ 331(7514):428, 2005.**

OBJECTIVES: To explore the effect of drivers' use of mobile (cell) phones on road safety. DESIGN: A case-crossover study. SETTING: Perth, Western Australia. PARTICIPANTS: 456 drivers aged >/=17 years who owned or used mobile phones and had been involved in road crashes necessitating hospital attendance between April 2002 and July 2004. MAIN OUTCOME MEASURE: Driver's use of mobile phone at estimated time of crash and on trips at the same time of day in the week before the crash. Interviews with drivers in hospital and phone company's records of phone use. RESULTS: Driver's use of a mobile phone up to 10 minutes before a crash was associated with a fourfold increased likelihood of crashing (odds ratio 4.1, 95% confidence interval 2.2 to 7.7, P<0.001). Risk was raised irrespective of whether or not a hands-free device was used (hands-free: 3.8, 1.8 to 8.0, P<0.001; hand held: 4.9, 1.6 to 15.5, P=0.003). Increased risk was similar in men and women and in drivers aged >/=30 and <30 years. A third (n=21) of calls before crashes and on trips during the previous week were reportedly on hand held phones.

CONCLUSIONS: When drivers use a mobile phone there is an increased likelihood of a crash resulting in injury. Using a hands-free phone is not any safer.

**McIntosh RL, Deppeler L, Oliva M, Parente J, Tambuwala F, Turner S, Winship D, Wood AW. Comparison of radiofrequency exposure of a mouse dam and foetuses at 900 MHz. Phys Med Biol. 55(4):N111-122, 2010.**

In vivo studies involving radiofrequency (RF) exposure of rodents require detailed dosimetric analysis to enable correct interpretation of biological outcomes. Detailed anatomical models of mice--a female, a pregnant female, a male and a foetus--have been developed for analyses using finite difference numerical techniques. The mouse models, consisting of 49 tissues, will be made freely available to the research community. In this note, the pregnant mouse model, which included eight mature foetuses, was utilized specifically to consider (a) the RF dosimetry in a radial cavity exposure system operated at a frequency of 900 MHz and (b) a 900 MHz plane wave exposure. A comparison was made between the exposure of the mouse dam and the foetuses as specified by the specific energy absorption rate (SAR) and the resultant temperature change. In general, the SAR levels in the foetuses were determined to be slightly lower (around 14% lower than the average values of the dam) and the peak temperature increase was significantly lower (45%) than the values in the dam.

**McNamee JP, Bellier PV, Gajda GB, Miller SM, Lemay EP, Lavallee BF, Marro L, Thansandote A. DNA damage and micronucleus induction in human leukocytes after acute in vitro exposure to a 1.9 GHz continuous-wave radiofrequency field. Radiat Res 158(4):523-533, 2002.**

Human blood cultures were exposed to a 1.9 GHz continuous-wave (CW) radiofrequency (RF) field for 2 h using a series of six circularly polarized, cylindrical waveguides. Mean specific absorption rates (SARs) of 0.0, 0.1, 0.26, 0.92, 2.4 and 10 W/kg were achieved, and the temperature within the cultures during a 2-h exposure was maintained at 37.0 +/- 0.5 degrees C. Concurrent negative (incubator) and positive (1.5 Gy (137)Cs gamma radiation) control cultures were run for each experiment. DNA damage was quantified immediately after RF-field exposure using the alkaline comet assay, and four parameters (tail ratio, tail moment, comet length and tail length) were used to assess DNA damage for each comet. No evidence of increased primary DNA damage was detected by any parameter for RF-field-exposed cultures at any SAR tested. The formation of micronuclei in the RF-field-exposed blood cell cultures was assessed using the cytokinesis-block micronucleus assay. There was no significant difference in the binucleated cell frequency, incidence of micronucleated binucleated cells, or total incidence of micronuclei between any of the RF-field-exposed cultures and the sham-exposed controls at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz CW RF-field exposure causes DNA damage in cultured human leukocytes.

**McNamee JP, Bellier PV, Gajda GB, Lavallee BF, Lemay EP, Marro L, Thansandote A. DNA Damage in human leukocytes after acute in vitro exposure to a 1.9 GHz pulse-modulated radiofrequency field. Radiat Res 158(4):534-537, 2002.**

Blood cultures from human volunteers were exposed to an acute 1.9 GHz pulse-modulated radiofrequency (RF) field for 2 h using a series of six circularly polarized,

cylindrical waveguides. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures during the exposure was maintained at 37.0 +/- 0.5 degrees C. DNA damage was quantified in leukocytes by the alkaline comet assay and the cytokinesis-block micronucleus assay. When compared to the sham-treated controls, no evidence of increased primary DNA damage was detected by any parameter for any of the RF-field-exposed cultures when evaluated using the alkaline comet assay. Furthermore, no significant differences in the frequency of binucleated cells, incidence of micronucleated binucleated cells, or total incidence of micronuclei were detected between any of the RF-field-exposed cultures and the sham-treated control at any SAR tested. These results do not support the hypothesis that acute, nonthermalizing 1.9 GHz pulse-modulated RF-field exposure causes DNA damage in cultured human leukocytes.

**McNamee, J. P., Bellier, P. V., Gajda, G. B., Lavallee, B. F., Marro, L., Lemay, E. and Thansandote, A. No Evidence for Genotoxic Effects from 24 h Exposure of Human Leukocytes to 1.9 GHz Radiofrequency Fields. Radiat Res 159:693-697, 2003.**

The current study extends our previous investigations of 2-h radiofrequency (RF)-field exposures on genotoxicity in human blood cell cultures by examining the effect of 24-h continuous-wave (CW) and pulsed-wave (PW) 1.9 GHz RF-field exposures on both primary DNA damage and micronucleus induction in human leukocyte cultures. Mean specific absorption rates (SARs) ranged from 0 to 10 W/kg, and the temperature within the cultures was maintained at 37.0 +/- 1.0 degrees C for the duration of the 24-h exposure period. No significant differences in primary DNA damage were observed between the sham-treated controls and any of the CW or PW 1.9 GHz RF-field-exposed cultures when processed immediately after the exposure period by the alkaline comet assay. Similarly, no significant differences were observed in the incidence of micronuclei, incidence of micronucleated binucleated cells, frequency of binucleated cells, or proliferation index between the sham-treated controls and any of the CW or PW 1.9 GHz RF-field-exposed cultures. In conclusion, the current study found no evidence of 1.9 GHz RF-field-induced genotoxicity in human blood cell cultures after a 24-h exposure period.

**McNamee JP, Bellier PV, Konkle AT, Thomas R, Wasoontarajaroen S, Lemay E, Gajda GB. Analysis of gene expression in mouse brain regions after exposure to 1.9 GHz radiofrequency fields. Int J Radiat Biol. 2016 Mar 30:1-13. [Epub ahead of print]**

PURPOSE: To assess 1.9 GHz radiofrequency (RF) field exposure on gene expression within a variety of discrete mouse brain regions using whole genome microarray analysis MATERIALS AND METHODS: Adult male C57BL/6 mice were exposed to 1.9 GHz pulse-modulated or continuous-wave RF fields for 4 h/day for 5 consecutive days at whole body average (WBA) specific absorption rates of 0 (sham), ~0.2 W/kg and ~1.4 W/kg. Total RNA was isolated from the auditory cortex, amygdala, caudate, cerebellum, hippocampus, hypothalamus, and medial prefrontal cortex and differential gene expression was assessed using Illumina MouseWG-6 (v2) BeadChip arrays. Validation of potentially responding genes was conducted by RT-PCR. RESULTS: When analysis of gene expression was conducted within individual brain regions when controlling the false discovery rate (FDR), no differentially expressed genes were identified relative to the sham control. However, it must be noted that most fold changes among groups were observed to be less than 1.5-fold and this study had limited ability to detect such small

changes. While some genes were differentially expressed without correction for multiple-comparisons testing, no consistent pattern of response was observed among different RF-exposure levels or among different RF-modulations. CONCLUSIONS: The current study provides the most comprehensive analysis of potential gene expression changes in the rodent brain in response to RF field exposure conducted to date. Within the exposure conditions and limitations of this study, no convincing evidence of consistent changes in gene expression was found in response to 1.9 GHz RF field exposure.

**Medeiros LN, Sanchez TG. Tinnitus and cell phones: the role of electromagnetic radiofrequency radiation. Brazilian Journal of Otorhinolaryngology. 82(1):97-104.January–February 2016. doi:10.1016/j.bjorl.2015.04.013**

Introduction Tinnitus is a multifactorial condition and its prevalence has increased on the past decades. The worldwide progressive increase of the use of cell phones has exposed the peripheral auditory pathways to a higher dose of electromagnetic radiofrequency radiation (EMRFR). Some tinnitus patients report that the abusive use of mobiles, especially when repeated in the same ear, might worsen ipsilateral tinnitus. Objective The aim of this study was to evaluate the available evidence about the possible causal association between tinnitus and exposure to electromagnetic waves. Methods A literature review was performed searching for the following keywords: tinnitus, electromagnetic field, mobile phones, radio frequency, and electromagnetic hypersensitivity. We selected 165 articles that were considered clinically relevant in at least one of the subjects. Results EMRFR can penetrate exposed tissues and safety exposure levels have been established. These waves provoke proved thermogenic effects and potential biological and genotoxic effects. Some individuals are more sensitive to electromagnetic exposure (electrosensitivity), and thus, present earlier symptoms. There may be a common pathophysiology between this electrosensitivity and tinnitus. Conclusion There are already reasonable evidences to suggest caution for using mobile phones to prevent auditory damage and the onset or worsening of tinnitus.

**Meena R, Kumari K, Kumar J, Rajamani P, Verma HN, Kesari KK. Therapeutic approaches of melatonin in microwave radiations-induced oxidative stress-mediated toxicity on male fertility pattern of Wistar rats. Electromagn Biol Med. 2013 May 15. [Epub ahead of print]**

Abstract Microwave (MW) radiation produced by wireless telecommunications and a number of electrical devices used in household or in healthcare institutions may adversely affects the reproductive pattern. Present study aimed to investigate the protective effects of melatonin (is well known antioxidant that protects DNA, lipids and proteins from free radical damage) against oxidative stress-mediated testicular impairment due to long-term exposure of MWs. For this, 70-day-old male Wistar rats were divided into four groups (n = 6/group): Sham exposed, Melatonin (Mel) treated (2 mg/kg), 2.45 GHz MWs exposed and MWs + Mel treated. Exposure took place in Plexiglas cages for 2 h a day for 45 days where, power density (0.21 mW/cm$^2$) and specific absorption rate (SAR 0.14 W/Kg) were estimated. After the completion of

exposure period, rats were sacrificed and various stress related parameters, that is LDH-X (lactate dehydrogenase isoenzyme) activity, xanthine oxidase (XO), ROS (reactive oxygen species), protein carbonyl content, DNA damage and MDA (malondialdehyde) were performed. Result shows that melatonin prevent oxidative damage biochemically by significant increase ($p < 0.001$) in the levels of testicular LDH-X, decreased ($p < 0.001$) levels of MDA and ROS in testis ($p < 0.01$). Meanwhile, it reversed the effects of MWs on XO, protein carbonyl content, sperm count, testosterone level and DNA fragmentation in testicular cells. These results concluded that the melatonin has strong antioxidative potential against MW induced oxidative stress mediated DNA damage in testicular cells.

**Megha K, Deshmukh PS, Banerjee BD, Tripathi AK, Abegaonkar MP. Microwave radiation induced oxidative stress, cognitive impairment and inflammation in brain of Fischer rats. Indian J Exp Biol. 50(12):889-896, 2012.**

Public concerns over possible adverse effects of microwave radiation emitted by mobile phones on health are increasing. To evaluate the intensity of oxidative stress, cognitive impairment and inflammation in brain of Fischer rats exposed to microwave radiation, male Fischer-344 rats were exposed to 900 MHz microwave radiation (SAR = 5.953 x 10(-4) W/kg) and 1800 MHz microwave radiation (SAR = 5.835 x 10(-4) W/kg) for 30 days (2 h/day). Significant impairment in cognitive function and induction of oxidative stress in brain tissues of microwave exposed rats were observed in comparison with sham exposed groups. Further, significant increase in level of cytokines (IL-6 and TNF-alpha) was also observed following microwave exposure. Results of the present study indicated that increased oxidative stress due to microwave exposure may contribute to cognitive impairment and inflammation in brain.

**Megha K, Deshmukh PS, Ravi AK, Tripathi AK, Abegaonkar MP, Banerjee BD. Effect of Low-Intensity Microwave Radiation on Monoamine Neurotransmitters and Their Key Regulating Enzymes in Rat Brain. Cell Biochem Biophys. 2015 Feb 12. [Epub ahead of print]**

The increasing use of wireless communication devices has raised major concerns towards deleterious effects of microwave radiation on human health. The aim of the study was to demonstrate the effect of low-intensity microwave radiation on levels of monoamine neurotransmitters and gene expression of their key regulating enzymes in brain of Fischer rats. Animals were exposed to 900 MHz and 1800 MHz microwave radiation for 30 days (2 h/day, 5 days/week) with respective specific absorption rates as $5.953 \times 10^{-4}$ and $5.835 \times 10^{-4}$ W/kg. The levels of monoamine neurotransmitters viz. dopamine (DA), norepinephrine (NE), epinephrine (E) and serotonin (5-HT) were detected using LC-MS/MS in hippocampus of all experimental animals. In addition, mRNA expression of key regulating enzymes for these neurotransmitters viz. tyrosine hydroxylase (TH) (for DA, NE and E) and tryptophan hydroxylase (TPH1 and TPH2) (for serotonin) was also estimated. Results showed significant reduction in levels of DA, NE, E and 5-HT in hippocampus of microwave-exposed animals in comparison with sham-exposed (control) animals. In addition, significant downregulation in mRNA

expression of TH, TPH1 and TPH2 was also observed in microwave-exposed animals ($p < 0.05$). In conclusion, the results indicate that low-intensity microwave radiation may cause learning and memory disturbances by altering levels of brain monoamine neurotransmitters at mRNA and protein levels.

**Meo SA, Al-Drees AM, Husain S, Khan MM, Imran MB. Effects of mobile phone radiation on serum testosterone in Wistar albino rats. Saudi Med J. 31(8):869-873, 2010.**

OBJECTIVE: To investigate the effects of electromagnetic field radiation generated by mobile phones on serum testosterone levels in Wistar albino rats. METHODS: This experimental interventional control study was conducted in the Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia during the period December 2006 to April 2008. A total of 34 male Albino rats [Wistar strain], 2 months of age, weighing 150-160 gm were used for the experiment. These animals were divided into 3 groups. The first group containing 6 rats was assigned as a control group. The second group containing 14 rats was exposed to mobile phone radiation for 30 minutes daily and the third group containing 14 rats was exposed to mobile phone radiation for 60 minutes daily for the total period of 3 months. At the end of experimental period, blood was collected into the container, and serum testosterone was analyzed using double-antibody radioimmunoassay method by Coat-A-Count. RESULTS: Exposure to mobile phone radiation for 60 minutes/day for the total period of 3 months significantly decrease the serum testosterone level [p=0.028] in Wistar Albino rats compared to their matched control. CONCLUSION: Long-term exposure to mobile phone radiation leads to reduction in serum testosterone levels. Testosterone is a primary male gender hormone and any change in the normal levels may be devastating for reproductive and general health.

**Meo SA, Arif M, Rashied S, Khan MM, Vohra MS, Usmani AM, Imran MB, Al-Drees AM. Hypospermatogenesis and spermatozoa maturation arrest in rats induced by mobile phone radiation. J Coll Physicians Surg Pak. 21(5):262-265, 2011.**

OBJECTIVE: To determine the morphological changes induced by mobile phone radiation in the testis of Wistar albino rats. STUDY DESIGN: Cohort study. Place and Duration of Study: Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia, from April 2007 to June 2008. METHODOLOGY: Forty male Wistar albino rats were divided in three groups. First group of eight served as the control. The second group [group B, n=16] was exposed to mobile phone radiation for 30 minutes/day and the third group [group C, n=16] was exposed to mobile phone radiation for 60 minutes/day for a total period of 3 months. Morphological changes in the testes induced by mobile phone radiations were observed under a light microscope. RESULTS: Exposure to mobile phone radiation for 60 minutes/day caused 18.75% hypospermatogenesis and 18.75% maturation arrest in the testis of albino rats compared to matched controls. However, no abnormal findings were observed in albino rats that were exposed to mobile phone radiation for 30 minutes/day for a total period of 3 months. CONCLUSION: Long-term exposure to mobile phone radiation can cause hypospermatogenesis and maturation arrest in the spermatozoa in the testis of Wistar albino rats.

**Meo SA, Al Rubeaan K. Effects of exposure to electromagnetic field radiation (EMFR) generated by activated mobile phones on fasting blood glucose. Int J Occup Med Environ Health. 26(2):235-241, 2013.**

**OBJECTIVE:** Extensive use of mobile phones has been accompanied by a common public debate about possible adverse effects on human health. No study has been published so far to establish any association between the fastest growing innovation of mobile phone and fasting blood glucose. The aim was to determine the effects of exposure to electromagnetic field radiation generated by mobile phones on fasting blood glucose in Wistar Albino rats. **MATERIALS AND METHODS:** 40 Male Albino rats (Wistar Strain) were divided into 5 equally numerous groups. Group A served as the control one, group B received mobile phone radiation for less than 15 min/day, group C: 15-30 min/day, group D: 31-45 min/day, and group E: 46-60 min/day for a total period of 3 months. Fasting blood glucose was determined by using Spectrophotometer and serum insulin by Enzyme-linked Immunosorbent Assay (ELISA). The Homeostatic Model (HOMA-B) was applied for the assessment of β-cell function and (HOMA-IR) for resistance to insulin. **RESULTS:** Wister Albino rats exposed to mobile phone radiation for longer than 15 min a day for a total period of 3 months had significantly higher fasting blood glucose ($p < 0.015$) and serum insulin ($p < 0.01$) compared to the control group. HOMA-IR for insulin resistance was significantly increased ($p < 0.003$) in the groups that were exposed for 15-30 and 46-60 min/day compared to the control rats. **CONCLUSION:** The results of the present study show an association between long-term exposure to activated mobile phones and increase in fasting blood glucose and serum insulin in Albino rats.

**Meltz ML, Eagan P, Erwin DN, Proflavin and microwave radiation: absence of a mutagenic interaction. Bioelectromagnetics 11(2):149-157, 1990.**

The potential ability of radiofrequency electromagnetic radiation (RFR) in the microwave range to induce mutagenesis, chromosomal aberrations, and sister chromatid exchanges in mammalian cells is being explored in our laboratories. In addition, we have also been examining the ability of simultaneous exposure to RFR and chemical mutagens to alter the genotoxic damage induced by chemical mutagens acting alone. We have performed experiments to determine whether there is an interaction between 2.45-GHz, pulsed-wave, RFR and proflavin, a DNA-intercalating drug. The endpoint studied was forward mutation at the thymidine kinase locus in L5178Y mouse leukemic cells. Any effect on the size distribution of the resulting colonies of mutated cells was also examined. The exposures were performed at net forward powers of 500 or 600 W, resulting in a specific absorption rate (SAR) of approximately 40 W/kg. The culture-medium temperature reached a 3 degrees C maximal increase during the 4-h exposure; appropriate 37 degrees C and convection-heating temperature controls (TC) were performed. In no case was there any indication of a statistically significant increase in the induced mutant frequency due to the simultaneous exposure to RFR and proflavin, as compared with the proflavin exposures alone. There was also no indication of any change in the colony-size distribution of the resulting mutant colonies, neither, and there was no evidence in these

experiments of any mutagenic action by the RFR exposure alone.

**Meo SA, Al-Drees AM. Mobile phone related-hazards and subjective hearing and vision symptoms in the Saudi population. Int J Occup Med Environ Health. 18(1):53-57, 2005**

OBJECTIVES: Over the past decade utilization of mobile phones has dramatically increased. They are now an essential part of business, commerce, and communication, however, their use may lead to health problems. Therefore, the present study was designed to investigate a link between the use of mobile phones and hearing and vision symptoms in the Saudi population and also to contribute to the increase in social awareness of health problems associated with the use of these devices. MATERIALS AND METHODS: A total of 873 (57.04% of males and 39.86% of females) subjects using mobile phones were invited to participate in the presented study. A structured questionnaire was distributed among them to collect a detailed medical history. The Chi-square test was employed to observe the relationship between duration of calls and hearing and vision complaints. RESULTS: The present study showed an association between the use of mobile phones and hearing and vision complaints. About 34.59% of problems were related with impaired hearing, ear ache and/or warmth on the ear, and 5.04% of complaints with the decreased and/or blurred vision. CONCLUSIONS: It is concluded that the use of mobile phone is a health risk factor, and thus it is suggested that excessive use of mobile phones should be avoided and social awareness increased through health promotion activities, such as group discussions or public presentations and via electronic and printed media sources.

**Meo SA, Arif M, Rashied S, Khan MM, Vohra MS, Usmani AM, Imran MB, Al-Drees AM. Hypospermatogenesis and spermatozoa maturation arrest in rats induced by mobile phone radiation. J Coll Physicians Surg Pak. 21(5):262-265, 2011.**

Abstract. Objective: To determine the morphological changes induced by mobile phone radiation in the testis of Wistar albino rats. Study Design: Cohort study. Place and Duration of Study: Department of Physiology, College of Medicine, King Saud University, Riyadh, Saudi Arabia, from April 2007 to June 2008. Methodology: Forty male Wistar albino rats were divided in three groups. First group of eight served as the control. The second group [group B, n=16] was exposed to mobile phone radiation for 30 minutes/day and the third group [group C, n=16] was exposed to mobile phone radiation for 60 minutes/day for a total period of 3 months. Morphological changes in the testes induced by mobile phone radiations were observed under a light microscope. Results: Exposure to mobile phone radiation for 60 minutes/day caused 18.75% hypospermatogenesis and 18.75% maturation arrest in the testis of albino rats compared to matched controls. However, no abnormal findings were observed in albino rats that were exposed to mobile phone radiation for 30 minutes/day for a total period of 3 months. Conclusion: Long-term exposure to mobile phone radiation can cause hypospermatogenesis and maturation arrest in the spermatozoa in the testis of Wistar albino rats.

**Meral I, Mert H, Mert N, Deger Y, Yoruk I, Yetkin A, Keskin S. Effects of 900-MHz electromagnetic field emitted from cellular phone on brain oxidative stress and some vitamin levels of guinea pigs. Brain Res1169:120-124, 2007.**

This study was designed to demonstrate the effects of 900-MHz electromagnetic field (EMF) emitted from cellular phone on brain tissue and also blood malondialdehyde (MDA), glutathione (GSH), retinol (vitamin A), vitamin D(3) and tocopherol (vitamin E) levels, and catalase (CAT) enzyme activity of guinea pigs. Fourteen male guinea pigs, weighing 500-800 g were randomly divided into one of two experimental groups: control and treatment (EMF-exposed), each containing seven animals. Animals in treatment group were exposed to 890- to 915-MHz EMF (217-Hz pulse rate, 2-W maximum peak power, SAR 0.95 w/kg) of a cellular phone for 12 h/day (11-h 45-min stand-by and 15-min spiking mode) for 30 days. Control guinea pigs were housed in a separate room without exposing EMF of a cellular phone. Blood samples were collected through a cardiac puncture and brains were removed after decapitation for the biochemical analysis at the end of the 30 days of experimental period. It was found that the MDA level increased ($P<0.05$), GSH level and CAT enzyme activity decreased ($P<0.05$), and vitamins A, E and D(3) levels did not change ($P>0.05$) in the brain tissues of EMF-exposed guinea pigs. In addition, MDA, vitamins A, D(3) and E levels, and CAT enzyme activity increased ($P<0.05$), and GSH level decreased ($P<0.05$) in the blood of EMF-exposed guinea pigs. It was concluded that electromagnetic field emitted from cellular phone might produce oxidative stress in brain tissue of guinea pigs. However, more studies are needed to demonstrate whether these effects are harmful or/and affect the neural functions.

**Meral I, Tekintangac Y, Demir H. Effects of 900 MHz electromagnetic field emitted by cellular phones on electrocardiograms of guinea pigs. Hum Exp Toxicol. 2013 Nov 12. [Epub ahead of print]**

This study was carried out to determine the effects of electromagnetic field (EMF) emitted by cellular phones (CPs) on electrocardiograms (ECGs) of guinea pigs. A total of 30 healthy guinea pigs weighing 500-800 g were used. After 1 week of adaptation period, animals were randomly divided into two groups: control group ($n = 10$) and EMF-exposed group ($n = 20$). Control guinea pigs were housed in a separate room without exposing them to EMFs of CPs. Animals in second group were exposed to 890-915 MHz EMF (217 Hz of pulse rate, 2 W of maximum peak power and 0.95 wt $kg^{-1}$ of specific absorption rate) for 12 h $day^{-1}$ (11 h 45 min stand-by and 15 min speaking mode) for 30 days. ECGs of guinea pigs in both the groups were recorded by a direct writing electrocardiograph at the beginning and 10th, 20th and 30th days of the experiment. All ECGs were standardized at 1 mV = 10 mm and with a chart speed of 50 mm $sec^{-1}$. Leads I, II, III, lead augmented vector right (aVR), lead augmented vector left (aVL) and lead augmented vector foot (aVF) were recorded. The durations and amplitudes of waves on the trace were measured in lead II. The data were expressed as mean with SEM. It was found that 12 h $day^{-1}$ EMF exposure for 30 days did not have any significant effects on ECG findings of guinea pigs. However, this issue needed to be further investigated in a variety of perspectives, such as longer duration of exposure to be able to elucidate the effects of mobile phone-induced EMFs on cardiovascular functions.

**Merola P, Marino C, Lovisolo GA, Pinto R, Laconi C, Negroni A. Proliferation and apoptosis in a neuroblastoma cell line exposed to 900 MHz modulated**

**radiofrequency field. Bioelectromagnetics.27(3):164-71, 2006.**

The aim of this study was to examine whether a modulated radiofrequency of the type used in cellular phone communications at a specific absorption rate (SAR) higher than International Commission on Non-ionizing Radiation Protection (ICNIRP) reference level for occupational exposure, could elicit alterations on proliferation, differentiation, and apoptosis processes in a neuroblastoma cell line. The cell line was exposed for 24, 48, and 72 h to 900 MHz radiofrequency and proliferation and differentiation were tested by WST-I assay and by a molecular analysis of specific markers, two oncogenes and a cytoskeleton protein, in exponential growth phase and in synchronized cell cultures. Apoptosis was evaluated by caspase activation analysis and by molecular detection of Poly (ADP-ribose) polimerase (PARP) cleavage. Combined exposures to radiofrequency and to the differentiative agent retinoic acid or to the apoptotic inducer camptothecin were carried out to test possible interference between electromagnetic field and chemical agents. Overall our data suggest that 900 MHz radiofrequency exposure up to 72 h does not induce significant alterations in the three principal cell activities in a neuroblastoma cell line.

**Mezhevikina LM, Khramov RN, Lepikhov KA , [The simulation of the cooperative effect of development in a culture of early mouse embryos after irradiation with electromagnetic waves in the millimeter range]. Ontogenez 31(1):27-31, 2000.** [Article in Russian]

We have found that two-cell mouse embryos cultured in vitro can be stimulated by electromagnetic irradiation in the millimeter range. After 30 min of exposure, they acquire the ability to develop in culture on their own and can reach the stage of blastocyst in a relatively large volume of Whitten cultural medium (150 microliters) without serum or growth factors. It is proposed that millimeter range electromagnetic waves activate metabolic processes and specifically the synthesis of factors controlling early embryonic development in culture.

**Michelozzi P, Ancona C, Fusco D, Forastiere F, Perucci CA, Risk of leukemia and residence near a radio transmitter in Italy. Epidemiology 9 (Suppl) 354p, 1998.**

We conducted a small area study to investigate a cluster of leukemia near a high power radio-transmitter in a peripheral area of Rome. The leukemia mortality within 3.5 km (5,863 inhabitants) was higher than expected (SMR=2.5, 95% confident interval 1.07-4.83); the excess was due to a significant higher mortality among men (7 cases observed, SMR=3.5). The results of the Stone's test, after adjusting for socio-economic confounding, showed a significant decline in risk with distance from the transmitter only among men (p=0.005), whereas the p-value for both sexes was p=0.07.

**Michelozzi P, Capon A, Kirchmayer U, Forastiere F, Biggeri A, Barca A, Perucci CA. Adult and childhood leukemia near a high-power radio station in Rome, Italy. Am J Epidemiol 155(12):1096-1103, 2002.**

Some recent epidemiologic studies suggest an association between lymphatic and hematopoietic cancers and residential exposure to high-frequency electromagnetic fields (100 kHz to 300 GHz) generated by radio and television transmitters. Vatican Radio is a very powerful station located in a northern suburb of Rome, Italy. In the 10-km area

around the station, with 49,656 residents (in 1991), leukemia mortality among adults (aged >14 years; 40 cases) in 1987-1998 and childhood leukemia incidence (eight cases) in 1987-1999 were evaluated. The risk of childhood leukemia was higher than expected for the distance up to 6 km from the radio station (standardized incidence rate = 2.2, 95% confidence interval: 1.0, 4.1), and there was a significant decline in risk with increasing distance both for male mortality (p = 0.03) and for childhood leukemia (p = 0.036). The study has limitations because of the small number of cases and the lack of exposure data. Although the study adds evidence of an excess of leukemia in a population living near high-power radio transmitters, no causal implication can be drawn. There is still insufficient scientific knowledge, and new epidemiologic studies are needed to clarify a possible leukemogenic effect of residential exposure to radio frequency radiation.

**Mickley GA, Cobb BL, Mason PA, Farrell S, Disruption of a putative working memory task and selective expression of brain c-fos following microwave-induced hyperthermia. Physiol Behav 55(6):1029-1038, 1994**.

To discern the effects of hyperthermia on working memory, we recorded the ability of rats to discriminate between objects following microwave radiation exposure. Memory changes were evaluated by measuring relative exploration time of a familiar vs. a new stimulus object. A subject that extensively reexplores a stimulus with which it has previous experience is presumed to exhibit memory loss associated with that object. Between training and testing, rats were exposed to various doses of microwave radiation, were sham irradiated, or remained in their home cage. Brain (dural) and rectal temperatures were recorded. To discern brain regions activated or possibly damaged by microwave exposure, we also used immunocytochemistry techniques to identify sites of c-fos protein expression in the brains of several irradiated/sham-irradiated subjects. Rats exposed to > 5 W/kg exhibited hyperthermia when compared to nonirradiated controls. Normothermic control subjects (sham-irradiated rats and rats exposed to 0.1 W/kg) showed a distinct preference for the new object although other microwave-exposed rats (1, 5, 8.5, 9.3, 10 W/kg) did not. Microwave hyperthermia evoked prominent c-fos expression in periventricular strata, hypothalamic nuclei, amygdala, and several areas of the cortex. These data suggest that performance on a putative working memory task may be disrupted by a sufficiently intense microwave-induced hyperthermia. The pattern of expression of the early proto-oncogene c-fos may suggest candidate brain nuclei that mediate the behavioral changes we observed.

**Mickley GA, Cobb BL, Thermal tolerance reduces hyperthermia-induced disruption of working memory: a role for endogenous opiates? Physiol Behav 63(5):855-865, 1998.**

Previous reports indicate that microwave-induced hyperthermia can impair learning and memory. Here, we report that preexposure to a single 20-min period of hyperthermia can produce thermal tolerance and, thereby, attenuate future physiological and behavioral reactions to heating. Because endogenous opioids have been implicated in thermoregulation and reactions to microwave exposure, we also determined how opioid receptor antagonism might modulate these effects. In an initial experiment, rats were exposed daily, over 5 successive days, to 600-MHz microwaves (at a whole-body specific absorption rate of 9.3 W/kg) or sham exposed.

In animals exposed to microwaves, thermal tolerance was evidenced by declining rectal temperatures over time. Temperature reductions following microwave exposure were prominent after a single previous exposure. Therefore, in a second study, a single hyperthermic episode was used to induce thermal tolerance. On Day 1, rats were either exposed, over a 20-min period, to 600-MHz microwaves (at a whole-body specific absorption rate of 9.3 W/kg) or sham exposed. Just prior to radiation/sham-radiation treatment, rats received either saline or naltrexone (0.1 or 10 mg/kg, intraperitoneally (i.p.)). The following day (Day 2), rats were either microwave or sham exposed and tested on a task which measures the relative time subjects explore a familiar versus a novel stimulus object. Normothermic rats spend significantly more time in contact with new environmental components and less time with familiar objects. Brain (dura) and rectal temperatures were recorded on both days of the study. Microwave exposure produced a reliable hyperthermia which was significantly lower (on Day 2) in rats receiving repeated treatments (tolerant group). On the behavioral test, rats exposed only once to microwave-induced hyperthermia (nontolerant group) exhibited significantly different patterns of object discrimination than did tolerant or sham-exposed animals. Sham-exposed and tolerant animals showed a distinct preference for the new object whereas the nontolerant animals did not. Naltrexone (10 mg/kg) antagonized the hyperthermia-induced disruption of the object discrimination task (in nontolerant rats) and produced patterns of object exploration that were similar to those of sham-irradiated and thermal-tolerant rats, suggesting that endogenous opioids play a role in the organism's response to heating. Taken together, these data are consistent with the conclusions that 1) microwave-induced hyperthermia can cause a dose-dependent disruption of the normal discrimination between new and familiar objects, 2) physiological reactions to a single hyperthermic episode can produce a thermotolerance that expresses itself in both reduced levels of hyperthermia and attenuated behavioral disruptions following microwave exposure, and 3) opioid antagonism can partially reverse some of the behavioral effects of microwave-induced hyperthermia.

**Mild KH, Andersen JB, Pedersen GF. Is there any exposure from a mobile phone in stand-by mode? Electromagn Biol Med. 31(1):52-56, 2012.**

Several studies have been using a GSM mobile phone in stand-by mode as the source for exposure, and they claimed that this caused effects on for instance sleep and testicular function. In stand-by mode the phone is only active in periodic location updates, and this occurs with a frequency set by the net operator. Typical updates occur with 2-5 h in between, and between these updates the phone is to be considered as a passive radio receiver with no microwave emission. Thus, the exposure in stand-by mode can be considered negligible.

**Millenbaugh NJ, Roth C, Sypniewska R, Chan V, Eggers JS, Kiel JL, Blystone RV, Mason PA. gene expression changes in the skin of rats induced by prolonged 35 GHz millimeter-wave exposure. Radiat Res 169(3):288-300, 2008.**

To better understand the cellular and molecular responses to overexposure to

millimeter waves, alterations in the gene expression profile and histology of skin after exposure to 35 GHz radiofrequency radiation were investigated. Rats were subjected to sham exposure, to 42 degrees C environmental heat, or to 35 GHz millimeter waves at 75 mW/cm(2). Skin samples were collected at 6 and 24 h after exposure for Affymetrix GeneChip analysis. The skin was harvested from a separate group of rats at 3-6 h or 24-48 h after exposure for histopathology analysis. Microscopic findings observed in the dermis of rats exposed to 35 GHz millimeter waves included aggregation of neutrophils in vessels, degeneration of stromal cells, and breakdown of collagen. Changes were detected in 56 genes at 6 h and 58 genes at 24 h in the millimeter-wave-exposed rats. Genes associated with regulation of transcription, protein folding, oxidative stress, immune response, and tissue matrix turnover were affected at both times. At 24 h, more genes related to extracellular matrix structure and chemokine activity were altered. Up-regulation of Hspa1a, Timp1, S100a9, Ccl2 and Angptl4 at 24 h by 35 GHz millimeter-wave exposure was confirmed by real-time RT-PCR. These results obtained from histopathology, microarrays and RT-PCR indicate that prolonged exposure to 35 GHz millimeter waves causes thermally related stress and injury in skin while triggering repair processes involving inflammation and tissue matrix recovery.

**Miller G, Zhu G, Wright MJ, Hansell NK, Martin, NG. The Heritability and Genetic Correlates of Mobile Phone Use: A Twin Study of Consumer Behavior. Twin Research and Human Genetics / Volume 15 / Issue 01 / February 2012, pp 97-106.**

There has been almost no overlap between behavior genetics and consumer behavior research, despite each field's importance in understanding society. In particular, both have neglected to study genetic influences on consumer adoption and usage of new technologies — even technologies as important as the mobile phone, now used by 5.8 out of 7.0 billion people on earth. To start filling this gap, we analyzed self-reported mobile phone use, intelligence, and personality traits in two samples of Australian teenaged twins (mean ages 14.2 and 15.6 years), totaling 1,036 individuals.

ACE modeling using Mx software showed substantial heritabilities for how often teens make voice calls (.60 and .34 in samples 1 and 2, respectively) and for how often they send text messages (.53 and. 50). Shared family environment – including neighborhood, social class, parental education, and parental income (i.e., the generosity of calling plans that parents can afford for their teens) — had much weaker effects. Multivariate modeling based on cross-twin, cross-trait correlations showed negative genetic correlations between talking/texting frequency and intelligence (around –.17), and positive genetic correlations between talking/texting frequency and extraversion (about .20 to .40).

Our results have implications for assessing the risks of mobile phone use such as radiofrequency field (RF) exposure and driving accidents, for studying adoption and use of other emerging technologies, for understanding the genetic architecture of the cognitive and personality traits that predict consumer behavior, and for challenging the common assumption that consumer behavior is shaped entirely by culture, media, and family environment.

**Miller SA, Bronson ME, Murphy MR, Ultrawideband radiation and pentylenetetrazol-induced convulsions in rats. Bioelectromagnetics 20(5):327-329, 1999.**

New non-ionizing pulsed systems using ultrawideband (UWB) require safety assessment before they can be used by either military or civilian communities.

The development of directed energy weaponry intended for use against electronically vulnerable targets, as well as ground-probing radar systems, have used fast-rise-time high-peak-power electromagnetic pulses characteristic of UWB emitters. It has been postulated that these ultrashort pulses might produce electromagnetic transients resulting in tissue damage. Several challenges to this notion have been posed, however. One report found that rats exposed to UWB after receiving a convulsant drug tended toward longer latency to the onset of convulsions than the no-exposure group. Although not statistically significant, the presence of this trend prompted the present study. An ED99 dose of the convulsant pentylenetetrazol (PTZ) or saline was given just before UWB or sham exposure and resultant seizure activity was recorded. The data from the current study show no effect of UWB exposure on PTZ-induced seizure activity, thereby not supporting the tissue damage concerns, at least for the exposure parameters used here.

**Min ST, Redelmeier DA, Car phones and car crashes: an ecologic analysis. Can J Public Health 89(3):157-161, 1998.**

OBJECTIVE: Some countries have regulations against using a cellular Telephone while driving. We used ecologic analysis to evaluate cellular telephone use and motor vehicle collisions in a city without such regulations. METHODS: We studied locations in Toronto, Ontario (n = 75) that were hazardous (total collisions = 3,234) and tested whether increases in collision rates from 1984 to 1993 correlated with increases in telephone usage over the same time interval. RESULTS: Locations with the largest increases in collision rates tended to have the smallest increases in estimated cellular telephone usage. Yet extreme assumptions about potential protective effects from cellular telephones failed to explain the magnitude observed. CONCLUSIONS: The effects of cellular telephones on driving ability are small relative to the biases in ecologic analysis. Claims from industry, which argue that cellular telephones are not dangerous based on ecologic analysis, can be misleading in the policy debate about whether to regulate cellular telephone use while driving.

**Mina D, Sagonas K, Fragopoulou AF, Pafilis P, Skouroliakou A, Margaritis LH, Tsitsilonis OE, Valakos ED. Immune responses of a wall lizard to whole-body exposure to radiofrequency electromagnetic radiation. Int J Radiat Biol. 92(3):162-168, 2016.**

PURPOSE: During the last three decades, the number of devices that emit non-ionizing electromagnetic radiation (EMR) at the wireless communication spectrum has rapidly increased and possible effects on living organisms have become a major concern. The purpose of this study was to investigate the effects of radiofrequency EMR emitted by a widely used wireless communication device, namely the Digital Enhanced Communication Telephony (DECT) base, on the immune responses of the Aegean wall

lizard (Podarcis erhardii).MATERIALS AND METHODS: Adult male lizards were exposed 24 h/day for 8 weeks to 1880-1900 MHz DECT base radiation at average electric field intensity of 3.2 V/m. Immune reactivity was assessed using the phytohemagglutinin (PHA) skin swelling and mixed lymphocyte reaction (MLR) tests.RESULTS: Our results revealed a noticeable suppression (approximately 45%) of inflammatory responses in EMR-exposed lizards compared to sham-exposed animals. T cell-mediated responses were marginally affected.CONCLUSION: Daily radiofrequency EMR exposure seems to affect, at least partially, the immunocompetence of the Aegean wall lizard.

**Mineta M, Katada R, Yamada T, Nagasawa K, Takahashi K, Aburano T, Yoshida I, [Bacterial mutation in high magnetic fields and radiofrequency radiation]. Nippon Igaku Hoshasen Gakkai Zasshi 59(9):467-469, 1999.** [Article in Japanese]

Epidemiological studies recently have indicated that magnetic fields and radiofrequency (RF) radiation have an adverse influence on the living body. The purpose of this study was to examine the safety of magnetic resonance imaging (MRI) by observing whether bacterial mutation occurs in an approximate MRI environment. We employed a GX-270 FT-NMR unit (JEOL, Ltd.) with a magnetic field strength of 6.3 Tesla. The Salmonella typhimurium tester strains used in the AMES test were exposed, and the incidence of point and frameshift mutations was evaluated. TA98 and TA7001-7006 mixed strains were used to detect frameshift and point mutations, respectively. Tester strains were exposed to the 6.3 Tesla magnetic field with RF radiation (90 degrees and 180 degrees refocusing pulses were repeated using the hydrogen Lamor frequency at 2-second intervals) for 15, 30, 45, and 60 minutes. After each exposure, the rate of revertant mutation was counted. The rates of revertant mutation in mixed strains and the TA98 strain were not statistically significant. Therefore, it was concluded that bacterial mutation is not increased by RF radiation under a 6.3 Tesla magnetic field.

**Misa Agustiño MJ, Leiro JM, Jorge Mora MT, Rodríguez-González JA, Jorge Barreiro FJ, Ares-Pena FJ, López-Martín E. Electromagnetic fields at 2.45 GHz trigger changes in heat shock proteins 90 and 70 without altering apoptotic activity in rat thyroid gland. Biol Open. 1(9):831-838, 2012.**

Non-ionizing radiation at 2.45 GHz may modify the expression of genes that codify heat shock proteins (HSP) in the thyroid gland. Using the enzyme-linked immunosorbent assay (ELISA) technique, we studied levels of HSP-90 and HSP-70. We also used hematoxilin eosin to look for evidence of lesions in the gland and applied the DAPI technique of fluorescence to search for evidence of chromatin condensation and nuclear fragmentation in the thyroid cells of adult female Sprague-Dawley rats. Fifty-four rats were individually exposed for 30 min to 2.45 GHz radiation in a Gigahertz transverse electromagnetic (GTEM) cell at different levels of non-thermal specific absorption rate (SAR), which was calculated using the finite difference time domain (FDTD) technique. Ninety minutes after radiation, HSP-90 and HSP-70 had decreased significantly ($P<0.01$) after applying a SAR of 0.046±1.10 W/Kg or 0.104±5.10(-3) W/Kg. Twenty-four hours after radiation, HSP-90 had partially recovered and HSP-70 had recovered completely. There were few indications of lesions in the glandular structure and signs of apoptosis were negative in all radiated animals. The results suggest that acute sub-thermal

radiation at 2.45 GHz may alter levels of cellular stress in rat thyroid gland without initially altering their anti-apoptotic capacity.

**Misa-Agustiño MJ, Leiro-Vidal JM, Gomez-Amoza JL, Jorge-Mora MT, Jorge-Barreiro FJ, Salas-Sánchez AA, Ares-Pena FJ, López-Martín E. EMF radiation at 2450MHz triggers changes in the morphology and expression of heat shock proteins and glucocorticoid receptors in rat thymus. Life Sci. 127:1-11, 2015.**

Aims. Electromagnetic fields (EMFs) can act as inducers or mediators of stress response through the production of heat shock proteins (HSPs) that modulate immune response and thymus functions. In this study, we analyzed cellular stress levels in rat thymus after exposure of the rats to a 2.45 GHz radio frequency (RF) using an experimental diathermic model in a Gigahertz Transverse Electromagnetic (GTEM) chamber. Main methods. In this experiment, we used H&E staining, the ELISA test and immunohistochemistry to examine Hsp70 and Hsp90 expression in the thymus and glucocorticoid receptors (GR) of 64 female Sprague–Dawley rats exposed individually to 2.45 GHz (at 0, 1.5, 3.0 or 12.0 W power). The 1 g averaged peak and mean SAR values in the thymus and whole body of each rat to ensure that sub-thermal levels of radiation were being reached. Key findings. The thymus tissue presented several morphological changes, including increased distribution of blood vessels along with the appearance of red blood cells and hemorrhagic reticuloepithelial cells. Levels of Hsp90 decreased in the thymus when animals were exposed to the highest power level (12 W), but only one group did not show recovery after 24 h. Hsp70 presented no significant modifications in any of the groups. The glucocorticoid receptors presented greater immunomarking on the thymic cortex in exposed animals.Significance. Our results indicate that non-ionizing sub-thermal radiation causes changes in the endothelial permeability and vascularization of the thymus, and is a tissue-modulating agent for Hsp90 and GR**.**

**Misa-Agustiño MJ, Jorge-Mora T, Jorge-Barreiro FJ, Suarez-Quintanilla J, Moreno-Piquero E, Ares-Pena FJ, López-Martín E. Exposure to non-ionizing radiation provokes changes in rat thyroid morphology and expression of HSP-90. Exp Biol Med (Maywood). 2015 Feb 2. pii: 1535370214567611. [Epub ahead of print]**

Non-ionizing radiation at 2.45 GHz may modify the morphology and expression of genes that codify heat shock proteins (HSP) in the thyroid gland. Diathermy is the therapeutic application of non-ionizing radiation to humans for its beneficial effects in rheumatological and musculo-skeletal pain processes.
We used a diathermy model on laboratory rats subjected to maximum exposure in the left front leg, in order to study the effects of radiation on the nearby thyroid tissue. Fifty-six rats were individually exposed once or repeatedly (10 times in two weeks) for 30 min to 2.45 GHz radiation in a commercial chamber at different non-thermal specific absorption rates (SARs), which were calculated using the finite difference time domain technique. We used immunohistochemistry methods to study the expression of HSP-90 and morphological changes in thyroid gland tissues. Ninety minutes after radiation with the highest SAR, the central and peripheral follicles presented increased size and the thickness of the peripheral septa had decreased. Twenty-four hours after radiation, only

peripheral follicles radiated at 12 W were found to be smaller. Peripheral follicles increased in size with repeated exposure at 3 W power. Morphological changes in the thyroid tissue may indicate a glandular response to acute or repeated stress from radiation in the hypothalamic-pituitary-thyroid axis. Further research is needed to determine if the effect of this physical agent over time may cause disease in the human thyroid gland.

**Miyakoshi J, Takemasa K, Takashima Y, Ding GR, Hirose H, Koyama S. Effects of exposure to a 1950 MHz radio frequency field on expression of Hsp70 and Hsp27 in human glioma cells. Bioelectromagnetics. 26(4):251-257, 2005.**

Human glioma MO54 cells were used to investigate whether radio frequency (RF) field exposure could activate stress response genes. Cells were exposed to continuous wave 1950 MHz or sham conditions for up to 2 h. Specific absorption rates (SARs) were 1, 2, and 10 W/kg. For the cell growth experiment, cell numbers were counted at 0-4 days after exposure. Expression of Hsp27 and Hsp70, as well as the level of phosphorylated Hsp27 (78Ser) protein, was determined by Western blotting. It was found that sham exposed and RF exposed cells demonstrated a similar growth pattern up to 4 days after RFfield exposure. RFfield exposure at both 2 and 10 W/kg did not affect the growth of MO54 cells. In addition, there were no significant differences in protein expression of Hsp27 and Hsp70 between sham exposed and RF exposed cells at a SAR of 1, 2, or 10 W/kg for 1 and 2 h. However, exposure to RFfield at a SAR of 10 W/kg for 1 and 2 h decreased the protein level of phosphorylated Hsp27 (78Ser) significantly. Our results suggest that although exposure to a 1950 MHz RFfield has no effect on cell proliferation and expression of Hsp 27 and Hsp70, it may inhibit the phosphorylation of Hsp27 at Serine 78 in MO54 cells.

**Mizuno Y, Moriguchi Y, Hikage T, Terao Y, Ohnishi T, Nojima T, Ugawa Y. Effects of W-CDMA 1950 MHz EMF emitted by mobile phones on regional cerebral blood flow in humans. Bioelectromagnetics.30(7):536-544,2009.**

Use of the third generation mobile phone system is increasing worldwide. This is the first study to investigate the effects of the third generation system on regional cerebral blood flow (rCBF) in humans. We compared effects of the electromagnetic field (EMF) emitted from the Wideband Code Division Multiple Access (W-CDMA) cellular system versus sham control exposure on rCBF in humans. Nine healthy male volunteers participated in this study. Positron emission tomography (PET) scans were obtained before, during, and after unilateral 30 min EMF exposure. The subtraction analysis revealed no significant rCBF changes caused by the EMF conditions compared with the sham exposure, suggesting that EMF emitted by a third generation mobile phone does not affect rCBF in humans.

**Mjøen G, Saetre DO, Lie RT, Tynes T, Blaasaas KG, Hannevik M, Irgens LM. Paternal occupational exposure to radiofrequency electromagnetic fields and risk of adverse pregnancy outcome. Eur J Epidemiol. 21(7):529-535, 2006**

BACKGROUND: During the last decades, public concern that radiofrequency radiation (RFR) may be related to adverse reproductive outcomes has been emerging. Our objective was to assess associations between paternal occupational exposure to RFR and adverse pregnancy outcomes including birth defects using population-based data from Norway. METHODS: Data on reproductive outcomes derived from the Medical Birth Registry of Norway were linked with data on paternal occupation derived from the general population censuses. An expert panel categorized occupations according to exposure. Using logistic regression, we analyzed 24 categories of birth defects as well as other adverse outcomes. RESULTS: In the offspring of fathers most likely to have been exposed, increased risk was observed for preterm birth (odds ratio (OR): 1.08, 95% confidence interval (CI): 1.03, 1.15). In this group we also observed a decreased risk of cleft lip (OR: 0.63, 95% CI: 0.41, 0.97). In the medium exposed group, we observed increased risk for a category of "other defects" (OR: 2.40, 95% CI: 1.22, 4.70), and a decreased risk for a category of "other syndromes" (OR: 0.75, 95% CI: 0.56, 0.99) and upper gastrointestinal defects (OR: 0.61, 95% CI: 0.40, 0.93). CONCLUSION: The study is partly reassuring for occupationally exposed fathers.

**Mohammed HS, Fahmy HM, Radwah NM, Elsayed AA. Non-thermal continuous and modulated electromagnetic radiation fields effects on sleep EEG of rats. J Adv Res 4(2) 181-187, 2013.**

In the present study, the alteration in the sleep EEG in rats due to chronic exposure to low-level non-thermal electromagnetic radiation was investigated. Two types of radiation fields were used; 900 MHz unmodulated wave and 900 MHz modulated at 8 and 16 Hz waves. Animals has exposed to radiation fields for 1 month (1 h/day). EEG power spectral analyses of exposed and control animals during slow wave sleep (SWS) and rapid eye movement sleep (REM sleep) revealed that the REM sleep is more susceptible to modulated radiofrequency radiation fields (RFR) than the SWS. The latency of REM sleep increased due to radiation exposure indicating a change in the ultradian rhythm of normal sleep cycles. The cumulative and irreversible effect of radiation exposure was proposed and the interaction of the extremely low frequency radiation with the similar EEG frequencies was suggested.

**Mohler E, Frei P, Braun-Fahrländer C, Fröhlich J, Neubauer G, Röösli M; Qualifex Team. Effects of everyday radiofrequency electromagnetic-field exposure on sleep quality: a cross-sectional study.Radiat Res. 174(3):347-356, 2010.**

The aim of this cross-sectional study was to investigate the association between exposure to various sources of radiofrequency electromagnetic fields (RF EMFs) in the everyday environment and sleep quality, which is a common public health concern. We assessed self-reported sleep disturbances and daytime sleepiness in a random population sample of 1,375 inhabitants from the area of Basel, Switzerland. Exposure to environmental far-field RF EMFs was predicted for each individual using a prediction model that had been developed and validated previously. Self-reported cordless and mobile phone use as well as objective mobile phone operator data for the previous 6 months were also considered in the analyses. In multivariable regression models,

adjusted for relevant confounders, no associations between environmental far-field RF EMF exposure and sleep disturbances or excessive daytime sleepiness were observed. The 10% most exposed participants had an estimated risk for sleep disturbances of 1.11 (95% CI: 0.50 to 2.44) and for excessive daytime sleepiness of 0.58 (95% CI: 0.31 to 1.05). Neither mobile phone use nor cordless phone use was associated with decreased sleep quality. The results of this large cross-sectional study did not indicate an impairment of subjective sleep quality due to exposure from various sources of RF EMFs in everyday life.

**Mohler E, Frei P, Fröhlich J, Braun-Fahrländer C, Röösli M; QUALIFEX-team. Exposure to radiofrequency electromagnetic fields and sleep quality: a prospective cohort study.PLoS One. 7(5):e37455, 2012.**

BACKGROUND: There is persistent public concern about sleep disturbances due to radiofrequency electromagnetic field (RF-EMF) exposure. The aim of this prospective cohort study was to investigate whether sleep quality is affected by mobile phone use or by other RF-EMF sources in the everyday environment. METHODS: We conducted a prospective cohort study with 955 study participants aged between 30 and 60 years. Sleep quality and daytime sleepiness was assessed by means of standardized questionnaires in May 2008 (baseline) and May 2009 (follow-up). We also asked about mobile and cordless phone use and asked study participants for consent to obtain their mobile phone connection data from the mobile phone operators. Exposure to environmental RF-EMF was computed for each study participant using a previously developed and validated prediction model. In a nested sample of 119 study participants, RF-EMF exposure was measured in the bedroom and data on sleep behavior was collected by means of actigraphy during two weeks. Data were analyzed using multivariable regression models adjusted for relevant confounders. RESULTS: In the longitudinal analyses neither operator-recorded nor self-reported mobile phone use was associated with sleep disturbances or daytime sleepiness. Also, exposure to environmental RF-EMF did not affect self-reported sleep quality. The results from the longitudinal analyses were confirmed in the nested sleep study with objectively recorded exposure and measured sleep behavior data. CONCLUSIONS: We did not find evidence for adverse effects on sleep quality from RF-EMF exposure in our everyday environment.

**Moisescu MG, Leveque P, Bertrand JR, Kovacs E, Mir LM. Microscopic observation of living cells during their exposure to modulated electromagnetic fields.Bioelectrochemistry. 74(1):9-15, 2008.**

Studying cell behaviour under irradiation with radiofrequency electromagnetic fields (RF-EMF) is often impeded by the difficulty to monitor cell characteristics during irradiation. Here we report the design and the application of a complete device for continuous microscopic observation of cells exposed to modulated EMF similar to mobile phones signals. The system allows the follow up of cell progression into mitosis under controlled temperature and CO(2) environment. Protocols are proposed in which the same cells are the controls before and after the EMF exposure and we demonstrate the interest of the "before exposure" controls. The exposure system was validated by cell endocytosis measurements. While the endocytosis rate was increased, no alteration of mitosis

progression and mitosis duration was observed in cells exposed to 900 MHz modulated EMF for 1 h, at 30 degrees C and at a Specific Absorption Rate of 2.2 W/kg.

**Moisescu MG, Leveque P, Verjus MA, Kovacs E, Mir LM. 900 MHz modulated electromagnetic fields accelerate the clathrin-mediated endocytosis pathway. Bioelectromagnetics30(3):222-230,2009.**

We report new data regarding the molecular mechanisms of GSM-induced increase of cell endocytosis rate. Even though endocytosis represents an important physical and biological event for cell physiology, studies on modulated electromagnetic fields (EMF) effects on this process are scarce. In a previous article, we showed that fluid phase endocytosis rate increases when cultured cells are exposed to 900 MHz EMF similar to mobile phones' modulated GSM signals (217 Hz repetition frequency, 576 micros pulse width) and to electric pulses similar to the GSM electrical component. Trying to distinguish the mechanisms sustaining this endocytosis stimulation, we exposed murine melanoma cells to Lucifer Yellow (LY) or to GSM-EMF/electric pulses in the presence of drugs inhibiting the clathrin- or the caveolin-dependent endocytosis. Experiments were performed at a specific absorption rate (SAR) of 3.2 W/kg in a wire patch cell under homogeneously distributed EMF field and controlled temperature (in the range of 28.5-29.5 degrees C). Thus, the observed increase in LY uptake was not a thermal effect. Chlorpromazine and ethanol, but not Filipin, inhibited this increase. Therefore, the clathrin-dependent endocytosis is stimulated by the GSM-EMF, suggesting that the cellular mechanism affected by the modulated EMF involves vesicles that detach from the cell membrane, mainly clathrin-coated vesicles.

**Moisescu MG, Leveque P, Bertrand JR, Kovacs E, Mir LM. Microscopic observation of living cells during their exposure to modulated electromagnetic fields. Bioelectrochemistry 74(1) 9-15, 2008.**

Studying cell behaviour under irradiation with radiofrequency electromagnetic fields (RF-EMF) is often impeded by the difficulty to monitor cell characteristics during irradiation. Here we report the design and the application of a complete device for continuous microscopic observation of cells exposed to modulated EMF similar to mobile phones signals. The system allows the follow up of cell progression into mitosis under controlled temperature and CO(2) environment. Protocols are proposed in which the same cells are the controls before and after the EMF exposure and we demonstrate the interest of the "before exposure" controls. The exposure system was validated by cell endocytosis measurements. While the endocytosis rate was increased, no alteration of mitosis progression and mitosis duration was observed in cells exposed to 900 MHz modulated EMF for 1 h, at 30 degrees C and at a Specific Absorption Rate of 2.2 W/kg.

**Mokarram P, Sheikhi M, Mortazavi SMJ, Saeb S, Shokrpour N. Effect of Exposure to 900 MHz GSM Mobile Phone Radiofrequency Radiation on Estrogen Receptor Methylation Status in Colon Cells of Male Sprague Dawley Rats. J Biomed Phys Eng. 7(1):79-86, 2017.**

BACKGROUND: Over the past several years, the rapidly increasing use of mobile phones has raised global concerns about the biological effects of exposure to radiofrequency (RF) radiation. Numerous studies have shown that exposure to electromagnetic fields (EMFs) can be associated with effects on the nervous, endocrine, immune, cardiovascular, hematopoietic and ocular systems. In spite of genetic diversity, the onset and progression of cancer can be controlled by epigenetic mechanisms such as gene promoter methylation. There are extensive studies on the epigenetic changes of the tumor suppressor genes as well as the identification of methylation biomarkers in colorectal cancer. Some studies have revealed that genetic changes can be induced by exposure to RF radiation. However, whether or not RF radiation is capable of inducing epigenetic alteration has not been clarified yet. To date, no study has been conducted on the effect of radiation on epigenetic alterations in colorectal cancer (CRC). Several studies have also shown that methylation of estrogen receptor α (ERα), MYOD, MGMT, SFRP2 and P16 play an important role in CRC. It can be hypothesized that RF exposure can be a reason for the high incidence of CRC in Iran. This study aimed to investigate whether epigenetic pattern of ERα is susceptible to RF radiation and if RF radiation can induce radioadaptive response as epigenetic changes after receiving the challenge dose (γ-ray). MATERIAL AND METHOD: 40 male Sprague-Dawley rats were divided into 4 equal groups (Group I: exposure to RF radiation of a GSM cell phone for 4 hours and sacrificed after 24 hours; Group II: RF exposure for 4 hours, exposure to Co-60 gamma radiation (3 Gy) after 24 hours and sacrificed after 72 hrs; Group III: only 3Gy gamma radiation; Group 4: control group). DNA from colon tissues was extracted to evaluate the methylation status by methylation specific PCR. RESULTS: Our finding showed that exposure to GSM cell phone RF radiation was capable of altering the pattern of ERα gene methylation compared to that of non-exposed controls. Furthermore, no adaptive response phenomenon was induced in the pattern of ERα gene methylation after exposure to the challenging dose of Co-60 γ-rays. CONCLUSION: It can be concluded that exposure to RF radiation emitted by GSM mobile phones can lead to epigenetic detrimental changes in ERα promoter methylation pattern.

**Momoli F, Siemiatycki J, McBride ML, Parent MÉ, Richardson L, Bedard D, Platt R, Vrijheid M, Cardis E, Krewski D. Probabilistic Multiple-Bias Modeling Applied to the Canadian Data From the Interphone Study of Mobile Phone Use and Risk of Glioma, Meningioma, Acoustic Neuroma, and Parotid Gland Tumors. Am J Epidemiol. 186(7):885-893, 2017.**

We undertook a re-analysis of the Canadian data from the 13-country case-control Interphone Study (2001-2004), in which researchers evaluated the associations of mobile phone use with the risks of brain, acoustic neuroma, and parotid gland tumors. In the main publication of the multinational Interphone Study, investigators concluded that biases and errors prevented a causal interpretation. We applied a probabilistic multiple-bias model to address possible biases simultaneously, using validation data from billing records and nonparticipant questionnaires as information on recall error and selective participation. In our modeling, we sought to adjust for these sources of uncertainty and to facilitate interpretation. For glioma, when comparing those in the highest quartile of use

(>558 lifetime hours) to those who were not regular users, the odds ratio was 2.0 (95% confidence interval: 1.2, 3.4). After adjustment for selection and recall biases, the odds ratio was 2.2 (95% limits: 1.3, 4.1). There was little evidence of an increase in the risk of meningioma, acoustic neuroma, or parotid gland tumors in relation to mobile phone use. Adjustments for selection and recall biases did not materially affect interpretation in our results from Canadian data.

**Moneda AP, Ioannidou MP, Chrissoulidis DP. Radio-wave exposure of the human head: analytical study based on a versatile eccentric spheres model including a brain core and a pair of eyeballs. IEEE Trans Biomed Eng. 50(6):667-676, 2003.**

A versatile eccentric-spheres model of the human head is used in this paper to investigate radio-wave absorption. Numerical results, obtained by use of an exact analytical solution, are presented for the total, percentage, and gram-specific absorption. Interest is mainly in the brain and in the eyes of an adult or an infant head. Our model comprises a host sphere and several spherical inclusions, all concentrically stratified with respect to their own center. Any number of inclusions and any number of concentric layers for the host sphere and each one of the inclusions can be considered. Excitation is provided either by a plane-wave or by a nearby electric dipole. The analytical solution is obtained by use of the indirect-mode matching method. The theory of this paper and the accompanying computer code constitute a versatile tool for analytical studies of cellular-phone interactions with the human head. Specific absorption rate maps in a horizontal cross section of the head model manifest the existence of hot spots in the eyes and near the center of the brain.

**Mortazavi SM, Daiee E, Yazdi A, Khiabani K, Kavousi A, Vazirinejad R, Behnejad B, Ghasemi M, Mood MB. Mercury release from dental amalgam restorations after magnetic resonance imaging and following mobile phone use. Pak J Biol Sci. 11(8):1142-1146, 2008.**

In the 1st phase of this study, thirty patients were investigated. Five milliliter stimulated saliva was collected just before and after MRI. The magnetic flux density was 0.23 T and the duration of exposure of patients to magnetic field was 30 minutes. In the 2nd phase, fourteen female healthy University students who had not used mobile phones before the study and did not have any previous amalgam restorations were investigated. Dental amalgam restoration was performed for all 14 students. Their urine samples were collected before amalgam restoration and at days 1, 2, 3 and 4 after restoration. The mean +/- SD saliva Hg concentrations of the patients before and after MRI were 8.6 +/- 3.0 and 11.3 +/- 5.3 microg L(-1), respectively ($p < 0.01$). A statistical significant ($p < 0.05$) higher concentration was observed in the students used mobile phone. The mean +/- SE urinary Hg concentrations of the students who used mobile phones were 2.43 +/- 0.25, 2.71 +/- 0.27, 3.79 +/- 0.25, 4.8 +/- 0.27 and 4.5 +/- 0.32 microg L(-1) before the amalgam restoration and at days 1, 2, 3 and 4, respectively. Whereas the respective Hg concentrations in the controls, were 2.07 +/- 0.22, 2.34 +/- 0.30, 2.51 +/- 0.25, 2.66 +/- 0.24 and 2.76 +/- 0.32 microg L(-1). It appears that MRI and microwave radiation emitted from mobile phones significantly release mercury from dental amalgam restoration. Further research is needed to clarify whether other common sources of electromagnetic field exposure may cause alterations in dental amalgam and accelerate the release of

mercury.

**Mortazavi SM, Mahbudi A, Atefi M, Bagheri Sh, Bahaedini N, Besharati A. An old issue and a new look: Electromagnetic hypersensitivity caused by radiations emitted by GSM mobile phones. Technol Health Care. 19(6):435-443, 2011.**

Abstract. University students use mobile phones frequently. We previously showed that there was no association between mobile phone use and EMF health hazards among university students. As our previous study was based only on self-reported symptoms this double-blind study was designed to answer two basic questions. Firstly, are self-reported hypersensitive individuals capable of sensing whether there is a real/sham microwave exposure? Secondly, do hypersensitive patients show alterations in their biological parameters such as heart rate, respiration, and blood pressure during microwave exposure? The study consisted of a preliminary screening phase and two subsequent complementary phases. In the 1st phase, 700 students were screened for EMF hypersensitivity. Fifty two participants were hypersensitive individuals but after applying the exclusion criteria only 28 students were invited to take part in the 2nd and 3rd phase of the study, but only 20 students (71.4%) declared their informed consent. In the 2nd phase, these self reported hypersensitive participants, were exposed/sham exposed to microwave radiation emitted from a mobile phone for 10 minutes and they were asked if they could sense the existence of microwave radiation. In the 3rd phase, all students were connected to ICU monitoring devices and their basic physiological parameters were recorded precisely. Among self-reported symptoms reported in our previous study, in this study only problem in concentration ($P< 0.05$) and low back pain ($P< 0.05$) were associated with mobile phone use. Furthermore, there was a significant association between the location of mobile phone during talk and the overall score of the severity of the symptoms ($P< 0.001$). When the participants were asked to report their perception about the real and sham exposures, only 5 students (25%) could discriminate the real exposure/sham exposure phases. This relative frequency can be only due to chance. In the 3rd phase all of the 20 participants were connected to intensive care unit monitors and the changes in their heart rate, respiration, and blood pressure during real/sham exposure were recorded. No statistically significant changes between the means of these parameters in real/sham exposure were observed. Our findings clearly confirm the results obtained inother provocative studies. These data also indicate the possible role of psychological factors in electromagnetic hypersensitivity.

**Mortazavi SMJ, Mosleh-Shirazi MA, Tavassoli AR, Taheri M, Bagheri Z, Ghalandari R, Bonyadi S, Shafie M , Haghani M. A comparative study on the increased radioresistance to lethal doses of gamma rays after exposure to microwave radiation and oral intake of flaxseed oil. Iran. J. Radiat. Res. 9(1): 9-14, 2011.**

**Background:** Mobile phones, use electromagnetic radiation in the microwave range. On the other hand, there is only one report on radioprotective effects of flaxseed oil. The aim of this study was to investigate the effect of irradiation of rats with microwaves and/or

treatment with flaxseed oil on the induction of adaptive response to a subsequent lethal dose (LD) of gamma rays. **Materials and Methods:** Eighty male rats were randomly divided into 6 groups of 13-15 animals. The animals in the 1st to 5th groups received microwave exposure, microwave+flaxseed oil (dissolved in olive oil), flaxseed (continued after LD), flaxseed, and olive oil. At day 5, all animals were whole-body irradiated with a previously reported LD 50/30 of 8 Gy gamma radiation. The 6th group (controls) received the same LD 50/30, but there was not any other treatment before or after the LD. **Results:** No death event was observed during days 1-9 after LD irradiation in either group. At day 10, death events started in the 4th group. Thirty days after irradiation of the animals, the survival fractions for the control group, as expected, was 53.3% while there was no death event in the 1st group (survival rate of 100% in microwave-pretreated animals). The survival fractions for the 2nd to 5th groups were 69.2%, 92.3%, 46.1%, and 61.5%, respectively. **Conclusion:** While these findings open new horizons in radiation protection, the radioresistance induced by microwave radiations emitted by a mobile phone may interfere with the outcome of any subsequent therapeutic application of photons or radioisotopes. 1

**Mortazavi S, Mosleh-Shirazi M, Tavassoli A, Taheri M, Mehdizadeh A, Namazi S, Jamali A, Ghalandari R, Bonyadi S, Haghani M, Shafie M. Increased Radioresistance to Lethal Doses of Gamma Rays in Mice and Rats after Exposure to Microwave Radiation Emitted by a GSM Mobile Phone Simulator. Dose Response. 11(2):281-292, 2012.**

The aim of this study was to investigate the effect of pre-irradiation with microwaves on the induction of radioadaptive response. In the 1(st) phase of the study, 110 male mice were divided into 8 groups. The animals in these groups were exposed/sham-exposed to microwave, low dose rate gamma or both for 5 days. On day six, the animals were exposed to a lethal dose (LD). In the 2(nd) phase, 30 male rats were divided into 2 groups of 15 animals. The 1(st) group received microwave exposure. The 2(nd) group (controls) received the same LD but there was no treatment before the LD. On day 5, all animals were whole-body irradiated with the LD. Statistically significant differences between the survival rate of the mice only exposed to lethal dose of gamma radiation before irradiation with a lethal dose of gamma radiation with those of the animals pre-exposed to either microwave (p=0.02), low dose rate gamma (p=0.001) or both of these physical adapting doses (p=0.003) were observed. Likewise, a statistically significant difference between survival rates of the rats in control and test groups was observed. Altogether, these experiments showed that exposure to microwave radiation may induce a significant survival adaptive response.

**Mortazavi SM, Vazife-Doost S, Yaghooti M, Mehdizadeh S, Rajaie-Far A. Occupational exposure of dentists to electromagnetic fields produced by magnetostrictive cavitrons alters the serum cortisol level. J Nat Sci Biol Med. 3(1):60-64, 2012.**

OBJECTIVES: Some studies indicate that dentistry is one of the job categories with high potential exposure to elevated levels of extremely low frequency magnetic fields. In spite of this, information on occupational exposure of dentists to these fields is scarce. Studies on other common sources of electromagnetic fields (EMFs) such as mobile base stations have shown alterations in the cortisol level following exposure of humans to these sources. The aim of this study is to compare the level of cortisol among dentists and dentistry students who are being occupationally exposed to EMFs emitted by magnetostrictive cavitrons (case group) and among their counterparts who are not being exposed to these fields (control group). MATERIALS AND METHODS: In this case-control study, blood samples were collected from 41 dentists and dentistry students, 21 of whom were exposed to EMFs emitted by cavitrons as the case group and 20 who were not exposed as the control group, twice; i.e. before work (at 8:30-9:30 a.m.) and after work (11:30-12:30 a.m.). The samples were coded and the serum cortisol level was investigated using the ELISA method (Cortisol AccuBind ELISA Kits). RESULTS: The serum cortisol level of dentists and dental students in the morning (before starting the work) in the control group was 189.15 ± 110.70 (mean ± SD) whereas it was 157.77 ± 112.03 in those who were occupationally exposed to EMFs produced by the use of cavitrons. This difference was not statistically significant (P = 0.373). In contrast, the serum cortisol level of the participants in the noon (after stopping the work) in the control group was 136.25 ± 67.91 (mean ± SD) while it was 88.58 ± 52.83 in those who were occupationally exposed to EMFs produced by the use of cavitrons. This time, the observed difference was statistically significant (P = 0.016). In this light, while the difference between serum cortisol levels of dentists and dental students in the morning and after stopping the work was not statistically significant (P = 0.06), in the EMF-exposed group the cortisol level decreased significantly from 157.77 ± 112.03 in the morning to 88.58 ± 52.83 in the noon (P = 0.001).CONCLUSIONS: As far as we know, this is the first study that evaluated the effect of occupational exposure of dentists to EMFs on their serum cortisol level. The EMFs produced by magnetostrictive cavitrons can decrease the serum cortisol level in dentists. As cortisol plays an important role in blood pressure regulation, cardiovascular, and immune system function, a low cortisol level may threaten health. More studies are needed to clearly understand the effects of EMFs emitted by magnetostrictive cavitron on the level of stress hormones. As some studies have shown that exposure to EMFs has no effect on the cortisol level, whereas other studies reported either an increase or a decrease in the cortisol level, it can be concluded that the effects of exposure to EMFs may occur only at specific absorbed energies or energy absorption rates (usually known as window) similar to that exists in the case of exposure to the low doses of ionizing radiations.

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**Mortazavi SM, Rouintan MS, Taeb S, Dehghan N, Ghaffarpanah AA, Sadeghi Z, Ghafouri F. Human short-term exposure to electromagnetic fields emitted by mobile phones decreases computer-assisted visual reaction time. Acta Neurol Belg. 112(2):171-175, 2012.**

The worldwide dramatic increase in mobile phone use has generated great concerns about the detrimental effects of microwave radiations emitted by these communication devices. Reaction time plays a critical role in performing tasks necessary to avoid hazards. As far as we know, this study is the first survey that reports decreased reaction time after exposure to electromagnetic fields generated by a high specific absorption rate mobile phone. It is also the first study in which previous history of mobile phone use is taken into account. The aim of this study was to assess both the acute and chronic effects of electromagnetic fields emitted by mobile phones on reaction time in university students. Visual reaction time (VRT) of young university students was recorded with a simple blind computer-assisted-VRT test, before and after a 10 min real/sham exposure to electromagnetic fields of mobile phones. Participants were 160 right-handed university students aged 18-31. To assess the effect of chronic exposures, the reaction time in sham-exposed phases were compared among low level, moderate and frequent users of mobile phones. The mean ± SD reaction time after real exposure and sham exposure were 286.78 ± 31.35 ms and 295.86 ± 32.17 ms ($P < 0.001$), respectively. The age of students did not significantly alter the reaction time either in talk or in standby mode. The reaction time either in talk or in standby mode was shorter in male students. The students' VRT was significantly affected by exposure to electromagnetic fields emitted by a mobile phone. It can be concluded that these exposures cause decreased reaction time, which may lead to a better response to different hazards. In this light, this phenomenon might decrease the chances of human errors and fatal accidents.

**Mortazavi SM, Taeb S, Dehghan N. Alterations of visual reaction time and short term memory in military radar personnel. Iran J Public Health. 42(4):428-435, 2013.**

BACKGROUND: Radar transmitters emit high-power radiofrequency radiation by creation of a high-voltage and high-frequency alternating electrical current. METHODS: Health effects of occupational exposure to military radar were investigated. Visual reaction time was recorded with a simple blind computer-assisted-visual reaction time test. To assess the short-term memory, modified Wechsler Memory Scale test was performed. RESULTS: The mean +/- SD reaction time in radar works (N=100) and the control group (N=57) were 238.58 +/- 23.47 milliseconds and 291.86 +/- 28.26 milliseconds ($P<0.0001$), respectively. The scores of forward digit span in radar works and the control group were 3.56 +/- 0.77 and 4.29 +/- 1.06 ($P<0.0001$), while the scores of backward digit span in radar works and the control group were 2.70 +/- 0.69 and 3.62 +/- 0.95 ($P<0.0001$). The scores of word recognition in radar works and the control group were 3.37 +/- 1.13 and 5.86 +/- 1.11 ($P<0.0001$). Finally, the scores of paired words in radar works and the control group were 13.56 +/- 1.78 and 15.21 +/- 2.20 ($P<0.0001$). It can be concluded that occupational exposures to radar radiations decreases reaction time, which may lead to a better response to different hazards. CONCLUSION: To the best of our knowledge, this is the first study to show that occupational exposure to radar microwave radiation leads to decreased reaction time and the lower performance of short-term memory. Altogether, these results indicate that occupational exposure to radar microwave radiations may be linked to some non-detrimental and detrimental health effects.

**Mohler E, Frei P, Braun-Fahrländer C, Fröhlich J, Neubauer G, Röösli M. Effects**

**of everyday radiofrequency electromagnetic-field exposure on sleep quality: a cross-sectional study. Radiat Res. 174(3):347-356, 2010.**

The aim of this cross-sectional study was to investigate the association between exposure to various sources of radiofrequency electromagnetic fields (RF EMFs) in the everyday environment and sleep quality, which is a common public health concern. We assessed self-reported sleep disturbances and daytime sleepiness in a random population sample of 1,375 inhabitants from the area of Basel, Switzerland. Exposure to environmental far-field RF EMFs was predicted for each individual using a prediction model that had been developed and validated previously. Self-reported cordless and mobile phone use as well as objective mobile phone operator data for the previous 6 months were also considered in the analyses. In multivariable regression models, adjusted for relevant confounders, no associations between environmental far-field RF EMF exposure and sleep disturbances or excessive daytime sleepiness were observed. The 10% most exposed participants had an estimated risk for sleep disturbances of 1.11 (95% CI: 0.50 to 2.44) and for excessive daytime sleepiness of 0.58 (95% CI: 0.31 to 1.05). Neither mobile phone use nor cordless phone use was associated with decreased sleep quality. The results of this large cross-sectional study did not indicate an impairment of subjective sleep quality due to exposure from various sources of RF EMFs in everyday life.

**Momoli F, Siemiatycki J, McBride ML, Parent MÉ, Richardson L, Bedard D, Platt R, Vrijheid M, Cardis E, Krewski D. Probabilistic Multiple-Bias Modeling Applied to the Canadian Data From the Interphone Study of Mobile Phone Use and Risk of Glioma, Meningioma, Acoustic Neuroma, and Parotid Gland Tumors. Am J Epidemiol. 186(7):885-893, 2017.**

We undertook a re-analysis of the Canadian data from the 13-country case-control Interphone Study (2001-2004), in which researchers evaluated the associations of mobile phone use with the risks of brain, acoustic neuroma, and parotid gland tumors. In the main publication of the multinational Interphone Study, investigators concluded that biases and errors prevented a causal interpretation. We applied a probabilistic multiple-bias model to address possible biases simultaneously, using validation data from billing records and nonparticipant questionnaires as information on recall error and selective participation. In our modeling, we sought to adjust for these sources of uncertainty and to facilitate interpretation. For glioma, when comparing those in the highest quartile of use (>558 lifetime hours) to those who were not regular users, the odds ratio was 2.0 (95% confidence interval: 1.2, 3.4). After adjustment for selection and recall biases, the odds ratio was 2.2 (95% limits: 1.3, 4.1). There was little evidence of an increase in the risk of meningioma, acoustic neuroma, or parotid gland tumors in relation to mobile phone use. Adjustments for selection and recall biases did not materially affect interpretation in our results from Canadian data.

**Monfrecola G, Moffa G, Procaccini EM. Non-ionizing electromagnetic radiations, emitted by a cellular phone, modify cutaneous blood flow. Dermatology. 207(1):10-14, 2003.**

BACKGROUND: Our surroundings are full of non-ionizing electromagnetic radiation (EMR) of different frequency and power. The non-ionizing EMRs emitted by television, computer and cellular phone (CF) sets have been increasing over the past few years. OBJECTIVE: The aim of our study was to assess the effects of non-ionizing EMRs (frequency 3 x 10(8) to 3 x 10(11) Hz), emitted by CFs, on cutaneous blood flow in healthy volunteers. METHODS: Thirty healthy volunteers (14 male and 16 female; age: 18-53 years) entered the study. Measurements of cutaneous blood flow were taken under standard conditions (temperature and humidity), using a laser Doppler He-Ne flowmeter that was applied to the ear skin by an optical fibre probe. Microflow values were recorded without CF contact with the skin (T0), with the CF turned off but in contact with the ear skin (T1), with CF contact and turned on (T2), with CF contact, turned on and receiving (T3). The microflow values were also recorded backwards: with CF contact and set turned on (T4), with CF contact and turned off (T5), without CF contact (T6). RESULTS: The mean value of basal microflow (T0), expressed as perfusion units (PU), was 51.26+/-11.93 PU. During the T1 phase, the microflow increase was 61.38%; in T2 it was 131.74%, in T3 157.67%, in T4 139.21% and in T5 122.90%; in T6, the microflow value was 57.58+/-10 PU (similar to the basal microflow). Statistically significant cutaneous microflow values ($p<0.050$) were observed comparing the T1 to T5 values with basal microflow (T0). Furthermore, in comparison with T1 values (CF turned off in contact with the ear skin), the T2, T3 and T4 data were statistically significant (T2 vs. T1: $t=7.763$ with $p<0.050$; T3 vs. T1: $t=9.834$ with $p<0.050$; T4 vs. T1: $t=8.885$ with $p<0.050$).

**Monnery PM, Srouji EI, Bartlett J. Is cochlear outer hair cell function affected by mobile telephone radiation? Clin Otolaryngol 29(6):747-749, 2004.**

Mobile telephones emit high-frequency pulsed electromagnetic fields (PEMF). These are known to have measurable biological effects, and possible effects on the auditory system. Otoacoustic emissions give an indication of the functional state of the auditory system. Otoacoustics are known to be highly specific for the individual when the test pulse is identical. In this way, subtle changes in the ear can be detected. We investigated whether there is a measurable effect on Otoacoustic emissions from PEMF radiation. A total of 12 volunteers were recruited who had normal hearing; confirmed by pure tone audiometry. An Otoacoustic emission trace was obtained. The test subjects were exposed to a mobile telephone that was placed over the test ears mastoid process. The subjects had Otoacoustic emissions measured without the telephone and again on receive and transmit. There was no change in the trace signature during the test. There was no statistically significant change in the trace figures. This would indicate that PEMF from commonly available hand held mobile telephones have no measurable effect on the outer hair cell function during the time of use.

**Monselise EB, Levkovitz A, Gottlieb HE, Kost D. Bioassay for assessing cell stress in the vicinity of radio-frequency irradiating antennas. J Environ Monit. 13(7):1890-1896, 2011.**

The 24 h exposure of water plants (etiolated duckweed) to RF-EMF between 7.8 V m(-1) and 1.8 V m(-1), generated by AM 1.287 MHz transmitting antennas, resulted in alanine accumulation in the plant cells, a phenomenon we have previously shown to be a universal stress signal. The magnitude of the effect corresponds qualitatively

to the level of RF-EMF exposure. In the presence of 10 mM vitamin C, alanine accumulation is completely suppressed, suggesting the involvement of free radicals in the process. A unique biological connection has thus been made between exposure to RF-EMF and cell stress, in the vicinity of RF transmitting antennas. This simple test, which lasts only 24 h, constitutes a useful bioassay for the quick detection of biological cell stress caused in the vicinity of RF irradiating antennas.

**Mora R, Crippa B, Mora F, Dellepiane M. A study of the effects of cellular telephone microwave radiation on the auditory system in healthy men. Ear Nose Throat J. 85(3):160, 162-163, 2006.**

We conducted a study of the effects of mobile cellular telephone microwave radiation on the auditory system in 20 healthy men. After the subjects underwent baseline measurements of transient evoked otoacoustic emission (TEOAE) and auditory brainstem response (ABR), they participated in three sessions of exposure to an electromagnetic field of 900 to 1,800 MHz produced by a cellular phone. Sessions ranged from 15 to 30 minutes in length. TEOAE and ABR were again measured after or during each exposure. Throughout the study, no significant changes in either measurement were noted. We conclude that the use of cellular phones does not alter the auditory system in the short-term.

**Moretti D, Garenne A, Haro E, Poulletier de Gannes F, Lagroye I, Lévêque P, Veyret B, Lewis N. In-vitro exposure of neuronal networks to the GSM-1800 signal. Bioelectromagnetics. 2013 Aug 1. doi: 10.1002/bem.21805. [Epub ahead of print]**

The central nervous system is the most likely target of mobile telephony radiofrequency (RF) field exposure in terms of biological effects. Several electroencephalography (EEG) studies have reported variations in the alpha-band power spectrum during and/or after RF exposure, in resting EEG and during sleep. In this context, the observation of the spontaneous electrical activity of neuronal networks under RF exposure can be an efficient tool to detect the occurrence of low-level RF effects on the nervous system. Our research group has developed a dedicated experimental setup in the GHz range for the simultaneous exposure of neuronal networks and monitoring of electrical activity. A transverse electromagnetic (TEM) cell was used to expose the neuronal networks to GSM-1800 signals at a SAR level of 3.2 W/kg. Recording of the neuronal electrical activity and detection of the extracellular spikes and bursts under exposure were performed using microelectrode arrays (MEAs). This work provides the proof of feasibility and preliminary results of the integrated investigation regarding exposure setup, culture of the neuronal network, recording of the electrical activity, and analysis of the signals obtained under RF exposure. In this pilot study on 16 cultures, there was a 30% reversible decrease in firing rate (FR) and bursting rate (BR) during a 3 min exposure to RF. Additional experiments are needed to further characterize this effect.

**Morgan RW, Kelsh MA, Zhao K, Exuzides KA, Heringer S, Negrete W, Radiofrequency exposure and mortality from cancer of the brain and lymphatic/hematopoietic systems. Epidemiology 11(2):118-127, 2000.**

The proliferation of wireless communication technologies has raised public concern regarding potential health effects of radiofrequency (RF) exposures. This is the first report of findings from a large-cohort mortality study among employees of Motorola, a manufacturer of wireless communication products. We examined all major causes of mortality, with brain cancers, lymphomas, and leukemias as a priori outcomes of interest. Using job titles, we classified workers into high, moderate, low, and background RF exposure groups. A total of 195,775 workers contributed 2.7 million person-years during the 1976-1996 period. Using external comparisons, the standardized mortality ratios for RF-exposed workers were 0.53 [95% confidence interval (CI) = 0.21-1.09] and 0.54 (95% CI = 0.33-0.83) for central nervous system/brain cancers and all lymphomas/leukemias. Rate ratios calculated from Poisson regression models based on internal comparisons were near 1.0 for brain cancers and below 1.0 for all lymphomas and leukemias. These findings were consistent across cumulative, peak, and usual exposure classifications. We did not observe higher risk with increased exposure duration or latency. Although this study is limited by the use of a qualitative exposure matrix and the relatively young age of the cohort, our findings do not support an association between occupational RF exposure and brain cancers or lymphoma/leukemia.

**Morimoto S, Takahashi T, Shimizu K, Kanda T, Okaishi K, Okuro M, Murai H, Nishimura Y, Nomura K, Tsuchiya H, Ohashi I, Matsumoto M. Electromagnetic fields inhibit endothelin-1 production stimulated by thrombin in endothelial cells. J Int Med Res. 33(5):545-554, 2005.**

Electromagnetic field (EMF) radiation has been found to induce arteriolar dilatation, but the mechanism of action remains largely unknown. This study investigated the effect of EMF radiation on the production of endothelin-1 (ET-1), a potent vasoconstrictor, by cultured endothelial cells. EMF radiation reduced ET-1 basal levels in human umbilical vein and microvascular endothelial cells, but failed to reduce ET-1 basal levels in bovine and human aortic endothelial cells. EMF radiation significantly inhibited thrombin-stimulated ET-1 production in all four endothelial cell types in a dose-dependent manner. EMF radiation significantly inhibited thrombin-induced endothelin-1 mRNA expression in all four cell types. The inhibitory effect of EMF radiation on ET-1 production was abolished by the nitric oxide synthase inhibitor NG-monomethyl-L-arginine (10(-3) mol/1). These results demonstrate that EMF radiation modulates ET-1 production in cultured vascular endothelial cells and the inhibitory effect of EMF radiation is, at least partly, mediated through a nitric oxide-related pathway.

**Morrissey JJ, Raney S, Heasley E, Rathinavelu P, Dauphinee M, Fallon JH, IRIDIUM exposure increases c-fos expression in the mouse brain only at levels which likely result in tissue heating. Neuroscience 92(4):1539-1546, 1999.**

With the rapid development of wireless communication technology over the last 20 years, there has been some public concern over possible health effects of long-term, low-level radiofrequency exposure from cellular telephones. As an initial step in compiling a

database for risk analysis by government agencies, the effects of 1-h exposure of mice to a 1.6-GHz radiofrequency signal, given as either a continuous wave or pulse modulated at 11 Hz with a duty cycle of 4:1 and a pulse duration of 9.2 ms IRIDIUM), on c-fos gene expression in the brain was investigated. The IRIDIUM signal is the operating frequency for a ground-to-satellite-to-ground cellular communications web which has recently become fully operational, and was named as such due to the original designed employment of the same number of low orbiting satellites as there are electrons orbiting the nucleus of an iridium atom. The expression of c-fos was not significantly elevated in the brains of mice until exposure levels exceeded six times the peak dose and 30 times the whole body average dose as maximal cellular telephone exposure limits in humans. Higher level exposure using either continuous wave (analog) or IRIDIUM signals elevated c-fos to a similar extent, suggesting no obvious pulsed modulation-specific effects. The pattern of c-fos elevation in limbic cortex and subcortex areas at higher exposure levels is most consistent with a stress response due to thermal perception coupled with restraint and/or neuron activity near thermoregulatory regions, and not consistent with any direct interaction of IRIDIUM energy with brain tissue.

**Morrissey JJ, Swicord M, Balzano Q. Characterization of electromagnetic interference of medical devices in the hospital due to cell phones. Health Phys 82(1):45-51, 2002.**

Concern over electromagnetic interference with medical devices due to cell phone emissions has stemmed from anecdotal reports and unpublished observations of hospital staff. In an effort to characterize electromagnetic interference concerns, representative medical devices from four large teaching hospitals were exposed to standard North American and European communication signal emissions. Of 33 medical devices tested, only 4 showed disruption of critical function due to cell phone emissions at a distance of 25 cm or greater. Although other cases of electromagnetic interference were observed, these were not critically disruptive and mainly occurred when the transmitters were at full power and placed 5 cm or closer to the medical device. Overall, no cell phone signal was exempt from producing electromagnetic interference effects. While sensitive medical devices were often affected by more than one signal type, the effects were not entirely predictable based upon the results of other signals or related medical device units or models. Because a comprehensive analysis of all medical devices in all possible electromagnetic environments was not performed, the data presented here are only intended to provide a general idea of the magnitude of electromagnetic interference effects that might be encountered in a hospital environment, as well as a standard protocol for clinical engineering groups to perform ad hoc electromagnetic interference surveys and methods to manage and/or eliminate electromagnetic interference with appropriate system engineering design including supplementary communication infrastructure, medical device shielding and positioning, and appropriate cell phone user guidelines.

**Mortazavi SM, Shirazi KR, Mortazavi G. The study of the effects of ionizing and non-ionizing radiations on birth weight of newborns to exposed mothers. J Nat Sci Biol Med. 4(1):213-217, 2013.**

OBJECTIVES: Life evolved in an environment filled with a wide variety of ionizing and non-ionizing radiation. It was previously reported that medical exposures to pregnant women increases the risk of low birth weight. This study intends to investigate the relationship between exposure to ionizing and non-ionizing radiation and the risk of low birth weight. MATERIALS AND METHODS: One thousand two hundred mothers with their first-term labor (vaginal or cesarean) whose newborns' history had been registered in neonates' screening program in Shiraz were interviewed and surveyed. Data collection was performed by the assessment of mother's history of radiography before and during pregnancy, physical examination of the mother for height and weight and weighing and examining the newborn for any diagnosis of disease and anomalies. RESULTS: There were no statistical significant differences between the mean weight of newborns whose mothers had been exposed to some common sources of ionizing and non-ionizing radiations such as dental or non dental radiographies, mobile phone, cordless phone and cathode ray tube (CRT) and those of non-exposed mothers. CONCLUSIONS: The findings of this study cast doubt on previous reports, which indicated that exposure to ionizing radiation during pregnancy increased the risk of low birth weight.

**Mortazavi S, Parsanezhad M, Kazempour M, Ghahramani P, Mortazavi A, Davari M. Male reproductive health under threat: Short term exposure to radiofrequency radiations emitted by common mobile jammers. J Hum Reprod Sci. 2013 Apr;6(2):124-8. doi: 10.4103/0974-1208.117178**.

BACKGROUND: Modern life prompted man to increasingly generate, transmit and use electricity that leads to exposure to different levels of electromagnetic fields (EMFs). Substantial evidence indicates that exposure to common sources of EMF such as mobile phones, laptops or wireless internet-connected laptops decreases human semen quality. In some countries, mobile jammers are occasionally used in offices, shrines, conference rooms and cinemas to block the signal. AIMS: To the best of our knowledge, this is the first study to investigate the effect of short term exposure of human sperm samples to radiofrequency (RF) radiations emitted by common mobile jammers. SUBJECTS AND METHODS: Fresh semen samples were collected by masturbation from 30 healthy donors who had referred to Infertility Treatment Center at the Mother and Child Hospital with their wives. Female problem was diagnosed as the reason for infertility in these couples. STATISTICAL ANALYSIS: T-test and analysis of variance were used to show statistical significance. RESULTS: The motility of sperm samples exposed to jammer RF radiation for 2 or 4 h were significantly lower than those of sham-exposed samples. These findings lead us to the conclusion that mobile jammers may significantly decrease sperm motility and the couples' chances of conception. CONCLUSION: Based on these results, it can be suggested that in countries that have not banned mobile jammer use, legislations should be urgently passed to restrict the use of these signal blocking devices in public or private places.

**Mortazavi SM, Motamedifar M, Namdari G, Taheri M, Mortazavi AR, Shokrpour N. Non-linear adaptive phenomena which decrease the risk of infection after pre-exposure to radiofrequency radiation. Dose Response. 12(2):233-245, 2014.**

Substantial evidence indicates that adaptive response induced by low doses of ionizing radiation can result in resistance to the damage caused by a subsequently high-dose radiation or cause cross-resistance to other non-radiation stressors. Adaptive response contradicts the linear-non-threshold (LNT) dose-response model for ionizing radiation. We have previously reported that exposure of laboratory animals to radiofrequency radiation can induce a survival adaptive response. Furthermore, we have indicated that pre-exposure of mice to radiofrequency radiation emitted by a GSM mobile phone increased their resistance to a subsequent Escherichia coli infection. In this study, the survival rates in animals receiving both adapting (radiofrequency) and challenge dose (bacteria) and the animals receiving only the challenge dose (bacteria) were 56% and 20%, respectively. In this light, our findings contribute to the assumption that radiofrequency-induced adaptive response can be used as an efficient method for decreasing the risk of infection in immunosuppressed irradiated individuals. The implication of this phenomenon in human's long term stay in the space is also discussed.

**Mortazavi SM, Owji SM, Shojaei-Fard MB, Ghader-Panah M, Mortazavi SA, Tavakoli-Golpayegani A, Haghani M, Taeb S, Shokrpour N, Koohi O. GSM 900 MHz Microwave Radiation-Induced Alterations of Insulin Level and Histopathological Changes of Liver and Pancreas in Rat. J Biomed Phys Eng. 6(4):235-242, 2016.**

BACKGROUND: The rapidly increasing use of **mobile phones** has led to public concerns about possible health effects of these popular communication devices. This study is an attempt to investigate the effects of radiofrequency (RF) radiation produced by GSM **mobile phones** on the insulin release in rats. METHODS: Forty two female adult Sprague Dawley rats were randomly divided into 4 groups. Group1 were exposed to RF radiation 6 hours per day for 7 days. Group 2 received sham exposure (6 hours per day for 7 days). Groups 3 and 4 received RF radiation 3 hours per day for 7 days and sham exposure (3 hours per day), respectively. The specific absorption rate (SAR) of RF was 2.0 W/kg. RESULTS: Our results showed that RF radiations emitted from **mobile phone** could not alter insulin release in rats. However, mild to severe inflammatory changes in the portal spaces of the liver of rats as well as damage in the cells of islet of Langerhans were observed. These changes were linked with the duration of the exposures. CONCLUSION: RF exposure can induce inflammatory changes in the liver as well causing damage in the cells of islet of Langerhans.

**Mortazavi SMJ, Mostafavi-Pour Z, Daneshmand M, Zal F, Zare R, Mosleh-Shirazi MA. Adaptive Response Induced by Pre-Exposure to 915 MHz Radiofrequency: A Possible Role for Antioxidant Enzyme Activity. J Biomed Phys Eng. 7(2):137-142, 2017.**

BACKGROUND: Over the past few years, the rapid use of high frequency electromagnetic fields like **mobile phones** has raised global concerns about the negative health effects of its use. Adaptive response is the ability of a **cell** or tissue to better resist stress damage by prior exposure to a lesser amount of stress. This study aimed to assess whether radiofrequency radiation can induce adaptive response by changing the

antioxidant balance.MATERIALS AND METHODS: In order to assess RF-induced adaptive response in tissues, we evaluated the level of GSH and the activity of GR in liver. 50 rats were divided into 5 groups. Three groups were pre-exposed to 915 MHz RF radiation, 4 hours per day for one week at different powers, as low, medium and high. 24 hours after the last exposure to radiation, they were exposed to 4 Gy sublethal dose of gamma radiation and then sacrificed after 5 hours. Their livers were removed, washed and were kept at -80o C until used.RESULTS: Our finding showed that pre-exposure to 915 MHz radiofrequency radiation with specific power could induce adaptive response in liver by inducing changes in the activity and level of antioxidant enzymes.CONCLUSION: It can be concluded that pre-exposure to microwave radiation could increase the level of GSH and the activity of GR enzyme, although these increases were seen just in low power group, and the GR activity was indicated in medium power group. This increase protects tissue from oxidative damage induced by sublethal dose of gamma radiation.

**Moszczynski P, Lisiewicz J, Dmoch A, Zabinski Z, Bergier L, Rucinska M, Sasiadek U, [The effect of various occupational exposures to microwave radiation on the concentrations of immunoglobulins and T lymphocyte subsets]. Wiad Lek 52(1-2):30-34, 1999.** [Article in Polish]

The immunoglobulins' concentrations and T lymphocyte subsets during occupational exposures to microwave radiation were assessed. In the workers of retransmission TV center and center of satellite communications on increased IgG and IgA concentration and decreased count of lymphocytes and T8 cells was found. However, in the radar operators IgM concentration was elevated and a decrease in the total T8 cell count was observed. The different behaviour of examined immunological parameters indicate that the effect of microwave radiation on immune system depends on character of an exposure. Disorders in the immunoglobulins' concentrations and in the T8 cell count did not cause any clinical consequences.

**Motawi TK, Darwish HA, Moustafa YM, Labib MM. Biochemical Modifications and Neuronal Damage in Brain of Young and Adult Rats After Long-Term Exposure to Mobile Phone Radiations. Cell Biochem Biophys. 2014 May 7. [Epub ahead of print]**

This study investigated the effect of exposure to mobile phone radiations on oxidative stress and apoptosis in brain of rats. Rats were allocated into six groups (three young and three adult). Groups 1 and 4 were not subjected to the radiation source and served as control groups. In groups 2 and 5, the mobile phones were only connected to the global system for mobile communication, while in groups 3 and 6, the option of calling was in use. Microwaves were generated by a mobile test phone (SAR = 1.13 W/kg) during 60 days (2 h/day). Significant increments in conjugated dienes, protein carbonyls, total oxidant status, and oxidative stress index along with a significant reduction of total antioxidant capacity levels were evident after exposure. Bax/Bcl-2 ratio, caspase-3 activity, and tumor necrosis factor-alpha level were enhanced, whereas no DNA fragmentation was detected. The relative brain weight of young rats was greatly affected, and histopathological examination reinforced the neuronal damage. The study highlights the detrimental effects of mobile phone radiations on brain during young and adult ages.

The interaction of these radiations with brain is via dissipating its antioxidant status and/or triggering apoptotic cell death.

**Mouradi R, Desai N, Erdemir A, Agarwal A.The use of FDTD in establishing in vitro experimentation conditions representative of lifelike cell phone radiation on the spermatozoa.Health Phys. 102(1):54-62, 2012.**

Recent studies have shown that exposing human semen samples to cell phone radiation leads to a significant decline in sperm parameters. In daily living, a cell phone is usually kept in proximity to the groin, such as in a trouser pocket, separated from the testes by multiple layers of tissue. The aim of this study was to calculate the distance between cell phone and semen sample to set up an in vitro experiment that can mimic real life conditions (cell phone in trouser pocket separated by multiple tissue layers). For this reason, a computational model of scrotal tissues was designed by considering these separating layers, the results of which were used in a series of simulations using the Finite Difference Time Domain (FDTD) method. To provide an equivalent effect of multiple tissue layers, these results showed that the distance between a cell phone and semen sample should be 0.8 cm to 1.8 cm greater than the anticipated distance between a cell phone and the testes.

**Mousavy SJ, Riazi GH, Kamarei M, Aliakbarian H, Sattarahmady N, Sharifizadeh A, Safarian S, Ahmad F, Moosavi-Movahedi AA. Effects of mobile phone radiofrequency on the structure and function of the normal human hemoglobin. Int J Biol Macromol. 44(3):278-285, 2009**

Widespread use of mobile phones has increased the human exposure to electromagnetic fields (EMFs). It is required to investigate the effect of EMFs on the biological systems. In this paper the effect of mobile phone RF (910MHz and 940 MHz) on structure and function of HbA was investigated. Oxygen affinity was measured by sodium dithionite with UV-vis spectrophotometer. Structural changes were studied by circular dichroism and fluorescence spectroscopy. The results indicated that mobile phone EMFs altered oxygen affinity and tertiary structure of HbA. Furthermore, the decrease of oxygen affinity of HbA corresponded to the EMFs intensity and time of exposure.

**Moustafa YM, Moustafa RM, Belacy A, Abou-El-Ela SH, Ali FM.Effects of acute exposure to the radiofrequency fields of cellular phones on plasma lipid peroxide and antioxidase activities in human erythrocytes. J Pharm Biomed Anal 26(4):605-608, 2001.**

Radiofrequency fields of cellular phones may affect biological systems by increasing free radicals, which appear mainly to enhance lipid peroxidation, and by changing the antioxidase activities of human blood thus leading to oxidative stress. To test this, we have investigated the effect of acute exposure to radiofrequency fields of commercially available cellular phones on some parameters indicative of oxidative stress in 12 healthy adult male volunteers. Each volunteer put the phone in his pocket in standby position with the keypad facing the body. The parameters measured were lipid peroxide and the

activities of superoxide dismutase (SOD), total glutathione peroxidase (GSH-Px) and catalase. The results obtained showed that the plasma level of lipid peroxide was significantly increased after 1, 2 and 4 h of exposure to radiofrequency fields of the cellular phone in standby position. Moreover, the activities of SOD and GSH-Px in human erythrocytes showed significant reduction while the activity of catalase in human erythrocytes did not decrease significantly. These results indicate that acute exposure to radiofrequency fields of commercially available cellular phones may modulate the oxidative stress of free radicals by enhancing lipid peroxidation and reducing the activation of SOD and GSH-Px, which are free radical scavengers. Therefore, these results support the interaction of radiofrequency fields of cellular phones with biological systems.

**Movvahedi MM, Tavakkoli-Golpayegani A, Mortazavi SA, Haghani M, Razi Z, Shojaie-Fard MB, Zare M, Mina E, Mansourabadi L, Nazari-Jahromi, Safari A, Shokrpour N, Mortazavi SM. Does exposure to GSM 900 MHz mobile phone radiation affect short-term memory of elementary school students? J Pediatr Neurosci. 9(2):121-124, 2014.**

BACKGROUND: Now-a-days, children are exposed to mobile phone radiation at a very early age. We have previously shown that a large proportion of children in the city of Shiraz, Iran use mobile phones. Furthermore, we have indicated that the visual reaction time (VRT) of university students was significantly affected by a 10 min real/sham exposure to electromagnetic fields emitted by mobile phone. We found that these exposures decreased the reaction time which might lead to a better response to different hazards. We have also revealed that occupational exposures to radar radiations decreased the reaction time in radar workers. The purpose of this study was to investigate whether short-term exposure of elementary school students to radiofrequency (RF) radiation leads to changes in their reaction time and short-term memory. MATERIALS AND METHODS: A total of 60 elementary school children ages ranging from 8 to 10 years studying at a public elementary school in Shiraz, Iran were enrolled in this study. Standardized computer-based tests of VRT and short-term memory (modified for children) were administered. The students were asked to perform some preliminary tests for orientation with the VRT test. After orientation, to reduce the random variation of measurements, each test was repeated ten times in both real and sham exposure phases. The time interval between the two subsequent sham and real exposure phases was 30 min. RESULTS: The mean ± standard deviation reaction times after a 10 min talk period and after a 10 min sham exposure (switched off mobile) period were 249.0 ± 82.3 ms and 252.9 ± 68.2 ms (P = 0.629), respectively. On the other hand, the mean short-term memory scores after the talk and sham exposure periods were 1062.60 ± 305.39, and 1003.84 ± 339.68 (P = 0.030), respectively. Conclusion: To the best of our knowledge, this is the first study to show that short-term exposure of elementary school students to RF radiation leads to the better performance of their short-term memory.

**Mugunthan N, Anbalagan J, Meenachi S, Samy AS. EXPOSURE OF MICE TO 900 - 1900 MHZ RADIATIONS FROM CELL PHONE RESULTING IN MICROSCOPIC CHANGES IN THE KIDNEY. IJCRR. 6(16): 44-49, 2014**

Objective: The study was to evaluate possible effects of chronic exposure to 900 - 1900 MHz radiations emitted from 2G cell phone on kidney of mice at the histological level. Methods: Mice were exposed to 2G ultra-high frequency radiation, 48 minutes per day for a period of 30 to 180 days. The amount of electromagnetic field (EMF) exposed was measured by radiation frequency meter. The sham control mice were subject to similar conditions without 2G exposure. Six animals each were sacrificed at the end of 30, 60, 90,120,150 and 180 days of exposure in the experimental group after 24 hours of last exposure. Same numbers of control animals were sacrificed on similar period. Both kidneys were harvested and processed for histomorphometric study. Kidneys size, weight and volume were measured and analysed. Kidney sections were analysed under the light microscope and structural changes were studied. Results: In 2G exposed group the kidney weight and volume was significantly reduced in the first month. Kidney weight alone was significantly increased in the fifth month. Glomerulus showed dilated capillaries and increased urinary space. Proximal convoluted tubule showed wider lumen with reduced cell size. Brush border interrupted at places and vacuolated cytoplasm and pyknotic nuclei. Wider lumen with decreased cell size and marked basal striations were found in the distal convoluted tubule. Conclusion: Chronic exposure to ultra-high frequency radiation from 2G cell phone could cause microscopic changes in glomerulus, proximal and distal convoluted tubules of the kidney.

**Mugunthan N, Anbalagan J, Samy AS, Rajanarayanan S, Meenachi S. EFFECTS OF CHRONIC EXPOSURE TO 2G AND 3G CELL PHONE RADIATION ON MICE TESTIS – A RANDOMIZED CONTROLLED TRIAL. IJCRR. 7(4): 36-47, 2015.**

Objective: The aim of our study is to evaluate possible effects of chronic exposure to 900 - 1800 MHz radiation emitted from 2G cell phone and 1900 -2200 MHz from 3G cell phone on the testis of mice and to compare the effects of 2G and 3G radiation on testis at the histological level. Methods: Mice were exposed to 2G and 3G ultra-high frequency radiation, 48 minutes per day for a period of 30 to 180 days. The sham control mice were exposed to similar conditions without 2G or 3G exposure. Animal's weight of 2G and 3G cell phone exposed group were recorded before sacrificing at the end of 30, 60, 90,120,150 and 180 days. Same numbers of control animals were sacrificed on the same period. Blood samples were collected to measure plasma testosterone. Both the testes were dissected and its size, weight and volume were measured. The testes were processed for histomorphometric study. Results: Following chronic exposure of 2G and 3G cell phone radiation in mice, there was significant reduction of animal weight at first, second and fourth month. The mean testis weight and volume of 2G and 3G radiation exposed mice were significantly reduced in the first three months. The comparison between 2G and 3G exposed groups, showed no significant changes in mean body weight, mean testis weight and mean testis volume. The mean density of seminiferous tubule, mean seminiferous tubule diameter, mean number of Sertoli and Leydig cells of 2G and 3G exposed groups had significantly lower value than the control. The following microscopic changes were observed in the 2G and 3G radiation exposed mice testis over control. 1. Wide interstitium 2. Detachment of Sertoli cells and spermatogonia from the basal lamina. 3. Vacuolar degeneration and desquamation of seminiferous epithelium. 4. Peripheral tubules showed reduced thickness of seminiferous epithelium and maturation

arrest in the spermatogenesis. 5. Seminiferous tubules scored 7 to 9 using Johnson testicular biopsy score count. The mean total serum testosterone level of first, second, third, fourth and sixth month 2G and 3G exposed mice had significantly lower serum testosterone level than control. However, comparison between 2G and 3G showed no significant difference in the mean serum testosterone level. Conclusion: Chronic exposure to ultra-high frequency radiation emitted from 2G and 3G cell phone could cause microscopic changes in the seminiferous epithelium, reduction of serum testosterone level, reduction in the number of Sertoli cells and Leydig cells.

**Mugunthan N, Shanmugasamy K, Anbalagan J, Rajanarayanan S, Meenachi S. Effects of Long Term Exposure of 900-1800 MHz Radiation Emitted from 2G Mobile Phone on Mice Hippocampus- A Histomorphometric Study. J Clin Diagn Res. 2016 Aug;10(8):AF01-6.**

INTRODUCTION: The advancement in the telecommunications technology with multi-functional added features in mobile phone, attracts more users of all age group. It is alarming to note that, the mobile phone use has increased amongst children and they are exposed to potentially harmful radiofrequency radiation in their lifetime. AIM: To investigate the long term exposure of 900 to 1800 MHz radiations emitted from 2G mobile phone in mice hippocampus at histomorphometric level. MATERIALS AND METHODS: With due approval from institutional animal ethics committee, 36 mice were exposed to 2G mobile phone radiation, 48 minutes per day for a period of 30-180 days. The control group was kept under similar conditions without 2G exposure. Mice were sacrificed and the brain was removed from the first month to six months period. Brain was removed from the cranial cavity and hippocampus region was dissected out carefully and processed for routine histological study. Random serial sections were analysed under microscope for histomorphometric changes. For statistical analysis, independent t-test was used for comparing control and 2G exposed groups.RESULTS: The mean density of neurons in the hippocampus regions CA1, CA2 and DGDB from first to sixth month was significantly lower in the 2G exposed groups; however, in CA3 and DGVB, the 2G exposed mice showed significantly higher density of neurons. The mean nuclear diameter of neurons in the hippocampus region of CA1, CA2, CA3, DGDB and DGVB from first to sixth months showed lower nuclear diameter in 2G exposed mice. CONCLUSION: The long term exposure to 900-1800 MHz frequency radiations emitted from 2G mobile phone could cause significantly reduced neuron density and decreased nuclear diameter in the hippocampus neurons of mice.

**Munoz S, Sebastian JL, Sancho M, Miranda JM. Transmembrane voltage induced on altered erythrocyte shapes exposed to RF fields. Bioelectromagnetics. 25(8):631-633, 2004.**

In this article, the transmembrane voltage induced on erythrocyte, codocyte, ovalocyte and spherocyte cell models exposed to a linearly polarised electromagnetic plane wave of frequency 1800 MHz is calculated. For this purpose, a finite element (FE) numerical technique with adaptive meshing is used. The results show that the value of the induced voltage on the original erythrocyte shape is higher than the one observed on the rest of the altered cell geometries studied. The erythrocyte shape and the membrane electric

permittivity are shown to play a fundamental role on the values of the induced transmembrane voltage.

**Murbach, M., Neufeld, E., Christopoulou, M., Achermann, P. and Kuster, N. (2014), Modeling of EEG electrode artifacts and thermal ripples in human radiofrequency exposure studies. Bioelectromagnetics. doi: 10.1002/bem.21837.**

The effects of radiofrequency (RF) exposure on wake and sleep electroencephalogram (EEG) have been in focus since mobile phone usage became pervasive. It has been hypothesized that effects may be explained by (1) enhanced induced fields due to RF coupling with the electrode assembly, (2) the subsequent temperature increase around the electrodes, or (3) RF induced thermal pulsing caused by localized exposure in the head. We evaluated these three hypotheses by means of both numerical and experimental assessments made with appropriate phantoms and anatomical human models. Typical and worst-case electrode placements were examined at 900 and 2140 MHz. Our results indicate that hypothesis 1 can be rejected, as the induced fields cause <20% increase in the 10 g-averaged specific absorption rate (SAR). Simulations with an anatomical model indicate that hypothesis 2 is also not supported, as the realistic worst-case electrode placement results in a maximum skin temperature increase of 0.31 °C while brain temperature elevations remained <0.1 °C. These local short-term temperature elevations are unlikely to change brain physiology during the time period from minutes to several hours after exposure. The maximum observed temperature ripple due to RF pulses is <0.001 °C for GSM-like signals and <0.004 °C for 20-fold higher pulse energy, and offers no support for hypothesis 3. Thus, the mechanism of interaction between RF and changes in the EEG power spectrum remains unknown.

**Musaev AV, Ismailova LF, Gadzhiev AM. [Influence of (460 MHz) electromagnetic fields on the induced lipid peroxidation in the structures of visual analyzer and hypothalamus in experimental animals] Vopr Kurortol Fizioter Lech Fiz Kult. (5):17-20, 2005.** [Article in Russian]

Changes in the intensity of ascorbate- and NADPN2-dependent induced lipid peroxidation (LPO) were studied in exposure of the visual analyzer and hypothalamus of 3- and 12-month-old rats to radiation with microwaves of high and low intensity. The exposure to microwaves of high intensity stimulated basal LPO but suppressed activity of LPO-inducing systems. This suggests disturbances in the activity of different sources of active oxygen forms. Microwaves of low intensity activated systems of induced LPO. This is accompanied with synchronous activity of the antioxidant defense system maintaining a normal oxidation-reduction balance of the cell. The conclusion is that, depending on their intensity, microwaves can be either beneficial to health or be a factor of oxidative stress.

**Muscat JE, Malkin MG, Thompson S, Shore RE, Stellman SD, McRee D, Neugut AI, Wynder EL, Handheld cellular telephone use and risk of brain cancer. JAMA 284(23):3001-3007, 2000.**

CONTEXT: A relative paucity of data exist on the possible health effects of using cellular telephones. OBJECTIVE: To test the hypothesis that using handheld cellular telephones is related to the risk of primary brain cancer. DESIGN AND SETTING: Case-control study

conducted in 5 US academic medical centers between 1994 and 1998 using a structured questionnaire. PATIENTS: A total of 469 men and women aged 18 to 80 years with primary brain cancer and 422 matched controls without brain cancer. MAIN OUTCOME MEASURE: Risk of brain cancer compared by use of handheld cellular telephones, in hours per month and years of use. RESULTS: The median monthly hours of use were 2.5 for cases and 2.2 for controls. Compared with patients who never used handheld cellular telephones, the multivariate odds ratio (OR) associated with regular past or current use was 0.85 (95% confidence interval [CI], 0.6-1.2). The OR for infrequent users (<0. 72 h/mo) was 1.0 (95% CI, 0.5-2.0) and for frequent users (>10.1 h/mo) was 0.7 (95% CI, 0.3-1.4). The mean duration of use was 2.8 years for cases and 2.7 years for controls; no association with brain cancer was observed according to duration of use (P =.54). In cases, cerebral tumors occurred more frequently on the same side of the head where cellular telephones had been used (26 vs 15 cases; P =.06), but in the cases with temporal lobe cancer a greater proportion of tumors occurred in the contralateral than ipsilateral side (9 vs 5 cases; P =.33). The OR was less than 1.0 for all histologic categories of brain cancer except for uncommon neuroepitheliomatous cancers (OR, 2.1; 95% CI, 0.9-4.7). CONCLUSIONS: Our data suggest that use of handheld cellular telephones is not associated with risk of brain cancer, but further studies are needed to account for longer induction periods, especially for slow-growing tumors with neuronal features.

**Muscat JE, Malkin MG, Shore RE,. Thompson S, Neugut AL, Stellman SD, Bruce J. Handheld cellular telephones and risk of acoustic neuroma. Neurology 58:1304-1306, 2002.**

The hypothesis that intracranial energy deposition from handheldcellular telephones causes acoustic neuroma was tested in anepidemiologic study of 90 patients and 86 control subjects.The relative risk was 0.9 (p = 0.07) and did not vary significantlyby the frequency, duration, and lifetime hours of use. In patientswho used cellular telephones, the tumor occurred more oftenon the contralateral than ipsilateral side of the head. Furthereffortsshould focus on potentially longer induction periods.

**Muscat JE, Hinsvark M, Malkin M. Mobile telephones and rates of brain cancer. Neuroepidemiology.27(1):55-56, 2006.**

The risk of most primary brain cancers including gliomas and acoustic neuromas is unrelated to the use of mobile telephones in several studies. The long-term effects of mobile phones remain to be determined. An increased risk caused by short-term mobile phone use was reported for neuroepithelial tumors, a rare histologic subgroup of brain cancers that are characterized by neuronal features.We analyzed time trends in the age-adjusted incidence rate of adult neuronal cancers in the Surveillance, Epidemiology and End Results program from 1973 to 2002. The rates did not change during this period, despite the exponential increase in mobile phone subscriptions starting in 1984. These results indicate that mobile phone use is unrelated to the risk of neuronal cancers.

**Myung SK**, **Ju W**, **McDonnell DD**, **Lee YJ**, **Kazinets G**, **Cheng CT**, **Moskowitz JM**. **Mobile Phone Use and Risk of Tumors: A Meta-Analysis. J Clin Oncol. 27:5565-5572, 2009.**

PURPOSE: Case-control studies have reported inconsistent findings regarding the association between mobile phone use and tumor risk. We investigated these associations using a meta-analysis. METHODS: We searched MEDLINE (PubMed), EMBASE, and the Cochrane Library in August 2008. Two evaluators independently reviewed and selected articles based on predetermined selection criteria. RESULTS: Of 465 articles meeting our initial criteria, 23 case-control studies, which involved 37,916 participants (12,344 patient cases and 25,572 controls), were included in the final analyses. Compared with never or rarely having used a mobile phone, the odds ratio for overall use was 0.98 for malignant and benign tumors (95% CI, 0.89 to 1.07) in a random-effects meta-analysis of all 23 studies. However, a significant positive association (harmful effect) was observed in a random-effects meta-analysis of eight studies using blinding, whereas a significant negative association (protective effect) was observed in a fixed-effects meta-analysis of 15 studies not using blinding. Mobile phone use of 10 years or longer was associated with a risk of tumors in 13 studies reporting this association (odds ratio = 1.18; 95% CI, 1.04 to 1.34). Further, these findings were also observed in the subgroup analyses by methodologic quality of study. Blinding and methodologic quality of study were strongly associated with the research group. CONCLUSION: The current study found that there is possible evidence linking mobile phone use to an increased risk of tumors from a meta-analysis of low-biased case-control studies. Prospective cohort studies providing a higher level of evidence are needed.

**Naegeli B, Osswald S, Deola M, Burkart F, Intermittent pacemaker dysfunction caused by digital mobile telephones. J Am Coll Cardiol 27(6):1471-1477, 1996.**

OBJECTIVES: This study was designed to evaluate possible interactions between digital mobile telephones and implanted pacemakers. BACKGROUND: Electromagnetic fields may interfere with normal pacemaker function. Development of bipolar sensing leads and modern noise filtering techniques have lessened this problem. However, it remains unclear whether these features also protect from high frequency noise arising from digital cellular phones. METHODS: In 39 patients with an implanted pacemaker (14 dual-chamber [DDD], 8 atrial-synchronized ventricular-inhibited [VDD(R)] and 17 ventricular-inhibited [VVI(R)] pacemakers), four mobile phones with different levels of power output (2 and 8 W) were tested in the standby, dialing and operating mode. During continuous electrocardiographic monitoring, 672 tests were performed in each mode with the phones positioned over the pulse generator, the atrial and the ventricular electrode tip. The tests were carried out at different sensitivity settings and, where possible, in the unipolar and bipolar pacing modes as well. RESULTS: In 7 (18%) of 39 patients, a reproducible interference was induced during 26 (3.9%) of 672 tests with the operating phones in close proximity (<10 cm) to the pacemaker. In 22 dual-chamber (14 DDD, 8 VDD) pacemakers, atrial triggering occurred in 7 (2.8%) of 248 and ventricular inhibition in 5 (2.8%) of 176 tests. In 17 VVI(R) systems, pacemaker inhibition was induced in 14 (5.6%) of 248 tests. Interference was more likely to occur at higher power output of the phone and at maximal sensitivity of the pacemakers (maximal vs. nominal sensitivity, 6% vs. 1.8% positive test results, $p = 0.009$). When the bipolar and unipolar pacing modes were compared in the same patients, ventricular inhibition was induced only in the unipolar mode (12.5% positive test results, $p = 0.0003$). CONCLUSION: Digital mobile phones in close proximity to implanted pacemakers may cause intermittent pacemaker dysfunction with

inappropriate ventricular tracking and potentially dangerous pacemaker inhibition.

**Nagaoka T, Watanabe S, Sakurai K, Kunieda E, Watanabe S, Taki M, Yamanaka Y. Development of realistic high-resolution whole-body voxel models of Japanese adult males and females of average height and weight, and application of models to radio-frequency electromagnetic-field dosimetry.Phys Med Biol. 49(1):1-15, 2004.**

With advances in computer performance, the use of high-resolution voxel models of the entire human body has become more frequent in numerical dosimetries of electromagnetic waves. Using magnetic resonance imaging, we have developed realistic high-resolution whole-body voxel models for Japanese adult males and females of average height and weight. The developed models consist of cubic voxels of 2 mm on each side; the models are segmented into 51 anatomic regions. The adult female model is the first of its kind in the world and both are the first Asian voxel models (representing average Japanese) that enable numerical evaluation of electromagnetic dosimetry at high frequencies of up to 3 GHz. In this paper, we will also describe the basic SAR characteristics of the developed models for the VHF/UHF bands, calculated using the finite-difference time-domain method.

**Nagaoka T, Togashi T, Saito K, Takahashi M, Ito K, Ueda T, Osada H, Ito H, Watanabe S. An anatomically realistic voxel model of the pregnant woman and numerical dosimetry for a whole-body exposure to RF electromagnetic fields.Conf Proc IEEE Eng Med Biol Soc. 1:5463-5467, 2006.**

The numerical dosimetry of pregnant women is one of the most important issues in electromagnetic-field safety. We have recently developed a whole-body numerical female model of an adult Japanese (non-pregnant) average figure. Therefore, a new fetus model including inherent tissues of pregnant women was constructed based on abdominal MRI data of a 7-month pregnant woman. A whole-body pregnant woman model was developed by combining the new fetus and the female models. The anatomical details of the developed pregnant woman model and basic SAR characteristics for whole-body exposure to RF electromagnetic fields are demonstrated.

**Nagaoka T, Watanabe S. Estimation of variability of specific absorption rate with physical description of children exposed to electromagnetic field in the VHF band.Conf Proc IEEE Eng Med Biol Soc. 2009:942-945, 2009.**

Recently, there has been an increasing concern regarding the effects of electromagnetic waves on the health of humans. The safety of radio frequency electromagnetic fields (RF-EMFs) is evaluated by the specific absorption rate (SAR). In recent years, SAR has been estimated by numerical simulation using fine-resolution and anatomically realistic reference whole-body voxel models of people of various ages. The variation in SAR with a change in the physical features of a real person is hardly studied, although every person has different physical features. In this study, in order to estimate the individual variability in SAR of persons, we obtained considerable 3D body shape data from actual three-year-old children and developed several homogeneous models of these children. The variability in SAR of the homogeneous models of three-year-old children for whole-

body exposure to RF electromagnetic fields in the very high frequency (VHF) band calculated using the finite-difference time-domain method has been described.

**Nagaoka T, Saito K, Takahashi M, Ito K, Watanabe S. Anatomically realistic reference models of pregnant women for gestation ages of 13, 18, and 26 weeks.Conf Proc IEEE Eng Med Biol Soc. 2008:2817-2820, 2008.**

The safety of a human body exposed to radio-frequency (RF) electromagnetic fields (EMFs) has become important today. In recent times, conducting numerical dosimetry on the mother and the fetus during pregnancy has become a particularly important issue. This paper outlines the development of pregnant woman models that were adjusted to the reference values of physiological characteristics of maternal tissues in pregnant women for gestation ages of 13, 18, and 26 weeks The models are composed of voxels of 2 x 2 x 2 mm(3), and there are 56 tissue types. The basic specific absorption rate (SAR) characteristics in the pregnant woman models for whole-body exposure to RF electromagnetic fields that were calculated using the finite-difference time-domain (FDTD) method are described here.

**Nagaoka T, Kunieda E, Watanabe S. Proportion-corrected scaled voxel models for Japanese children and their application to the numerical dosimetry of specific absorption rate for frequencies from 30 MHz to 3 GHz.Phys Med Biol. 53(23):6695-6711, 2008.**

The development of high-resolution anatomical voxel models of children is difficult given, inter alia, the ethical limitations on subjecting children to medical imaging. We instead used an existing voxel model of a Japanese adult and three-dimensional deformation to develop three voxel models that match the average body proportions of Japanese children at 3, 5 and 7 years old. The adult model was deformed to match the proportions of a child by using the measured dimensions of various body parts of children at 3, 5 and 7 years old and a free-form deformation technique. The three developed models represent average-size Japanese children of the respective ages. They consist of cubic voxels (2 mm on each side) and are segmented into 51 tissues and organs. We calculated the whole-body-averaged specific absorption rates (WBA-SARs) and tissue-averaged SARs for the child models for exposures to plane waves from 30 MHz to 3 GHz; these results were then compared with those for scaled down adult models. We also determined the incident electric-field strength required to produce the exposure equivalent to the ICNIRP basic restriction for general public exposure, i.e., a WBA-SAR of 0.08 W kg(-1).

**Nageswari KS, Sarma KR, Rajvanshi VS, Sharan R, Sharma M, Barathwal V, Singh V, Effect of chronic microwave radiation on T cell-mediated immunity in the rabbit. Int J Biometeorol 35(2):92-97, 1991.**

Experiments were conducted to elucidate the effects of chronic low power-level microwave radiation on the immunological systems of rabbits. Fourteen male Belgian white rabbits were exposed to microwave radiation at 5 mW/cm2, 2.1 GHz, 3 h daily, 6 days/week for 3 months in two batches of 7 each in specially designed miniature

anechoic chambers. Seven rabbits were subjected to sham exposure for identical duration. The microwave energy was provided through S band standard gain horns connected to a 4K3SJ2 Klystron power amplifier. The first batch of animals were assessed for T lymphocyte-mediated cellular immune response mechanisms and the second batch of animals for B lymphocyte-mediated humoral immune response mechanisms. The peripheral blood samples collected monthly during microwave/sham exposure and during follow-up (5/14 days after termination of exposures, in the second batch animals only) were analysed for T lymphocyte numbers and their mitogen responsiveness to ConA and PHA. Significant suppression of T lymphocyte numbers was noted in the microwave group at 2 months (P less than 0.01, delta % 21.5%) and during follow-up (P less than 0.01, delta % 30.2%). The first batch animals were initially sensitised with BCG and challenged with tuberculin (0.03 ml) at the termination of microwave irradiation/sham exposure and the increase in foot pad thickness (delta mm), which is a measure of T cell-mediated immunity (delayed type hypersensitivity response, DTH) was noted in both the groups. The microwave group revealed a better response than the control group (delta % +12.4 vs. +7.54). The animals were sacrificed and the tissue T lymphocyte counts (spleen and lymph node) were analysed.

**Nakamura, H, Seto, T, Nagase, H, Yoshida, M, Dan, S, Ogino, K, Effects of exposure to microwaves on cellular immunity and placental steroids in pregnant rats. Occup Environ Med 54(9):676-680, 1997.**

OBJECTIVES: Microwaves produce various detrimental changes based on actions of heat or non-specific stress, although the effects of microwaves on pregnant organisms has not been uniform. This study was designed to clarify the effect of exposure to microwaves during pregnancy on endocrine and immune functions. METHODS: Natural killer cell activity and natural killer cell subsets in the spleen were measured, as well as some endocrine indicators in blood--corticosterone and adrenocorticotrophic hormone (ACTH) as indices of the hypothalamic-pituitary-adrenal axis--beta-endorphin, oestradiol, and progesterone in six female virgin rats and six pregnant rats (nine to 11 days gestation) exposed to microwaves at 10 mW/cm2 incident power density at 2450 MHz for 90 minutes. The same measurements were performed in control rats (six virgin and six pregnant rats). RESULTS: Skin temperature in virgin and pregnant rats increased immediately after exposure to microwaves. Although splenic activity of natural killer cells and any of the subset populations identified by the monoclonal antibodies CD16 and CD57 did not differ in virgin rats with or without exposure to microwaves, pregnant rats exposed to microwaves showed a significant reduction of splenic activity of natural killer cells and CD16+CD57-. Although corticosterone and ACTH increased, and oestradiol decreased in exposed virgin and pregnant rats, microwaves produced significant increases in beta-endorphin and progesterone only in pregnant rats. CONCLUSIONS: Microwaves at the power of 10 mW/cm2 produced activation of the hypothalamic-pituitary-adrenal axis and increased oestradiol in both virgin and pregnant rats, suggesting that microwaves greatly stress pregnant organisms. These findings in pregnant rats suggest that--with exposure to microwaves--pregnancy induces immunosuppression, which could result in successful maintainance of pregnancy. This enhancement of adaptability to heat stress with pregnancy may be mediated by activation of placental progesterone and placental or pituitary beta-endorphin.

**Nakamura, H, Seto, T, Hatta, K, Matsuzaki, I, Nagase, H, Yoshida, M, Ogino, K, Natural killer cell activity reduced by microwave exposure during pregnancy is mediated by opioid systems. Environ Res 79(2):106-113, 1998.**

We have previously demonstrated immunosuppression including reduced splenic natural killer cell activity (NKCA) in pregnant rats exposed to microwaves produced mainly by their thermal action. To examine the involvement of opioid systems in reduced NKCA in pregnant rats exposed to microwaves at a relatively low level (2 mW/cm2 incident power density at 2450 MHz for 90 min), we assayed beta-endorphin (betaEP) in blood, pituitary lobes, and placenta as well as splenic NKCA in virgin and/or pregnant rats. Although microwaves elevated colonic temperatures by 0.8 degreesC for virgin and 0.9 degreesC for pregnant rats, and betaEP in blood and anterior pituitary lobes (AP) significantly, it did not change blood corticosterone as an index of hypothalamic-pituitary adrenal axis. There were significant interactions between pregnancy and microwave exposure on splenic NKCA, betaEP in both blood and AP, and blood progesterone. Intra-peritoneal administration of opioid receptor antagonist naloxone prior to microwave exposure increased NKCA, blood, and placental betaEP in pregnant rats. Alterations in splenic NKCA, betaEP and progesterone in pregnant rats exposed to microwaves may be due to both thermal and nonthermal actions. These results suggest that NKCA reduced by microwaves during pregnancy is mediated by the pituitary opioid system.

**Nakamura H, Nagase H, Ogino K, Hatta K, Matsuzaki I, Uteroplacental circulatory disturbance mediated by prostaglandin F(2alpha) in rats exposed to microwaves. Reprod Toxicol 14(3):235-240, 2000.**

To clarify the effects of microwaves on pregnancy, uterine or uteroplacental blood flow and endocrine and biochemical mediators, including corticosterone, estradiol, prostaglandin E(2) (PGE(2)), and prostaglandin F(2)alpha (PGF(2)alpha), were measured in rats exposed to continuous-wave (CW) microwave at 2 mW/cm(2) incident power density at 2450 MHz for 90 min. Colonic temperature in virgin and pregnant rats was not significantly altered by microwave treatment. Microwaves decreased uteroplacental blood flow and increased progesterone and PGF(2)alpha in pregnant, but not in virgin rats. Intraperitoneal (i.p.) administration of angiotensin II, a uteroplacental vasodilator, before microwave exposure prevented the reduction in uteroplacental blood flow and the increased progesterone and PGF(2)alpha in pregnant rats. Increased corticosterone and decreased estradiol during microwave exposure were observed independent of pregnancy and pretreatment with angiotensin II. These results suggest that microwaves (CW, 2 mW/cm(2), 2450 MHz) produce uteroplacental circulatory disturbances and ovarian and placental dysfunction during pregnancy, probably through nonthermal actions. The uteroplacental disturbances appear to be due to actions of PGF(2)alpha and may pose some risk for pregnancy.

**Nakamura H, Matsuzaki I, Hatta K, Nobukuni Y, Kambayashi Y, Ogino K. Nonthermal effects of mobile-phone frequency microwaves on uteroplacental functions in pregnant rats. Reprod Toxicol 2003 17(3):321-326, 2003.**

Exposure to high-density microwaves can cause detrimental effects on the testis, eye, and other tissues, and induce significant biologic changes through thermal actions. To examine nonthermal effect of continuous wave (CW) 915MHz microwaves used in

cellular phones, we compared the effects of microwaves with those of heat. Thirty-six pregnant rats were assigned to six groups: rats exposed to microwaves at 0.6 or 3mW/cm(2) incident power density at 915MHz for 90min, rats immersed in water at 38 or 40 degrees C, which induces about the same increase in colonic temperature of 1.0 or 3.5 degrees C as 0.6 or 3mW/cm(2) microwaves, respectively; rats immersed in water at 34 degrees C, which is considered to be thermoneutral; and control rats. We identified significant differences in the uteroplacental circulation, and in placental endocrine and immune functions between pregnant rats immersed in water at 34 and 38 degrees C, but not between rats immersed at 38 degrees C and those exposed to microwaves at 0.6mW/cm(2). By contrast, we observed significant decreases in uteroplacental blood flow and estradiol in rats exposed to microwaves at 3mW/cm(2) as compared with those immersed in water at 40 degrees C. These results suggest microwaves at 0.6mW/cm(2) at 915MHz, equal to a specific absorption rate (SAR) of 0.4W/kg, which is the maximum permissible exposure level recommended by the American National Standards Institute (ANSI), do not exert nonthermal effects on blood estradiol and progesterone, on splenic natural killer cell activity, on the uteroplacental circulation.

**Nakatani-Enomoto S, Furubayashi T, Ushiyama A, Groiss SJ, Ueshima K, Sokejima S, Simba AY, Wake K, Watanabe SI, Nishikawa M, Miyawaki K, Taki M, Ugawa Y. Effects of electromagnetic fields emitted from W-CDMA-like mobile phones on sleep in humans. Bioelectromagnetics. 2013 Aug 22. doi: 10.1002/bem.21809. [Epub ahead of print]**

In this study, we investigated subjective and objective effects of mobile phones using a Wideband Code Division Multiple Access (W-CDMA)-like system on human sleep. Subjects were 19 volunteers. Real or sham electromagnetic field (EMF) exposures for 3 h were performed before their usual sleep time on 3 consecutive days. They were exposed to real EMF on the second or third experimental day in a double-blind design. Sleepiness and sleep insufficiency were evaluated the next morning. Polysomnograms were recorded for analyses of the sleep variables and power spectra of electroencephalograms (EEG). No significant differences were observed between the two conditions in subjective feelings. Sleep parameters including sleep stage percentages and EEG power spectra did not differ significantly between real and sham exposures. We conclude that continuous wave EMF exposure for 3 h from a W-CDMA-like system has no detectable effects on human sleep.

**Nakatani-Enomoto S, Okutsu M, Suzuki S, Suganuma R, Groiss SJ, Kadowaki S, Enomoto H, Fujimori K, Ugawa Y. Effects of 1950 MHz W-CDMA-like signal on human spermatozoa. Bioelectromagnetics. 2016 Jun 11. doi: 10.1002/bem.21985. [Epub ahead of print]**

There are growing concerns about how electromagnetic waves (EMW) emitted from mobile phones affect human spermatozoa. Several experiments have suggested harmful effects of EMW on human sperm quality, motility, velocity, or the deoxyribonucleic acid (DNA) of spermatozoa. In this study, we analyzed the effects on human spermatozoa (sperm motility and kinetic variables) induced by 1 h of exposure to 1950 MHz Wideband Code Division Multiple Access (W-CDMA)-like EMW with specific absorption rates of

either 2.0 or 6.0 W/kg, using a computer-assisted sperm analyzer system. We also measured the percentage of 8-hydroxy-2'-deoxyguanosine (8-OHdG) positive spermatozoa with flow cytometry to evaluate damage to DNA. No significant differences were observed between the EMW exposure and the sham exposure in sperm motility, kinetic variables, or 8-OHdG levels. We conclude that W-CDMA-like exposure for 1 h under temperature-controlled conditions has no detectable effect on normal human spermatozoa. Differences in exposure conditions, humidity, temperature control, baseline sperm characteristics, and age of donors may explain inconsistency of our results with several previous studies.

**Nam KC, Kim SW, Kim SC, Kim DW. Effects of RF exposure of teenagers and adults by CDMA cellular phones. Bioelectromagnetics. 27(7):509-514, 2006.**

Many cellular phone provocation studies have been conducted since the question of increased health risk from extended usage of cellular phones became a social issue. Internationally, most studies have been conducted regarding the effects of GSM cellular phones on blood pressure and heart rate of adult volunteers. On the other hand, very few provocation studies have been conducted regarding the physiological effects of CDMA phones on teenagers. In this study, two volunteer groups consisting of 21 teenagers and 21 adults were exposed to 300 mW of radio frequency (RF) electromagnetic field emitted by a CDMA cellular phone for half an hour. Physiological parameters such as systolic and diastolic blood pressures, heart rate, respiration rate, and skin resistance were simultaneously measured. All the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the teenager group ($P < .0001$). For the regrouped 23 male and 19 female subjects, all the parameters for both groups were unaffected during the exposure except for decreased skin resistance of the male subjects ($P = .0026$). Those resistances at 10 min after the terminated exposure returned to the resistances at rest regardless of the different groups of age and sex.

**Nam KC, Lee JH, Noh HW, Cha EJ, Kim NH, Kim DW. Hypersensitivity to RF fields emitted from CDMA cellular phones: a provocation study. Bioelectromagnetics. 30(8):641-650, 2009.**

With the number of cellular phone users rapidly increasing, there is a considerable amount of public concern regarding the effects that electromagnetic fields (EMFs) from cellular phones have on health. People with self-attributed electromagnetic hypersensitivity (EHS) complain of subjective symptoms such as headaches, insomnia, and memory loss, and attribute these symptoms to radio frequency (RF) radiation from cellular phones and/or base stations. However, EHS is difficult to diagnose because it relies on a person's subjective judgment. Various provocation studies have been conducted on EHS caused by Global System for Mobile Communications (GSM) phones in which heart rate and blood pressure or subjective symptoms were investigated. However, there have been few sham-controlled provocation studies on EHS with Code Division Multiple Access (CDMA) phones where physiological parameters, subjective symptoms, and perception of RF radiation for EHS and non-EHS groups were simultaneously investigated. In this study, two volunteer groups of 18 self-reported EHS and 19 non-EHS persons were

tested for both sham and real RF exposure from CDMA cellular phones with a 300 mW maximum exposure that lasted half an hour. We investigated not only the physiological parameters such as heart rate, respiration rate, and heart rate variability (HRV), but also various subjective symptoms and the perception of EMF. In conclusion, RF exposure did not have any effects on physiological parameters or subjective symptoms in either group. As for EMF perception, there was no evidence that the EHS group better perceived EMF than the non-EHS group.

**Narasimhan V, Huh WK, Altered restriction patterns of microwave irradiated lambdaphage DNA. Biochem Int 25(2):363-370, 1991.**

Samples of lambdaphage DNA exposed to short pulses of microwave irradiation were subjected to restriction fragmentation by Eco RI and Bam HI. Eco RI digests of microwaved DNA samples yielded three additional fragments ranging in base pair lengths between 24,226 and 7,421 besides the six expected fragments. While Bam HI digests of the microwaved samples did not yield any additional fragments, mobilities of the Bam HI fragments from the microwaved DNA samples were slower and the bands were broader in comparison to those from native samples. We attribute these altered restriction patterns to the conformational anomolies in DNA resulting from single strand breaks and localized strand separations induced by microwave irradiation.

**Narayanan SN, Kumar RS, Potu BK, Nayak S, Mailankot M. Spatial memory performance of Wistar rats exposed to mobile phone. Clinics. 64(3):231-234, 2009.**

INTRODUCTION: With the tremendous increase in number of mobile phone users world wide, the possible risks of this technology have become a serious concern. OBJECTIVE: We tested the effects of mobile phone exposure on spatial memory performance. MATERIALS AND METHODS: Male Wistar rats (10-12 weeks old) were exposed to 50 missed calls/day for 4 weeks from a GSM (900/1800 MHz) mobile phone in vibratory mode (no ring tone). After the experimental period, the animals were tested for spatial memory performance using the Morris water maze test. RESULTS: Both phone exposed and control animals showed a significant decrease in escape time with training. Phone exposed animals had significantly (approximately 3 times) higher mean latency to reach the target quadrant and spent significantly (approximately 2 times) less time in the target quadrant than age- and sex-matched controls. CONCLUSION: Mobile phone exposure affected the acquisition of learned responses in Wistar rats. This in turn points to the poor spatial navigation and the object place configurations of the phone-exposed animals.

**Narayanan SN, Kumar RS, Potu BK, Nayak S, Bhat PG, Mailankot M. Effect of radio-frequency electromagnetic radiations (RF-EMR) on passive avoidance behaviour and hippocampal morphology in Wistar rats. Ups J Med Sci.115(2):91-96, 2010.**

Abstract Introduction. The interaction of mobile phone radio-frequency electromagnetic radiation (RF-EMR) with the brain is a serious concern of our society. Objective. We evaluated the effect of RF-EMR from mobile phones on passive avoidance behaviour and hippocampal morphology in rats. Materials and methods. Healthy male albino Wistar rats were exposed to RF-EMR by giving 50

missed calls (within 1 hour) per day for 4 weeks, keeping a GSM (0.9 GHz/1.8 GHz) mobile phone in vibratory mode (no ring tone) in the cage. After the experimental period, passive avoidance behaviour and hippocampal morphology were studied. Results. Passive avoidance behaviour was significantly affected in mobile phone RF-EMR-exposed rats demonstrated as shorter entrance latency to the dark compartment when compared to the control rats. Marked morphological changes were also observed in the CA(3) region of the hippocampus of the mobile phone-exposed rats in comparison to the control rats. Conclusion. Mobile phone RF-EMR exposure significantly altered the passive avoidance behaviour and hippocampal morphology in rats.

**Narayanan SN, Kumar RS, Paval J, Kedage V, Bhat MS, Nayak S, Bhat PG. Analysis of emotionality and locomotion in radio-frequency electromagnetic radiation exposed rats.Neurol Sci. 34(7):1117-1124, 2013.**

In the current study the modulatory role of mobile phone radio-frequency electromagnetic radiation (RF-EMR) on emotionality and locomotion was evaluated in adolescent rats. Male albino Wistar rats (6-8 weeks old) were randomly assigned into the following groups having 12 animals in each group. Group I (Control): they remained in the home cage throughout the experimental period. Group II (Sham exposed): they were exposed to mobile phone in switch-off mode for 28 days, and Group III (RF-EMR exposed): they were exposed to RF-EMR (900 MHz) from an active GSM (Global system for mobile communications) mobile phone with a peak power density of 146.60 μW/cm(2) for 28 days. On 29th day, the animals were tested for emotionality and locomotion. Elevated plus maze (EPM) test revealed that, percentage of entries into the open arm, percentage of time spent on the open arm and distance travelled on the open arm were significantly reduced in the RF-EMR exposed rats. Rearing frequency and grooming frequency were also decreased in the RF-EMR exposed rats. Defecation boli count during the EPM test was more with the RF-EMR group. No statistically significant difference was found in total distance travelled, total arm entries, percentage of closed arm entries and parallelism index in the RF-EMR exposed rats compared to controls. Results indicate that mobile phone radiation could affect the emotionality of rats without affecting the general locomotion.

**Narayanan SN, Kumar RS, Kedage V, Nalini K, Nayak S, Bhat PG. Evaluation of oxidant stress and antioxidant defense in discrete brain regions of rats exposed to 900 MHz radiation. Bratisl Lek Listy. 115(5):260-266, 2014.**

AIM: In the current study, the effects of 900 MHz radio-frequency electromagnetic radiation (RF-EMR) on levels of thiobarbituric acid-reactive substances (TBARS), total antioxidants (TA), and glutathione S-transferase (GST) activity in discrete brain regions were studied in adolescent rats. MATERIALS AND METHODS: Thirty-six male Wistar rats (6-8 weeks old) were allotted into three groups (n = 12 in each group). Control group (1) remained undisturbed in their home cage; sham group (2) was exposed to mobile phone in switch off mode for four weeks; RF-EMR-exposed group (3) was exposed to 900 MHz of RF-EMR (1 hr/day with peak power density of 146.60 μW/cm2) from an activated Global System for Mobile communication (GSM) mobile phone (kept in silent

mode; no ring tone and no vibration) for four weeks. On 29th day, behavioral analysis was done. Followed by this, six animals from each group were sacrificed and biochemical parameters were studied in amygdala, hippocampus, frontal cortex, and cerebellum. RESULTS: Altered behavioral performances were found in RF-EMR-exposed rats. Additionally, elevated TBARS level was found with all brain regions studied. RF-EMR exposure significantly decreased TA in the amygdala and cerebellum but its level was not significantly changed in other brain regions. GST activity was significantly decreased in the hippocampus but, its activity was unaltered in other brain regions studied. CONCLUSION: RF-EMR exposure for a month induced oxidative stress in rat brain, but its magnitude was different in different regions studied. RF-EMR-induced oxidative stress could be one of the underlying causes for the behavioral deficits seen in rats after RF-EMR exposure (Fig. 5, Ref. 37).

**Narayanan SN, Kumar RS, Karun KM, Nayak SB, Bhat PG. Possible cause for altered spatial cognition of prepubescent rats exposed to chronic radiofrequency electromagnetic radiation. Metab Brain Dis. 2015 Jun 3. [Epub ahead of print]**

The effects of chronic and repeated radiofrequency electromagnetic radiation (RFEMR) exposure on spatial cognition and hippocampal architecture were investigated in prepubescent rats. Four weeks old male Wistar rats were exposed to RF-EMR (900 MHz; SAR-1.15 W/kg with peak power density of 146.60 μW/cm$^2$) for 1 h/day, for 28 days. Followed by this, spatial cognition was evaluated by Morris water maze test. To evaluate the hippocampal morphology; H&E staining, cresyl violet staining, and Golgi-Cox staining were performed on hippocampal sections. CA3 pyramidal neuron morphology and surviving neuron count (in CA3 region) were studied using H&E and cresyl violet stained sections. Dendritic arborization pattern of CA3 pyramidal neuron was investigated by concentric circle method. Progressive learning abilities were found to be decreased in RF-EMR exposed rats. Memory retention test performed 24 h after the last training revealed minor spatial memory deficit in RF-EMR exposed group. However, RF-EMR exposed rats exhibited poor spatial memory retention when tested 48 h after the final trial. Hirano bodies and Granulovacuolar bodies were absent in the CA3 pyramidal neurons of different groups studied. Nevertheless, RF-EMR exposure affected the viable cell count in dorsal hippocampal CA3 region. RF-EMR exposure influenced dendritic arborization pattern of both apical and basal dendritic trees in RF-EMR exposed rats. Structural changes found in the hippocampus of RF-EMR exposed rats could be one of the possible reasons for altered cognition.

**Nasri K, Daghfous D, Landoulsi A. Effects of microwave (2.45 GHz) irradiation on some biological characters of Salmonella typhimurium. C R Biol. 2013 Apr;336(4):194-202.**

The present study was carried out to evaluate the effects of sub-lethal doses of microwave radiation on some biological characteristics in Salmonella typhimurium. The aim was to show the relationship between this treatment and the development of radiotolerance in this pathogen because there is a need for more information on

physiological responses of pathogens to sub-lethal doses of microwave radiation. So, the bacterial strain was treated with a dose of 3600J (40-s exposure with power P=90 W) to cause cellular damage. The results have shown that the exposure of bacteria to microwaves resulted in a significant inhibition of cellular growth. This treatment has notably increased the effectiveness of the most tested antibiotics by the amelioration or the appearance of sensitivity in exposed bacteria. Gas chromatography (GC) analysis was performed to demonstrate the modification of the fatty acids (FA) composition. Results obtained have shown that this treatment had a significant effect on the FA content with an increase of unsaturated FA percentage. The acquisition of sensitivity to the sodium deoxycholate and the significant increase in the amount of extracellular proteins in exposed bacteria has confirmed the weakening of the bacterial membrane by microwaves. This study represents one of the few demonstrating the modifications on the bacterial membrane as a cellular response to survive the non-ionising radiation stress.

**Nasseri S, Monazzam M, Beheshti M, Zare S, Mahvi A. The vertical pattern of microwave radiation around BTS (Base Transceiver Station) antennae in Hashtgerd township. J Environ Health Sci Eng. 2013 Dec 20;11(1):40. doi: 10.1186/2052-336X-11-40.**

New environmental pollutants interfere with the environment and human life along with technology development. One of these pollutants is electromagnetic field. This study determines the vertical microwave radiation pattern of different types of Base Transceiver Station (BTS) antennae in the Hashtgerd city as the capital of Savojbolagh County, Alborz Province of Iran. The basic data including the geographical location of the BTS antennae in the city, brand, operator type, installation and its height was collected from radio communication office, and then the measurements were carried out according to IEEE STD 95. 1 by the SPECTRAN 4060. The statistical analyses were carried out by SPSS16 using Kolmogorov Smirnov test and multiple regression method. Results indicated that in both operators of Irancell and Hamrah-e-Aval (First Operator), the power density rose with an increase in measurement height or decrease in the vertical distance of broadcaster antenna. With mix model test, a significant statistical relationship was observed between measurement height and the average power density in both types of the operators. With increasing measuring height, power density increased in both operators. The study showed installing antennae in a crowded area needs more care because of higher radiation emission. More rigid surfaces and mobile users are two important factors in crowded area that can increase wave density and hence raise public microwave exposure.

**Nasta F, Prisco MG, Pinto R, Lovisolo GA, Marino C, Pioli C. Effects of GSM-modulated radiofrequency electromagnetic fields on B-cell peripheral differentiation and antibody production. Radiat Res. 165(6):664-670, 2006.**

We examined the effects of in vivo exposure to a GSM-modulated 900 MHz RF field on B-cell peripheral differentiation and antibody production in mice. Our results show that exposure to a whole-body average specific absorption rate (SAR) of 2 W/kg, 2 h/day for 4

consecutive weeks does not affect the frequencies of differentiating transitional 1 (T1) and T2 B cells or those of mature follicular B and marginal zone B cells in the spleen. IgM and IgG serum levels are also not significantly different among exposed, sham-exposed and control mice. B cells from these mice, challenged in vitro with LPS, produce comparable amounts of IgM and IgG. Moreover, exposure of immunized mice to RF fields does not change the antigen-specific antibody serum level. Interestingly, not only the production of antigen-specific IgM but also that of IgG (which requires T-B-cell interaction) is not affected by RF-field exposure. This indicates that the exposure does not alter an ongoing in vivo antigen-specific immune response. In conclusion, our results do not indicate any effects of GSM-modulated RF radiation on the B-cell peripheral compartment and antibody production and thus provide no support for health-threatening effects.

**Natarajan M, Vijayalaxmi , Szilagyi M, Roldan FN, Meltz ML. NF-κB DNA-binding activity after high peak power pulsed microwave (8.2 GHz) exposure of normal human monocytes. Bioelectromagnetics 23:271-277, 2002.**

The hypothesis investigated is that exposure of a mammalian cell to high peak power pulsed RF, at the frequency of 8.2 GHz, can result in the activation of an important eukaryotic transcriptional regulator, nuclear factor kappa B (NF-κB). This DNA-binding protein controls genes involved in long term cellular regulation. The selection of 8.2 GHz was based on the availability of a high peak power pulsed RF transmitter. In these studies, triplicate cultures of human monocytes (Mono Mac-6) were exposed to the pulsed wave radiation. The peak to average power ratio was 455:1 (2.2 μs pulse width and pulse repetition rate of 1000 pulses/s). The average power density at the position of exposure was 50 W/m$^2$, and the mean SAR at the bottom of the culture flask was 10.8 ± 7.1 W/kg. The FDTD analysis indicated that 10% of the cells had an SAR of 22-29 W/kg. The cells were exposed continuously for 90 min at 37 °C, reincubated at this temperature, and harvested 4 h postexposure. The nuclear extracts were analyzed by electrophoretic mobility shift assay. The results showed a profound increase (3.6-fold) in the DNA binding activity of NF-κB in monocytes at 4 h after the pulsed RF exposure compared to sham irradiated controls. Competition experiments with cold NF-κB- specific oligonucleotides confirmed the specificity of the DNA binding activity. These results provide evidence that high peak power pulsed radiofrequency radiation can perturb the cell and initiate cell signaling pathways. However, at this point, we are not prepared to advocate that the cause is a nonthermal mechanism. Because of the broad distribution of SAR's in the flask, experiments need to be performed to determine if the changes observed are associated with cells exposed to high or low SARs.

**Natarajan M, Nayak BK, Galindo C, Mathur SP, Roldan FN, Meltz ML. Nuclear translocation and DNA-binding activity of NFKB (NF-kappaB) after exposure of human monocytes to pulsed ultra-wideband electromagnetic fields (1 kV/cm) fails to transactivate kappaB-dependent gene expression. Radiat Res. 165(6):645-654, 2006.**

The objective of this study was to investigate whether exposure of human monocytes to a pulsed ultra-wideband electromagnetic field (EMF) of 1 kV/cm average peak power

triggers a signaling pathway responsible for the transcriptional regulation of NFKB (NF-kappaB)-dependent gene expression. Human Mono Mac 6 (MM6) cells were exposed intermittently to EMF pulses for a total of 90 min. The pulse width was 0.79+/-0.01 ns and the pulse repetition rate was 250 pps. The temperature of the medium was maintained at 37 degrees C in both sham- and EMF-exposed flasks. Total NFKB DNA-binding activity was measured in the nuclear extracts by the electrophoretic mobility shift assay. Cells exposed to the EMFs and incubated for 24 h postexposure showed a 3.5+/-0.2-fold increase in the NFKB DNA-binding activity. Since activation of NFKB was observed, the possibility of kappaB-dependent gene expression in response to exposure to the EMFs was investigated using NFKB signal-specific gene arrays. The results revealed no difference in the NFKB-dependent gene expression profiles at 8 or 24 h postexposure, indicating that activated NFKB does not lead to the differential expression of kappaB-dependent target genes. To determine whether the absence of the kappaB-dependent gene expression was due to compromised transcriptional regulation of NFKB, the functional activity of NFKB was examined in cells transiently transfected with Mercury Pathway constructs containing 4x NFKB binding sites associated either with the luciferase reporter system or a control vector. Pulsed EMF exposure did not induce NFKB-driven luciferase activity in these cells, indicating that the activation of NFKB at 24 h after the 1 kV/cm EMF exposure is functionally inactive. From these results, it is clear that the EMF-induced NFKB activation is only a transient response, with minimal or no downstream effect.

**Navakatikian MA, Tomashevskaya LA, Phasic behavioral and endocrine effects of microwaves of nonthermal intensity. In “Biological Effects of Electric and Magnetic Fields, Volume 1," D.O. Carpenter (ed) Academic Press, San Diego, CA, 1994, pp.333-342.**

Microwaves at nonthermal levels are able to induce behavioral and endocrine changes at low power densities (0.01-0.1 mW/cm2). Our studies have demonstrated several phases of inhibition and activation. We suggest that inhibition of behavior by microwaves has many mechanisms depending on the strength and duration of exposure, and most inhibitory effects from direct actions on the nervous system. Activation, on the other hand, is correlated well with decreases in serum concentrations of testosterone and insulin. CW microwaves, however, have no influence on the secretion of insulin.

**Navarro EA, Sequra J, Portoles M, Gomez-Perretta de Mateo C. The Microwave Syndrome: A Preliminary Study in Spain. Electromag Biol Med 22:161-169, 2003.**

A health survey was carried out in Murcia, Spain, in the vicinity of a Cellular Phone Base Station working in DCS-1800 MHz. This survey contained health items related to “microwave sickness” or “RF syndrome.” The microwave power density was measured at the respondents' homes. Statistical analysis showed significant correlation between the declared severity of the symptoms and the measured power density. The separation of respondents into two different exposure groups also showed an increase of the declared severity in the group with the higher exposure.

**Nayyeri V, Hashemi SM, Borna M, Jalilian HR, Soleimani M. ASSESSMENT OF RF RADIATION LEVELS IN THE VICINITY OF 60 GSM MOBILE PHONE BASE STATIONS IN IRAN. Radiat Prot Dosimetry. 155 (2):241-244, 2013.**

Increasing development of mobile communication infrastructure while enhancing availability of the technology raises concerns among the public, who see more cell towers erected each day, about possible health effects of electromagnetic radiations. Thereon, a survey of radio-frequency radiation from 60 GSM base stations was carried out in Tehran, Iran at several places mostly located in major medical and educational centres. Measurements were performed at 15 locations near each base station site, i.e. 900 locations in total. Since there are other RF radiation sources such as broadcasting services whose carrier frequencies are <3 GHz, the whole band of 27 MHz to 3 GHz has been assessed for hazardous exposures as well. The results were compared with the relevant guideline of International Commission on Non-Ionising Radiation Protection and that of Iran, confirming radiation exposure levels being satisfactorily below defined limits and non-detrimental.

**Naziroğlu M, Gümral N. Modulator effects of L-carnitine and selenium on wireless devices (2.45 GHz)-induced oxidative stress and electroencephalography records in brain of rat. Int J Radiat Biol. 85(8):680-689, 2009.**
PURPOSE: Electromagnetic radiation (EMR) from wireless devices may affect biological systems by increasing free radicals. The present study was designed to determine the effects of 2.45 GHz EMR on the brain antioxidant redox system and electroencephalography (EEG) records in rat. The possible protective effects of selenium and L-carnitine were also tested and compared to untreated controls. MATERIALS AND METHODS: Thirty rats were equally divided into five different groups, namely Group A(1): Cage control, Group A(2): Sham control, group B: 2.45 GHz EMR, group C: 2.45 GHz EMR + selenium, group D: 2.45 GHz EMR + L-carnitine. Groups B, C and D were exposed to 2.45 GHz EMR during 60 min/day for 28 days. End of the experiments, EEG records and the brain cortex samples were taken. RESULTS: The cortex brain vitamin A ($p < 0.05$), vitamin C ($p < 0.01$) and vitamin E ($p < 0.05$) concentrations values were lower in group B than in group A1 and A2 although their concentrations were increased by selenium and L-carnitine supplementation. Lipid peroxidation, levels were lower in group C ($p < 0.05$) and D ($p < 0.01$) than in group B where as reduced glutathione levels were higher in group C ($p < 0.05$) than in group A1, A2 and B. However, B-carotene levels did not change in the five groups. CONCLUSIONS: L-carnitine and selenium seem to have protective effects on the 2.45 GHz-induced decrease of the vitamins by supporting antioxidant redox system. L-carnitine on the vitamin concentrations seems to more protective affect than in selenium.

**Nazıroğlu M, Ciğ B, Doğan S, Uğuz AC, Dilek S, Faouzi D. 2.45-Gz wireless devices induce oxidative stress and proliferation through cytosolic $Ca^{2+}$ influx in human leukemia cancer cells. Int J Radiat Biol. 88(6):449-456, 2012.**

PURPOSE: Electromagnetic radiation from wireless devices may affect biological systems by increasing free radicals. The present study was designed to determine the

effects of 2.45 GHz radiation on the antioxidant redox system, calcium ion signaling, cell count and viability in human leukemia 60 cells. MATERIALS AND METHODS: Twelve cell cultures were equally divided into two main groups as controls (n = 6) and irradiated (n = 6) and then subdivided into four different subgroups depending on the duration of exposure, namely 1, 2, 12 and 24 hours. The samples were analyzed immediately after the experimental period. RESULTS: The extent of lipid peroxidation, cytosolic free $Ca^{2+}$ and cell numbers were higher in 2.45 GHz groups than in the controls. The increase of cytosolic free $Ca^{2+}$ concentrations was radiation time-dependent and was highest at 24-h exposure. The reduced glutathione, glutathione peroxidase, vitamin C and cell viability values did not show any changes in any of the experimental groups. 2-aminoethyl diphenylborinate inhibits $Ca^{2+}$ ions influx by blockage of the transient receptor potential melastatin 2. CONCLUSIONS: 2.45 GHz electromagnetic radiation appears to induce proliferative effects through oxidative stress and $Ca^{2+}$ influx although blocking of transient receptor potential melastatin 2 channels by 2-aminoethyl diphenylborinate seems to counteract the effects on $Ca^{2+}$ ions influx.

**Nazıroğlu M, Çelik Ö, Özgül C, Çiğ B, Doğan S, Bal R, Gümral N, Rodríguez AB, Pariente JA. Melatonin modulates wireless (2.45 GHz)-induced oxidative injury through TRPM2 and voltage gated Ca(2+) channels in brain and dorsal root ganglion in rat. Physiol Behav. 105(3):683-692, 2012.**

We aimed to investigate the protective effects of melatonin and 2.45 GHz electromagnetic radiation (EMR) on brain and dorsal root ganglion (DRG) neuron antioxidant redox system, Ca(2+) influx, cell viability and electroencephalography (EEG) records in the rat. Thirty two rats were equally divided into four different groups namely group A1: Cage control, group A2: Sham control, group B: 2.45 GHz EMR, group C: 2.45 GHz EMR+melatonin. Groups B and C were exposed to 2.45 GHz EMR during 60 min/day for 30 days. End of the experiments, EEG records and the brain cortex and DRG samples were taken. Lipid peroxidation (LP), cell viability and cytosolic Ca(2+) values in DRG neurons were higher in group B than in groups A1 and A2 although their concentrations were increased by melatonin, 2-aminoethyldiphenyl borinate (2-APB), diltiazem and verapamil supplementation. Spike numbers of EEG records in group C were lower than in group B. Brain cortex vitamin E concentration was higher in group C than in group B. In conclusion, Melatonin supplementation in DRG neurons and brain seems to have protective effects on the 2.45 GHz-induced increase Ca(2+) influx, EEG records and cell viability of the hormone through TRPM2 and voltage gated Ca(2+) channels.

**Nazıroğlu M, Yüksel M, Köse SA, Özkaya MO. Recent reports of Wi-Fi and mobile phone-induced radiation on oxidative stress and reproductive signaling pathways in females and males. J Membr Biol. 246(12):869-875, 2013.**

Environmental exposure to electromagnetic radiation (EMR) has been increasing with the increasing demand for communication devices. The aim of the study was to discuss the mechanisms and risk factors of EMR changes on reproductive functions and membrane oxidative biology in females and males. It was reported that even chronic exposure to EMR did not increase the risk of reproductive functions such as increased levels of

neoantigens abort. However, the results of some studies indicate that EMR induced endometriosis and inflammation and decreased the number of follicles in the ovarium or uterus of rats. In studies with male rats, exposure caused degeneration in the seminiferous tubules, reduction in the number of Leydig cells and testosterone production as well as increases in luteinizing hormone levels and apoptotic cells. In some cases of male and female infertility, increased levels of oxidative stress and lipid peroxidation and decreased values of antioxidants such as melatonin, vitamin E and glutathione peroxidase were reported in animals exposed to EMR. In conclusion, the results of current studies indicate that oxidative stress from exposure to Wi-Fi and mobile phone-induced EMR is a significant mechanism affecting female and male reproductive systems. However, there is no evidence to this date to support an increased risk of female and male infertility related to EMR exposure.

**Nazıroğlu M, Özkan FF, Hapil SR, Ghazizadeh V, Çiğ B. Epilepsy but not mobile phone frequency (900 MHz) induces apoptosis and calcium entry in hippocampus of epileptic rat: involvement of TRPV1 channels. J Membr Biol. 248(1):83-91, 2015.**

Electromagnetic radiation (EMR) and epilepsy are reported to mediate the regulation of apoptosis and oxidative stress through Ca(2+) influx. Results of recent reports indicated that EMR can increase temperature and oxidative stress of body cells, and TRPV1 channel is activated by noxious heat, oxidative stress, and capsaicin (CAP). We investigated the effects of mobile phone (900 MHz) EMR exposure on Ca(2+) influx, apoptosis, oxidative stress, and TRPV1 channel activations in the hippocampus of pentylenetetrazol (PTZ)-induced epileptic rats. Freshly isolated hippocampal neurons of twenty-one rats were used in study within three groups namely control, PTZ, and PTZ + EMR. The neurons in the three groups were stimulated by CAP. Epilepsy was induced by PTZ administration. The neurons in PTZ + EMR group were exposed to the 900 MHz EMR for 1 h. The apoptosis, mitochondrial membrane depolarization, intracellular reactive oxygen species (ROS), and caspase-3 and caspase-9 values were higher in PTZ and PTZ + EMR groups than in control. However, EMR did not add additional increase effects on the values in the hippocampal neurons. Intracellular-free Ca(2+) concentrations in fura-2 analyses were also higher in PTZ + CAP group than in control although their concentrations were decreased by TRPV1 channel blocker, capsazepine. However, there were no statistical changes on the Ca(2+) concentrations between epilepsy and EMR groups. In conclusion, apoptosis, mitochondrial, ROS, and Ca(2+) influx via TRPV1 channel were increased in the hippocampal neurons by epilepsy induction although the mobile phone did not change the values. The results indicated that TRPV1 channels in hippocampus may possibly be a novel target for effective target of epilepsy.

**Nelson BK, Conover DL, Brightwell WS, Shaw PB, Werren D, Edwards RM, Lary JM, Marked increase in the teratogenicity of the combined administration of the industrial solvent 2-methoxyethanol and radiofrequency radiation in rats. Teratology 43(6):621-634, 1991.**

Limited published animal research reports synergistic teratogenic effects following combined hyperthermia (induced by elevated ambient temperature) and

administration of chemical teratogens. Radiofrequency (RF) radiation is widely used in occupational environments. Since RF radiation also elevates the body temperature of, and is teratogenic to, exposed animals, concurrent RF radiation and chemical agent administration may enhance teratogenicity. The present exploratory study, consisting of preliminary dose-finding studies and the primary study, was designed to investigate whether concurrent exposure of rats to RF radiation and the industrial solvent 2-methoxyethanol (2ME) can enhance the developmental toxicity of either agent acting alone. Preliminary dose-finding studies using small numbers of rats investigated the ability of various RF radiation conditions and doses of 2ME to produce external malformations (primarily of the paws) when administered on gestation day 13. Based on these preliminary studies, RF radiation exposure [sufficient to elevate rectal temperature to 42.0 degrees C (4 degrees C above normal for rats) for 30 min] and 2ME administration (150 mg/kg) were selected for the primary study. In the primary study, groups of 18 to 27 pregnant rats were administered RF radiation exposure and distilled water gavage, 2ME gavage and sham RF exposure, RF radiation exposure and 2ME gavage concurrently, or sham RF exposure and distilled water gavage. Pregnant rats were sacrificed on gestation day 20, and the offspring were examined for external malformations. Combined exposures enhanced the adverse effects produced by either experimental agent alone (no malformations were detected in the double sham group). Mean fetal malformations/litter increased from 14% after 2ME and sham RF (15/26 litters affected, with an average of 2 fetuses/litter malformed) and 30% after RF radiation and water gavage (10/18 litters affected, with an average of 4 fetuses/litter malformed), to 76% after the combined treatment (18/18 litters affected, with an average of 12 fetuses/litter malformed). In addition to a significant increase in the frequency of malformations, the severity of malformations also was enhanced by the combination treatment (on a relative severity ranking scale, the 2ME severity score was less than 1, the RF score was 3, and the combination score was 6). This study provided evidence of synergism between RF radiation and 2ME administration, but additional research will be required to characterize the extent of synergism between these two agents. Potential interactive effects between chemical and physical agents need to be investigated to determine the extent to which such interactions should impact occupational exposure standards.

**Nelson BK, Conover DL, Shaw PB, Werren DM, Edwards RM, Hoberman AM, Interactive developmental toxicity of radiofrequency radiation and 2-methoxyethanol in rats. Teratology 50(4):275-293, 1994.**

Concurrent exposures to chemical and physical agents occur in the workplace; exposed workers include those involved with the microelectronics industry, plastic sealers, and electrosurgical units. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to radiofrequency (RF; 10 MHz) radiation, which also induces hyperthermia and is teratogenic to exposed animals, and the industrial solvent, 2-methoxyethanol (2ME), produces enhanced teratogenicity in rats. The present study replicates and extends the previous research investigating the enhanced teratogenicity of combined RF radiation and 2ME exposures.

The interactive dose-related teratogenicity of RF radiation (sham exposure or maintaining colonic temperatures at 42.0 degrees C for 0, 10, 20, or 30 min) and 2ME (0, 75, 100, 125, or 150 mg/kg) was investigated by administering various combinations of RF radiation and 2ME to groups of rats on gestation days 9 or 13; gestation-day 20 fetuses were examined for external, skeletal, and visceral malformations. The results are consistent with and extend our previous research findings. Synergism was observed between RF radiation and 2ME for some treatment combinations, but not for others. The study also clarified which gestational periods, RF radiation exposure durations, and 2ME doses would be most informative in future interaction studies to determine the lowest interactive effect level. Day 9 exposures generally evidenced little effect by 2ME, either by itself or in combination with RF radiation. In contrast, day 13 exposures resulted in highly significant effects from 2ME and RF radiation. The structures showing strong evidence of effects from both 2ME and RF radiation after exposure on gestation day 13 were the forepaw digits, forepaw phalanges, hindpaw digits, hindpaw phalanges, hind limbs, metacarpals, and metatarsals. Statistical analyses did not show a global synergistic effect, but did show evidence for a synergistic effect at intermediate levels of the dose ranges. Future research will address potential interactions at lower doses.

**Nelson BK, Conover DL, Krieg EF Jr, Snyder DL, Edwards RM, Interactions of radiofrequency radiation-induced hyperthermia and 2-methoxyethanol teratogenicity in rats. Bioelectromagnetics. 18(5):349-359, 1997.**

Radiofrequency (RF) radiation is used in a variety of workplaces. In addition to RF radiation, many workers are concurrently exposed to numerous chemicals; exposed workers include those involved with the microelectronics industry, plastic sealers, and electrosurgical units. The developmental toxicity of RF radiation is associated with the degree and duration of hyperthermia induced by the exposure. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to RF radiation (10 MHz) and the industrial solvent, 2-methoxyethanol (2ME), produces enhanced teratogenicity in rats. The purpose of the present research is to determine the effects of varying the degree and duration of hyperthermia induced by RF radiation (sufficient to maintain colonic temperatures at control [38.5], 39.0, 40.0, or 41.0 degrees C for up to 6 h) and 2ME (100 mg/kg) administered on gestation day 13 of rats. Focusing on characterizing the dose-response pattern of interactions, this research seeks to determine the lowest interactive effect level. Day 20 fetuses were examined for external and skeletal malformations. The results are consistent with previous observations. Significant interactions were observed between 2MEand RF radiation sufficient to maintain colonic temperatures at 41 degrees C for 1 h, but no consistent interactions were seen at lower temperatures even with longer durations. These data indicate that combined exposure effects should be considered when developing both RF radiation and chemical exposure guidelines and intervention strategies.

**Nelson BK, Conover DL, Shaw PB, Snyder DL, Edwards RM, Interactions of radiofrequency radiation on 2-methoxyethanol teratogenicity in rats. J Appl Toxicol 17(1):31-39, 1997.**

Concurrent exposures to chemical and physical agents occur in the workplace; exposed workers include those involved with microelectronics industry, plastic sealers and electrosurgical units. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to radiofrequency (r.f.; 10 MHz) radiation, which also induces hyperthermia and is teratogenic to exposed animals, and the industrial solvent 2-methoxyethanol (2ME) produces enhanced teratogenicity in rats. A subsequent study replicated and extended that research by investigating the interactive dose-related teratogenicity of r.f. radiation (sham exposure or maintaining colonic temperatures at 42.0 degrees C for 0, 10, 20 or 30 min by r.f. radiation absorption) and 2ME (0, 75, 100, 125 or 150 mg/kg) on gestation days 9 or 13 of rats. The purpose of the present research is to determine the effects of r.f. radiation (sufficient to maintain colonic temperatures at 42.0 degrees C for 10 min) on a range of doses of 2ME (0, 20, 40, 60, 80, 100, 120 and 140 mg kg-1) administered on gestation day 13of rats. Focusing on characterizing the dose-response pattern of interactions, this research seeks to determine the lowest interactive effect level. Day 20 fetuses were examined for external and skeletal malformations. The results are consistent with previous observations. Dose-related developmental toxicity was observed for 2ME both in the presence and absence of r.f. radiation. However, concurrent RF radiation exposure changed the shape of the dose-effect curve of 2ME. These data indicate that combined exposure effects should be considered when developing exposure guidelines and intervention strategies.

**Nelson BK, Conover DL, Krieg EF Jr, Snyder DL, Edwards RM, Effect of environmental temperature on the interactive developmental toxicity of radiofrequency radiation and 2-methoxyethanol in rats. Int Arch Occup Environ Health 71(6):413-423, 1998.**

OBJECTIVE: This research was conducted to determine if altered environmental temperatures would affect the interactive developmental toxicity of radiofrequency (RF) radiation and the industrial solvent, 2-methoxyethanol (2ME). This is important because RF radiation is used in a variety of workplaces that have poorly controlled environmental temperatures, and many workers are concurrently exposed to various chemicals. Furthermore, we have previously demonstrated that combined exposure to RF radiation (10 MHz) and 2ME produces enhanced teratogenicity in rats. METHODS: RF radiation sufficient to maintain colonic temperatures at the control value (38degrees ), 39.0degrees or 40.0 degrees C for 2 or 4 h combined with either 0 or 100 mg/ kg 2ME at environmental temperatures of 18 degrees , 24 degrees and 30 degrees C (65 degrees , 75 degrees , and 85 degrees F) were given on gestation day 13 to Sprague-Dawley rats. Dams were killed on gestation day 20, and the fetuses were examined for external malformations. RESULTS AND CONCLUSIONS: Environmental temperature does affect the specific absorption rate (SAR) necessary to maintain a specific colonic temperature but does not affect the interactive developmental toxicity of RF radiation and 2ME in rats. These results, consistent with the literature, add to the evidence that the developmental toxicity of RF radiation (combined or alone) is associated with colonic temperature, not with SAR.

**Nelson BK, Snyder DL, Shaw PB, Developmental toxicity interactions of salicylic**

**acid and radiofrequency radiation or 2-methoxyethanol in rats. Reprod Toxicol 13(2):137-145, 1999.**

Radiofrequency (RF) radiation is used in a variety of workplaces where workers are concurrently exposed to chemicals. Combined exposure to RF radiation (10 MHz) and the industrial solvent, 2-methoxyethanol (2ME), produces enhanced teratogenicity in rats. The purpose of the present research was to determine if the synergistic effects noted for RF radiation and 2ME are generalizable to other chemicals. Since salicylic acid (SA) is widely used as an analgesic and is teratogenic in animals, SA was selected to address generalizability. Based on the literature and our pilot studies, 0, 250, or 350 mg/kg SA were administered by gavage on gestation Day 9 or 13 to rats. Concurrently rats given SA on Day 9 were exposed to RF radiation sufficient to maintain colonic temperature at 41 degrees C for 60 min (or sham). Those given SA on Day 13 were also given 0 or 100 mg/kg 2ME (gavage). Dams were sacrificed on gestation Day 20, and the fetuses were examined for external malformations. The data provide no evidence of synergistic interactions between RF radiation and salicylic acid (resorptions and malformations). Limited evidence of antagonism was observed between 2ME and salicylic acid (fetal weights). This investigation highlights the importance of additional research on interactions in developmental toxicology, and emphasizes the need to consider combined exposure effects when developing both physical agent and chemical agent exposure guidelines and intervention strategies.

**Nelson BK, Snyder DL, Shaw PB, Developmental toxicity interactions of methanol and radiofrequency radiation or 2-methoxyethanol in rats. Int J Toxicol 20(2):89-100, 2001.**

This research was undertaken to determine potential interactions among chemical and physical agents. Radiofrequency (RF) radiation is used in numerous workplaces, and many workers are concurrently exposed to RF radiation and various chemicals. The developmental toxicity of RF radiation is associated with the degree and duration of hyperthermia induced by the exposure. Previous animal research indicates that hyperthermia induced by an elevation in ambient temperature can potentiate the toxicity and teratogenicity of some chemical agents. We previously demonstrated that combined exposure to RF radiation (10 MHz) and the industrial solvent, 2-methoxyethanol (2ME), enhanced teratogenicity in rats. Interactions were noted at even the lowest levels of 2ME tested, but only at hyperthermic levels of RF radiation. The purpose of the present research is to investigate if the interactive effects noted for RF radiation and 2ME are unique to these agents, or if similar interactions might be seen with other chemicals. Because methanol is widely used as a solvent as well as fuel additive, and, at high levels, is teratogenic in animals, we selected methanol as a chemical to address generalizability. Based on the literature and our pilot studies, 0, 2, or 3 g/kg methanol (twice, at 6-hour intervals) were administered on gestation day 9 or 13 to groups of 10 Sprague-Dawley rats. Dams treated on day 9 were given methanol and exposed to RF radiation sufficient to maintain colonic temperature at 41 degrees C for 60 minutes (or sham). Those treated on day 13 were given methanol plus either 0 or 100 mg/kg 2ME. Because we observed that methanol produced hypothermia, some groups were given the initial dose of methanol concurrently with the RF or 2ME, and others were given the first dose of methanol 1.5 hours prior to RF or 2ME. Dams were sacrificed on gestation day 20, and

the fetuses were examined for external malformations. The results indicate that RF radiation or methanol on day 9 increased the incidence of resorbed fetuses, but no interactive effects were observed. The resorptions were highest in groups given the experimental treatments 1.5 hours apart. The higher dose of methanol also reduced fetal weights. Administration of 2ME or methanol on day 13 increased the rate of malformations, and there was evidence of a positive interaction between 2ME and methanol. Fetal weights were reduced by 2ME and methanol alone, but no interaction was observed. Also, separation of the dosing with the teratogens did not affect the results. These results point out that interactions in developmental toxicology, such as those of RF radiation, 2ME, and methanol that we have studied, are complex, and such interactions cannot be fully understood or predicted without more research. It is important that combined exposure effects be considered when developing both physical agent and chemical agent exposure guidelines and intervention strategies.

**Neshev NN, Kirilova EI, Environmental-health aspects of pulse-modulated microwaves. Rev Environ Health 11(1-2):85-88, 1996.**

Our theoretical model describes the potential influence of irradiation with pulse-modulated microwaves on the conformational oscillations of enzymes in living organisms. Certain values of pulse-repetition time, determined by the period of conformational oscillations of the corresponding type of enzyme, can produce the effect at extremely low power levels. Synchronized oscillations in identical enzyme molecules produce in turn large-scale oscillations within living cells. Thus, short periods of exposure to pulse-modulated microwaves could be beneficial to cellular function, whereas maintaining the amplitude of such oscillations at a maximum for long periods may have a stressful effect on biochemical processes. The model discloses the possible environmental-health risks of long-term exposure in ambient fields that are created by radar, navigation, and communication systems.

**Neubauer C, Phelan AM, Kues H, Lange DG, Microwave irradiation of rats at 2.45 GHz activates pinocytotic-like uptake of tracer by capillary endothelial cells of cerebral cortex. Bioelectromagnetics 11(4):261-268, 1990.**

Far-field exposures of male albino rats to 2.45-GHz microwaves (10-microseconds pulses, 100 pps) at a low average power density (10 mW/cm2; SAR approximately 2 W/kg) and short durations (30-120 min) resulted in increased uptakes of tracer through the blood-brain barrier (BBB). The uptake of systemically administered rhodamine-ferritin complex by capillary endothelial cells (CECs) of the cerebral cortex was dependent on power density and on duration of exposure. At 5 mW/cm2, for example, a 15-min exposure had no effect. Near-complete blockade of uptake resulted when rats were treated before exposure to microwaves with a single dose of colchicine, which inhibits microtubular function. A pinocytotic-like mechanism is presumed responsible for the microwave-induced increase in BBB permeability.

**Nieto-Hernandez R, Rubin GJ, Cleare AJ, Weinman JA, Wessely S. Can evidence change belief? Reported mobile phone sensitivity following individual feedback of an inability to discriminate active from sham signals. J Psychosom Res. 65(5):453-460, 2008.**

OBJECTIVE: In this study, we tested whether providing individuals, who described being sensitive to mobile phone signals, with accurate feedback about their ability to discriminate an active mobile phone signal from a sham signal had any impact on their subsequent symptom levels or their perceived sensitivity to mobile phones. METHODS: Sixty-nine participants who reported sensitivity to mobile phones took part in a double-blind, placebo-controlled provocation study. Perceived sensitivity to mobile phones was assessed using a version of the Sensitive Soma Assessment Scale (SSAS) and the severity of any symptoms attributed to mobile phones was recorded. Both the overall ("negative") findings of the provocation study and the participant's own individual results ("correct" or "incorrect" at detecting a mobile phone signal) were then described to them. Six months later, perceived sensitivity and symptom severity were measured again. RESULTS: Fifty-eight participants (84%) received feedback and participated in the 6-month follow-up. No significant differences in SSAS scores or in symptom severity scores were found between individuals told that they were correct (n=31) or incorrect (n=27) in their ability to detect mobile phone signals in the provocation study. CONCLUSION: The provision of accurate feedback was insufficient to change attributions or reduce symptoms in this study. However, an overtly negative reaction to feedback was not observed among most participants, and some participants were willing to consider that factors other than electromagnetic field may be relevant in causing or exacerbating their symptoms. Discussing possible psychological factors with electromagnetic hypersensitivity patients may be beneficial for some.

**Nikolova T, Czyz J, Rolletschek A, Blyszczuk P, Fuchs J, Jovtchev G, Schuderer J, Kuster N, Wobus AM. Electromagnetic fields affect transcript levels of apoptosis-related genes in embryonic stem cell-derived neural progenitor cells. ASEB J. 19(12):1686-1688, 2005.**

Mouse embryonic stem (ES) cells were used as an experimental model to study the effects of electromagnetic fields (EMF). ES-derived nestin-positive neural progenitor cells were exposed to extremely low frequency EMF simulating power line magnetic fields at 50 Hz (ELF-EMF) and to radiofrequency EMF simulating the Global System for Mobile Communication (GSM) signals at 1.71 GHz (RF-EMF). Following EMF exposure, cells were analyzed for transcript levels of cell cycle regulatory, apoptosis-related, and neural-specific genes and proteins; changes in proliferation; apoptosis; and cytogenetic effects. Quantitative RT-PCR analysis revealed that ELF-EMF exposure to ES-derived neural cells significantly affected transcript levels of the apoptosis-related bcl-2, bax, and cell cycle regulatory "growth arrest DNA damage inducible" GADD45 genes, whereas mRNA levels of neural-specific genes were not affected. RF-EMF exposure of neural progenitor cells resulted in down-regulation of neural-specific Nurr1 and in up-regulation of bax and GADD45 mRNA levels. Short-term RF-EMF exposure for 6 h, but not for 48 h, resulted in a low and transient increase of DNA double-strand breaks. No effects of ELF- and RF-EMF on mitochondrial function, nuclear apoptosis, cell proliferation, and chromosomal alterations were observed. We may conclude that EMF exposure of ES-derived neural progenitor cells transiently affects the transcript level of genes related to apoptosis and cell cycle control. However, these responses are not associated with detectable changes of cell physiology, suggesting compensatory mechanisms at the translational and

posttranslational level.

**Ning W, Xu SJ, Chiang H, Xu ZP, Zhou SY, Yang W, Luo JH. Effects of GSM 1800 MHz on dendritic development of cultured hippocampal neurons.Acta Pharmacol Sin.28(12):1873-1880, 2007.**

**AIM:** To evaluate the effects of global system for mobile communications (GSM) 1800 MHz microwaves on dendritic filopodia, dendritic arborization, and spine maturation during development in cultured hippocampal neurons in rats.**METHODS:** The cultured hippocampal neurons were exposed to GSM 1800 MHz microwaves with 2.4 and 0.8 W/kg, respectively, for 15 min each day from 6 days in vitro (DIV6) to DIV14. The subtle structures of dendrites were displayed by transfection with farnesylated enhanced green fluorescent protein (F-GFP) and GFP-actin on DIV5 into the hippocampal neurons.**RESULTS:** There was a significant decrease in the density and mobility of dendritic filopodia at DIV8 and in the density of mature spines at DIV14 in the neurons exposed to GSM 1800 MHz microwaves with 2.4 W/kg. In addition, the average length of dendrites per neuron at DIV10 and DIV14 was decreased, while the dendritic arborization was unaltered in these neurons. However, there were no significant changes found in the neurons exposed to the GSM 1800 MHz microwaves with 0.8 W/kg.**CONCLUSION:** These data indicate that the chronic exposure to 2.4 W/kg GSM 1800 MHz microwaves during the early developmental stage may affect dendritic development and the formation of excitatory synapses of hippocampal neurons in culture.

**Nirwane A, Sridhar V, Majumdar A. Neurobehavioural Changes and Brain Oxidative Stress Induced by Acute Exposure to GSM900 Mobile Phone Radiations in Zebrafish (Danio rerio). Toxicol Res. 2016 Apr;32(2):123-32. doi: 10.5487/TR.2016.32.2.123. Epub 2016 Apr 30.**

The impact of mobile phone (MP) radiation on the brain is of specific interest to the scientific community and warrants investigations, as MP is held close to the head. Studies on humans and rodents revealed hazards MP radiation associated such as brain tumors, impairment in cognition, hearing etc. Melatonin (MT) is an important modulator of CNS functioning and is a neural antioxidant hormone. Zebrafish has emerged as a popular model organism for CNS studies. Herein, we evaluated the impact of GSM900MP (GSM900MP) radiation exposure daily for 1 hr for 14 days with the SAR of 1.34W/Kg on neurobehavioral and oxidative stress parameters in zebrafish. Our study revealed that, GSM900MP radiation exposure, significantly decreased time spent near social stimulus zone and increased total distance travelled, in social interaction test. In the novel tank dive test, the GSM900MP radiation exposure elicited anxiety as revealed by significantly increased time spent in bottom half; freezing bouts and duration and decreased distance travelled, average velocity, and number of entries to upper half of the tank. Exposed zebrafish spent less time in the novel arm of the Y-Maze, corroborating significant impairment in learning as compared to the control group. Exposure decreased superoxide dismutase (SOD), catalase (CAT) activities whereas, increased levels of reduced glutathione (GSH) and lipid peroxidation (LPO) was encountered showing compromised antioxidant defense. Treatment with MT significantly reversed the above neurobehavioral and oxidative derangements induced by GSM900MP radiation

exposure. This study traced GSM900MP radiation exposure induced neurobehavioral aberrations and alterations in brain oxidative status. Furthermore, MT proved to be a promising therapeutic candidate in ameliorating such outcomes in zebrafish.

**Nittby H, Widegren B, Krogh M, Grafström G, Berlin H, Rehn G, Eberhardt JL, Malmgren L, Persson BRR, Salford L. Exposure to radiation from global system for mobile communications at 1,800 MHz significantly changes gene expression in rat hippocampus and cortex. Environmentalist 28(4), 458-465, 2008.**

We have earlier shown that radio frequency electromagnetic fields can cause significant leakage of albumin through the blood–brain barrier of exposed rats as compared to non-exposed rats, and also significant neuronal damage in rat brains several weeks after a 2 h exposure to a mobile phone, at 915 MHz with a global system for mobile communications (GSM) frequency modulation, at whole-body specific absorption rate values (SAR) of 200, 20, 2, and 0.2 mW/kg. We have now studied whether 6 h of exposure to the radiation from a GSM mobile test phone at 1,800 MHz (at a whole-body SAR-value of 13 mW/kg, corresponding to a brain SAR-value of 30 mW/kg) has an effect upon the gene expression pattern in rat brain cortex and hippocampus—areas where we have observed albumin leakage from capillaries into neurons and neuronal damage. Microarray analysis of 31,099 rat genes, including splicing variants, was performed in cortex and hippocampus of 8 Fischer 344 rats, 4 animals exposed to global system for mobile communications electromagnetic fields for 6 h in an anechoic chamber, one rat at a time, and 4 controls kept as long in the same anechoic chamber without exposure, also in this case one rat at a time. Gene ontology analysis (using the gene ontology categories biological processes, molecular functions, and cell components) of the differentially expressed genes of the exposed animals versus the control group revealed the following highly significant altered gene categories in both cortex and hippocampus: extracellular region, signal transducer activity, intrinsic to membrane, and integral to membrane. The fact that most of these categories are connected with membrane functions may have a relation to our earlier observation of albumin transport through brain capillaries.

**Nittby H, Grafström G, Tian DP, Malmgren L, Brun A, Persson BR, Salford LG, Eberhardt J. Cognitive impairment in rats after long-term exposure to GSM-900 mobile phone radiation. Bioelectromagnetics. 29:219-232, 2008.**

Considering the frequent use of mobile phones, we have directed attention to possible implications on cognitive functions. In this study we investigated in a rat model the long-term effects of protracted exposure to Global System for Mobile Communication-900 MHz (GSM-900) radiation. Out of a total of 56 rats, 32 were exposed for 2 h each week for 55 weeks to radio-frequency electromagnetic radiation at different SAR levels (0.6 and 60 mW/kg at the initiation of the experimental period) emitted by a (GSM-900) test phone. Sixteen animals were sham exposed and eight animals were cage controls, which never left the animal house. After this protracted exposure, GSM-900 exposed rats were compared to sham exposed controls. Effects on exploratory behaviour were evaluated in the open-field test, in which no difference was seen. Effects on cognitive functions were evaluated in the episodic-like memory

test. In our study, GSM exposed rats had impaired memory for objects and their temporal order of presentation, compared to sham exposed controls (P = 0.02). Detecting the place in which an object was presented was not affected by GSM exposure. Our results suggest significantly reduced memory functions in rats after GSM microwave exposure (P = 0.02).

**Nittby H, Brun A, Eberhardt J, Malmgren L, Persson BR, Salford LG. Increased blood-brain barrier permeability in mammalian brain 7 days after exposure to the radiation from a GSM-900 mobile phone. Pathophysiology6(2-3):103-112, 2009.**

Microwaves were for the first time produced by humans in 1886 when radio waves were broadcasted and received. Until then microwaves had only existed as a part of the cosmic background radiation since the birth of universe. By the following utilization of microwaves in telegraph communication, radars, television and above all, in the modern mobile phone technology, mankind is today exposed to microwaves at a level up to 10(20) times the original background radiation since the birth of universe. Our group has earlier shown that the electromagnetic radiation emitted by mobile phones alters the permeability of the blood-brain barrier (BBB), resulting in albumin extravasation immediately and 14 days after 2h of exposure. In the background section of this report, we present a thorough review of the literature on the demonstrated effects (or lack of effects) of microwave exposure upon the BBB. Furthermore, we have continued our own studies by investigating the effects of GSM mobile phone radiation upon the blood-brain barrier permeability of rats 7 days after one occasion of 2h of exposure. Forty-eight rats were exposed in TEM-cells for 2h at non-thermal specific absorption rates (SARs) of 0mW/kg, 0.12mW/kg, 1.2mW/kg, 12mW/kg and 120mW/kg. Albumin extravasation over the BBB, neuronal albumin uptake and neuronal damage were assessed. Albumin extravasation was enhanced in the mobile phone exposed rats as compared to sham controls after this 7-day recovery period (Fisher's exact probability test, p=0.04 and Kruskal-Wallis, p=0.012), at the SAR-value of 12mW/kg (Mann-Whitney, p=0.007) and with a trend of increased albumin extravasation also at the SAR-values of 0.12mW/kg and 120mW/kg. There was a low, but significant correlation between the exposure level (SAR-value) and occurrence of focal albumin extravasation (r(s)=0.33; p=0.04). The present findings are in agreement with our earlier studies where we have seen increased BBB permeability immediately and 14 days after exposure. We here discuss the present findings as well as the previous results of altered BBB permeability from our and other laboratories.

**Nittby H, Moghadam MK, Sun W, Malmgren L, Eberhardt J, Persson BR, Salford LG. Analgetic effects of non-thermal GSM-1900 radiofrequency electromagnetic fields in the land snail Helix pomatia. Int J Radiat Biol. ;88(3):245-252, 2012**

Abstract. Abstract Purpose: To investigate whether mobile phone radiation might affect snail nociception, employing radiofrequency (RF) electromagnetic fields (EMF) which, to our knowledge, have hitherto not been studied in a snail model. Exposure to extremely low frequency (ELF) magnetic fields has however been shown to significantly affect nociceptive responses. Materials and methods: In the present study, we exposed 29 land snails of the strain Helix pomatia to global system for mobile communications (GSM) EMF at 1900 MHz at the non-thermal level 48 mW/kg for 1 hour each and 29 snails were sham controls. The experiments took place during

the onset of summer, with all snails being well out of hibernation. Before and after GSM or sham exposure, the snails were subjected to thermal pain by being placed on a hot plate. The reaction time for retraction from the hot plate was measured by two blinded observers. Results: Comparing the reaction pattern of each snail before and after exposure, the GSM exposed snails were less sensitive to thermal pain as compared to the sham controls, indicating that RF exposure induces a significant analgesia (Mann-Whitney $p < 0.001$). Conclusion: This study might support earlier findings, describing beneficial effects of EMF exposure upon nociception.

**Noor NA, Mohammed HS, Ahmed NA, Radwan NM. Variations in amino acid neurotransmitters in some brain areas of adult and young male albino rats due to exposure to mobile phone radiation.Eur Rev Med Pharmacol Sci. 15(7):729-742, 2011.**

**BACKGROUND AND OBJECTIVES:** Mobile phone radiation and health concerns have been raised, especially following the enormous increase in the use of wireless mobile telephony throughout the world. The present study aims to investigate the effect of one hour daily exposure to electromagnetic radiation (EMR) with frequency of 900 Mz (SAR 1.165 w/kg, power density 0.02 mW/cm2) on the levels of amino acid neurotransmitters in the midbrain, cerebellum and medulla of adult and young male albino rats. **MATERIALS AND METHODS:** Adult and young rats were divided into two main groups (treated and control). The treated group of both adult and young rats was exposed to EMR for 1 hour daily. The other group of both adult and young animals was served as control. The determination of amino acid levels was carried out after 1 hour, 1 month, 2 months and 4 months of EMR exposure as well as after stopping radiation. **RESULTS:** Data of the present study showed a significant increase in both excitatory and inhibitory amino acids in the cerebellum of adult and young rats and midbrain of adult animals after 1 hour of EMR exposure. In the midbrain of adult animals, there was a significant increase in glycine level after 1 month followed by significant increase in GABA after 4 months. Young rats showed significant decreases in the midbrain excitatory amino acids. In the medulla, the equilibrium ratio percent (ER%) calculations showed a state of neurochemical inhibition after 4 months in case of adult animals, whereas in young animals, the neurochemical inhibitory state was observed after 1 month of exposure due to significant decrease in glutamate and aspartate levels. This state was converted to excitation after 4 months due to the increase in glutamate level. **CONCLUSION:** The present changes in amino acid concentrations may underlie the reported adverse effects of using mobile phones.

**Nordin S, Neely G, Olsson D, Sandström M. Odor and Noise Intolerance in Persons with Self-Reported Electromagnetic Hypersensitivity. Int J Environ Res Public Health. 11(9):8794-8805, 2014.**

Lack of confirmation of symptoms attributed to electromagnetic fields (EMF) and triggered by EMF exposure has highlighted the role of individual factors. Prior observations indicate intolerance to other types of environmental exposures among persons with electromagnetic hypersensitivity (EHS). This study assessed differences in odor and noise intolerance between persons with EHS and healthy controls by use of subscales and global measures of the Chemical Sensitivity Scale (CSS) and the Noise Sensitivity

Scale (NSS). The EHS group scored significantly higher than the controls on all CSS and NSS scales. Correlation coefficients between CSS and NSS scores ranged from 0.60 to 0.65 across measures. The findings suggest an association between EHS and odor and noise intolerance, encouraging further investigation of individual factors for understanding EMF-related symptoms.

**Novoselova ET, Fesenko EE, [[Stimulation of production of tumor necrosis factor by murine macrophages when exposed in vio and in vitro to weak electromagnetic waves in the centimeter range]]. Biofizika 43(6):1132-1333, 1998.** [Article in Russian]

Whole-body microwave sinusoidal irradiation of male NMRI mice, exposure of macrophages in vitro, and preliminary irradiation of culture medium with 8.15-18 GHz (1 Hz within) at a power density of 1 microW/cm2 caused a significant enhancement of tumor necrosis factor production in peritoneal macrophages. The role of microwaves as a factor interfering with the process of cell immunity is discussed.

**Novoselova, EG, Fesenko, EE, Makar, VR, Sadovnikov, VB, Microwaves and cellular immunity. II. Immunostimulating effects of microwaves and naturally occurring antioxidant nutrients. Bioelectrochem Bioenerg 49(1):37-41, 1999.**

The effect of 8.15-18 GHz (1 Hz within) microwave radiation at a power density of 1 microW/cm2 on the tumor necrosis factor (TNF) production and immune response was tested. A single 5 h whole-body exposure induced a significant increase in TNF production in peritoneal macrophages and splenic T cells. The mitogenic response in T lymphocytes increased after microwave exposure. The activation of cellular immunity was observed within 3 days after exposure. The diet containing lipid-soluble nutrients (beta-carotene, alpha-tocopherol and ubiquinone Q9) increased the activity of macrophages and T cells from irradiated mice. These results demonstrate that irradiation with low-power density microwaves stimulates the immune potential of macrophages and T cells, and the antioxidant treatment enhances the effect of microwaves, in particular at later terms, when the effect of irradiation is reduced.

**Novoselova EG, Ogai VB, Sorokina OV, Novikov VV, Fesenko EE., [Effect of centimeter microwaves and the combined magnetic field on the tumor necrosis factor production in cells of mice with experimental tumors]. Biofizika 46(1):131-135, 2001.** [Article in Russian]

The effect of fractionated exposure to low-intensity microwaves (8.15-18 GHz, 1 microW/cm2, 1.5 h daily for 7 days) and combined weak magnetic field (constant 65 1 microT; alternating--100 nT, 3-10 Hz) on the production of tumor necrosis factor in macrophages of mice with experimental solid tumors produced by transplantation of Ehrlich ascites carcinoma was studied. It was found that exposure of mice to both microwaves and magnetic field enhanced the adaptive response of the organism to the onset of tumor growth: the production of tumor necrosis factor in peritoneal macrophages of tumor-bearing mice was higher than in unexposed mice.

**Novoselova EG, Ogay VB, Sorokina OV, Glushkova OV, Sinotova OA, Fesenko EE.The production of tumor necrosis factor in cells of tumor-bearing mice after total-body microwave irradiation and antioxidant diet. Electromag Biol Med**

**23:167-180, 2004.**

The effects of repeated treatment with weak microwaves (MW) (8.15–18 GHz, 1 μW/cm$^2$, 1.5 h daily) and diet with antioxidants (AO) (β-carotene, α-tocopherol, and ubiquinone $Q_9$) on production of tumor necrosis factor (TNF) in macrophages and T lymphocytes of healthy and tumor-bearing mice (TBM) were studied. Tumor size and mortality of TBM were also followed. Microwave radiation and antioxidant diet stimulated production of TNF in cells from healthy mice. At early stages, tumor growth induced TNF production in mouse cells; however, this effect decreased as tumors grew. In TBM exposed to MW, TNF production was higher than in unirradiated TBM. Oppositely, AO diet induced TNF production in healthy mice but did not affect TNF secretion in TBM. Accordingly, prolonged treatment of TBM to MW, but not to AO diet, decreased tumor growth rate and increased overall animal longevity. These results suggest that diminished tumor growth rate due to extremely low-level MW exposure of mice carrying tumors, at least in part, was caused by enhancement in TNF production and accumulation of plasma TNF.

**Nowak B, Rosocha S, Zellerhoff C, Liebrich A, Himmrich E, Voigtlander T, Meyer J, Is there a risk for interaction between mobile phones and single lead VDD pacemakers? Pacing Clin Electrophysiol 19(10):1447-1450, 1996.**

Mobile phones may cause pacemaker interference. Patients with a single lead VDD pacemaker might be at special risk, since the atrial sensitivity is often programmed to low (high sensitivity) threshold values and the majority of patients are pacemaker dependent due to the underlying high degree AV block. We evaluated 31 patients with three types of single lead VDD pacemakers: 12 Unity, 292-07 (Intermedics, Inc.); 10 Thera VDD, 8948 or 8968i (Medtronic, Inc.); and 9 Saphir 600 (Vitatron, Inc.) for interference from a cellular mobile phone with a power of 2 W (D-net). For this purpose, atrial and ventricular sensitivity settings were programmed to their most sensitive values (A: 0.1-0.25 mV; V: 1.0 mV) and ventricular sensing was programmed to unipolar. With the ECG continuously monitored, the phone's extendable antenna was brought in direct contact with the patient's skin at the right sternal border, with the tip of the antenna in skin contact just below the clavicle, within 5 cm of the pacemaker connector. Then multiple phases of phone calls were performed, and the effects on the pacemakers recorded. In our group of patients with three different types of single lead VDD pacemakers, no interference could be detected using a 2-W mobile phone in the digital D-net. The programmed values remained unchanged after the interference test. Therefore, the risk of interference seems to be low for the VDD pacemakers tested, although our study design does not allow to entirely exclude the possibility of interference from a mobile phone.

**Ntzouni MP, Stamatakis A, Stylianopoulou F, Margaritis LH. Short-term memory in mice is affected by mobile phone radiation. Pathophysiology. 18(3):193-199, 2011.**

Abstract. The effects of mobile phone electromagnetic fields (EMFs) were studied on a non-spatial memory task (Object Recognition Task - ORT) that requires entorhinal cortex function. The task was applied to three groups of mice Mus musculus C57BL/6 (exposed, sham-exposed and control) combined with 3 different radiation exposure protocols. In the first protocol designated "acute exposure", mice 45 days old (PND45

- postnatal day 45) were exposed to mobile phone (MP) radiation (SAR value 0.22W/kg) during the habituation, the training and the test sessions of the ORT, but not during the 10min inter-trial interval (ITI) where consolidation of stored object information takes place. On the second protocol designated "chronic exposure-I", the same mice were exposed for 17 days for 90min/per day starting at PND55 to the same MP radiation. ORT recognition memory was performed at PND72 with radiation present only during the ITI phase. In the third protocol designated "chronic exposure-II", mice continued to be exposed daily under the same conditions up to PND86 having received radiation for 31 days. One day later the ORT test was performed without irradiation present in any of the sessions. The ORT-derived discrimination indices in all three exposure protocols revealed a major effect on the "chronic exposure-I" suggesting a possible severe interaction of EMF with the consolidation phase of recognition memory processes. This may imply that the primary EMF target may be the information transfer pathway connecting the entorhinal-parahippocampal regions which participate in the ORT memory task.

**Ntzouni MP, Skouroliakou A, Kostomitsopoulos N, Margaritis LH. Transient and cumulative memory impairments induced by GSM 1.8 GHz cell phone signal in a mouse model. Electromagn Biol Med. 32(1):95-120, 2013.**

This study was designed to investigate the transient and cumulative impairments in spatial and non-spatial memory of C57Bl/6J mice exposed to GSM 1.8 GHz signal for 90 min daily by a typical cellular (mobile) phone at a specific absorption rate value of 0.11 W/kg. Free-moving male mice 2 months old were irradiated in two experimental protocols, lasting for 66 and for 148 days respectively. Each protocol used three groups of animals (n = 8 each for exposed, sham exposed and controls) in combination with two behavioural paradigms, the object recognition task and the object location task sequentially applied at different time points. One-way analysis of variance revealed statistically significant impairments of both types of memory gradually accumulating, with more pronounced effects on the spatial memory. The impairments persisted even 2 weeks after interruption of the 8 weeks daily exposure, whereas the memory of mice as detected by both tasks showed a full recovery approximately 1 month later. Intermittent every other day exposure for 1 month had no effect on both types of memory. The data suggest that visual information processing mechanisms in hippocampus, perirhinal and entorhinal cortex are gradually malfunctioning upon long-term daily exposure, a phenotype that persists for at least 2 weeks after interruption of radiation, returning to normal memory performance levels 4 weeks later. It is postulated that cellular repair mechanisms are operating to eliminate the memory affecting molecules. The overall contribution of several possible mechanisms to the observed cumulative and transient impairments in spatial and non-spatial memory is discussed.

**Nyakyi CP, Mrutu SI, Sam A, Anatory J, Safety Zone Determination for Wireless Cellular Tower - A Case Study for Tanzania. IJRET: International Journal of Research in Engineering and Technology. 2(9). Sep 2013. eISSN: 2319-1163 | pISSN: 2321-7308**

Safety zone determination for wireless cellular towers has attracted attention from many

researchers in the last decade. This is caused by the rapid growth of the wireless cellular industry which has led to the installation of towers even in the residential areas. There are many reports and ongoing researches regarding the biological and thermal effects of wireless cellular electromagnetic fields exposures to people. Cancer, hyperthermia, neural and behaviour effects of people exposed to these electromagnetic fields have been reported. This motivates the research to determine safety zones from wireless cellular towers to assure safety to those living in the vicinity of these towers. A model for safety zone determination is developed. The model takes the received power at the object, power transmitted by the transmitter and gain of the transmitter as inputs to determine the safe distance from the radiation of a wireless cellular transmitter. The power density received by the object and its geographical location from the radiation source are measured using the selective radiation meter. Transmitted power and the gain of the transmitter together with the height of the tower were obtained from the respective wireless cellular network operator. Based on the geographical location of the object, the distance from the radiation source was calculated using the haversine formula. These inputs are then used to determine the safety zone based on the standards and guidelines developed by WHO and ICNIRP.

**Nylund R, Leszczynski D. Proteomics analysis of human endothelial cell line EA.hy926 after exposure to GSM 900 radiation. Proteomics 4:1359-1365, 2004.**

The human endothelial cell line EA.hy926 was exposed to mobile phone radiation and the effect on protein expression was examined using two-dimensional electrophoresis (2-DE). Up to 38 various proteins have statistically significantly altered their expression levels following the irradiation. Four proteins were identified with matrix-assisted laser desorption/ionization-mass spectrometry (MALDI-MS). Two of the affected proteins were determined to be isoforms of cytoskeletal vimentin. This finding supports our earlier presented working hypothesis which indicated that the mobile phone radiation might affect the cytoskeleton and might have an effect on the physiological functions that are regulated by the cytoskeleton.

**Nylund R, Leszczynski D.Mobile phone radiation causes changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome-dependent. Proteomics.6(17):4769-4780, 2006.**

We have examined in vitro cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell line: EA.hy926 and EA.hy926v1. Gene expression changes were examined in three experiments using cDNA Expression Arrays and protein expression changes were examined in ten experiments using 2-DE and PDQuest software. Obtained results show that gene and protein expression were altered, in both examined cell lines, in response to one hour mobile phone radiation exposure at an average specific absorption rate of 2.8 W/kg. However, the same genes and proteins were differently affected by the exposure in each of the cell lines. This suggests that the cell response to mobile phone radiation might be genome- and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus. Our findings might also explain, at least in part, the origin of discrepancies in replication studies between different laboratories.

**Nylund R, Kuster N, Leszczynski D. Analysis of proteome response to the mobile phone radiation in two types of human primary endothelial cells. Proteome Sci 8(1):52, 2010.**

ABSTRACT: Background Use of mobile phones has widely increased over the past decade. However, in spite of the extensive research, the question of potential health effects of the mobile phone radiation remains unanswered. We have earlier proposed, and applied, proteomics as a tool to study biological effects of the mobile phone radiation, using as a model human endothelial cell line EA.hy926. Exposure of EA.hy926 cells to 900 MHz GSM radiation has caused statistically significant changes in expression of numerous proteins. However, exposure of EA.hy926 cells to 1800 MHz GSM signal had only very small effect on cell proteome, as compared with 900 MHz GSM exposure. In the present study, using as model human primary endothelial cells, we have examined whether exposure to 1800 MHz GSM mobile phone radiation can affect cell proteome. Results Primary human umbilical vein endothelial cells and primary human brain microvascular endothelial cells were exposed for 1 hour to 1800 MHz GSM mobile phone radiation at an average specific absorption rate of 2.0 W/kg. The cells were harvested immediately after the exposure and protein expression patterns of the sham-exposed and radiation-exposed cells were examined using two dimensional difference gel electrophoresis-based proteomics (2DE-DIGE). There were observed numerous differences between the proteomes of human umbilical vein endothelial cells and human brain microvascular endothelial cells (both sham-exposed). These differences are most likely representing physiological differences between endothelia in different vascular beds. However, the exposure of both types of primary endothelial cells to mobile phone radiation did not cause any statistically significant changes in protein expression. Conclusions Exposure of primary human endothelial cells to the mobile phone radiation, 1800 MHz GSM signal for 1 hour at an average specific absorption rate of 2.0 W/kg, does not affect protein expression, when the proteomes were examined immediately after the end of the exposure and when the false discovery rate correction was applied to analysis. This observation agrees with our earlier study showing that the 1800 MHz GSM radiation exposure had only very limited effect on the proteome of human endothelial cell line EA.hy926, as compared with the effect of 900 MHz GSM radiation.

**Oberto G, Rolfo K, Yu P, Carbonatto M, Peano S, Kuster N, Ebert S, Tofani S. Carcinogenicity Study of 217 Hz Pulsed 900 MHz electromagnetic fields in pim1 transgenic mice. Radiat Res 168(3):316-326, 2007.**

In an 18-month carcinogenicity study, Pim1 transgenic mice were exposed to pulsed 900 MHz (pulse width: 0.577 ms; pulse repetition rate: 217 Hz) radiofrequency (RF) radiation at a whole-body specific absorption rate (SAR) of 0.5, 1.4 or 4.0 W/kg [uncertainty (k = 2): 2.6 dB; lifetime variation (k = 1): 1.2 dB]. A total of 500 mice, 50 per sex per group, were exposed, sham-exposed or used as cage controls. The experiment was an extension of a previously published study in female Pim1 transgenic mice conducted by Repacholi et al. (Radiat. Res. 147, 631-640, 1997) that reported a significant increase in lymphomas after exposure to the same 900 MHz RF signal. Animals were exposed for 1 h/day, 7 days/week in plastic tubes similar to

those used in inhalation studies to obtain well-defined uniform exposure. The study was conducted blind. The highest exposure level (4 W/kg) used in this study resulted in organ-averaged SARs that are above the peak spatial SAR limits allowed by the ICNIRP (International Commission on Non-ionizing Radiation Protection) standard for environmental exposures. The whole-body average was about three times greater than the highest average SAR reported in the earlier study by Repacholi et al. The results of this study do not suggest any effect of 217 Hz-pulsed RF-radiation exposure (pulse width: 0.577 ms) on the incidence of tumors at any site, and thus the findings of Repacholi et al. were not confirmed. Overall, the study shows no effect of RF radiation under the conditions used on the incidence of any neoplastic or non-neoplastic lesion, and thus the study does not provide evidence that RF radiation possesses carcinogenic potential.

**Obukhan KI, [The effect of ultrahigh-frequency radiation on adaptation thresholds and the damages to blood system cells]. Lik Sprava (7):71-73, 1998.** [Article in Ukrainian]

Cytologic investigations designed to study bone marrow, peripheral blood, spleen, and thymus of albino rats irradiated by an electromagnetic field, 2375, 2450, and 3000 MEGS, revealed structural and functional changes in populations of megakaryocytes, immunocompetent cells as well as of undifferentiated cells, and of other types of cells that are dependent on the intensity of irradiation and permit establishing the probability-threshold levels of exposure taking account of reactions of perception and physiologic adaptation together with compensatory and regenerative processes and the injury sustained. It is shown that changes in bone marrow cells differentiation and reproduction rather than integral shifts in the peripheral blood that acquire the utmost significance. Subjected to a particular scrutiny in the paper are blast cells, which cells' repopulation was noted to be getting increased in low-intensity exposure as were disturbances in their mitosis pattern.

**Occhetta E, Plebani L, Bortnik M, Sacchetti G, Trevi G, Implantable cardioverter defibrillators and cellular telephones: is there any interference? Pacing Clin Electrophysiol 22(7):983-989, 1999.**

The aim of our study was to consider cellular telephone interference using different cellular telephones and implantable cardioverter defibrillator (ICD) models. Thirty (26 men, 4 women) patients with ICDs were considered during follow-up. The ICD models were: Telectronics (7), CPI (7), Medtronic (7), Ventritex (5), and Ela Medical (4). All patients were monitored with surface ECG; permanent telemetric endo-ECG monitoring was activated. Then, the effect of two different European telephone systems were tested: TACS system (Sony CM-R111, 2W power) and GSM system (Motorola MG1-4A11, 2 W power). For both systems, the effect during call, reception, active conversation (dialogue), and passive conversation (listening) were observed. Cellular telephones were located first in contact with the programming head, then near the leads system, and lastly, in the hands of the patient. At the end of the evaluations, memories were interrogated again to check for false arrhythmia detections. In five of these patients during arrhythmia induction at device implant (first implant or ICD replacement), we also evaluated possible interference between cellular telephones in the reception phase and the ventricular

fibrillation detection phase of the ICD. All evaluated models showed significant noise in the telemetric transmission when the cellular telephone (both TACS and GSM) was located near the ICD and the programming head; noise was particularly significant during call and reception, in most cases leading to loss of telemetry. No false arrhythmia detections have been observed during tests with cellular telephones located on the ICDs. During tests performed with cellular telephones located near the leads or in the hands of patients, no telemetric noises orfalse arrhythmia detections were observed. During induced ventricularfibrillation and cellular telephones in reception mode near the device, the arrhythmia recognition was always correct and not delayed. In conclusion, present ICD models seem to be well protected from electromagnetic interference caused by European cellular telephones (TACS and GSM), without under-/oversensing of ventricular arrhythmias. However, cellular telephones disturb telemetry when located near the programming head. ICD patients should not be advised against the use of cellular telephones, but it has to be avoided during ICD interrogation and programming.

**O'Connor RP, Madison SD, Leveque P, Roderick HL, Bootman MD. Exposure to GSM RF fields does not affect calcium homeostasis in human endothelial cells, rat pheocromocytoma cells or rat hippocampal neurons. PLoS One. 5(7):e11828, 2010.**

In the course of modern daily life, individuals are exposed to numerous sources of electromagnetic radiation that are not present in the natural environment. The strength of the electromagnetic fields from sources such as hairdryers, computer display units and other electrical devices is modest. However, in many home and office environments, individuals can experience perpetual exposure to an "electromagnetic smog", with occasional peaks of relatively high electromagnetic field intensity. This has led to concerns that such radiation can affect health. In particular, emissions from mobile phones or mobile phone masts have been invoked as a potential source of pathological electromagnetic radiation. Previous reports have suggested that cellular calcium (Ca(2+)) homeostasis is affected by the types of radiofrequency fields emitted by mobile phones. In the present study, we used a high-throughput imaging platform to monitor putative changes in cellular Ca(2+) during exposure of cells to 900 MHz GSM fields of differing power (specific absorption rate 0.012-2 W/Kg), thus mimicking the type of radiation emitted by current mobile phone handsets. Data from cells experiencing the 900 Mhz GSM fields were compared with data obtained from paired experiments using continuous wave fields or no field. We employed three cell types (human endothelial cells, PC-12 neuroblastoma and primary hippocampal neurons) that have previously been suggested to be sensitive to radiofrequency fields. Experiments were designed to examine putative effects of radiofrequency fields on resting Ca(2+), in addition to Ca(2+) signals evoked by an InsP(3)-generating agonist. Furthermore, we examined putative effects of radiofrequency field exposure on Ca(2+) store emptying and store-operated Ca(2+) entry following application of the Ca(2+)ATPase inhibitor thapsigargin. Multiple parameters (e.g., peak amplitude, integrated Ca(2+) signal, recovery rates) were analysed to explore potential impact of radiofrequency field exposure on Ca(2+) signals. Our data indicate that 900 MHz GSM fields do not affect either basal Ca(2+) homeostasis or provoked Ca(2+) signals. Even at the highest field strengths applied,

which exceed typical phone exposure levels, we did not observe any changes in cellular Ca(2+) signals. We conclude that under the conditions employed in our experiments, and using a highly-sensitive assay, we could not detect any consequence of RF exposure.

**Odaci E, Bas O, Kaplan S. Effects of prenatal exposure to a 900 MHz electromagnetic field on the dentate gyrus of rats: a stereological and histopathological study.Brain Res. 1238:224-229, 2008.**

Electromagnetic fields (EMFs) inhibit the formation and differentiation of neural stem cells during embryonic development. In this study, the effects of prenatal exposure to EMF on the number of granule cells in the dentate gyrus of 4-week-old rats were investigated. This experiment used a control (Cont) group and an EMF exposed (EMF) group (three pregnant rats each group). The EMF group consisted of six offspring (n=6) of pregnant rats that were exposed to an EMF of up to 900 megahertz (MHz) for 60 min/day between the first and last days of gestation. The control group consisted of five offspring (n=5) of pregnant rats that were not treated at all. The offspring were sacrificed when they were 4 weeks old. The numbers of granule cells in the dentate gyrus were analyzed using the optical fractionator technique. The results showed that prenatal EMF exposure caused a decrease in the number of granule cells in the dentate gyrus of the rats ($P<0.01$). This suggests that prenatal exposure to a 900 MHz EMF affects the development of the dentate gyrus granule cells in the rat hippocampus. Cell loss might be caused by an inhibition of granule cell neurogenesis in the dentate gyrus.

**Odacı E, Unal D, Mercantepe T, Topal Z, Hancı H, Türedi S, Erol H, Mungan S, Kaya H, Colakoğlu S.Pathological effects of prenatal exposure to a 900 MHz electromagnetic field on the 21-day-old male rat kidney. Biotech Histochem. 2014 Aug 27:1-9. [Epub ahead of print]**

We investigated the effects on kidney tissue of 900 megahertz (MHz) EMF applied during the prenatal period. Pregnant rats were exposed to 900 MHz EMF, 1 h/day, on days 13-21 of pregnancy; no procedure was performed on control group pregnant rats or on mothers or newborns after birth. On postnatal day 21, kidney tissues of male rat pups from both groups were examined by light and electron microscopy. Malondialdehyde (MDA), superoxide dismutase (SOD), catalase (CAT) and glutathione levels also were investigated. Light microscopy revealed some degenerative changes in the tubule epithelium, small cystic formations in the primitive tubules and large cysts in the cortico-medullary or medullary regions in the experimental group. Electron microscopy revealed a loss of peritubular capillaries and atypical parietal layer epithelial cells in the experimental group. Biochemical analysis showed significantly increased MDA levels in the experimental group and decreased SOD and CAT levels. EMF applied during the prenatal period can caused pathological changes in kidney tissue in 21-day-old male rats owing to oxidative stress and decreased antioxidant enzyme levels.

**Odacı E, Özyılmaz C. Exposure to a 900 MHz electromagnetic field for one hour a day over 30 days does change the histopathology and biochemistry of the rat testis. Int J Radiat Biol. 2015 Mar 19:1-20. [Epub ahead of print]**

PURPOSE: This study investigated the effect of exposure to a 900-megahertz (MHz) electromagnetic field (EMF) on the rat testicle. MATERIALS AND METHODS: Twenty-four adult male rats were divided into control, sham and EMF groups. The EMF group rats were exposed to 900-MHz EMF (1 h / 30 day), and testicles were extracted at the end of the experiment. Malondialdehyde, superoxide dismutase, catalase and glutathione levels and apoptotic index and histopathological damage scores were compared. RESULTS: Histopathologically, EMF group rats exhibited vacuoles in seminiferous tubules basal membrane and edema in the intertubular space. Seminiferous tubule diameters and germinal epithelium thickness were both smaller, and apoptotic index was higher, in the EMF group than in the other groups. Malondialdehyde, superoxide dismutase, catalase and glutathione values in the EMF group decreased significantly compared to those of the control group. CONCLUSIONS: The results show that exposure to 900-MHz EMF causes alterations in adult rat testicular morphology and biochemistry.

**Odacı E, Hancı H, Yuluğ E, Türedi S, Aliyazıcıoğlu Y, Kaya H, Çolakoğlu S. Effects of prenatal exposure to a 900 MHz electromagnetic field on 60-day-old rat testis and epididymal sperm quality. Biotech Histochem. 91(1):9-19, 2016.**

We investigated the effects of exposure in utero to a 900 megahertz (MHz) electromagnetic field (EMF) on 60-day-old rat testis and epididymis. Pregnant rats were divided into control (CG; no treatment) and EMF (EMFG) groups. The EMFG was exposed to 900 MHz EMF for 1 h each day during days 13 - 21 of pregnancy. Newborn rats were either newborn CG (NCG) or newborn EMF groups (NEMFG). On postnatal day 60, a testis and epididymis were removed from each animal. Epididymal semen quality, and lipid and DNA oxidation levels, apoptotic index and histopathological damage to the testis were compared. We found a higher apoptotic index, greater DNA oxidation levels and lower sperm motility and vitality in the NEMFG compared to controls. Immature germ cells in the seminiferous tubule lumen, and altered seminiferous tubule epithelium and seminiferous tubule structure also were observed in hematoxylin and eosin stained sections of NEMFG testis. Nuclear changes that indicated apoptosis were identified in TUNEL stained sections and large numbers of apoptotic cells were observed in most of the seminiferous tubule epithelium in the NEMFG. Sixty-day-old rat testes exposed to 900 MHz EMF exhibited altered sperm quality and biochemical characteristics.

**Oftedal G, Wilen J, Sandstrom M, Mild KH, Symptoms experienced in connection with mobile phone use. Occup Med (Lond) 50(4):237-245, 2000.**

Many people in Norway and Sweden reported headaches, fatigue, and other symptoms experienced in connection with the use of a mobile phone (MP). Therefore, we initiated a cross-sectional epidemiological study among 17,000 people, all using an MP in their job. Thirty-one percent of the respondents in Norway and 13% of those in Sweden had experienced at least one symptom in connection with MP use. Next to the sensations of warmth on the ear and behind/around the ear, burning sensations in the facial skin and headaches were most commonly reported. Most symptoms usually began during or within half an hour after the call and lasted for up to 2 h. Relatively few had consulted a

physician or been on sick leave because of the symptoms, but about 45% among those with an MP attributed symptom had taken steps to reduce the symptom. These results suggest an awareness of the symptoms, but not necessarily a serious health problem.

**Oftedal G, Straume A, Johnsson A, Stovner L. Mobile phone headache: a double blind, sham-controlled provocation study. Cephalalgia.27(5):447-55, 2007.**

The objective was to test whether exposure to radio frequency (RF) fields from mobile phones may cause head pain or discomfort and whether it may influence physiological variables in individuals attributing symptoms to mobile phones, but not to electromagnetic fields in general. Seventeen eligible individuals, who experienced these symptoms in an open provocation test, took part in a double-blind, randomized provocation study with cross-over design. Sixty-five pairs of sham and mobile phone RF exposures were conducted. The increase in pain or discomfort (visual analogue scales) in RF sessions was 10.1 and in sham sessions 12.6 (P = 0.30). Changes in heart rate or blood pressure were not related to the type of exposure (P: 0.30-0.88). The study gave no evidence that RF fields from mobile phones may cause head pain or discomfort or influence physiological variables. The most likely reason for the symptoms is a nocebo effect.

**Ogawa K, Nabae K, Wang J, Wake K, Watanabe S, Kawabe M, Fujiwara O, Takahashi S, Ichihara T, Tamano S, Shirai T. Effects of gestational exposure to 1.95-GHz W-CDMA signals for IMT-2000 cellular phones: Lack of embryotoxicity and teratogenicity in rats. Bioelectromagnetics. 30(3):205-212, 2009.**

The present study was designed to evaluate whether gestational exposure to an EMF targeting the head region, similar to that from cellular phones, might affect embryogenesis in rats. A 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is one applied for the International Mobile Telecommunication 2000 (IMT-2000) system and used for the freedom of mobile multimedia access (FOMA), was employed for exposure to the heads of four groups of pregnant CD(SD) IGS rats (20 per group) for gestational days 7-17. The exposure was performed for 90 min/day in the morning. The spatial average specific absorption rate (SAR) for individual brains was designed to be 0.67 and 2.0 W/kg with peak brain SARs of 3.1 and 7.0 W/kg for low (group 3) and high (group 4) exposures, respectively, and a whole-body average SAR less than 0.4 W/kg so as not to cause thermal effects due to temperature elevation. Control and sham exposure groups were also included. At gestational day 20, all dams were killed and fetuses were taken out by cesarean section. There were no differences in maternal body weight gain. No adverse effects of EMF exposure were observed on any reproductive and embryotoxic parameters such as number of live (243-271 fetuses), dead or resorbed embryos, placental weights, sex ratios, weights or external, visceral or skeletal abnormalities of live fetuses.

**Ohmoto Y, Fujisawa H, Ishikawa T, Koizumi H, Matsuda T, Ito H, Sequential changes in cerebral blood flow, early neuropathological consequences and blood-brain barrier disruption following radiofrequency-induced localized hyperthermia in the rat. Int J Hyperthermia 12(3):321-334, 1996.**

We investigated the temperature distribution, early histological changes, blood brain barrier (BBB) disruption and sequential changes in cerebral blood flow (CBF) following hyperthermia ranging from 37 to 45 degrees C in a new rat model of radiofrequency-induced localized cerebral hyperthermia. Significant histological changes and BBB disruption were observed in brain regions heated to 43 degrees C and above. In the cortex heated to 41 degrees C, the CBF doubled 20 min after hyperthermia induction, and then returned gradually to the pre-hyperthermic level. In the cortex heated to 43 degrees C, the CBF increased to 134% of the baseline level 10 min after hyperthermia induction, and then fell gradually to reach its minimum level (31% of the baseline level). In the cortex heated to 45 degrees C, the CBF decreased immediately after hyperthermia induction to reach 10% of the baseline level. The results indicate that hyperthermia-induced cellular injury in the central nervous system is associated with cerebral ischaemia and the threshold temperature for such injury is 43 degrees C. This model is useful for investigating the effects of hyperthermia on various cerebral functions and the CBF changes demonstrated in the present study may provide key information for the analysis of other cerebral functions.

**Okano T, Terao Y, Furubayashi T, Yugeta A, Hanajima R, Ugawa Y. The effect of electromagnetic field emitted by a mobile phone on the inhibitory control of saccades. Clin Neurophysiol.121(4):603-611, 2010.**

OBJECTIVE: To investigate whether exposure to a pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on the inhibitory control of saccades. METHODS: A double-blind, counterbalanced crossover study design was employed. We assessed the performance of 10 normal subjects on antisaccade (AS) and cued saccade (CUED) tasks as well as two types of overlap saccade (OL1, OL2) task before and after 30min of exposure to EMF emitted by a mobile phone or sham exposure. RESULTS: After EMF or sham exposure, we observed a slight but significant shortening of latency in the CUED and OL2 tasks. AS amplitude decreased as well as the saccade velocities in the AS, CUED, and OL1 tasks after exposure. These changes occurred regardless of whether exposure was real or sham. The frequencies of prosaccades in the AS task, saccades to cue in the CUED task, and prematurely initiated saccades in the overlap (OL2) task did not change significantly after real or sham EMF exposure. CONCLUSIONS: Thirtyminutes of mobile phone exposure has no significant short-term effect on the inhibitory control of saccades. SIGNIFICANCE: The cortical processing responsible for saccade inhibition is not affected by exposure to EMF emitted by a mobile phone.

**Oksay T, Naziroğlu M, Doğan S, Güzel A, Gümral N, Koşar PA. Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. Andrologia. 2012 Nov 12. doi: 10.1111/and.12044. [Epub ahead of print]**

Wireless devices have become part of everyday life and mostly located near reproductive organs while they are in use. The present study was designed to determine the possible protective effects of melatonin on oxidative stress-dependent testis injury induced by 2.45-GHz electromagnetic radiation (EMR). Thirty-two rats were equally divided into four different groups, namely cage control (A1), sham

control (A2), 2.45-GHz EMR (B) and 2.45-GHz EMR+melatonin (C). Group B and C were exposed to 2.45-GHz EMR during 60 min day(-1) for 30 days. Lipid peroxidation levels were higher in Group B than in Group A1 and A2. Melatonin treatment prevented the increase in the lipid peroxidation induced by EMR. Also reduced glutathione (GSH) and glutathione peroxidase (GSH-Px) levels in Group D were higher than that of exposure group. Vitamin A and E concentrations decreased in exposure group, and melatonin prevented the decrease in vitamin E levels. In conclusion, wireless (2.45 GHz) EMR caused oxidative damage in testis by increasing the levels of lipid peroxidation and decreasing in vitamin A and E levels. Melatonin supplementation prevented oxidative damage induced by EMR and also supported the antioxidant redox system in the testis.

**Oktay MF**, **Dasdag S**. **Effects of intensive and moderate cellular phone use on hearing function. Electromagn Biol Med. 25(1):13-21, 2006.**

The purpose of this study is to investigate the effects of radiation emitted by mobile phones on the hearing of users. The study was carried out on three groups: 1) 20 men who have used a cellular phone frequently and spoken approximately 2 h per day for four years; 2) 20 men who have used a cellular phone for 10-20 min per day for four years; and 3) 20 healthy men who have never used a cellular phone (the control group). Brainstem evoked response audiometric (BERA) and pure tone audiometric (PTA) methods were used to measure the effects of exposure on hearing function of the subjects. In BERA measurements, I-III, III-V, and I-V interpeak latencies were evaluated. Interpeak latency of subjects in two experimental groups was compared to that of subjects in the control group. The BERA results showed no differences among the groups ($p > 0.05$).In PTA measurements, detection thresholds at 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz frequencies were measured in all three groups. No differences were observed between moderate mobile phone users (10-20 min. per day) and control subjects. However, detection thresholds in those who talked approximately 2 h per day were found to be higher than those in either moderate users or control subjects. Differences at 4000 Hz for both bone and air conduction for right ears, and 500 Hz, and 4000 Hz bone and air conduction for left ears were significant for mean hearing threshold. This study shows that a higher degree of hearing loss is associated with long-term exposure to electromagnetic (EM) field generated by cellular phones.

**Oktem F, Ozguner F, Mollaoglu H, Koyu A, Uz E. Oxidative damage in the kidney induced by 900-MHz-emitted mobile phone: protection by melatonin. Arch Med Res.36(4):350-355, 2005.**

BACKGROUND: The mobile phones emitting 900-MHz electromagnetic radiation (EMR) may be mainly absorbed by kidneys because they are often carried in belts. Melatonin, the chief secretory product of the pineal gland, was recently found to be a potent free radical scavenger and antioxidant. The aim of this study was to examine 900-MHz mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) on renal tubular damage and the role of melatonin on kidney tissue against possible oxidative damage in rats. METHODS: The animals were randomly grouped as follows: 1) sham-operated control group and 2) study groups: i) 900-MHz EMR exposed (30 min/day for 10 days) group and ii) 900-MHz EMR exposed+melatonin (100 mug kg(-

1) s.c. before the daily EMR exposure) treated group. Malondialdehyde (MDA), an index of lipid peroxidation), and urine N-acetyl-beta-d-glucosaminidase (NAG), a marker of renal tubular damage were used as markers of oxidative stress-induced renal impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status. RESULTS: In the EMR-exposed group, while tissue MDA and urine NAG levels increased, SOD, CAT, and GSH-Px activities were reduced. Melatonin treatment reversed these effects as well. In this study, the increase in MDA levels of renal tissue and in urine NAG and also the decrease in renal SOD, CAT, GSH-Px activities demonstrated the role of oxidative mechanism induced by 900-MHz mobile phone exposure, and melatonin, via its free radical scavenging and antioxidant properties, ameliorated oxidative tissue injury in rat kidney. CONCLUSIONS: These results show that melatonin may exhibit a protective effect on mobile phone-induced renal impairment in rats.

**Olchowik G, [Evaluation of bone density in rats after hydrocortisone and microwave radiation]. Chir Narzadow Ruchu Ortop Pol 62(2):163-167, 1997.** [Article in Polish]

The influence of hydrocortisone and microwave radiation on bone in rats have been investigated. Hydrocortisone hemisuccinate has been administered intraperitoneally for 12 weeks with concomitant microwave irradiation of two power densities. The results achieved indicate protective effect of electromagnetic microwave radiation on bone tissue exposed to corticotherapy.

**Olchowik G, Maj JG, Inhibitory action of microwave radiation on gamma-glutamyl transpeptidase activity in liver of rats treated with hydrocortisone. Folia Histochem Cytobiol 38(4):189-191, 2000.**

The influence of microwave irradiation on the activity of gamma-glutamyl transpeptidase (GGT) induced by hydrocortisone (HC) in the liver of rats was investigated. Animals were subjected to microwave irradiation (frequency 53.57 GHz, power density 10 mW/cm2 and 1 mW/cm2) during and after hydrocortisone (HC) treatment (20 mg/kg for 60 days). The results indicate that microwave radiation may block an inducible effect of HC on GGT activity in the liver of rats. This effect depends on the power density of millimetre microwaves.

**Olchowik G. Influence of hydrocortisone and microwave radiation on the mechanical characteristics of rat bone tissue. Cytobios 105(410):147-152, 2001.**

This work deals with the mutual action of hydrocortisone and low intensity microwave radiation (MWR) on the bone tissue of rats. The bone density and velocity of ultrasound was measured in order to evaluate the Young's modulus of the femur. The results show a stimulating effect of the low-intensity MWR field on regeneration of the bone tissue of rats. The MWR, during a long application of hydrocortisone, may be a characteristic protective factor for the bone tissue.

**Olgar Y, Hidisoglu E, Celen MC, Yamasan BE, Yargicoglu P, Ozdemir S. 2.1 GHz electromagnetic field does not change contractility and intracellular Ca2+ transients but decreases β-adrenergic responsiveness through nitric oxide**

**signaling in rat ventricular myocytes. Int J Radiat Biol. 2015 Jul 1:1-23. [Epub ahead of print]**

PURPOSE: Due to the increasing use of wireless technology in developing countries, particularly mobile phones, the influence of electromagnetic fields (EMF) on biologic systems has become the subject of an intense debate. Therefore, in this study we investigated the effect of 2.1 GHz EMF on contractility and beta-adrenergic (β-AR) responsiveness of ventricular myocytes. MATERIALS AND METHODS: Rats were randomized to the following groups: sham rats (SHAM) and rats exposed to 2.1 GHz EMF for 2 hours/day for 10 weeks (EM-10). Sarcomere shortening and $Ca^{2+}$ transients were recorded in isolated myocytes loaded with Fura2-AM and electrically stimulated at 1 Hz, while L-type $Ca^{2+}$ currents ($I_{CaL}$) were measured using whole-cell patch clamping at 36±1°C. Cardiac nitric oxide (NO) levels were measured in tissue samples using a colorimetric assay kit. RESULTS: Fractional shortening and amplitude of the matched $Ca^{2+}$ transients were not changed in EM-10 rats. Although the isoproterenol-induced ($10^{-6}$ M) $I_{CaL}$ response was reduced in rats exposed to EMF, basal $I_{CaL}$ density in myocytes was similar between the two groups ($p<0.01$). Moreover, EMF exposure led to a significant increase in nitric oxide levels in rat heart ($p<0.02$). CONCLUSIONS: Long-term exposure to 2.1 GHz EMF decreases β-AR responsiveness of ventricular myocytes through NO signaling.

**Ono T, Saito Y, Komura J, Ikehata H, Tarusawa Y, Nojima T, Goukon K, Ohba Y, Wang J, Fujiwara O, Sato R. Absence of mutagenic effects of 2.45 GHz radiofrequency exposure in spleen, liver, brain, and testis of lacZ-transgenic mouse exposed in utero. Tohoku J Exp Med 202(2):93-103, 2004.**

A possible mutagenic effect of 2.45 GHz radiofrequency exposure was examined using lacZ-transgenic Muta mice. Pregnant animals were exposed intermittently at a whole-body averaged specific absorption rate of 0.71 W/kg (10 seconds on, 50 seconds off which is 4.3 W/kg during the 10 seconds exposure). Offspring that were exposed in utero for 16 hours a day, from the embryonic age of 0 to 15 days, were examined at 10 weeks of age. To minimize thermal effects, the exposure was given in repeated bursts of 10 seconds of exposure followed by 50 seconds of no exposure. Mutation frequencies at the lacZ gene in spleen, liver, brain, and testis were similar to those observed in non-exposed mice. Quality of mutation assessed by sequencing the nucleotides of mutant DNAs revealed no appreciable difference between exposed and non-exposed samples. The data suggest that the level of radiofrequency exposure studied is not mutagenic when administered in utero in short repeated bursts.

**Oommen BS, Stahl JS. Inhibited head movements: A risk of combining phoning with other activities? Neurology 65(5):754-756, 2005.**

Abstract-- Studies of cellular phone use while driving have attributed impaired performance to the distractions of conversation. We determined that holding an inactive phone to the ear reduces the probability of eccentric head positions, potentially indicating reduced ability to monitor the visual surround. This effect may constitute a risk of cellular phone use independent of conversation and peculiar to handheld models.

**Oral B, Guney M, Ozguner F, Karahan N, Mungan T, Comlekci S, Cesur G. Endometrial Apoptosis Induced by a 900-MHz Mobile Phone: Preventive Effects of Vitamins E and C. Adv Ther. 23(6):957-973, 2006.**

Numerous reports have described the effects induced by an electromagnetic field (EMF) in various cellular systems. The purposes of this study were to examine oxidative stress that promotes production of reactive oxygen species induced by a 900-megahertz (MHz) mobile phone and the possible ameliorating effects of vitamins E and C on endometrial tissue against EMF-induced endometrial impairment and apoptosis in rats. Animals were randomly grouped as follows: (1) sham-operated control group (n=8), (2) 900 MHz EMF-exposed group (n=8; 30 min/d for 30 d), and (3) 900 MHz EMF-exposed group, treated with vitamins E and C (n=8; 50 mg/kg intramuscularly and 20 mg/kg body weight intraperitoneally before daily EMF exposure). Malondialdehyde (an index of lipid peroxidation) was used as a marker of oxidative stress-induced endometrial impairment; Bcl-2, Bax, caspase-3, and caspase-8 were assessed immunohistochemically. In this study, increased malondialdehyde levels in endometrial tissue and apoptosis illustrated the role of the oxidative mechanism induced by exposure to a 900-MHz mobile phone-like device and vitamins E and C; via free radical scavenging and antioxidant properties, oxidative tissue injury and apoptosis were ameliorated in rat endometrium. In conclusion, exposure to 900-MHz radiation emitted by mobile phones may cause endometrial apoptosis and oxidative stress, but treatment with vitamins E and C can diminish these changes and may have a beneficial effect in preventing endometrial changes in rats.

**Orhan Baş, Osman Fikret Sönmez, Ali Aslan, Ayşe İkinci, Hatice Hancı, Mehmet Yıldırım, Haydar Kaya, Metehan Akça, Ersan Odacı. Pyramidal Cell Loss in the Cornu Ammonis of 32-day-old Female Rats Following Exposure to a 900 Megahertz Electromagnetic Field During Prenatal Days 13–21. NeuroQuantology 11:591-599, 2013.**

The number of studies reporting that the electromagnetic field (EMF) emitted by mobile phones affects human health is increasing by the day. In previous studies we reported that a 900 megahertz (MHz) EMF applied throughout the prenatal period reduced the number of pyramidal cells in the cornu ammonis of rat pups in the postnatal period. In this study we investigated the effect of a 900 MHz EMF applied on days 13-21 of the prenatal period on the number of pyramidal cells in the cornu ammonis of rat pups in the postnatal period. For that purpose, pregnant rats were divided into experimental and control groups. Experimental group pregnant rats were exposed to the effect of a 900 MHz EMF on days 13-21 of pregnancy. No procedure was applied to the control group. Newborn female rat pups were added to the study, and no procedure was performed on these after birth. Five newborn female rats were obtained from the experimental group and six from the control group. All female rat pups were decapitated on the postnatal 32nd day, and histological procedures were performed on the brain tissues. Sections were stained with Cresyl fast violet. The optical dissector technique was used to estimate the total number of pyramidal cells in the cornu ammonis. Sections of cornu ammonis were subjected to

histopathological evaluations. Our results showed that exposure to 900 MHz EMF during prenatal days 13-21 led to a significant decrease in the number of pyramidal cells in the cornu ammonis of the experimental group female rat pups ($P<0.05$). Histopathological examination revealed picnotic cells in the cornu ammonis in experimental female rat pups. The pyramidal cell loss in the cornu ammonis may therefore be attributed to exposure to 900 MHz EMF in days 13-21 of the prenatal period.

**Oster S, Daus AW, Erbes C, Goldhammer M, Bochtler U, Thielemann C. Long-term electromagnetic exposure of developing neuronal networks: A flexible experimental setup. Bioelectromagnetics. 37(4):264-278, 2016**

Neuronal networks in vitro are considered one of the most promising targets of research to assess potential electromagnetic field induced effects on neuronal functionality. A few exposure studies revealed there is currently no evidence of any adverse health effects caused by weak electromagnetic fields. Nevertheless, some published results are inconsistent. Particularly, doubts have been raised regarding possible athermal biological effects in the young brain during neuronal development. Therefore, we developed and characterized a flexible experimental setup based on a transverse electromagnetic waveguide, allowing controlled, reproducible exposure of developing neuronal networks in vitro. Measurement of S-parameters confirmed very good performance of the Stripline in the band of 800-1000 MHz. Simulations suggested a flexible positioning of cell culture dishes throughout a large exposure area, as specific absorption rate values were quite independent of their position ($361.7 \pm 11.4$ mW/kg) at 1 W, 900 MHz. During exposure, thermal drift inside cellular medium did not exceed 0.1 K. Embryonic rat cortical neurons were cultivated on microelectrode array chips to non-invasively assess electrophysiological properties of electrogenic networks. Measurements were taken for several weeks, which attest to the experimental setup being a reliable system for long-term studies on developing neuronal tissue.

**Othman H, Ammari M, Sakly M, Abdelmelek H. Effects of prenatal exposure to WIFI signal (2.45GHz) on postnatal development and behavior in rat: Influence of maternal restraint. Behav Brain Res. 326:291-302, 2017.**

The present study was carried out to investigate the potential combined influence of maternal restraint stress and 2.45GHz WiFi signal exposure on postnatal development and behavior in the offspring of exposed rats. 24 pregnant albino Wistar rats were randomly assigned to four groups: Control, WiFi-exposed, restrained and both WiFi-exposed and restrained groups. Each of WiFi exposure and restraint occurred 2h/day along gestation till parturition. The pups were evaluated for physical development and neuromotor maturation. Moreover, elevated plus maze test, open field activity and stationary beam test were also determined on postnatal days 28, 30 and 31, respectively. After behavioral tests, the rats were anesthetized and their brains were removed for biochemical analysis. Our main findings showed no detrimental effects on gestation progress and outcomes at delivery in all groups. Subsequently, WiFi and restraint, per se and mainly in concert altered physical development of pups with slight differences between genders. Behaviorally, the gestational WiFi irradiation, restraint and especially

the associated treatment affected the neuromotor maturation mainly in male progeny. At adult age, we noticed anxiety, motor deficit and exploratory behavior impairment in male offspring co-exposed to WiFi radiation and restraint, and in female progeny subjected to three treatments. The biochemical investigation showed that, all three treatments produced global oxidative stress in brain of both sexes. As for serum biochemistry, phosphorus, magnesium, glucose, triglycerides and calcium levels were disrupted. Taken together, prenatal WiFi radiation and restraint, alone and combined, provoked several behavioral and biochemical impairments at both juvenile and adult age of the offspring.

**Ouellet-Hellstrom R, Stewart WF, Miscarriages among female physical therapists who report using radio- and microwave-frequency electromagnetic radiation. Am J Epidemiol 138(10):775-786, 1993.**

Physical therapists are exposed to radio- and microwave-frequency electromagnetic radiation by operating shortwave and microwave diathermy units. Recent studies suggest that use of shortwave diathermy is associated with an excess risk of birth defects, perinatal deaths, and late spontaneous abortions among the offspring of exposed female therapists. To assess the impact of occupational use of microwave and shortwave diathermy at the time of conception, the authors mailed questionnaires to 42,403 physical therapists in 1989. Both occupational and reproductive histories were obtained. Exposures to shortwave and microwave diathermy were both assessed in the same fashion and were examined in relation to early recognized fetal loss in a nested case-control design. A total of 1,753 case pregnancies (miscarriages) were matched to 1,753 incidence density control pregnancies (other pregnancies except ectopic pregnancies). A pregnancy was considered "exposed" if the mother reported using microwave or shortwave diathermy anytime during the 6 months prior to the first trimester or during the first trimester. Pregnancies of mothers reporting microwave use 6 months prior to the pregnancy or during the first trimester were more likely to result in miscarriage (odds ratio (OR) = 1.28, 95% confidence interval (CI) 1.02-1.59). The odds ratio increased with increasing level of exposure (chi 2 = 7.25, $p < 0.005$). The odds ratio in the highest exposure group (20 or more exposures/month) was 1.59. The overall odds ratio was slightly lower after it was controlled for prior fetal loss (OR = 1.26, 95% CI 1.00-1.59), but the exposure-response effect remained (chi 2 = 5.17, $p < 0.01$). The risk of miscarriage was not associated with reported use of shortwave diathermy equipment (OR = 1.07, 95% CI 0.91-1.24). The odds ratio in the highest exposure group was 0.87.

**Ozguner F, Aydin G, Mollaoglu H, Gokalp O, Koyu A, Cesur G. Prevention of mobile phone induced skin tissue changes by melatonin in rat: an experimental study. Toxicol Ind Health. 20(6-10):133-139, 2004.**

Most of the mobile phones in Turkey emit 900 MHz radiation which is mainly absorbed by the skin and, to a lesser extent, muscle. The aim of this study was to investigate the effects the 900 MHz electromagnetic irradiation emitted by these devices on the induction of histopathologic changes in skin and the effect of melatonin (Mel) on any of these changes. Thirty male Wistar-Albino rats were used in the study. The experimental groups were composed of: a nontreated control group, an irradiated group (IR) without Mel and an irradiated with Mel treatment group (IR + Mel). 900 MHz radiation was applied to IR group for 10 days (30 min/day). The IR + Mel group received 10 mg/kg per day melatonin

in tap water for 10 days before irradiation. At the end of the tenth day, the skin graft was excized from the thoraco-abdominal area. Histopathologic changes in skin were analyzed. In the IR group, increased thickness of stratum corneum, atrophy of epidermis, papillamatosis, basal cell proliferation, increased granular cell layer (hypergranulosis) in epidermis and capillary proliferation, impairment in collagen tissue distribution and separation of collagen bundles in dermis were all observed compared to the control group. Most of these changes, except hypergranulosis, were prevented with melatonin treatment. In conclusion, exposure to 900 MHz radiation emitted by mobile phones caused mild skin changes. Furthermore, melatonin treatment can reduce these changes and may have a beneficial effect to prevent 900 MHz mobile phone-induced rat skin changes.

**Ozguner M, Koyu A, Cesur G, Ural M, Ozguner F, Gokcimen A, Delibas N. Biological and morphological effects on the reproductive organ of rats after exposure to electromagnetic field. Saudi Med J. 26(3):405-410, 2005.**

OBJECTIVE: The biological effect of electromagnetic field (EMF) emitted from mobile phones is a current debate and still a controversial issue. Therefore, little is known on the possible adverse effects on reproduction as mobile phone bio-effects are only a very recent concern. The aim of this experimental study was to determine the biological and morphological effects of 900 MHz radiofrequency (RF) EMF on rat testes. METHODS: The study was performed in the Physiology and Histology Research Laboratories of Suleyman Demirel University, Faculty of Medicine, Isparta, Turkey in May 2004. Twenty adult male Sprague-Dawley rats weighing 270 - 320 gm were randomized into 2 groups of 10 animals: Group I (control group) was not exposed to EMF and Group II (EMF group) was exposed to 30 minutes per day, 5 days a week for 4 weeks to 900 MHz EMF. Testes tissues were submitted for histologic and morphologic examination. Testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were registered. Serum testosterone, plasma luteinizing hormone (LH) and follicle stimulating hormone (FSH) levels were assayed biochemically. RESULTS: The weight of testes, testicular biopsy score count and the percentage of interstitial tissue to the entire testicular tissue were not significantly different in EMF group compared to the control group. However, the diameter of the seminiferous tubules and the mean height of the germinal epithelium were significantly decreased in EMF group ($p<0.05$). There was a significant decrease in serum total testosterone level in EMF group ($p<0.05$). Therefore, there was an insignificant decrease in plasma LH and FSH levels in EMF group compared to the control group ($p>0.05$). CONCLUSION: The biological and morphological effects resulting from 900 MHz RF EMF exposure lends no support to suggestions of adverse effect on spermatogenesis, and on germinal epithelium. Therefore, testicular morphologic alterations may possibly be due to hormonal changes.

**Ozguner F, Oktem F, Ayata A, Koyu A, Yilmaz HR. A novel antioxidant agent caffeic acid phenethyl ester prevents long-term mobile phone exposure-induced renal impairment in rat. Prognostic value of malondialdehyde, N-acetyl-beta-D-glucosaminidase and nitric oxide determination.Mol Cell Biochem. 277(1-2):73-80, 2005.**

Caffeic acid phenethyl ester (CAPE), a flavonoid like compound, is one of the major

components of honeybee propolis. It has been used in folk medicine for many years in Middle East countries. It was found to be a potent free radical scavenger and antioxidant recently. The aim of this study was to examine long-term applied 900 MHz emitting mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) and, was to investigate the role of CAPE on kidney tissue against the possible electromagnetic radiation (EMR)-induced renal impairment in rats. In particular, the ROS such as superoxide and nitric oxide (NO) may contribute to the pathophysiology of EMR-induced renal impairment. Malondialdehyde (MDA, an index of lipid peroxidation) levels, urinary N-acetyl-beta-D: -glucosaminidase (NAG, a marker of renal tubular injury) and nitric oxide (NO, an oxidant product) levels were used as markers of oxidative stress-induced renal impairment and the success of CAPE treatment. The activities of superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) in renal tissue were determined to evaluate the changes of antioxidant status. The rats used in the study were randomly grouped (10 each) as follows: i) Control group (without stress and EMR), ii) Sham-operated rats stayed without exposure to EMR (exposure device off), iii) Rats exposed to 900 MHz EMR (EMR group), and iv) A 900 MHz EMR exposed + CAPE treated group (EMR + CAPE group). In the EMR exposed group, while tissue MDA, NO levels and urinary NAG levels increased ($p < 0.0001$), the activities of SOD, CAT, and GSH-Px in renal tissue were reduced ($p < 0.001$). CAPE treatment reversed these effects as well ($p < 0.0001$, $p < 0.001$ respectively). In conclusion, the increase in NO and MDA levels of renal tissue, and in urinary NAG with the decrease in renal SOD, CAT, GSH-Px activities demonstrate the role of oxidative mechanisms in 900 MHz mobile phone-induced renal tissue damage, and CAPE, via its free radical scavenging and antioxidant properties, ameliorates oxidative renal damage. These results strongly suggest that CAPE exhibits a protective effect on mobile phone-induced and free radical mediated oxidative renal impairment in rats.

**Ozguner F, Oktem F, Armagan A, Yilmaz R, Koyu A, Demirel R, Vural H, Uz E. Comparative analysis of the protective effects of melatonin and caffeic acid phenethyl ester (CAPE) on mobile phone-induced renal impairment in rat. Mol Cell Biochem. 276(1-2):31-37, 2005.**

Melatonin and caffeic acid phenethyl ester (CAPE), a component of honeybee propolis, were recently found to be potent free radical scavengers and antioxidants. There are a number of reports on the effects induced by electromagnetic radiation (EMR) in various cellular systems. Mechanisms of adverse effects of EMR indicate that reactive oxygen species may play a role in the biological effects of this radiation. The present study was carried out to compare the protective effects of melatonin and CAPE against 900 MHz EMR emitted mobile phone-induced renal tubular injury. Melatonin was administered whereas CAPE was given for 10 days before the exposure. Urinary N-acetyl-beta-D-glucosaminidase (NAG, a marker of renal tubular injury) and malondialdehyde (MDA, an index of lipid peroxidation), were used as markers of oxidative stress-induced renal impairment in rats exposed to EMR. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status in renal tissue. Urinary NAG and renal MDA were increased in EMR exposed rats while both melatonin and CAPE caused a significant reduction in the levels of these parameters. Likewise, renal SOD and GSH-Px activities were decreased in EMR

exposed animals while melatonin caused a significant increase in the activities of these antioxidant enzymes but CAPE did not. Melatonin caused a significant decrease in urinary NAG activity and MDA levels which were increased because of EMR exposure. CAPE also reduced elevated MDA levels in EMR exposed renal tissue, but the effect of melatonin was more potent than that of CAPE. Furthermore, treatment of EMR exposed rats with melatonin increased activities of SOD and GSH-Px to higher levels than those of control rats. In conclusion, melatonin and CAPE prevent renal tubular injury by reducing oxidative stress and protect the kidney from oxidative damage induced by 900 MHz mobile phone. Nevertheless, melatonin seems to be a more potent antioxidant compared with CAPE in kidney.

**Ozguner F, Altinbas A, Ozaydin M, Dogan A, Vural H, Kisioglu AN, Cesur G, Yildirim NG. Mobile phone-induced myocardial oxidative stress: protection by a novel antioxidant agent caffeic acid phenethyl ester. Toxicol Ind Health. 21(9):223-230, 2005.**

Electromagnetic radiation (EMR) or radiofrequency fields of cellular mobile phones may affect biological systems by increasing free radicals, which appear mainly to enhance lipid peroxidation, and by changing the antioxidant defense systems of human tissues, thus leading to oxidative stress. Mobile phones are used in close proximity to the heart, therefore 900 MHz EMR emitting mobile phones may be absorbed by the heart. Caffeic acid phenethyl ester (CAPE), one of the major components of honeybee propolis, was recently found to be a potent free radical scavenger and antioxidant, and is used in folk medicine. The aim of this study was to examine 900 MHz mobile phone-induced oxidative stress that promotes production of reactive oxygen species (ROS) and the role of CAPE on myocardial tissue against possible oxidative damage in rats. Thirty rats were used in the study. Animals were randomly grouped as follows: sham-operated control group (N: 10) and experimental groups: (a) group II: 900 MHz EMR exposed group (N: 10); and (b) group III: 900 MHz EMR exposed+CAPE-treated group (N: 10). A 900 MHz EMR radiation was applied to groups II and III 30 min/day, for 10 days using an experimental exposure device. Malondialdehyde (MDA, an index of lipid peroxidation), and nitric oxide (NO, a marker of oxidative stress) were used as markers of oxidative stress-induced heart impairment. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status. In the EMR exposed group, while tissue MDA and NO levels increased, SOD, CAT and GSH-Px activities were reduced. CAPE treatment in group III reversed these effects. In this study, the increased levels of MDA and NO and the decreased levels of myocardial SOD, CAT and GSH-Px activities demonstrate the role of oxidative mechanisms in 900 MHz mobile phone-induced heart tissue damage, and CAPE, via its free radical scavenging and antioxidant properties, ameliorates oxidative heart injury. These results show that CAPE exhibits a protective effect on mobile phone-induced and free radical mediated oxidative heart impairment in rats.

**Ozguner F, Bardak Y, Comlekci S. Protective effects of melatonin and caffeic acid phenethyl ester against retinal oxidative stress in long-term use of mobile phone: A comparative study. Mol Cell Biochem. 282(1-2):83-88, 2006.**

There are numerous reports on the effects of electromagnetic radiation (EMR) in various

cellular systems. Melatonin and caffeic acid phenethyl ester (CAPE), a component of honeybee propolis, were recently found to be potent free radical scavengers and antioxidants. Mechanisms of adverse effects of EMR indicate that reactive oxygen species may play a role in the biological effects of this radiation. The present study was carried out to compare the efficacy of the protective effects of melatonin and CAPE against retinal oxidative stress due to long-term exposure to 900 MHz EMR emitting mobile phones. Melatonin and CAPE were administered daily for 60 days to the rats prior to their EMR exposure during our study. Nitric oxide (NO, an oxidant product) levels and malondialdehyde (MDA, an index of lipid peroxidation), were used as markers of retinal oxidative stress in rats following to use of EMR. Superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) activities were studied to evaluate the changes of antioxidant status in retinal tissue. Retinal levels of NO and MDA increased in EMR exposed rats while both melatonin and CAPE caused a significant reduction in the levels of NO and MDA. Likewise, retinal SOD, GSH-Px and CAT activities decreased in EMR exposed animals while melatonin and CAPE caused a significant increase in the activities of these antioxidant enzymes. Treatment of EMR exposed rats with melatonin or CAPE increased the activities of SOD, GSH-Px and CAT to higher levels than those of control rats. In conclusion, melatonin and CAPE reduce retinal oxidative stress after long-term exposure to 900 MHz emitting mobile phone. Nevertheless, there was no statistically significant difference between the efficacies of these two antioxidants against to EMR induced oxidative stress in rat retina. The difference was in only GSH-Px activity in rat retina. Melatonin stimulated the retinal GSH-Px activity more efficiently than CAPE did.

**Özgür A, Tümkaya L, Terzi S, Kalkan Y, Erdivanlı ÖÇ, Dursun E. Effects of chronic exposure to electromagnetic waves on the auditory system. Acta Otolaryngol. 2015 Apr 2:1-6. [Epub ahead of print]**

OBJECTIVES: Numerous researches have been done about the risks of exposure to the electromagnetic fields that occur during the use of these devices, especially the effects on hearing. The aim of this study is to evaluate the effects of the electromagnetic waves emitted by the mobile phones through the electrophysiological and histological methods. METHODS: Twelve adult Wistar albino rats were included in the study. The rats were divided into two groups of six rats. The study group was exposed to the electromagnetic waves over a period of 30 days. The control group was not given any exposure to the electromagnetic fields. After the completion of the electromagnetic wave application, the auditory brainstem responses of both groups were recorded under anesthesia. The degeneration of cochlear nuclei was graded by two different histologists, both of whom were blinded to group information. RESULTS: The histopathologic and immunohistochemical analysis showed neuronal degeneration signs, such as increased vacuolization in the cochlear nucleus, pyknotic cell appearance, and edema in the group exposed to the electromagnetic fields compared to the control group. The average latency of wave in the ABR was similar in both groups ($p > 0.05$). CONCLUSION: The results support that chronic electromagnetic field exposure may cause damage by leading to neuronal degeneration of the auditory system.

**Ozgur E, Güler G, Seyhan N. Mobile phone radiation-induced free radical**

**damage in the liver is inhibited by the antioxidants n-acetyl cysteine and epigallocatechin-gallate. Int J Radiat Biol.86(11):935-945, 2010.**

Purpose: To investigate oxidative damage and antioxidant enzyme status in the liver of guinea pigs exposed to mobile phone-like radiofrequency radiation (RFR) and the potential protective effects of N-acetyl cysteine (NAC) and epigallocatechin-gallate (EGCG) on the oxidative damage. Materials and methods: Nine groups of guinea pigs were used to study the effects of exposure to an 1800-MHz Global System for Mobile Communications (GSM)-modulated signal (average whole body Specific Absorption Rate (SAR) of 0.38 W/kg, 10 or 20 min per day for seven days) and treatment with antioxidants. Results: Significant increases in malondialdehyde (MDA) and total nitric oxide (NO(x)) levels and decreases in activities of superoxide dismutase (SOD), myeloperoxidase (MPO) and glutathione peroxidase (GSH-Px) were observed in the liver of guinea pigs after RFR exposure. Only NAC treatment induces increase in hepatic GSH-Px activities, whereas EGCG treatment alone attenuated MDA level. Extent of oxidative damage was found to be proportional to the duration of exposure ($P < 0.05$). Conclusion: Mobile phone-like radiation induces oxidative damage and changes the activities of antioxidant enzymes in the liver. The adverse effect of RFR may be related to the duration of mobile phone use. NAC and EGCG protect the liver tissue against the RFR-induced oxidative damage and enhance antioxidant enzyme activities.

**Ozgur E, Kismali G, Guler G, Akcay A, Ozkurt G, Sel T, Seyhan N. Effects of Prenatal and Postnatal Exposure to GSM-Like Radiofrequency on Blood Chemistry and Oxidative Stress in Infant Rabbits, an Experimental Study. Cell Biochem Biophys. 2013 Mar 24. [Epub ahead of print]**

We aimed to investigate the potential hazardous effects of prenatal and/or postnatal exposure to 1800 MHz GSM-like radiofrequency radiation (RFR) on the blood chemistry and lipid peroxidation levels of infant rabbits. A total of 72 New Zealand female and male white rabbits aged 1-month were used. Thirty-six female and 36 male were divided into four groups which were composed of nine infants: (i) Group 1 were the sham exposure (control), (ii) Group 2 were exposed to RFR, 15 min daily for 7 days in the prenatal period (between 15th and 22nd days of the gestational period) (prenatal exposure group). (iii) Group 3 were exposed to RFR 15 min/day (14 days for male, whereas 7 days for female) after they reached 1-month of age (postnatal exposure group). (iv) Group 4 were exposed to RFR for 15 min daily during 7 days in the prenatal period (between 15th and 22nd days of the gestational period) and 15 min/day (14 days for male, whereas 7 days for female) after they reached 1-month of age (prenatal and postnatal exposure group). Results showed that serum lipid peroxidation level in both female and male rabbits changed due to the RFR exposure. However, different parameters of the blood biochemistry were affected by exposure in male and female infants. Consequently, the whole-body 1800 MHz GSM-like RFR exposure may lead to oxidative stress and changes on some blood chemistry parameters. Studies on RFR exposure during prenatal and postnatal periods will help to establish international standards for the protection of pregnants and newborns from environmental RFR.

**Ozgur E, Guler G, Kismali G, Seyhan N. Mobile Phone Radiation Alters Proliferation of Hepatocarcinoma Cells. Cell Biochem Biophys. 2014 May 11. [Epub ahead of print]**

This study investigated the effects of intermittent exposure (15 min on, 15 min off for 1, 2, 3, or 4 h, at a specific absorption rate of 2 W/kg) to enhanced data rates for global system for mobile communication evolution-modulated radiofrequency radiation (RFR) at 900- and 1,800-MHz frequencies on the viability of the Hepatocarcinoma cells (Hep G2). Hep G2 cell proliferation was measured by a colorimetric assay based on the cleavage of the tetrazolium salt WST-1 by mitochondrial dehydrogenases in viable cells. Cell injury was evaluated by analyzing the levels of lactate dehydrogenase (LDH) and glucose released from lysed cells into the culture medium. Morphological observation of the nuclei was carried out by 4',6-diamidino-2-phenylindole (DAPI) staining using fluorescence microscopy. In addition, TUNEL assay was performed to confirm apoptotic cell death. It was observed that cell viability, correlated with the LDH and glucose levels, changed according to the frequency and duration of RFR exposure. Four-hour exposure produced more pronounced effects than the other exposure durations. 1,800-MHz RFR had a larger impact on cell viability and Hep G2 injury than the RFR at 900 MHz. Morphological observations also supported the biochemical results indicating that most of the cells showed irregular nuclei pattern determined by using the DAPI staining, as well as TUNEL assay which shows DNA damage especially in the cells after 4 h of exposure to 1,800-MHz RFR. Our results indicate that the applications of 900- and 1,800-MHz (2 W/kg) RFR cause to decrease in the proliferation of the Hep G2 cells after 4 h of exposure. Further studies will be conducted on other frequency bands of RFR and longer duration of exposure.

**Ozgur E, Sahin D, Tomruk A, Guler G, Sepici-Dinçel A, Altan N, Seyhan N. The Effects of N-acetyl-L-cysteine and Epigallocatechin-3-gallate on Liver Tissue Protein Oxidation and Antioxidant Enzyme Levels After the Exposure to Radio Frequency Radiation. Int J Radiat Biol. 2014 Sep 24:1-19. [Epub ahead of print]**

PURPOSE: The widespread and sustained use of mobile and cordless phones causes unprecedented increase of radiofrequency radiation (RFR). The aim of this experimental study was to investigate the effect of 900 MHz Global System for Mobile Communications (GSM) modulated RFR (average whole body Specific Absorption Rate (SAR) of 0,4 W/kg, 10 or 20 min daily for consecutive 7 days) to the liver tissue of guinea pigs and the protective effects of antioxidant treatments. MATERIALS and METHODS: Adult male guinea pigs were randomly divided into nine groups as; Group I (Sham/saline), Group II (Sham/EGCG), Group III (Sham/NAC), Group IV (10-min RF-exposure/saline), Group V (20-min RF-exposure/saline), Group VI (10-min RF-exposure/EGCG), Group VII (20-min RF-exposure/EGCG), Group VIII (10-min RF-exposure/NAC), Group IX (20-min RF-exposure/NAC). Protein oxidation (PCO), advanced oxidation protein products (AOPP) and antioxidant enzyme activities of superoxide dismutase (SOD) were evaluated after the exposure and the treatments with N-acetylcysteine (NAC) and (-)-epigallocatechin-3-gallate (EGCG). RESULTS and CONCLUSIONS: Significant decreases in the activities of SOD were observed in the liver of guinea pigs after RFR exposure. Protein damage did

not change due to RFR exposure. On the other hand, only NAC treatment induces increase PCO levels, whereas EGCG treatment alone elevated the level of AOPP. Due to antioxidants have pro-oxidant behavior, the well decided doses and treatment time tables of NAC and ECGC is needed.

**Ozlem Nisbet H, Nisbet C, Akar A, Cevik M, Karayigit MO. Effects of exposure to electromagnetic field (1.8/0.9 GHz) on testicular function and structure in growing rats. Res Vet Sci. 93(2):1001-1005, 2012.**

The aim of our study was to evaluate the possible effects of whole-body electromagnetic field (EMF) exposure on reproduction in growing male rats. Male albino Wistar rats (2 days old) were exposed to EMF 1800 and 900 MHz for 2 h continuously per day for 90 days. Sham control was kept under similar conditions except that the field was not applied for the same period. After blood samples were collected, the animals were sacrificed 24 h after the last exposure and the tissues of interest were harvested. The mean plasma total testosterone showed similarity among the two study groups and was significantly higher than the sham control rats. The percentage of epididymal sperm motility was significantly higher in the 1800 MHz group ($P<0.05$). The morphologically normal spermatozoa rates were higher and the tail abnormality and total percentage abnormalities were lower in the 900 MHz group ($P<0.05$). Histopathologic parameters in the 1800 MHz group were significantly higher ($P<0.05$). In conclusion, the present study indicated that exposure to electromagnetic wave caused an increase in testosterone level, epididymal sperm motility (forward), and normal sperm morphology of rats. As a consequences, 1800 and 900 MHz EMF could be considered to be a cause of precocious puberty in growing rats.

**Ozturan O, Erdem T, Miman MC, Kalcioglu MT, Oncel S. Effects of the electromagnetic field of mobile telephones on hearing. Acta Otolaryngol. 122(3):289-293, 2002.**

The widespread use of mobile telephones has given rise to concern about the potential influences of electromagnetic fields (EMFs) on human health. Anatomically, the ear is in close proximity to the mobile telephone during use. Hearing loss due to mobile telephone use has not been described in the medical literature; however, if there is a subtle cochlear involvement, it might be detected by means of changes in evoked otoacoustic emissions (OAEs). Thirty volunteers with normal hearing were exposed to mobile telephone EMFs for 10 min and evoked OAEs were measured before and after exposure. No measurable change in evoked OAEs was detected and none of the subjects reported a deterioration in hearing level. To the best of our knowledge, this is the first study on the effects of EMFs emitted by mobile telephones on hearing. It was concluded that a 10-min exposure to the EMF emitted from a mobile telephone had no effect on hearing, at least at outer ear, middle ear and cochlear levels.

**Pachón-García FT, Fernández-Ortiz K, Paniagua-Sánchez JM. Assessment of Wi-Fi radiation in indoor environments characterizing the time & space-varying electromagnetic fields. Measurement 63:309-321, 2015.**

This paper focuses on the study of emissions in Wi-Fi networks in a typical indoor place, inside a building, by quantifying exposure levels detected in different locations of the

house, when router-terminal devices are in specific positions, and also by characterizing the fluctuations arising from the type of traffic which is sent through the network. The assessment of exposure was carried out collecting measurements with the novel dosimeter 'EME Spy-140' in a real scenario and comparing the results with the corresponding theoretical levels and other studies. A global sum of 4875 samples were collected, analyzing 25 locations in the mentioned house. The ROS-MLE method was used for fitting levels to statistical distributions. Maximum background exposure to WLAN (our WiFi network off) is 0.039 V/m. With our WiFi network in operation, maximum exposure increases to 2.6 V/m in the far field region of the transmitters (with 90th percentile of 2.2 V/m). Concerning the type of traffic, oscillations up to 10 dB were detected for exactly the same position, depending on whether Web-browsing or P2P traffic was being sent. Differences around 62 dB in mean values between the different rooms of the house were found. All values are below the threshold of 61 V/m that standards set (at least 12 times below it). Undoubtedly, this type of study is important to raise awareness that radiation coming from this technology is not negligible, and should be controlled, as well as providing an overview of level fluctuations in a given context. This information helps clarify epidemiological studies about exposure levels.

**Pacini S, Ruggiero M, Sardi I, Aterini S, Gulisano F, Gulisano M. Exposure to global system for mobile communication (GSM) cellular phone radiofrequency alters gene expression, proliferation, and morphology of human skin fibroblasts. Oncol Res 13(1):19-24, 2002.**

Human skin fibroblasts were exposed to global system for mobile communication (GSM) cellular phone radiofrequency for 1 h. GSM exposure induced alterations in cell morphology and increased the expression of mitogenic signal transduction genes (e.g., MAP kinase kinase 3, G2/mitotic-specific cyclin G1), cell growth inhibitors (e.g., transforming growth factor-beta), and genes controlling apoptosis (e.g., bax). A significant increase in DNA synthesis and intracellular mitogenic second messenger formation matched the high expression of MAP kinase family genes. These findings show that these electromagnetic fields have significant biological effects on human skin fibroblasts.

**Paffi A, Apollonio F, Pinto R, Liberti M. Cenarios approach to the electromagnetic exposure: the case study of a train compartment. Biomed Res Int. 2015;2015:869895. doi: 10.1155/2015/869895. Epub 2015 Feb 23.**

Previous studies identified the train compartment as the place where people can experience the highest exposure levels (still below the international guideline limits) to electromagnetic fields in the radiofrequency range. Here a possible scenario of a train compartment has been reproduced and characterized, both numerically and experimentally. A good agreement between the simulated electric field distributions and measurements has been found. Results indicate that the higher values of exposure in specific positions inside the train compartment depend on the number of active cell phones, the bad coverage condition, the cell orientation, and the presence of metallic walls. This study shows that the proposed approach, based on the scenarios characterization, may efficiently support the assessment of the individual electromagnetic exposure.

**Paglialonga A, Tognola G, Parazzini M, Lutman ME, Bell SL, Thuroczy G, Ravazzani P. Effects of mobile phone exposure on time frequency fine structure of transiently evoked otoacoustic emissions. J Acoust Soc Am. 122(4):2174-2182, 2007.**

Mobile phones have become very commonly used worldwide within a short period of time. To date there is only limited knowledge about interaction between electromagnetic fields (EMFs) emitted by mobile phones and the auditory function. Moreover, there is widespread concern that there may be potential for harm. The aim of this study was to assess potential subtle changes in cochlear function by measuring the temporal and spectral fine structure of transiently evoked otoacoustic emissions (TEOAE) in normal hearing subjects after exposure to EMFs emitted by Global System for Mobile Communication (GSM) mobile phones. TEOAEs were recorded in 27 healthy young adults before and after 10 min of real or sham exposure in a double-blind design. TEOAE data were analyzed both globally (broadband analysis) and using the Wavelet Transform (analysis of the time-frequency fine structure). The broadband analysis revealed no significant effect on TEOAEs related to exposure, confirming results of previous studies; in addition, no significant change was detected in the analysis of the elementary wavelet components, suggesting that the temporal and spectral fine structure of TEOAEs is not affected by 10 min exposure to low-intensity EMFs emitted by GSM mobile phones.

**Paik MJ, Kim HS, Lee YS, Do Choi H, Pack JK, Kim N, Ahn YH. Metabolomic study of urinary polyamines in rat exposed to 915 MHz radiofrequency identification signal. Amino Acids. 2015 Aug 29. [Epub ahead of print]**

Metabolomic analysis of urinary polyamines (PAs) from rat exposed to 915 MHz radiofrequency identification (RFID) signal for 8 h/day for 2 weeks was performed by gas chromatography-mass spectrometry as N-ethoxycarbonyl/N-pentafluoropropionyl derivatives. Large alterations in nine PA levels including four aliphatic and five acetylated PAs were monitored in sham-exposed and RFID-exposed groups. Total PA and urinary levels of N $^{1}$-acetylputrescine, N $^{1}$-acetylcadaverine, putrescine, cadaverine, N $^{1}$-acetylspermidine, N $^{8}$-acetylspermidine, spermidine and spermine were reduced, whereas N $^{1}$-acetylspermine was significantly increased after sham and RFID exposure compared with those before exposure. Their levels were normalized to the corresponding group means before exposure and then plotted into star symbol patterns. N $^{1}$-Acetylspermine after RFID exposure was 54 % higher compared to the level before RFID exposure, while it was elevated by only 17 % in the sham group. The results suggest that 915 MHz RFID exposure may induce metabolic disturbance of PA. It may also elevate spermidine/spermine acetyltransferase (SSAT) activity. Thus, the present metabolic profiling combined with star pattern recognition method might be useful for understanding the complexity of biochemical events after exposure to RFID signal.

**Pakhomov AG, [Non-thermal microwave effect on nerve fiber function]. Biofizika 38(2):367-371, 1993.** [Article in Russian]

Effects of microwave radiation (915 MHz, PW, peak SAR 20-30 W/g, pulse duration 1 mcs, 50.000 and 25.000 p.p.s.) were investigated in isolated frog nerve cord preparation.

Nerve VHF heating didn't exceed 2.2 degrees C due to intense Ringer's solution perfusion. It was established that nerve irradiation simultaneously with its stimulation lead to significant decrease of action potential amplitude and peak latency. Since the equal conventional heating of the nerve caused the opposite changes (amplitude increase), the results obtained argue for non-thermal mechanism of microwave action.

**Pakhomov AG, Dubovick BV, Degtyariov IG, Pronkevich AN, Microwave influence on the isolated heart function: II. Combined effect of radiation and some drugs. Bioelectromagnetics 16(4):250-254, 1995.**

The combined effects of microwave radiation and some drugs were studied in an isolated frog auricle preparation. The experiments established that exposure to pulse-modulated 915 MHz microwaves for up to 40 min had no effect on either the rate or the amplitude of spontaneous auricle twitches, unless the average absorbed power was high enough to produce preparation heating. Treatment of the preparation with saline containing (0.6-3.0) 10(-5) M of propranolol or (0.5-1.5) 10(-7) M of atropine altered neither its pacemaker nor its contractile functions; these drugs also had no effect when they were combined with nonthermal microwave irradiation. Caffeine (1 mM) strongly increased the average heart power, which was calculated as the product of twitch rate and amplitude. The caffeine effect appeared to be significantly augmented (by about 15%, $P < 0.02$) under exposure to burst-type pulsed microwaves (pulse width, 1.5 msec; pause, 2.5 msec; 8 pulses/burst, 16 bursts/s; average SAR, 8-10 W/kg). By itself, this modulation was not effective; the heating of the preparation and saline during exposure was approximately 0.1 degrees C, which could not account for the detected changes. The experimental results demonstrate that caffeine treatment increases the microwave sensitivity of the frog auricle preparation and reveals primarily subthreshold, nonthermal microwave effect.

**Pakhomov AG, Dubovick BV, Degtyariov IG, Pronkevich AN, Microwave influence on the isolated heart function: I. Effect of modulation. Bioelectromagnetics 16(4):241-249, 1995.**

Dependence of the microwave effect on modulation parameters (pulse width, duty ratio, and peak intensity) was studied in an isolated frog auricle preparation. The rate and amplitude of spontaneous auricle twitches were measured during and after a 2 min exposure to 915 or 885 MHz microwaves and were compared to preexposure values. The studied ranges of modulation parameters were: pulse width, 10(-6)-10(-2) s; duty ratio, 7:100000, and peak specific absorption rate, 100-3000 W/kg. Combinations of the parameters were chosen by chance, and about 400 various exposure regimes were tested. The experiments established that no regime was effective unless the average microwave power was high enough to induce preparation heating (0.1-0.4 degree C). The twitch rate instantly increased, and the amplitude decreased, as the temperature rose; similar changes could be induced by equivalent conventional heating. The data provide evidence that the effect of short-term microwave exposure on the isolated heart pacemaker and contractile functions depends on pulse modulation just as much as modulation determines the average absorbed power. These functions demonstrated no specific dependence on exposure parameters such as frequency or power windows.

**Pakhomova ON, Belt ML, Mathur SP, Lee JC, Akyel Y, Ultra-wide band**

**electromagnetic radiation does not affect UV-induced recombination and mutagenesis in yeast. Bioelectromagnetics 19(2):128-130, 1998.**

Cell samples of the yeast Saccharomyces cerevisiae were exposed to 100 J/m2 of 254 nm ultraviolet (UV) radiation followed by a 30 min treatment with ultra-wide band (UWB) electromagnetic pulses. The UWB pulses (101-104 kV/m, 1.0 ns width, 165 ps rise time) were applied at the repetition rates of 0 Hz (sham), 16 Hz, or 600 Hz. The effect of exposures was evaluated from the colony-forming ability of the cells on complete and selective media and the number of aberrant colonies. The experiments established no effect of UWB exposure on the UV-induced reciprocal and non-reciprocal recombination, mutagenesis, or cell survival.

**Pakhomov AG, Mathur SP, Doyle J, Stuck BE, Kiel JL, Murphy MR, Comparative effects of extremely high power microwave pulses and a brief CW irradiation on pacemaker function in isolated frog heart slices. Bioelectromagnetics 21(4):245-254, 2000.**

The existence of specific bioeffects due to high peak power microwaves and their potential health hazards are among the most debated but least explored problems in microwave biology. The present study attempted to reveal such effects by comparing the bioeffects of short trains of extremely high power microwave pulses (EHPP, 1 micros width, 250-350 kW/g, 9.2 GHz) with those of relatively low power pulses (LPP, 0.5-10 s width, 3-30 W/g, 9.2 GHz). EHPP train duration and average power were made equal to those of an LPP; therefore both exposure modalities produced the same temperature rise. Bioeffects were studied in isolated, spontaneously beating slices of the frog heart. In most cases, a single EHPP train or LPP immediately decreased the inter-beat interval (IBI). The effect was proportional to microwave heating, fully reversible, and easily reproducible. The magnitude and time course of EHPP- and LPP-induced changes always were the same. No delayed or irreversible effects of irradiation were observed. The same effect could be repeated in a single preparation numerous times with no signs of adaptation, sensitization, lasting functional alteration, or damage. A qualitatively different effect, namely, a temporary arrest of preparation beats, could be observed when microwave heating exceeded physiologically tolerable limits. This effect also did not depend on whether the critical temperature rise was produced by LPP or EHPP exposure. Within the studied limits, we found no indications of EHPP-specific bioeffects. EHPP- and LPP-induced changes in the pacemaker rhythm of isolated frog heart preparation were identical and could be entirely attributed to microwave heating.

**Pakhomov AG, Gajšek P, Allen L, Stuck BE, Murphy MR. Comparison of dose dependences for bioeffects of continuous-wave and high-peak power microwave emissions using gel-suspended cell cultures. Bioelectromagnetics 23: 158-167, 2002.**

The study compared bioeffects of continuous wave (CW) microwaves and short, extremely high power pulses (EHPP) at the same carrier frequency (9.3 GHz) and average power (1.25 W). The peak transmitted power for EHPP was 250 kW (0.5-μs pulse width, 10 p.p.s.), producing the E field of 1.57 MV/m in the waveguide. A biological endpoint was the density of yeast cells, achieved after a 6 h growth period in a solid nutrient medium (agarose gel) during EHPP or CW exposure. Owing to power losses in

the medium, the specific absorption rate (SAR) ranged from 3.2 kW/kg at the exposed surface of the sample to 0.6 mW/kg at 24 mm depth. Absorption and penetration of EHPP was identical to CW, producing peak SAR values 200 000 times higher than the average SAR, as high as 650 MW/kg at the surface. CW and EHPP exposures produced highly nonuniform but identical heating patterns in exposed samples. Following the exposure, the samples were sliced in a plane perpendicular to the wave propagation, in order to separate cell masses exposed at different SAR levels. Cell density in the slices was determined by nephelometry and compared to unexposed parallel control samples. Cell density was strongly affected by irradiation, and the changes correlated well with the local temperature rise. However, the data revealed no statistically significant difference between CW and EHPP samples across the entire studied range of SAR levels (over six orders of magnitude). A trend ($P < 0.1$) for such a difference was observed in slices that were exposed at a time average SAR of 100 W/kg and higher, which corresponded to peak SAR above 20 MW/kg for the EHPP condition. These numbers could be indicative of a threshold for a specific (not merely thermal) exposure effect if the trend is confirmed by future studies.

**Palfia Z, Somosy Z, Rez G. Tight junctional changes upon microwave and x-ray irradiation. Acta Biol Hung 52(4):411-416, 2001.**

Tight junctions (zonulae occludentes, ZO) are cellularly regulated dynamic structures sensitive to environmental stress agents including ionizing radiation. Radiation induced pathological alterations of the small intestine (gastrointestinal radiation syndrome) are related to altered ZO-mediated paracellular transport. We carried out a quantitative morphological evaluation of the murine jejunal epithelial tight junctional structure in freeze fracture replicas as changed upon whole body X-ray irradiation and low energy microwave exposition. X-ray treatment (4 Gy, 1, 24 h) brought about a partial dearrangement of the ZO strand network which regenerated only partially by 24 h. This observation is in line with data on paracellular permeability increases and ZO-bound calcium drop caused by X-ray irradiation. On the other hand, microwave treatment (16 Hz-modulated 2.45 GHz wave, 1 mW/cm2 power density, I h exposition, samples at I and 3 h after exposition) did not cause dearrangement but, rather an increase in the integration of thight junctional structure, which is in agreement with an increase in cytochemically detectable ZO-bound calcium.

**Palumbo R, Brescia F, Capasso D, Sannino A, Sarti M, Capri M, Grassilli E, Scarfì MR. Exposure to 900 MHz radiofrequency radiation induces caspase 3 activation in proliferating human lymphocytes. Radiat Res. 170(3):327-334, 2008.**

In this study, the induction of apoptosis after exposure to 900 MHz radiofrequency radiation (GSM signal) was investigated by assessing caspase 3 activation in exponentially growing Jurkat cells and in quiescent and proliferating human peripheral blood lymphocytes (PBLs). The exposure was carried out at an average specific absorption rate of 1.35 W/kg in a dual wire patch cell exposure system where the temperature of cell cultures was accurately controlled. After 1 h exposure to the radiofrequency field, a slight but statistically significant increase in caspase 3 activity, measured 6 h after exposure, was observed in Jurkat cells (32.4%) and in proliferating human PBLs (22%). In contrast, no effect was detected in quiescent

human PBLs. In the same experimental conditions, apoptosis was also evaluated in Jurkat cells by Western blot analysis and in both cell types by flow cytometry. To evaluate late effects due to caspase 3 activity, flow cytometry was also employed to assess apoptosis and viability 24 h after radiofrequency-radiation exposure in both cell types. Neither the former nor the latter was affected. Since in recent years it has been reported that caspases are also involved in processes other than apoptosis, additional cell cycle studies were carried out on proliferating T cells exposed to radiofrequency radiation; however, we found no differences between sham-exposed and exposed cultures. Further studies are warranted to investigate the biological significance of our findings of a dose-response increase in caspase 3 activity after exposure to radiofrequency radiation.

**Panagopoulos DJ, Karabarbounis A, Margaritis LH. Effect of gsm 900-mhz mobile phone radiation on the reproductive capacity of drosophila melanogaster. Electromag Biol Med 23:29-43, 2004.**

Pulsed radio frequency, (RF), electromagnetic radiation from common GSM mobile phones, (Global System for Mobile Telecommunications) with a carrier frequency at 900 MHz, “modulated” by human voice, (speaking emission) decreases the reproductive capacity of the insect Drosophila melanogaster by 50%–60%, whereas the corresponding “nonmodulated” field (nonspeaking emission) decreases the reproductive capacity by 15%–20%. The insects were exposed to the near field of the mobile phone antenna for 6 min per day during the first 2–5 days of their adult lives. The GSM field is found to affect both females and males. Our results suggest that this field-radiation decreases the rate of cellular processes during gonad development in insects.

**Panagopoulos DJ, Chavdoula ED, Nezis IP, Margaritis LH Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation. Mutat Res.626(1-2):69-78, 2007.**

In the present study, the TUNEL (Terminal deoxynucleotide transferase dUTP Nick End Labeling) assay - a well known technique widely used for detecting fragmented DNA in various types of cells - was used to detect cell death (DNA fragmentation) in a biological model, the early and mid stages of oogenesis of the insect Drosophila melanogaster. The flies were exposed in vivo to either GSM 900-MHz (Global System for Mobile telecommunications) or DCS 1800-MHz (Digital Cellular System) radiation from a common digital mobile phone, for few minutes per day during the first 6 days of their adult life. The exposure conditions were similar to those to which a mobile phone user is exposed, and were determined according to previous studies of ours [D.J. Panagopoulos, A. Karabarbounis, L.H. Margaritis, Effect of GSM 900-MHz mobile phone radiation on the reproductive capacity of D. melanogaster, Electromagn. Biol. Med. 23 (1) (2004) 29-43; D.J. Panagopoulos, N. Messini, A. Karabarbounis, A.L. Philippetis, L.H. Margaritis, Radio frequency electromagnetic radiation within "safety levels" alters the physiological function of insects, in: P. Kostarakis, P. Stavroulakis (Eds.), Proceedings of the Millennium International Workshop on Biological Effects of Electromagnetic Fields, Heraklion, Crete, Greece, October 17-20, 2000, pp. 169-175, ISBN: 960-86733-0-5; D.J. Panagopoulos, L.H.

Margaritis, Effects of electromagnetic fields on the reproductive capacity of D. melanogaster, in: P. Stavroulakis (Ed.), Biological Effects of Electromagnetic Fields, Springer, 2003, pp. 545-578], which had shown a large decrease in the oviposition of the same insect caused by GSM radiation. Our present results suggest that the decrease in oviposition previously reported, is due to degeneration of large numbers of egg chambers after DNA fragmentation of their constituent cells, induced by both types of mobile telephony radiation. Induced cell death is recorded for the first time, in all types of cells constituting an egg chamber (follicle cells, nurse cells and the oocyte) and in all stages of the early and mid-oogenesis, from germarium to stage 10, during which programmed cell death does not physiologically occur. Germarium and stages 7-8 were found to be the most sensitive developmental stages also in response to electromagnetic stress induced by the GSM and DCS fields and, moreover, germarium was found to be even more sensitive than stages 7-8.

**Panagopoulos DJ, Chavdoula ED, Karabarbounis A, Margaritis LH. Comparison of bioactivity between GSM 900 MHz and DCS 1800 MHz mobile telephony radiation. Electromagn Biol Med. 26(1):33-44, 2007.**

An increasing number of studies find that pulsed Radio Frequency (RF), electromagnetic radiation of both systems of digital mobile telephony, established and commonly used in Europe during the last years, GSM 900 MHz (Global System for Mobile telecommunications) and DCS 1800 MHz (Digital Cellular System), exert intense biological action on different organisms and cells (Hardell et al., 2006; Hyland, 2000; Kundi, 2004; Panagopoulos et al., 2004, 2007). The two types of cellular telephony radiation use different carrier frequencies and give different frequency spectra, but they usually also differ in intensity, as GSM 900 MHz antennas operate at about double the power output than the corresponding DCS 1800 MHz ones. In our present experiments, we used a model biological system, the reproductive capacity of Drosophila melanogaster, to compare the biological activity between the two systems of cellular mobile telephony radiation. Both types of radiation were found to decrease significantly and non thermally the insect's reproductive capacity, but GSM 900 MHz seems to be even more bioactive than DCS 1800 MHz. The difference seems to be dependent mostly on field intensity and less on carrier frequency.

**Panagopoulos DJ, Chavdoula ED, Margaritis LH. Bioeffects of mobile telephony radiation in relation to its intensity or distance from the antenna. Int J Radiat Biol. 86(5):345-357, 2010.**

PURPOSE: To examine the bioactivity of GSM 900 and 1800 (Global System for Mobile Telecommunications) radiations, in relation to the distance from the antenna or to the radiation-field intensities. MATERIALS AND METHODS: Drosophila melanogaster adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, and the effect on their reproductive capacity and cell death induction in the gonads by the use of TUNEL (Terminal deoxynucleotide transferase dUTP Nick End Labeling) assay, was studied. RESULTS: These radiations/fields decreased the reproductive capacity by cell death induction, at all the different distances tested. The effect diminished with the distance/decreasing intensities. An increased bioactivity 'window' was revealed at

distances of 20-30 cm from the mobile phone antenna, (radiation intensity around 10 microW/cm(2)) where the effect became highest, in relation to smaller or longer distances. The effect diminished considerably for distances longer than 40-50 cm and became not evident for distances longer than 1 m or radiation intensities smaller than 1 microW/cm(2). CONCLUSIONS: GSM bioactivity is highest for intensities down to less than 10 microW/cm(2) and still evident until 1 microW/cm(2) exhibiting 'window' effects

**Panagopoulos DJ, Margaritis LH. The identification of an intensity 'window' on the bioeffects of mobile telephony radiation. Int J Radiat Biol. 86(5):358-366, 2010.** Erratum in Int J Radiat Biol. 2010 Sep;86(9):809.

PURPOSE: The increased bioactivity 'windows' of GSM 900 and 1800 MHz radiations, (Global System for Mobile telecommunications) revealed recently by us and published in this issue, manifesting themselves as a maximum decrease in the reproductive capacity of the insect Drosophila melanogaster, were examined to discover whether they depend on the intensity of radiation-fields. METHODS: In each experiment, one group of insects were exposed to the GSM 900 or 1800 radiation at 30 or 20 cm distances, respectively, from the antenna of a mobile phone, where the bioactivity 'window' appears for each type of radiation and another group was exposed at 8 or 5 cm, respectively, behind a metal grid, shielding both microwave radiation and the extremely low frequency (ELF) electric and magnetic fields for both types of radiation in a way that radiation and field intensities were roughly equal between the two groups. Then the effect on reproductive capacity was compared between groups for each type of radiation. RESULTS: The decrease in the reproductive capacity did not differ significantly between the two groups. CONCLUSIONS: The bioactivity window seems to be due to the intensity of radiation-field (10 microW/cm(2), 0.6-0.7 V/m) at 30 or 20 cm from the GSM 900 or 1800 mobile phone antenna, respectively

**Panagopoulos DJ, Margaritis LH. The effect of exposure duration on the biological activity of mobile telephony radiation. Mutat Res699(1-2):17-22,2010.**

In the present experiments we studied the effects of different durations of a single, (continuous), daily exposure, ranging from 1min up to 21min, to the two established systems of digital mobile telephony radiation that are commonly used in Europe, viz. GSM 900MHz (Global System for Mobile telecommunications) and DCS 1800MHz (Digital Cellular System - referred to also as GSM 1800MHz), on a well-tested biological model, the reproductive capacity of the insect Drosophila melanogaster. The insects were exposed to each type of radiation at an intensity of about 10muW/cm(2), corresponding to a distance of 20cm or 30cm from the antenna of a DCS 1800 or a GSM 900 mobile phone handset, respectively. At these distances the bioactivity of mobile telephony radiation was found to be at a maximum due to the existence of a "window" of increased bioactivity around this value, as we have proposed recently [1-4]. The results show that the reproductive capacity decreases almost linearly with increasing exposure duration to both GSM 900 and DCS 1800 radiation, suggesting that short-term exposures to these radiations have cumulative

effects on living organisms. Additionally, our results show again that GSM 900MHz radiation is slightly more bioactive than DCS 1800MHz radiation, at the same exposure durations and under equal radiation intensities, as shown in our previous experiments [5].

**Panagopoulos DJ. Effect of microwave exposure on the ovarian development of Drosophila melanogaster.Cell Biochem Biophys. 63(2):121-132, 2012.**

In the present experiments the effect of GSM radiation on ovarian development of virgin Drosophila melanogaster female insects was studied. Newly emerged adult female flies were collected and divided into separate identical groups. After the a lapse of certain number of hours-different for each group-the insects (exposed and sham-exposed) were dissected and their intact ovaries were collected and photographed under an optical microscope with the same magnification. The size of the ovaries was compared between exposed and sham-exposed virgin female insects, during the time needed for the completion of oogenesis and maturation of the first eggs in the ovarioles. Immediately after the intact ovaries were photographed, they were further dissected into individual ovarioles and treated for TUNEL and acridine-orange assays to determine the degree of DNA damage in the egg chamber cells. The study showed that the ovarian size of the exposed insects is significantly smaller than that of the corresponding sham-exposed insects, due to destruction of egg chambers by the GSM radiation, after DNA damage and consequent cell death induction in the egg chamber cells of the virgin females as shown in previous experiments on inseminated females. The difference in ovarian size between sham-exposed and exposed virgin female flies becomes most evident 39-45 h after eclosion when the first eggs within the ovaries are at the late vitellogenic and post-vitellogenic stages (mid-late oogenesis). More than 45 h after eclosion, the difference in ovarian size decreases, as the first mature eggs of the sham-exposed insects are leaving the ovaries and are laid.

**Panda NK, Jain R, Bakshi J, Munjal S. Audiologic disturbances in long-term mobile phone users. J Otolaryngol Head Neck Surg. 39(1):5-11, 2010.**

Abstract. INTRODUCTION:There is general concern regarding the possible hazardous health effects of exposure to radiofrequency electromagnetic radiation emitted from mobile phones. This study aimed to assess the effects of chronic exposure to electromagnetic waves emitted from Global System for Mobile Communication (GSM) mobile phones on auditory functions.MATERIAL AND METHODS:A retrospective, cross-sectional, randomized, case control study was carried out in a tertiary care hospital. One hundred twelve subjects who were long-term mobile phone users (more than 1 year) and 50 controls who had never used a mobile phone underwent a battery of audiologic investigations including pure-tone audiometry (both speech and high frequency), tympanometry, distortion product otoacoustic emissions, auditory brain responses, and middle latency responses. Changes in the various parameters were studied in the mobile phone- and non-mobile phone-using ears of subjects and corresponding ears of the controls to ascertain the effects of electromagnetic exposure.RESULTS:There was no significant difference between users and controls for any of the audiologic parameters. However, trends for audiologic abnormalities were seen within the users. High-frequency

loss and absent distortion product otoacoustic emissions were observed with an increase in the duration of mobile phone use, excessive use of mobile phones, and age more than 30 years. Additionally, users with some complaints during mobile phone use demonstrated absent distortion product otoacoustic emissions and abnormalities in auditory brainstem response.CONCLUSION:Long-term and intensive mobile phone use may cause inner ear damage. A large sample size would be required to reach definitive conclusions.

**Panda NK, Modi R, Munjal S, Virk RS. Auditory changes in mobile users: is evidence forthcoming?Otolaryngol Head Neck Surg. 144(4):581-585, 2011.**

OBJECTIVE: Genuine concerns are being raised as to the potential health risks posed by electromagnetic frequency exposure secondary to mobile phone usage. This study was undertaken to assess and compare potential changes in hearing function at the level of the inner ear and central auditory pathway due to chronic exposure to electromagnetic waves from both global system for mobile communications (GSM) and code division multiple access (CDMA) mobile phone usage. DESIGN: Cohort study. SETTING: Tertiary referral center. SUBJECTS AND METHODS: One hundred twenty-five subjects who were long-term mobile phone users (more than 1 year; 63 GSM and 62 CDMA) and 58 controls who had never used mobile phones underwent audiological investigations including pure tone audiometry (250-12 kHz), tympanometry, distortion product otoacoustic emissions (DPOAE), auditory brain responses (ABR), and middle latency responses (MLRs). The changes in various parameters were studied in mobile-using and non-mobile-using ears of both GSM and CDMA subjects and corresponding ears of the controls to ascertain the effects of electromagnetic exposure. RESULTS: GSM and CDMA users were found to be at a significantly higher risk of having DPOAE absent as compared with controls ($P < .05$). They were found to have higher speech frequency thresholds and lower MLR wave and Na and Pa amplitudes. More than 3 years of mobile phone usage emerged as a risk factor ($P < .05$). The damage done was bilateral, with the quantum of damage being the same for both GSM and CDMA. CONCLUSION:Long-term and intensive GSM and CDMA mobile phone use may cause damage to cochlea as well as the auditory cortex.

**Pandey N, Giri S, Das S, Upadhaya P. Radiofrequency radiation (900 MHz)-induced DNA damage and cell cycle arrest in testicular germ cells in swiss albino mice. Toxicol Ind Health. 33(4):373-384, 2017.**

Even though there are contradictory reports regarding the cellular and molecular changes induced by mobile phone emitted radiofrequency radiation (RFR), the possibility of any biological effect cannot be ruled out. In view of a widespread and extensive use of mobile phones, this study evaluates alterations in male germ cell transformation kinetics following RFR exposure and after recovery. Swiss albino mice were exposed to RFR (900 MHz) for 4 h and 8 h duration per day for 35 days. One group of animals was terminated after the exposure period, while others were kept for an additional 35 days post-exposure. RFR exposure caused depolarization of mitochondrial membranes resulting in destabilized cellular redox homeostasis. Statistically significant increases in the damage index in germ cells and sperm head defects were noted in RFR-exposed

animals. Flow cytometric estimation of germ cell subtypes in mice testis revealed 2.5-fold increases in spermatogonial populations with significant decreases in spermatids. Almost fourfold reduction in spermatogonia to spermatid turnover (1C:2C) and three times reduction in primary spermatocyte to spermatid turnover (1C:4C) was found indicating arrest in the premeiotic stage of spermatogenesis, which resulted in loss of post-meiotic germ cells apparent from testis histology and low sperm count in RFR-exposed animals. Histological alterations such as sloughing of immature germ cells into the seminiferous tubule lumen, epithelium depletion and maturation arrest were also observed. However, all these changes showed recovery to varied degrees following the post-exposure period indicating that the adverse effects of RFR on mice germ cells are detrimental but reversible. To conclude, RFR exposure-induced oxidative stress causes DNA damage in germ cells, which alters cell cycle progression leading to low sperm count in mice.

**Papageorgiou CC, Nanou ED, Tsiafakis VG, Capsalis CN, Rabavilas AD. Gender related differences on the EEG during a simulated mobile phone signal. Neuroreport. 15(16):2557-2560, 2004.**

The present study investigated the gender-related influence of electromagnetic fields (EMF), similar to that emitted by mobile phones, on brain activity. Ten women and nine men performed a short memory task (Wechsler test), both without (baseline) and with exposure to a 900 MHz signal. The EEG energy of the total waveform and the alpha, beta, delta and theta; rhythms were calculated from the recordings of 15 scalp electrodes. Baseline EEG energy of males was greater than that of females, while exposure to EMF decreased EEG energy of males and increased that of females. Memory performance was invariant to EMF exposure and gender influences. These findings indicate that EMF may exert a gender-related nfluence on brain activity.

**Papageorgiou CC, Nanou ED, Tsiafakis VG, Kapareliotis E, Kontoangelos KA, Capsalis CN, Rabavilas AD, Soldatos CR. Acute mobile phone effects on pre-attentive operation. Neurosci Lett397(1-2):99-103, 2006.**

There is a debate whether electromagnetic field (EMF) emitted by mobile phones (MP) have an effect on cognitive functions. Since the auditory P50 component of event-related potentials (ERPs) reflects pre-attentive processing and working memory (WM) operation, the present study was designed to investigate whether the exposure to MP-EMF affects the patterns of the P50 component of ERPs elicited during a WM test. The P50 elicited during a WM task and evoked by two warning stimuli low and high frequency (500 and 3000Hz) has been assessed in 19 normal subjects (10 women and 9 men) both without and with exposure to a 900MHz signal, emitted by a dipole antenna placed near the subjects. Results showed that the presence of MP-EMFs induced statistically significant increase in the amplitude of P50 evoked by the low frequency stimuli, at Fp1 and O1 electrode leads as compared to themselves without MP-EMF exposure. In contrast the exposure to MP-EMFs revealed statistically significant decrease of the amplitude of P50 evoked by the high frequency stimuli, at Fp1 electrode lead as compared to themselves without MP-EMF exposure. These findings provide evidence that the MP-EMF emitted by mobile phone affect pre-attentive information processing as it is reflected in P50 evoked

potential. The basis of such an effect is unclear, although several possibilities exist and call for potential directions of future research.

**Papageorgiou CC, Hountala CD, Maganioti AE, Kyprianou MA, Rabavilas AD, Papadimitriou GN, Capsalis CN. Effects of wi-fi signals on the p300 component of event-related potentials during an auditory hayling task. J Integr Neurosci. 10(2):189-202, 2011.**

The P300 component of event-related potentials (ERPs) is believed to index attention and working memory (WM) operation of the brain. The present study focused on the possible gender-related effects of Wi-Fi (Wireless Fidelity) electromagnetic fields (EMF) on these processes. Fifteen male and fifteen female subjects, matched for age and education level, were investigated while performing a modified version of the Hayling Sentence Completion test adjusted to induce WM. ERPs were recorded at 30 scalp electrodes, both without and with the exposure to a Wi-Fi signal. P300 amplitude values at 18 electrodes were found to be significantly lower in the response inhibition condition than in the response initiation and baseline conditions. Independent of the above effect, within the response inhibition condition there was also a significant gender X radiation interaction effect manifested at 15 leads by decreased P300 amplitudes of males in comparison to female subjects only at the presence of EMF. In conclusion, the present findings suggest that Wi-Fi exposure may exert gender-related alterations on neural activity associated with the amount of attentional resources engaged during a linguistic test adjusted to induce WM.

**Paparini A, Rossi P, Gianfranceschi G, Brugaletta V, Falsaperla R, De Luca P, Romano Spica V. No evidence of major transcriptional changes in the brain of mice exposed to 1800 MHz GSM signal.Bioelectromagnetics. 29(4):312-323, 2008.**

To analyze possible effects of microwaves on gene expression, mice were exposed to global system for mobile communication (GSM) 1800 MHz signal for 1 h at a whole body SAR of 1.1 W/kg. Gene expression was studied in the whole brain, where the average SAR was 0.2 W/kg, by expression microarrays containing over 22,600 probe sets. Comparison of data from sham and exposed animals showed no significant difference in gene expression modulation. However, when less stringent constraints were adopted to analyze microarray results, 75 genes were found to be modulated following exposure. Forty-two probes showed fold changes ranging from 1.5 to 2.8, whereas 33 were down-regulated from 0.67- to 0.29-fold changes, but these differences in gene expression were not confirmed by real-time PCR. Under these specific limited conditions, no consistent indication of gene expression modulation in whole mouse brain was found associated to GSM 1800 MHz exposure.

**Parazzini M, Ravazzani P, Tognola G, Thuroczy G, Molnar FB, Sacchettini A, Ardesi G, Mainardi LT. Electromagnetic fields produced by GSM cellular phones and heart rate variability. Bioelectromagnetics.28(2):122-129, 2007.**

In this study, 26 healthy young volunteers were submitted to 900 MHz (2 W) GSM cellular phone exposure and to sham exposure in separate sessions. The study was

designed to assess cardiac regulatory mechanism in different autonomic nervous system (ANS) states during exposure to low-intensity EMF. Rest-to-stand protocol was applied to evaluate ANS in quiet condition (rest, vagal prevalence) and after a sympathetic activation (stand). The procedure is conducted twice in a double-blind design: once with a genuine EMF exposure and once with a sham exposure (at least 24 h apart). During each session three-leads electrocardiograms were recorded and RR series extracted off-line. Time domain and frequency domain HRV parameters were calculated in every phase of the protocol and during different exposures. The analysis of the data show there was no statistically significant effect due to EMF exposure both on main (i.e., RR mean) and most of the other HRV parameters. A weak interaction between some HRV parameters (i.e., SDNN, TINN, and triangular index in time domain and LF power in frequency domain analysis) and RF exposure was observed and this effect seems to be gathered around the sympathetic response to stand.

**Parazzini M, Brazzale AR, Paglialonga A, Tognola G, Collet L, Moulin A, Lutman ME, Bell SL, Thomas NA, Uloziene I, Uloza V, Thuroczy G, Tavartkiladze G, Tsalighopoulos M, Kyriafinis G, Ravazzani P. Effects of GSM Cellular Phones on Human Hearing: The European Project "GUARD". Radiat Res. 168(5):608-613, 2007.**

The European multicenter project named GUARD involved nine centers and aimed to assess potential changes in auditory function as a consequence of exposure to low-intensity electromagnetic fields (EMFs) produced by GSM cellular phones. Participants were healthy young adults without any evidence of hearing or ear disorders. Auditory function was assessed immediately before and after exposure to EMFs, and only the exposed ear was tested. The procedure was conducted twice in a double blinded design, once with a genuine EMF exposure and once with a sham exposure (at least 24 h apart). Tests for assessment of auditory function were hearing threshold level (HTL), transient otoacoustic emissions (TEOAE), distortion product otoacoustic emissions (DPOAE), and auditory brainstem response (ABR). The exposure consisted of speech at a typical conversational level delivered via an earphone to one ear, plus genuine or sham EMF exposure. The EMF exposure used the output of a software-controlled consumer cellular phone at full power for 10 min. A system of phone positioning that allowed participants to freely move their heads without affecting exposure was used. Analysis of the data showed there were no effects of exposure to GSM mobile phone signals on the main measures of the status of the auditory system.

**Parazzini M, Sibella F, Lutman ME, Mishra S, Moulin A, Sliwinska-Kowalska M, Woznicka E, Politanski P, Zmyslony M, Thuroczy G, Molnár F, Kubinyi G, Tavartkiladze G, Bronyakin S, Uloziene I, Uloza V, Gradauskiene E, Ravazzani P. Effects of UMTS Cellular Phones on Human Hearing: Results of the European Project "EMFnEAR". Radiat Res. 172(2):244-251, 2009.**

Abstract The European project EMFnEAR was undertaken to assess potential changes in human auditory function after a short-term exposure to radiofrequency (RF) radiation produced by UMTS (Universal Mobile Telecommunication System) mobile phones. Participants were healthy young adults with no hearing or ear disorders. Auditory function

was assessed immediately before and after exposure to radiofrequency radiation, and only the exposed ear was tested. Tests for the assessment of auditory function were hearing threshold level (HTL), distortion product otoacoustic emissions (DPOAE), contralateral suppression of transiently evoked otoacoustic emission (CAS effect on TEOAE), and auditory evoked potentials (AEP). The exposure consisted of speech at a typical conversational level delivered via an earphone to one ear, plus genuine or sham RF-radiation exposure produced by a commercial phone controlled by a personal computer. Results from 134 participants did not show any consistent pattern of effects on the auditory system after a 20-min UMTS exposure at the maximum output of the phone with 69 mW/kg SAR in the cochlea region in a double blind comparison of genuine and sham exposure. An isolated effect on the hearing threshold at high frequencies was identified, but this was statistically nonsignificant after correction for multiple comparisons. It is concluded that UMTS short-term exposure at the maximum output of consumer mobile phones does not cause measurable immediate effects on the human auditory system.

**Parazzini M, Lutman ME, Moulin A, Barnel C, Sliwinska-Kowalska M, Zmyslony M, Hernadi I, Stefanics G, Thuroczy G, Ravazzani P. Absence of short-term effects of UMTS exposure on the human auditory system. Radiat Res. 173(1):91-97, 2010.**

The aim of this study, which was performed in the framework of the European project EMFnEAR, was to investigate the potential effects of Universal Mobile Telecommunications System (UMTS, also known as 3G) exposure at a high specific absorption rate (SAR) on the human auditory system. Participants were healthy young adults with no hearing or ear disorders. Auditory function was assessed immediately before and after exposure to radiofrequency (RF) radiation, and only the exposed ear was tested. Tests for the assessment of auditory function were hearing threshold level (HTL), distortion product otoacoustic emissions (DPOAE), contralateral suppression of transiently evoked otoacoustic emission (CAS effect on TEOAE), and auditory evoked potentials (AEP). The exposure consisted of speech at a typical conversational level delivered via an earphone to one ear, plus genuine or sham RF-radiation exposure obtained by an exposure system based on a patch antenna and controlled by software. Results from 73 participants did not show any consistent pattern of effects on the auditory system after a 20-min UMTS exposure at 1947 MHz at a maximum SAR over 1 g of 1.75 W/kg at a position equivalent to the cochlea. Analysis entailed a double-blind comparison of genuine and sham exposure. It is concluded that short-term UMTS exposure at this relatively high SAR does not cause measurable immediate effects on the human auditory system.

**Paredi P, Kharitonov SA, Hanazawa T, Barnes PJ, Local vasodilator response to mobile phones. Laryngoscope 111(1):159-162, 2001.**

OBJECTIVES: The use of mobile phones with the resulting generation of potentially harmful electromagnetic fields (EMF) is the focus of public interest. Heat generation and the activation of the inducible form of nitric oxide (NO) synthase may be possible causes of the biological effects of EMF exposure. We investigated if a mobile telephone conversation can modify skin temperature, NO, and nasal resistance. METHODS: We

studied the effect of an EMF (900 MHz) generated by a commercially available cellular phone during a 30-minute telephone conversation on skin temperature, nasal NO measured by chemiluminescence, and nasal minimal cross-sectional area (MCA) measured by rhinometry. Eleven normal subjects (mean age +/- standard error of mean [SEM], 32 +/- 5 y; 10 male) were studied. RESULTS: There was a similar and significant increase in skin temperature of the nostril and occipital area on the same side as the telephone (maximal increase 2.3 +/- 0.2 degrees C at 6 min) as well as a tendency for higher nasal NO levels (maximal increase 12.9 +/- 4.9% at 10 min), whereas the MCA was significantly reduced (maximal decrease -27 +/- 6% at 15 min). Such changes were not recorded when an earpiece was used to avoid the direct exposure to the electromagnetic field. There were no changes in the skin temperature and nasal NO measured on the opposite side to the mobile phone, whereas the MCA was significantly increased (38 +/- 10%). CONCLUSIONS: Exposure to EMF produced by a mobile phone produces biological effects that can be easily measured. Microwaves may increase skin temperature and therefore cause vasodilation and reduce MCA. Further studies are needed to study the long-term effects of mobile phone use and the relation among NO production, vasodilation, and temperature.

**Park SK,Ha M, Im H-J.Ecological study on residences in the vicinity of AM radio broadcasting towers and cancer death: preliminary observations in Korea. Int Arch Occup Environ Health 77(6):387-394, 2004.**

**Abstract**. Objectives  Public health concern about the health effects of radio-frequency electromagnetic fields (RF-EMFs) has increased with the increase in public exposure. This study was to evaluate some health effect of RF exposure by the AM radio broadcasting towers in Korea. Methods  We calculated cancer mortality rates using Korean death certificates over the period of 1994–1995 and population census data in ten RF-exposed areas, defined as regions that included AM radio broadcasting towers of over 100 kW, and in control areas, defined as regions without a radio broadcasting tower inside and at least 2 km away from the towers. Results  All cancers-mortality was significantly higher in the exposed areas [direct standardized mortality rate ratio (MRR) =1.29, 95%CI=1.12–1.49]. When grouped by each exposed area and by electrical power, MRRs for two sites of 100 kW, one site of 250 kW and one site of 500 kW, for all subjects, and for one site of 100 kW and two sites of 250 kW, for male subjects, showed statistically significant increases without increasing trends according to the groups of electric power. Leukemia mortality was higher in exposed areas (MRR=1.70, 95% CI=0.84–3.45), especially among young adults aged under 30 years (0–14 years age group, MRR=2.29, 95% CI=1.05–5.98; 15–29 age group, MRR=2.44, 95% CI=1.07–5.24) . Conclusions  We observed higher mortality rates for all cancers and leukemia in some age groups in the area near the AM radio broadcasting towers. Although these findings do not prove a causal link between cancer and RF exposure from AM radio broadcasting towers, it does suggest that further analytical studies on this topic are needed in Korea.

**Park J, Kwon JH, Kim N, Song K. Effects of 1950 MHz radiofrequency electromagnetic fields on Aβ processing in human neuroblastoma and mouse hippocampal neuronal cells. J Radiat Res. 2017 Oct 6:1-9. doi: 10.1093/jrr/rrx045. [Epub ahead of print]**

Alzheimer's disease (AD) is a neurodegenerative disease leading to progressive loss of memory and other cognitive functions. One of the well-known pathological markers of AD is the accumulation of amyloid-beta protein (Aβ), and its plaques, in the brain. Recent studies using Tg-5XFAD mice as a model of AD have reported that exposure to radiofrequency electromagnetic fields (RF-EMF) from cellular phones reduced Aβ plaques in the brain and showed beneficial effects on AD. In this study, we examined whether exposure to 1950 MHz RF-EMF affects Aβ processing in neural cells. We exposed HT22 mouse hippocampal neuronal cells and SH-SY5Y human neuroblastoma cells to RF-EMF (SAR 6 W/kg) for 2 h per day for 3 days, and analyzed the mRNA and protein expression of the key genes related to Aβ processing. When exposed to RF-EMF, mRNA levels of APP, BACE1, ADAM10 and PSEN1 were decreased in HT22, but the mRNA level of APP was not changed in SH-SY5Y cells. The protein expression of APP and BACE1, as well as the secreted Aβ peptide, was not significantly different between RF-EMF-exposed 7w-PSML, HT22 and SH-SY5Y cells and the unexposed controls. These observations suggest that RF-EMF exposure may not have a significant physiological effect on Aβ processing of neural cells in the short term. However, considering that we only exposed HT22 and SH-SY5Y cells to RF-EMF for 2 h per day for 3 days, we cannot exclude the possibility that 1950 MHz RF-EMF induces physiological change in Aβ processing with long-term and continuous exposure.

**Parker JE, Kiel JL, Winters WD. Effect of radiofrequency radiation on mRNA expression in cultured rodent cells. Physiol Chem Phys Med NMR 20(2):129-134, 1988.**

Four rodent cell lines were exposed to 2450 MHz microwave radiation at a Specific Absorption Rate (SAR) of 103.5 +/- 4.2 W/kg for varying lengths of time at 37 degrees, 40 degrees, 42 degrees and 45 degrees C. mRNA was extracted from microwave-exposed and sham-exposed cells and dot blotted or Northern blotted to nitrocellulose. Radioisotope labelled DNA probes of oncogenes, heat shock protein or long terminal repeat sequences were hybridized to the mRNA, and the resulting autoradiographs analyzed for differences in levels of mRNA expression between exposed and nonexposed samples. With the cell lines and probes used in this study no significant differences in mRNA expression were observed after microwave exposure.

**Parodi S, Merlo DF, Ranucci A, Miligi L, Benvenuti A, Rondelli R, Magnani C, Haupt R; SETIL Working Group. Risk of neuroblastoma, maternal characteristics and perinatal exposures: The SETIL study. Cancer Epidemiol. 2014 Sep 30. pii: S1877-7821(14)00157-X. doi: 10.1016/j.canep.2014.09.007. [Epub ahead of print]**

PURPOSE: Neuroblastoma (NB) is the most common extra-cranial paediatric solid tumour. Incidence peaks in infancy, suggesting a role of in-utero and neonatal exposures but its aetiology is largely unknown. The aim of the present study is to evaluate the association between maternal characteristics and perinatal factors with the risk of NB, using data from the SETIL database. METHODS: SETIL is a large Italian population-based case-control study established to evaluate several potential cancer risk factors in 0-10 year olds. Information about maternal characteristics, reproductive history, environmental and occupational exposures during pregnancy, as well as newborns' characteristics were obtained using a structured questionnaire. Extremely low frequency

**magnetic field** (**ELF**-MF) home exposure was measured. The study included 1044 healthy controls and 153 NB cases, diagnosed between 1998 and 2001. RESULTS: A twofold risk was associated to exposure in pregnancy to chemical products for domestic work and to hair dye. The risk associated with the latter was higher among 0-17 month old children (OR=5.5, 95%CI: 1.0-29.3). Risk was increased for children whose mothers had suffered work related exposure in the preconception period to solvents (OR=2.0 95%CI: 1.0-4.1) and in particular to aromatic hydrocarbons (OR=9.2, 95%CI: 2.4-34.3). No association was observed with **ELF**-MF exposure. A higher risk was found among children with congenital malformations (OR=4.9, 95%CI: 1.8-13.6) or neurofibromatosis (2 cases and 0 controls, p=0.016). CONCLUSIONS: Our study suggests maternal exposure to hair dyes and aromatic hydrocarbons plays a role and deserves further investigation. The association with congenital malformations might also be explained by over-diagnosis. External exposure, in particular during and before pregnancy might contribute to NB occurrence.

**Parslow RC, Hepworth SJ, McKinney PA. Recall of past use of mobile phone handsets. Radiat Prot Dosimetry. 106(3):233-240, 2003.**

Previous studies investigating health effects of mobile phones have based their estimation of exposure on self-reported levels of phone use. This UK validation study assesses the accuracy of reported voice calls made from mobile handsets. Data collected by postal questionnaire from 93 volunteers was compared to records obtained prospectively over 6 months from four network operators. Agreement was measured for outgoing calls using the kappa statistic, log-linear modelling, Spearman correlation coefficient and graphical methods. Agreement for number of calls gained moderate classification (kappa = 0.39) with better agreement for duration (kappa = 0.50). Log-linear modelling produced similar results. The Spearman correlation coefficient was 0.48 for number of calls and 0.60 for duration. Graphical agreement methods demonstrated patterns of over-reporting call numbers (by a factor of 1.7) and duration (by a factor of 2.8). These results suggest that self-reported mobile phone use may not fully represent patterns of actual use. This has implications for calculating exposures from questionnaire data.

**Partsvania B, Sulaberidze T, Shoshiashvili L, Modebadze Z. Acute effect of exposure of mollusk single neuron to 900-MHz mobile phone radiation.Electromagn Biol Med. 30(3):170-179, 2011.**

The goal of the present work was to explore the influence of commercially available cell phone irradiation on the single neuron excitability and memory processes. A Transverse Electromagnetic Cell (TEM Cell) was used to expose single neurons of mollusk to the electromagnetic field. Finite-Difference Time-Domain (FDTD) method was used for modeling the TEM Cell and the electromagnetic field interactions with living nerve ganglion and neurons. Neuron electrophysiology was investigated using standard microelectrode technique. The specific absorption rate (SAR) deposited into the single neuron was calculated to be 0.63 W/kg with a temperature increment of 0.1°C. After acute exposure, average firing threshold of the action potentials was not changed. However, the average latent period was significantly decreased. This

indicates that together with latent period the threshold and the time of habituation might be altered during exposure. However, these alterations are transient and only latent period remains on the changed level.

**Pashovkina MS, Akoev IG. [Effect of low intensity pulse-modulated electromagnetic radiation on activity of alkaline phosphatase in blood serum]. Radiats Biol Radioecol 41(1):62-66, 2001.** [Article in Russian]

The change in alkaline phosphotase activity in vitro with frequencies modulation at low intensity of pulse-modulated electromagnetic radiation was experimentally shown (EMR, 2375 MHz, intensity: 0.8, 8.0; 40.0 microW/cm2; range modulation: 30-310 Hz; time of interaction: 1-3 min). Revealed effects could be regarded as an evidence of informative character of interaction of modulated EMR.

**Pashovkina MS, Akoev IG. [Effect of low-intensity pulse-modulated microwave on human blood aspartate aminotransferase activity]. Radiats Biol Radioecol 41(1):59-61, 2001.** [Article in Russian]

Pulse-modulated microwaves (frequency 2375 MHz, intensity: 2 microW/cm2 and 8 microW/cm2, pulse modulation from 50 to 390 Hz with step of 20 Hz; exposure time 5 min) changed the activity of aspartataminotranspherase of the donor blood. Aspartataminotranspherase activity was strongly dependent both on modulation frequency and microwave intensity. Maximum activity was found at 390 Hz and 8 microW/cm2. Maximum observed activity was about six times greater than control level of activity.

**Pashovkina MS, Akoev IG, [Changes in serum alkaline phosphatase activity during in vitro exposure to amplitude-modulated electromagnetic field of ultrahigh frequency (2375 MHz) in guinea pigs]. Biofizika 45(1):130-136, 2000.** [Article in Russian]

The activity of alkaline phosphatase by the action of pulse-modulated microwave radiation was studied. The carrier frequency of radiation was 2375 MHz, the range of modulation pulse rate was 10-390 Hz with the on-off time ratio 2, and the specific absorption rate was 8 and 0.8 microW/cm2. Time of exposure was 1 and 3 min under conditions of continuous temperature control. It was shown that the activity of alkaline phosphatase depends on both modulation frequency and intensity of superhigh-frequency electromagnetic radiation. At a frequency of 70 Hz, the activity of alkaline phosphatases increased 1.8-2.0 times.

**Pashovskina MS, Akoev IG, [Effects of 2375 MHz pulse-modulated microwave radiation on ATPase activity of the rat muscle actomyosin]. Radiats Biol Radioecol 36(5):700-705, 1996**. [Article in Russian]

Solution of rat muscle actomyosin (AM) was exposed to pulse-modulated microwave. Carried frequency was 2375 MHz. The rectangular pulse modulation was in the range of 50-300 pulses per second. It was shown that AM activity was dependent both on modulation frequency as well as on microwave intensity. It was shown the frequencies of modulation which were changed ATP-ase activity of AM.

**Pau HW, Sievert U, Eggert S, Wild W. Can electromagnetic fields emitted by mobile phones stimulate the vestibular organ? Otolaryngol Head Neck Surg. 132(1):43-49, 2005.**

Objectives Pulsating electromagnetic (EM) radiation emitted by mobile phones is often incriminated for causing tissue alterations by caloric effects. In particular, the eye and the ear were regarded as possible "hot spots," with heating up to 1 degrees C, in which EM radiation might have negative effects. If so, these temperature increments should be large enough to cause vestibular excitation. In this study, we attempted to verify this theory by clinical testing and in vitro experiments. Methods and measures In our laboratory, a simulated GSM signal (889.6 MHz/2.2 W) was applied to 1 ear at a time, while video nystagmography was performed. The experimental setup was similar to that used for caloric (hot and cold water) testing of the peripheral vestibular organ. Data were evaluated by a computer system. There were 13 volunteers (26 ears) included in our study. In an additional experiment, temperatures of human temporal bones were measured by thermography, while a continuous or pulsating EM field was applied. Results In no volunteer could EM radiation-induced nystagmus be recorded. This corresponds well to our findings that in the human temporal bone very weak caloric effects could only be found in the tissue layers next to the radiation source (antenna of the mobile phone), whereas deeper regions (horizontal semicircular canal) seemed unaffected (at least less than 0.1 degrees C). Clinical significance These results do not support the theory that mobile phone-induced EM radiation may cause caloric negative effects in the human ear.

**Paul Raj R, Behari J, Rao AR, Effect of amplitude modulated RF radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. Indian J Biochem Biophys 36(5):337-340, 1999.**

The effect of exposing rats to amplitude modulated radiofrequency radiation (112 MHz modulated to 16 Hz) during development and growth has been examined. Wistar rats (35 days old) when exposed at above frequency at the power level 1.0 mW/cm2 (SAR, 0.75 W/kg) for 35 days showed enhanced ornithine decarboxylase activity and Ca2+ efflux in brain indicating potential health hazards due to exposure.

**Paulraj R, Behari J. Radio frequency radiation effects on protein kinase C activity in rats' brain. Mutat Res. 545(1-2):127-130, 2004.**

The present work describes the effect of amplitude modulated radio frequency (rf) radiation (112 MHz amplitude-modulated at 16 Hz) on calcium-dependent protein kinase C (PKC) activity on developing rat brain. Thirty-five days old Wistar rats were used for this study. The rats were exposed 2 h per day for 35 days at a power density of 1.0 mW/cm2 (SAR = 1.48 W/kg). After exposure, rats were sacrificed and PKC was determined in whole brain, hippocampus and whole brain minus hippocampus separately. A significant decrease in the enzyme level was observed in the exposed group as compared to the sham exposed group. These results indicate that this type of radiation could affect membrane bound enzymes associated with cell signaling, proliferation and differentiation. This may also suggest an affect on the behavior of chronically exposed rats.

**Paulraj R, Behari J. The effect of low level continuous 2.45 GHz waves on enzymes of developing rat brain. Electromag Biol Med 21:221-231, 2002.**

The present work describes the effect of low level continuous microwaves (2.45 GHz) on developing rat brain. Some 35-day-old Wistar rats were used for this study. The animals were exposed 2 hr/day for 35 days at a power density of 0.34 mW/cm$^2$ [specific absorption rate (SAR), 0.1 W/kg] in a specially made anechoic chamber. After the exposure, the rats were sacrificed and the brain tissue was dissected out and used for various biochemical assays. A significant increase in calcium ion efflux and ornithine decarboxylase (ODC) activity was observed in the exposed group as compared to the control. Correspondingly, a significant decrease in the calcium-dependent protein kinase activity was observed. These results indicate that this type of radiation affects the membrane bound enzymes, which are associated with cell proliferation and differentiation, thereby pointing out its possible role as a tumor promoter.

**Paulraj R, Behari J. Single strand DNA breaks in rat brain cells exposed to microwave radiation. Mutat Res. 596:76-80, 2006.**

This investigation concerns with the effect of low intensity microwave (2.45 and 16.5GHz, SAR 1.0 and 2.01W/kg, respectively) radiation on developing rat brain. Wistar rats (35 days old, male, six rats in each group) were selected for this study. These animals were exposed for 35 days at the above mentioned frequencies separately in two different exposure systems. After the exposure period, the rats were sacrificed and the whole brain tissue was dissected and used for study of single strand DNA breaks by micro gel electrophoresis (comet assay). Single strand DNA breaks were measured as tail length of comet. Fifty cells from each slide and two slides per animal were observed. One-way ANOVA method was adopted for statistical analysis. This study shows that the chronic exposure to these radiations cause statistically significant ($p<0.001$) increase in DNA single strand breaks in brain cells of rat.

**Paulraj R, Behari J. Protein Kinase C Activity in developing rat brain cells exposed to 2.45 GHz radiation. Electromag Biol Med 25(1) 61-70, 2006.**

There is growing concern by the public regarding the potential human health hazard due to exposure to microwave frequencies. 2.45 GHz radiation widespread use in industry, research, and medicine, and leakage into the environment is possible. In order to quantitate this, experiments were performed on developing rat brain. Male Wistar 35-day-old rats ($n = 6$) were used for this study. Animals were exposed to 2.45 GHz radiation for 2 h/day for a period of 35 days at a power density of 0.344 mW/cm$^2$ (SAR 0.11 W/kg). The control group was sham irradiated. After 35 days these rats were sacrificed and whole brain tissue was isolated for protein kinase C (PKC) assay. For morphological study the forebrain was isolated from the whole brain and PKC activity was measured using $P^{32}$ labeled ATP. Our study reveals a statistically significant ($p < 0.05$) decrease in PKC activity in hippocampus as compared to the remaining portion of the whole brain and the control group. A similar experiment conducted on hippocampus and the whole brain gave a similar result. Electron microscopic study shows an increase in the glial cell population in the exposed group as compared to the control group. This present study is indicative of a significant change after exposure to the above-mentioned field intensity.

This suggests that chronic exposures may affect brain growth and development.

**Pavel A, Ungureanu CE, Bara Il, Gassner P, Creanga DE, [Cytogenetic changes induced by low-intensity microwaves in the species Triticum aestivum]. Rev Med Chir Soc Med Nat Iasi 102(3-4):89-92, 1998.** [Article in Romanian]

Seeds of Triticum aestivum having an uniform genophond have been exposed to a microwave flow, with a frequency of 9.75 GHz and a low intensity. The effects of microwaves at various doses on mitotic activity have been followed. Our results show that as compared to the controls different types of chromosomal aberrations appeared: delayed chromosomes, micronuclei, interchromosomal bridges, chromosomal fragments.

**Pavicic I, Trosic I, Sarolic A. Comparison of 864 MHz and 935 MHz microwave radiation effects on cell culture. Arh Hig Rada Toksikol. 57(2):149-154, 2006.**

The objective of this study was to compare the effects of 864 MHz and 935 MHz radiofrequency/microwave radiation on the ability of V79 cells to proliferate, form colonies and on their viability. For one, two and three hours, the cells were exposed to the 864 MHz field in a transversal electromagnetic mode cell (TEM) connected with amplifier and to the 935 MHz field in a gigahertz transversal electromagnetic mode cell (GTEM) equipped with a signal generator. The average specific absorption rate (SAR) was 0.08 W kg(-1) for the 864 MHz field and 0.12 W kg(-1) for the 935 MHz field. In comparison to the control cell samples, the growth curve of the 864 MHz irradiated cells showed a significant decrease after two-hour and three-hour exposure on the Day 3 after exposure. Likewise, cells exposed to 935 MHz microwaves for three hours showed a significant growth on Day 3 after exposure. The colony-forming ability and viability of cells exposed to 864 MHz and 935 MHz microwaves did not significantly differ from the matched controls. The applied RF/MW fields showed a similar effect on cell culture growth, colony-forming ability and viability of V79 cells.

**Pavicic I, Trosic I. Impact of 864 MHz or 935 MHz radiofrequency microwave radiation on the basic growth parameters of V79 cell line. Acta Biol Hung. 59(1):67-76, 2008.**

The aim of this study was to evaluate and compare the influence of 864 MHz and 935 MHz radiofrequency/microwave (RF/MW) fields on the growth, colony-forming ability, and viability of V79 cells (continuous line). Cell samples with 1 x 10(4) V79 cells each, were exposed to continuous wave frequencies of 864 MHz and 935 MHz for 1, 2 and 3 hours. Exposed samples were matched with unexposed control samples. Specific absorption rate (SAR) was 0.08 W/kg for the 864 MHz or 0.12 W/kg for the 935 MHz field. Cell growth and viability were determined by counting cells every day for five days after exposure. Colony-forming ability was assessed by counting colonies seven days after exposure. The growth of the 864 MHz-irradiated cells was significant after two- and three-hour exposure 72 hours after irradiation ($p < 0.05$). The similar was observed 72 hours after exposure for cells exposed to 935 MHz microwaves for three hours ($p < 0.05$). Colony-forming ability and cell viability in V79 cells exposed to 864 MHz or 935 MHz microwaves did not significantly differ from control cells. The two applied RF/MW fields showed similar effects on the growth, colony-forming ability and viability of V79 cells. Cell growth impact was time-

dependent for both fields.

**Pawlak K, Sechman A, Nieckarz Z. Plasma thyroid hormones and corticosterone levels in blood of chicken embryos and post hatch chickens exposed during incubation to 1800 MHz electromagnetic field. Int J Occup Med Environ Health. 2014 Jan 31. [Epub ahead of print]**

INTRODUCTION: This study attempted to determine the effect of a 1800 MHz electromagnetic field (EMF) (only carrier frequency) on thyroxine (T4), triiodothyronine (T3) and corticosterone (CORT) concentrations in the blood plasma of chick embryos, and to investigate the effect of electromagnetic field (EMF) exposure during embryogenesis on the level of these hormones in birds that are ready for slaughter. MATERIAL AND METHODS: Throughout the incubation period, embryos from the experimental group were exposed to a 1800 MHz EMF with power density of 0.1 W/m2, 10 times during 24 h for 4 min. Blood samples were collected to determine T4, T3 and CORT concentrations on the 12th (E12) and 18th (E18) day of incubation, from newly hatched chicks (D1) and from birds ready for slaughter (D42). RESULTS: The experiment showed that T4 and T3 concentrations decreased markedly and CORT levels increased in the embryos and in the newly hatched chicks exposed to EMF during embryogenesis. However, no changes were found in the level of the analyzed hormones in the birds ready for slaughter. Differences in T4 and T3 plasma concentrations between the EMF-exposed group and the embryos incubated without additional EMF were the highest in the newly hatched chicks, which may be indicative of the cumulative effect of electromagnetic field on the hypothalamo-pituitary-thyroid axis (HPT). DISCUSSION: The obtained results suggest that additional 1800 MHz radio frequency electromagnetic field inhibits function of HPT axis, however, it stimulates hypothalamo-pituitary-adrenal axis by inducing adrenal steroidogenic cells to synthesize corticosterone. Further investigations are needed to elucidate the mechanisms by which radio EMFs affect HPT and HPA axis function in the chicken embryos.

**Pedersen W. [Mobile phones, web chat, and sex among Norwegian adolescents] Tidsskr Nor Laegeforen. 124(13-14):1756-1759, 2004.** [article in Norwegian]

BACKGROUND: We investigated the associations between new interactive technology for communication, such as web chat or mobile phones, and sexual behaviour among Norwegian adolescents. MATERIALS AND METHODS: A representative sample of adolescents (age 13-18, N = 10,926) filled in a questionnaire during school hours; the response rate was 92%. RESULTS: Most adolescents have access to communication technology, but how much they use it varies. In particular with regard to mobile phones, a strong association to sexual behaviour was found. Among those who did not use the new technology, less than 10% reported having had intercourse while two out of three of the most active users reported intercourse. The associations remained significant when controls were made for age and a range of contextual, family, peer and individual factors. INTERPRETATION: Norwegian adolescents have changed their sexual behaviour over the last decade. The introduction and widespread use of new communication technology is one of the most salient changes over the same period. The findings suggest that this

technology may in fact be of importance to teenagers' sexual socialisation.

**Peinnequin A, Piriou A, Mathieu J, Dabouis V, Sebbah C, Malabiau R, Debouzy JC Non-thermal effects of continuous 2.45 GHz microwaves on Fas-induced apoptosis in human Jurkat T-cell line. Bioelectrochemistry 51(2):157-161, 2000.**

Non-thermal effects of microwaves (MWs) are one of the main issues studied for revising standards. The effects of MW exposure on apoptosis at non-thermal level (48 h, 2.45 GHz, 5 mW/cm2) have been studied. Results obtained assess non-thermal MW effects on Fas, but neither on butyrate- nor on ceramide-induced apoptosis in human Jurkat T-cell line. These data show that MW interacts either with Fas pathway between receptor and caspase-3 activation or on membrane proteins (i.e. Fas receptor or neurosphyngomyelinase).

**Pelletier A, Delanaud S, Décima P, Thuroczy G, de Seze R, Cerri M, Bach V, Libert JP, Loos N. Effects of chronic exposure to radiofrequency electromagnetic fields on energy balance in developing rats. Environ Sci Pollut Res Int. 20(5):2735-2746, 2013.**

The effects of radiofrequency electromagnetic fields (RF-EMF) on the control of body energy balance in developing organisms have not been studied, despite the involvement of energy status in vital physiological functions. We examined the effects of chronic RF-EMF exposure (900MHz, 1 V m(-1)) on the main functions involved in body energy homeostasis (feeding behaviour, sleep and thermoregulatory processes). Thirteen juvenile male Wistar rats were exposed to continuous RF-EMF for 5 weeks at 24 °C of air temperature (T (a)) and compared with 11 non-exposed animals. Hence, at the beginning of the 6th week of exposure, the functions were recorded at T (a) of 24 °C and then at 31 °C. We showed that the frequency of rapid eye movement sleep episodes was greater in the RF-EMF-exposed group, independently of T (a) (+42.1 % at 24 °C and +31.6 % at 31 °C). The other effects of RF-EMF exposure on several sleep parameters were dependent on T (a). At 31 °C, RF-EMF-exposed animals had a significantly lower subcutaneous tail temperature (-1.21 °C) than controls at all sleep stages; this suggested peripheral vasoconstriction, which was confirmed in an experiment with the vasodilatator prazosin. Exposure to RF-EMF also increased daytime food intake (+0.22 g h(-1)). Most of the observed effects of RF-EMF exposure were dependent on T (a). Exposure to RF-EMF appears to modify the functioning of vasomotor tone by acting peripherally through α-adrenoceptors. The elicited vasoconstriction may restrict body cooling, whereas energy intake increases. Our results show that RF-EMF exposure can induce energy-saving processes without strongly disturbing the overall sleep pattern.

**Pelletier A, Delanaud S, de Seze R, Bach V, Libert JP, Loos N. Does Exposure to a Radiofrequency Electromagnetic Field Modify Thermal Preference in Juvenile Rats? PLoS One. 2014 Jun 6;9(6):e99007. doi: 10.1371/journal.pone.0099007. eCollection 2014.**

Some studies have shown that people living near a mobile phone base station may report sleep disturbances and discomfort. Using a rat model, we have previously shown that chronic exposure to a low-intensity radiofrequency electromagnetic field (RF-EMF) was

associated with paradoxical sleep (PS) fragmentation and greater vasomotor tone in the tail. Here, we sought to establish whether sleep disturbances might result from the disturbance of thermoregulatory processes by a RF-EMF. We recorded thermal preference and sleep stage distribution in 18 young male Wistar rats. Nine animals were exposed to a low-intensity RF-EMF (900 MHz, 1 V.m-1) for five weeks and nine served as non-exposed controls. Thermal preference was assessed in an experimental chamber comprising three interconnected compartments, in which the air temperatures (Ta) were set to 24°C, 28°C and 31°C. Sleep and tail skin temperature were also recorded. Our results indicated that relative to control group, exposure to RF-EMF at 31°C was associated with a significantly lower tail skin temperature (-1.6°C) which confirmed previous data. During the light period, the exposed group preferred to sleep at Ta=31°C and the controls preferred Ta=28°C. The mean sleep duration in exposed group was significantly greater (by 15.5%) than in control group (due in turn to a significantly greater amount of slow wave sleep (SWS, +14.6%). Similarly, frequency of SWS was greater in exposed group (by 4.9 episodes.h-1). The PS did not differ significantly between the two groups. During the dark period, there were no significant intergroup differences. We conclude that RF-EMF exposure induced a shift in thermal preference towards higher temperatures. The shift in preferred temperature might result from a cold thermal sensation. The change in sleep stage distribution may involve signals from thermoreceptors in the skin. Modulation of SWS may be a protective adaptation in response to RF-EMF exposure.

**Penafiel LM, Litovitz T, Krause D, Desta A, Mullins JM, Role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells. Bioelectromagnetics 18(2):132-141, 1997.**

The effect of 835 MHz microwaves on the activity of ornithine decarboxylase (ODC) in L929 murine cell was investigated at an SAR of approximately 2.5 W/kg. The results depended upon the type of modulation employed. AM frequencies of 16 Hz and 60 Hz produced a transient increase in ODC activity that reached a peak at 8 h of exposure and returned to control levels after 24 h of exposure. In this case, ODC was increased by a maximum of 90% relative to control levels. A 40% increase in ODC activity was also observed after 8 h of exposure with a typical signal from a TDMA digital cellular telephone operating in the middle of its transmission frequency range (approximately 840 MHz). This signal was burst modulated at 50 Hz, with approximately 30% duty cycle. By contrast, 8 h exposure with 835 MHz microwaves amplitude modulated with speech produced no significant change in ODC activity. Further investigations, with 8 h of exposure to AM microwaves, as a function of modulation frequency, revealed that the response is frequency dependent, decreasing sharply at 6 Hz an 600 Hz. Exposure with 835 MHz microwaves, frequency modulated with a 60 Hz sinusoid, yielded no significant enhancement in ODC activity for exposure times ranging between 2 and 24 h. Similarly, exposure with a typical signal from an AMPS analog cellular telephone, which uses a form of frequency modulation, produced no significant enhancement in ODC activity. Exposure with 835 MHz continuous wave microwaves produced no effects for exposure times between 2 and 24 h, except for a small but statistically significant enhancement in ODC activity after 6 h of exposure. Comparison of these results suggests that effects are much more robust when the modulation causes low-frequency periodic changes in the

amplitude of the microwave carrier.

**Pereira C, Edwards M, Parotid nodular fasciitis in a mobile phone user. J Laryngol Otol 114(11):886-887, 2000.**

We describe the first case of nodular fasciitis affecting the deep lobe of the parotid gland in a 39-year-old male telephone engineer and its possible association with the high usage of mobile phones.

**Perentos N, Croft RJ, McKenzie RJ, Cvetkovic D, Cosic I. Comparison of the effects of continuous and pulsed mobile phone like RF exposure on the human EEG. Australas Phys Eng Sci Med. 30(4):274-280, 2007.**

It is not clear yet whether Global System for Mobiles (GSM) mobile phone radiation has the ability to interfere with normal resting brain function. There have been reports that GSM exposure increases alpha band power, and does so only when the signal is modulated at low frequencies (Huber, R., Treyer, V., Borbely, A. A., Schuderer, J., Gottselig, J. M., Landolt, H.P., Werth, E., Berthold,T., Kuster, N., Buck, A and Achermann, P. Electromagnetic fields, such as those from mobile phones, alter regional cerebral blood flow and sleep and waking EEG. J Sleep Res 11, 289-295, 2002.) However, as that research employed exposure distributions that are not typical of normal GSM handset usage (deep brain areas were overexposed), it remains to be determined whether a similar result patterning would arise from a more representative exposure. In this fully counterbalanced cross-over design, we recruited 12 participants and tried to replicate the modulation linked post exposure alpha band power increase described above, but with an exposure source (dipole antenna) more closely resembling that of a real GSM handset. Exposures lasted for 15 minutes. No changes to alpha power were found for either modulated or unmodulated radiofrequency fields, and thus we failed to replicate the above results. Possible reasons for this failure to replicate are discussed, with the main reason argued to be the lower and more representative exposure distribution employed in the present study. In addition we investigated the possible GSM exposure related effects on the non-linear features of the resting electroencephalogram using the Approximate Entropy (ApEn) method of analysis. Again, no effect was demonstrated for either modulated or unmodulated radiofrequency exposures.

**Perentos N, Croft RJ, McKenzie RJ, Cvetkovic D, Cosic I. The effect of GSM-like ELF radiation on the alpha band of the human resting EEG. Conf Proc IEEE Eng Med Biol Soc. 1:5680-5683, 2008.**

Mobile phone handsets such as those operating in the GSM network emit extremely low frequency electromagnetic fields ranging from DC to at least 40 kHz. As a subpart of an extended protocol, the influence of these fields on the human resting EEG has been investigated in a fully counter balanced, double blind, cross-over design study that recruited 72 healthy volunteers. A decrease in the alpha frequency band was observed during the 20 minutes of ELF exposure in the exposed hemisphere only. This result suggests that ELF fields as emitted from GSM handsets during the DTX mode may have an effect on the resting alpha band of the human EEG.

**Pérez-Castejón C, Pérez-Bruzón RN, Llorente M, Pes N, Lacasa C, Figols T,**

**Lahoz M, Maestú C, Vera-Gil A, Del Moral A, Azanza MJ. Exposure to ELF-pulse modulated X band microwaves increases in vitro human astrocytoma cell proliferation. Histol Histopathol. 24(12):1551-1561, 2009.**

Common concern about the biological effects of electromagnetic fields (EMF) is increasing with the expansion of X-band microwaves (MW). The purpose of our work was to determine whether exposure to MW pulses in this range can induce toxic effects on human astrocytoma cells. Cultured astrocytoma cells (Clonetics line 1321N1) were submitted to 9.6 GHz carrier, 90% amplitude modulated by extremely low frequency (ELF)-EMF pulses inside a Gigahertz Transversal Electromagnetic Mode cell (GTEM-cell). Astrocytoma cultures were maintained inside a GTEM-incubator in standard culture conditions at 37+/-0.1 degrees C, 5% CO2, in a humidified atmosphere. Two experimental conditions were applied with field parameters respectively of: PW 100-120 ns; PRF 100-800 Hz; PRI 10-1.25 ms; power 0.34-0.60 mW; electric field strength 1.25-1.64 V/m; magnetic field peak amplitude 41.4-54.6 microOe. SAR was calculated to be 4.0 x 10-4 W/Kg. Astrocytoma samples were grown in a standard incubator. Reaching 70-80% confluence, cells were transferred to a GTEM-incubator. Experimental procedure included exposed human astrocytoma cells to MW for 15, 30, 60 min and 24 h and unexposed sham-control samples. Double blind method was applied. Our results showed that cytoskeleton proteins, cell morphology and viability were not modified. Statistically significant results showed increased cell proliferation rate under 24h MW exposure. Hsp-70 and Bcl-2 antiapoptotic proteins were observed in control and treated samples, while an increased expression of connexin 43 proteins was found in exposed samples. The implication of these results on increased proliferation is the subject of our current research.

**Persson BRR, Salford LG, Brun A, Blood-brain barrier permeability in rats exposed to electromagnetic fields used in wireless communication. Wireless Network 3:455-461, 1997.**

Biological effects of radio frequency electromagnetic fields (EMF) on the blood-brain barrier (BBB) have been studied in Fischer 344 rats of both sexes. The rats were not anesthetised during the exposure. The brains were perfused with saline for 3-4 minutes, and thereafter perfusion fixed with 4% formaldehyde for 5-6 minutes. Whole coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 micrometers. Albumin and fibinogen were demonstrated immunochemically and classified as normal versus pathological leakage. In the present investigation we exposed male and female Fischer 344 rats in a Transverse Electromagnetic Transmission line camber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with different pulse power and at various time intervals. The CW-pulse power varied from 0.001 W to 10 W and the exposure time from 2 min to 960 min. In each experiment we exposed 4-6 rats with 2-4 controls randomly placed in excited and non-excited TEM cells, respectively. We have in total investigated 630 exposed rats at various modulation frequencies and 372 controls. The frequency of pathological rats is significantly increased ($P < 0.0001$) from 62/372 (ratio 0.17 + 0.02) for control rats to 244/630 (ratio: 0.39 + 0.043) in all exposed rats. Grouping the exposed animals according to the level or specific absorption energy (J/kg) give significant difference in all levels above 1.5 J/kg. The

exposure was 915 MHz microwaves either pulse modulated (PW) at 217 Hz with 0.57 ms pulse width, at 50 Hz with 6.6 ms pulse width or continuous wave (CW). The frequency of pathological rats (0.17) among controls in the various groups is not significantly different. The frequency of pathological rats was 170/480 (0.35 + 0.03) among rats exposed to pulse modulated (PW) and 74/149 (0.50 + 0.07) among rats exposed to continuous wave exposure (CW). These results are both highly significantly different to their corresponding controls ($p < 0.0001$) and the frequency of pathological rats after exposure to pulsed radiation (PW) is significantly less ($p < 0.002$) than after exposure to continuous wave radiation (CW).

**Pesnya DS, Romanovsky AV. Comparison of cytotoxic and genotoxic effects of plutonium-239 alpha particles and mobile phone GSM 900 radiation in the Allium cepa test.Mutat Res. 2012 Oct 8. pii: S1383-5718(12)00291-4. doi: 10.1016/j.mrgentox.2012.08.010. [Epub ahead of print]**

The goal of this study was to compare the cytotoxic and genotoxic effects of plutonium-239 alpha particles and GSM 900 modulated mobile phone (model Sony Ericsson K550i) radiation in the Allium cepa test. Three groups of bulbs were exposed to mobile phone radiation during 0 (sham), 3 and 9h. A positive control group was treated during 20min with plutonium-239 alpha-radiation. Mitotic abnormalities, chromosome aberrations, micronuclei and mitotic index were analyzed. Exposure to alpha-radiation from plutonium-239 and exposure to modulated radiation from mobile phone during 3 and 9h significantly increased the mitotic index. GSM 900 mobile phone radiation as well as alpha-radiation from plutonium-239 induced both clastogenic and aneugenic effects. However, the aneugenic activity of mobile phone radiation was more pronounced. After 9h of exposure to mobile phone radiation, polyploid cells, three-groups metaphases, amitoses and some unspecified abnormalities were detected, which were not registered in the other experimental groups. Importantly, GSM 900 mobile phone radiation increased the mitotic index, the frequency of mitotic and chromosome abnormalities, and the micronucleus frequency in a time-dependent manner. Due to its sensitivity, the A. cepa test can be recommended as a useful cytogenetic assay to assess cytotoxic and genotoxic effects of radiofrequency electromagnetic fields.

**Petitdant N, Lecomte A, Robidel F, Gamez C, Blazy K, Villégier AS. Cerebral radiofrequency exposures during adolescence: Impact on astrocytes and brain functions in healthy and pathologic rat models. Bioelectromagnetics. 37(5):338-350, 2016.**

The widespread use of mobile phones by adolescents raises concerns about possible health effects of radiofrequency electromagnetic fields (RF EMF 900 MHz) on the immature brain. Neuro-development is a period of particular sensitivity to repeated environmental challenges such as pro-inflammatory insults. Here, we used rats to assess whether astrocyte reactivity, perception, and emotionality were affected by RF EMF exposures during adolescence. We also investigated if adolescent brains were more sensitive to RF EMF exposures after neurodevelopmental inflammation. To do so, we either performed 80 µg/kg intra-peritoneal injections of lipopolysaccharides during gestation or 1.25 µg/h intra-cerebro-ventricular infusions during adolescence. From

postnatal day (P)32 to 62, rats were subjected to 45 min RF EMF exposures to the brain (specific absorption rates: 0, 1.5, or 6 W/kg, 5 days/week). From P56, they were tested for perception of novelty, anxiety-like behaviors, and emotional memory. To assess astrocytic reactivity, Glial Fibrillary Acidic Protein was measured at P64. Our results did not show any neurobiological impairment in healthy and vulnerable RF EMF-exposed rats compared to their sham-exposed controls. These data did not support the hypothesis of a specific cerebral sensitivity to RF EMF of adolescents, even after a neurodevelopmental inflammation.

**Pettersson D, Mathiesen T, Prochazka M, Bergenheim T, Florentzson R, Harder H, Nyberg G, Siesjö P, Feychting M. Long-term Mobile Phone Use and Acoustic Neuroma Risk. Epidemiology 25(2):233-41, 2014.**

BACKGROUND: There is concern about potential effects of radiofrequency fields generated by mobile phones on cancer risk. Most previous studies have found no association between mobile phone use and acoustic neuroma, although information about long-term use is limited. METHODS: We conducted a population-based, nation-wide, case-control study of acoustic neuroma in Sweden. Eligible cases were persons aged 20 to 69 years, who were diagnosed between 2002 and 2007. Controls were randomly selected from the population registry, matched on age, sex, and residential area. Postal questionnaires were completed by 451 cases (83%) and 710 controls (65%).RESULTS: Ever having used mobile phones regularly (defined as weekly use for at least 6 months) was associated with an odds ratio (OR) of 1.18 (95% confidence interval = 0.88 to 1.59). The association was weaker for the longest induction time (≥10 years) (1.11 [0.76 to 1.61]) and for regular use on the tumor side (0.98 [0.68 to 1.43]). The OR for the highest quartile of cumulative calling time (≥680 hours) was 1.46 (0.98 to 2.17). Restricting analyses to histologically confirmed cases reduced all ORs; the OR for ≥680 hours was 1.14 (0.63 to 2.07). A similar pattern was seen for cordless land-line phones, although with slightly higher ORs. Analyses of the complete history of laterality of mobile phone revealed considerable bias in laterality analyses. CONCLUSIONS:The findings do not support the hypothesis that long-term mobile phone use increases the risk of acoustic neuroma. The study suggests that phone use might increase the likelihood that an acoustic neuroma case is detected and that there could be bias in the laterality analyses performed in previous studies.

**Peyman A, Rezazadeh AA, Gabriel C. Changes in the dielectric properties of rat tissue as a function of age at microwave frequencies. Phys Med Biol 46(6):1617-1629, 2001.**

The dielectric properties of ten rat tissues at six different ages were measured at 37 degrees C in the frequency range of 130 MHz to 10 GHz using an open-ended coaxial probe and a computer controlled network analyser. The results show a general decrease of the dielectric properties with age. The trend is more apparent for brain, skull and skin tissues and less noticeable for abdominal tissues. The variation in the dielectric properties with age is due to the changes in the water content and the organic composition of tissues. The percentage decrease in the dielectric properties of certain tissues in the 30 to 70 day old rats at cellular phone frequencies have been tabulated. These data provide an

important input in the provision of rigorous dosimetry in lifetime-exposure animal experiments. The results provide some insight into possible differences in the assessment of exposure for children and adults.

**Peyman A, Gabriel C, Grant EH, Vermeeren G, Martens L.Variation of the dielectric properties of tissues with age: the effect on the values of SAR in children when exposed to walkie-talkie devices. Phys Med Biol. 54(2):227-241, 2009.**

In vitro dielectric properties of ageing porcine tissues were measured in the frequency range of 50 MHz-20 GHz, and the total combined uncertainties of the measurements were assessed. The results show statistically significant reduction with age in both permittivity and conductivity of 10 out of 15 measured tissues. At microwave frequencies, the observed variations are mainly due to the reduction in the water content of tissues as an animal ages. The results obtained were then used to calculate the SAR values in children of age 3 and 7 years when they are exposed to RF induced by walkie-talkie devices. No significant differences between the SAR values for the children of either age or for adults were observed.

**Peyman A, Holden SJ, Watts S, Perrott R, Gabriel C. Dielectric properties of porcine cerebrospinal tissues at microwave frequencies: in vivo, in vitro and systematic variation with age. Phys Med Biol. 52(8):2229-2245, 2007.**

The dielectric properties of pig cerebrospinal tissues were measured in vivo and in vitro, in the frequency range of 50 MHz-20 GHz. The total combined measurement uncertainty was calculated at each frequency point and is reported over representative frequency regions. Comparisons were made for each tissue between the two sets of data and with the literature of the past decade. The in vitro study was extended to include tissue from pigs weighing approximately 10, 50 and 250 kg to re-visit the question of the variation of dielectric properties with age. White matter and spinal chord showed significant variation as function of animal age, no age-related variations were recorded for grey matter.

**Peyman A, Khalid M, Calderon C, Addison D, Mee T, Maslanyj M, Mann S. Assessment of exposure to electromagnetic fields from wireless computer networks (wi-fi) in schools; results of laboratory measurements. Health Phys. 100(6):594-612, 2011.**

Abstract. Laboratory measurements have been carried out with examples of Wi-Fi devices used in UK schools to evaluate the radiofrequency power densities around them and the total emitted powers. Unlike previous studies, a 20 MHz bandwidth signal analyzer was used, enabling the whole Wi-Fi signal to be captured and monitored. The radiation patterns of the laptops had certain similarities, including a minimum toward the torso of the user and two maxima symmetrically opposed across a vertical plane bisecting the screen and keyboard. The maxima would have resulted from separate antennas mounted behind the top left and right corners of the laptop screens. The patterns for access points were more symmetrical with generally higher power densities at a given distance. The spherically-integrated radiated power (IRP) ranged from 5 to 17 mW for 15 laptops in the 2.45 GHz band and from 1 to 16 mW for eight laptops in the 5 GHz band. For practical reasons and because access points are generally wall-mounted with beams directed into the rooms, their powers were

integrated over a hemisphere. These ranged from 3 to 28 mW for 12 access points at 2.4 GHz and from 3 to 29 mW for six access points at 5 GHz. In addition to the spherical measurements of IRP, power densities were measured at distances of 0.5 m and greater from the devices, and consistent with the low radiated powers, these were all much lower than the ICNIRP reference level.

**Pfützner, H. (2016) "Hot Nano Spots" as an Interpretation of So-Called Non-Thermal Biological Mobile Phone Effects. Journal of Electromagnetic Analysis and Applications, 8, 62-69. doi: 10.4236/jemaa.2016.83007. Environ Res. 2016 Apr 27;148:367-375. doi: 10.1016/j.envres.2016.04.018. [Epub ahead of print]**

Indications exist that mobile phones may cause non-specific biological effects. They are classified as being of implausible non-thermal nature due to low quantum energy and low specific absorption rate levels, even if considering worst cases of "hot spots" of only millimeter size. The considerations of this paper demonstrate that classical theory of polarization offers a conventional interpretation for all three the existence of so far unclarified effects, their low reproducibility and their low intensity. The basis of this explanation is given by the assumption that hot spots contain even hotter "nano spots" on a molecular level according to well known mechanisms of γ-relaxation. In this paper, the concept is put for discussion assuming a heterogeneous system that consists of water molecules as well as larger-sized functional molecules. A consistent interpretation through temperature increase on the level of nanometer sized molecular compounds promises to favor interdisciplinary discussions with respect to safety regulations.

**Phelan AM, Lange DG, Kues HA, Lutty GA, Modification of membrane fluidity in melanin-containing cells by low-level microwave radiation. Bioelectromagnetics13(2):131-146, 1992.**

The treatment of a B16 melanoma cell line with 2.45-GHz pulsed microwaves (10 mW/cm2, 10-microseconds pulses at 100 pps, 1-h exposure; SAR, 0.2 W/kg) resulted in changes of membrane ordering as measured by EPR (electron paramagnetic resonance) reporter techniques. The changes reflected a shift from a more fluid-like phase to a more solid (ordered) state of the cell membrane. Exposure of artificially prepared liposomes that were reconstituted with melanin produced similar results. In contrast, neither B16 melanoma cells treated with 5-Bromo-2-Deoxyuridine (3 micrograms/day x 7 days) to render them amelanotic, nor liposomes prepared without melanin, exhibited the microwave-facilitated increase of ordering. Inhibition of the ordering was achieved by the use of superoxide dismutase (SOD), which strongly implicates oxygen radicals as a cause of the membrane changes. The data indicate that a significant, specific alteration of cell-membrane ordering followed microwave exposure. This alteration was unique to melanotic membranes and was due, at least in part, to the generation of oxygen radicals.

**Phelan AM, Neubauer CF, Timm R, Neirenberg J, Lange DG, Athermal alterations in the structure of the canalicular membrane and ATPase activity induced by thermal levels of microwave radiation. Radiat Res 137(1):52-58, 1994.**

Sprague-Dawley rats (200-250 g) were exposed 30 min/day for 4 days to thermogenic levels (rectal temperature increase of 2.2 degrees C) of microwave radiation [2.45 GHz, 80 mW/cm2, continuous-wave mode (CW)] or to a radiant heat source resulting in an equivalent increase in body temperature of 2.2 degrees C. On the fifth day after the 4 days of exposure to microwave radiation, the animals were sacrificed and their livers removed. The canalicular membranes were isolated and evaluated for adenosinetriphosphatase (ATPase) activity, total fatty acid composition and membrane fluidity characteristics. Mg(++)-ATPase activity (Vmax) decreased by 48.5% in the group exposed to microwave radiation, with no significant change in the group exposed to radiant heat. The decrease in Mg(++)-ATPase was partially compensated by a concomitant increase in Na+/K(+)-ATPase activity (170% increase in Vmax over control) in animals exposed to microwave radiation, while no change occurred in the group exposed to radiant heat. This alteration in ATPase activity in the group exposed to microwave radiation is associated with a large decrease in the ratio of saturated to unsaturated fatty acids. Conversely, the group exposed to radiant heat had an increase in the ratio of saturated to unsaturated fatty acids. The most dramatic changes were found in the levels of arachidonic acid. Finally, the electron paramagnetic resonance (EPR) spin label technique used to measure the fluidity of the canalicular membranes of the animals in the three groups (sham, microwave radiation and radiant heat) indicated that the results were different in the three groups, reflecting the changes found in their fatty acid composition. The physiological response to "equivalent" thermal loads in rats is expressed differently for different types of energy sources. Possible mechanisms producing these divergent thermogenic responses are discussed.

**Phillips, J.L., Ivaschuk, O., Ishida-Jones, T., Jones, R.A., Campbell-Beachler, M. and Haggren, W. DNA damage in Molt-4 T- lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. Bioelectrochem. Bioenerg. 45:103-110, 1998.**

Molt-4 T-lymphoblastoid cells have been exposed to pulsed signals at cellular telephone frequencies of 813.5625 MHz (iDEN signal) and 836.55 MHz (TDMA signal). These studies were performed at low SAR (average = 2.4 and 24 microwatt/g for iDEN and 2.6 and 26 microwatt/g for TDMA) in studies designed to look for athermal RF effects. The alkaline comet, or single cell gel electrophoresis, assay was employed to measure DNA single-strand breaks in cell cultures exposed to the radiofrequency (RF) signal as compared to concurrent sham-exposed cultures. Tail moment and comet extent were calculated as indicators of DNA damage. Statistical differences in the distribution of values for tail moment and comet extent between exposed and control cell cultures were evaluated with the SKolmogorov-Smirnoff distribution test. Data points for all experiments of each exposure condition were pooled and analyzed as single groups. It was found that: 1) exposure of cells to the iDEN signal at an SAR of 2.4 microwatt/g for 2 h or 21 h significantly decreased DNA damage; 2) exposure of cells to the TDMA signal at an SAR of 2.6 microwatt/g for 2 h and 21 h significantly decreased DNA damage; 3) exposure of cells to the iDEN signal at an SAR of 24 microwatt/g for 2 h and 21 h significantly increased DNA damage; 4) exposure of cells to the TDMA signal at an SAR of 26 microwatt/g for 2 h significantly decreased DNA damage. The data indicate a need to

study the effects of exposure to RF signals on direct DNA damage and on the rate at which DNA damage is repaired.

**Philippova TM, Novoselov VI, Alekseev SI, Influence of microwaves on different types of receptors and the role of peroxidation of lipids on receptor-protein shedding. Bioelectromagnetics 15(3):183-192, 1994.**

The effects of a continuous wave or pulse-modulated, 900 MHz microwave field were studied by in vitro assays of rat chemoreceptors. The pulsed field was modulated as rectangular waves at rates of 1, 6, 16, 32, 75, or 100 pps. The pulse-period to pulse-duration ratio was 5 in all cases, and specific absorption rates (SARs) ranged from 0.5 to 18 W/kg. Binding of ligands to cell membranes was differentially affected by exposure to microwaves. For example, binding of H3-glutamic acid to hippocampal cells was not altered by a 15 min exposure to a continuous wave field at 1 W/kg, but binding of H3-dihydroalprenolol to liver-cell membranes of neonates underwent a fivefold decrease under the same field conditions. This effect was not dependent on modulation or on a change in the constant of stimulus-receptor binding but depended on a shedding of the membrane's receptor elements into solution. The magnitude of inhibition correlated with the oxygen concentration in the exposed suspension. Antioxidants (dithiothreitol and ionol) inhibited the shedding of receptor elements. The microwave exposure did not cause an accumulation of products from the peroxidation of lipids (POL). Ascorbate-dependent or non-enzymatic POL was not responsible for the inhibition, and POL was not found in other model systems. However, enzymatic POL mechanisms in localized areas of receptor binding remain a possibility.

**Pilla AA. Electromagnetic fields instantaneously modulate nitric oxide signaling in challenged biological systems.Biochem Biophys Res Commun. 426(3):330-333, 2012.**

This study shows that a non-thermal pulse-modulated RF signal (PRF), configured to modulate calmodulin (CaM) activation via acceleration of Ca(2+) binding kinetics, produced an immediate nearly 3-fold increase in nitric oxide (NO) from dopaminergic MN9D cultures ($P<0.001$). NO was measured electrochemically in real-time using a NO selective membrane electrode, which showed the PRF effect occurred within the first seconds after lipopolysaccharide (LPS) challenge. Further support that the site of action of PRF involves CaM is provided in human fibroblast cultures challenged with low serum and exposed for 15min to the identical PRF signal. In this case a CaM antagonist W-7 could be added to the culture 3h prior to PRF exposure. Those results showed the PRF signal produced nearly a two-fold increase in NO, which could be blocked by W-7 ($P<0.001$). To the authors' knowledge this is the first report of a real-time effect of non-thermal electromagnetic fields (EMF) on NO release from challenged cells. The results provide mechanistic support for the many reported bioeffects of EMF in which NO plays a role. Thus, in a typical clinical application for acute post operative pain, or chronic pain from, e.g., osteoarthritis, EMF therapy could be employed to modulate the dynamics of NO via Ca/CaM-dependent constitutive nitric oxide synthase (cNOS) in the target tissue. This, in turn, would modulate the dynamics of the signaling pathways the body uses in response to the various phases of healing after physical or chemical insult or injury.

**Pinto R, Lopresto V, Galloni P, Marino C, Mancini S, Lodato R, Pioli C, Lovisolo GA. Dosimetry of a set-up for the exposure of newborn mice to 2.45-GHZ WiFi frequencies. Radiat Prot Dosimetry. 140(4):326-332, 2010.**

This work describes the dosimetry of a two waveguide cell system designed to expose newborn mice to electromagnetic fields associated with wireless fidelity signals in the frequency band of 2.45 GHz. The dosimetric characterisation of the exposure system was performed both numerically and experimentally. Specific measures were adopted with regard to the increase in both weight and size of the biological target during the exposure period. The specific absorption rate (SAR, W kg(-1)) for 1 W of input power vs. weight curve was assessed. The curve evidenced an SAR pattern varying from <1 W kg(-1) to >6 W kg(-1) during the first 5 weeks of the life of mice, with a peak resonance phenomenon at a weight around 5 g. This curve was used to set the appropriate level of input power during experimental sessions to expose the growing mice to a defined and constant dose.

**Platano D, Mesirca P, Paffi A, Pellegrino M, Liberti M, Apollonio F, Bersani F, Aicardi G. Acute exposure to low-level CW and GSM-modulated 900 MHz radiofrequency does not affect Ba(2+) currents through voltage-gated calcium channels in rat cortical neurons. Bioelectromagnetics.28(8):599-607, 2007.**

We have studied the non-thermal effects of radiofrequency (RF) electromagnetic fields (EMFs) on Ba(2+) currents ($I_{{\rm Ba};{2+ } }$) through voltage-gated calcium channels (VGCC), recorded in primary cultures of rat cortical neurons using the patch-clamp technique. To assess whether low-level acute RF field exposure could modify the amplitude and/or the voltage-dependence of $I_{{\rm Ba};{2+ } }$, Petri dishes containing cultured neurons were exposed for 1-3 periods of 90 s to 900 MHz RF-EMF continuous wave (CW) or amplitude-modulated according to global system mobile communication standard (GSM) during whole-cell recording. The specific absorption rates (SARs) were 2 W/kg for CW and 2 W/kg (time average value) for GSM-modulated signals, respectively. The results obtained indicate that single or multiple acute exposures to either CW or GSM-modulated 900 MHz RF-EMFs do not significantly alter the current amplitude or the current-voltage relationship of $I_{{\rm Ba};{2+ } }$, through VGCC.

**Podkovkin VG, [The modification of the effect of microwave radiation on the biochemical processes in anaphylactic shock by using exposure to a weak and perturbed geomagnetic field]. Radiobiologiia 33(1):166-169, 1993.** [Article in Russian]

Repeated exposure of guinea pigs to microwave radiation (1 mW/cm2) caused in some animals inhibition of anaphylactic response accompanied by increasing the content of histamine, epinephrine and norepinephrine in the blood. This increase was more pronounced in irradiated guinea pigs died from anaphylactic shock than in nonirradiated animals. The long-term stay in the perturbed and weak geometric field reduced the effect induced by microwave radiation.

**Pologea-Moraru R, Kovacs E, Iliescu KR, Calota V, Sajin G. The effects of low level microwaves on the fluidity of photoreceptor cell membrane. Bioelectrochemistry**

**56(1-2):223-225, 2002.**

Due to the extensive use of electromagnetic fields in everyday life, more information is required for the detection of mechanisms of interaction and the possible side effects of electromagnetic radiation on the structure and function of the organism.In this paper, we study the effects of low-power microwaves (2.45 GHz) on the membrane fluidity of rod photoreceptor cells. The retina is expected to be very sensitive to microwave irradiation due to the polar character of the photoreceptor cells [Biochim. Biophys. Acta 1273 (1995) 217] as well as to its high water content [Stud. Biophys. 81 (1981) 39].

**Port M, Abend M, Romer B, Van Beuningen D. Influence of high-frequency electromagnetic fields on different modes of cell death and gene expression. Int J Radiat Biol. 79(9):701-708, 2003.**

PURPOSE: International thresholds for exposure to non-ionizing radiation leading to non-thermal effects were conservatively set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). The aim of this study was to examine whether biological effects such as different modes of cell death and gene expression modifications related to tumorgenesis are detectable above the threshold defined. MATERIALS AND METHODS: Human leukaemia cells (HL-60) grown in vitro were exposed to electromagnetic fields (EMF; t 1/2(r) about 1 ns; field strength about 25 times higher than the ICNIRP reference levels for occupational exposure) leading to non-thermal effects using a high-voltage-improved GTEM cell 5302 (EMCO) connected to a pulse generator NP20 (C = 1 nF, U(Load) = 20kV). HL-60 cells were harvested at 0, 24, 48 and 72 h after radiation exposure. Micronuclei, apoptosis and abnormal cells (e.g. necrosis) were determined using morphological criteria. In parallel, the expression of 1176 genes was measured using Atlas Human 1.2. Array. Based on high data reproducibility calculated from two independent experiments (> 99%), array analysis was performed. RESULTS: No significant change in apoptosis, micronucleation, abnormal cells and differential gene expression was found. CONCLUSIONS: Exposure of HL-60 cells to EMFs 25 times higher than the ICNIRP reference levels for occupational exposure failed to induce any changes in apoptosis, micronucleation, abnormal morphologies and gene expression. Further experiments using EMFs above the conservatively defined reference level set by the ICNIRP may be desirable.

**Poulletier de Gannes F, Haro E, Hurtier A, Taxile M, Ruffié G, Billaudel B, Veyret B, Lagroye I. Effect of exposure to the edge signal on oxidative stress in brain cell models. Radiat Res. 175(2):225-230, 2011.**

In this study we investigated the effect of the Enhanced Data rate for GSM Evolution (EDGE) signal on cells of three human brain cell lines, SH-SY5Y, U87 and CHME5, used as models of neurons, astrocytes and microglia, respectively, as well as on primary cortical neuron cultures. SXC-1800 waveguides (IT'IS-Foundation, Zürich, Switzerland) were modified for in vitro exposure to the EDGE signal radiofrequency (RF) radiation at 1800 MHz. Four exposure conditions were tested: 2 and 10 W/kg for 1 and 24 h. The production of reactive oxygen species (ROS) was measured by flow cytometry using the dichlorofluorescein diacetate (DCFH-DA) probe at the end of the 24-h exposure or 24 h after the 1-h exposure. Rotenone treatment was used as a positive control. All cells tested responded to rotenone treatment by increasing ROS

production. These findings indicate that exposure to the EDGE signal does not induce oxidative stress under these test conditions, including 10 W/kg. Our results are in agreement with earlier findings that RF radiation alone does not increase ROS production.

**Poulletier de Gannes F, Haro E, Hurtier A, Taxile M, Athane A, Ait-Aissa S, Masuda H, Percherncier Y, Ruffié G, Billaudel B, Dufour P, Veyret B, Lagroye I. Effect of in utero wi-fi exposure on the pre- and postnatal development of rats. Birth Defects Res B Dev Reprod Toxicol. 95(2):130-136, 2012.**

BACKGROUND: The increase in exposure to the Wireless Fidelity (Wi-Fi) wireless communication signal has raised public health concerns especially for young people. Animal studies looking at the effects of early life and prenatal exposure to this source of electromagnetic fields, in the radiofrequency (RF) range, on development and behavior have been considered as high priority research needs by the World Health Organization. METHODS: For the first time, our study assessed the effects of in utero exposure to a 2450 MHz Wi-Fi signal (2 hr/day, 6 days/week for 18 days) on pregnant rats and their pups. Three levels in terms of whole-body specific absorption rate were used: 0.08, 0.4, and 4 W/kg. The prenatal study on fetuses delivered by caesarean (P20) concerned five females/group. The dams and their offspring were observed for 28 days after delivery (15 females/group). RESULTS: For all test conditions, no abnormalities were noted in the pregnant rats and no significant signs of toxicity were observed in the pre- and postnatal development of the pups, even at the highest level of 4 W/kg. CONCLUSIONS: In the present study, no teratogenic effect of repeated exposures to the Wi-Fi wireless communication signal was demonstrated even at the highest level of 4 W/kg. The results from this screening study aimed at investigating Wi-Fi effects, strengthen the previous conclusions that teratology and development studies have not detected any noxious effects of exposures to mobile telephony-related RF fields at exposure levels below standard limits.

**Poulletier de Gannes F, Billaudel B, Haro E, Taxile M, Le Montagner L, Hurtier A, Ait Aissa S, Masuda H, Percherancier Y, Ruffié G, Dufour P, Veyret B, Lagroye I. Rat fertility and embryo fetal development: influence of exposure to the Wi-Fi signal. Reprod Toxicol. 36:1-5, 2013.**

In recent decades, concern has been growing about decreasing fecundity and fertility in the human population. Exposure to non-ionizing electromagnetic fields (EMF), especially radiofrequency (RF) fields used in wireless communications has been suggested as a potential risk factor. For the first time, we evaluated the effects of exposure to the 2450MHz Wi-Fi signal (1h/day, 6days/week) on the reproductive system of male and female Wistar rats, pre-exposed to Wi-Fi during sexual maturation. Exposure lasted 3 weeks (males) or 2 weeks (females), then animals were mated and couples exposed for 3 more weeks. On the day before delivery, the fetuses were observed for lethality, abnormalities, and clinical signs. In our experiment, no deleterious effects of Wi-Fi exposure on rat male and female reproductive organs and fertility were observed for 1h per days. No macroscopic abnormalities in fetuses were noted, even at the critical level of 4W/kg.

**Poulletier de Gannes F, Masuda H, Billaudel B, Poque-Haro E, Hurtier A, Lévêque P, Ruffié G, Taxile M, Veyret B, Lagroye I. Effects of GSM and UMTS mobile telephony signals on neuron degeneration and blood-brain barrier permeation in the rat brain. Sci Rep. 2017 Nov 14;7(1):15496. doi: 10.1038/s41598-017-15690-1.**

Blood-brain barrier (BBB) permeation and neuron degeneration were assessed in the rat brain following exposure to mobile communication radiofrequency (RF) signals (GSM-1800 and UMTS-1950). Two protocols were used: (i) single 2 h exposure, with rats sacrificed immediately, and 1 h, 1, 7, or 50 days later, and (ii) repeated exposures (2 h/day, 5 days/week, for 4 weeks) with the effects assessed immediately and 50 days after the end of exposure. The rats' heads were exposed at brain-averaged specific absorption rates (BASAR) of 0.026, 0.26, 2.6, and 13 W/kg. No adverse impact in terms of BBB leakage or neuron degeneration was observed after single exposures or immediately after the end of repeated exposure, with the exception of a transient BBB leakage (UMTS, 0.26 W/kg). Fifty days after repeated exposure, the occurrence of degenerating neurons was unchanged on average. However, a significant increased albumin leakage was detected with both RF signals at 13 W/kg. In this work, the strongest, delayed effect was induced by GSM-1800 at 13 W/kg. Considering that 13 W/kg BASAR in the rat head is equivalent to 4 times as much in the human head, deleterious effects may occur following repeated human brain exposure above 50 W/kg.

**Poulsen AH, Friis S, Johansen C, Jensen A, Frei P, Kjær SK, Dalton SO, Schüz J. Mobile Phone Use and the Risk of Skin Cancer: A Nationwide Cohort Study in Denmark. Am J Epidemiol. 2013 Jun 20. [Epub ahead of print]**

The International Agency for Research on Cancer has classified radiofrequency radiation as possibly carcinogenic. Previous studies have focused on intracranial tumors, although the skin receives much radiation. In a nationwide cohort study, 355,701 private mobile phone subscribers in Denmark from 1987 to 1995 were followed up through 2007. We calculated incidence rate ratios (IRRs) for melanoma, basal cell carcinoma, and squamous cell carcinoma by using Poisson regression models adjusted for age, calendar period, educational level, and income. Separate IRRs for head/neck tumors and torso/leg tumors were compared (IRRs) to further address potential confounders. We observed no overall increased risk for basal cell carcinoma, squamous cell carcinoma, or melanoma of the head and neck. After a follow-up period of at least 13 years, the IRRs for basal cell carcinoma and squamous cell carcinoma remained near unity. Among men, the IRR for melanoma of the head and neck was 1.20 (95% confidence interval: 0.65, 2.22) after a minimum 13-year follow-up, whereas the corresponding IRR for the torso and legs was 1.16 (95% confidence interval: 0.91, 1.47), yielding an IRR of 1.04 (95% confidence interval: 0.54, 2.00). A similar risk pattern was seen among women, though it was based on smaller numbers. In this large, population-based cohort study, little evidence of an increased skin cancer risk was observed among mobile phone users.

**Poysti L, Rajalin S, Summala H. Factors influencing the use of cellular (mobile) phone during driving and hazards while using it. Accid Anal Prev. 37(1):47-51, 2005.**

This study addressed the strategic decisions on not using a mobile phone at all while driving, and phone-related driving hazards among those drivers who do use one, reflecting tactical and operational level processes. A representative sample of 834 licensed drivers who own a mobile phone were interviewed on their phone use and hazards, background factors, and self-image as a driver. Logistic regression models indicated that older age, female gender, smaller amount of driving, and occupation promoted not using a phone at all while driving. Additionally, low skill level and high safety motivation contributed to this decision. Among those who used a phone while driving, exposure to risk in terms of higher mileage and more extensive phone use increased phone-related hazards, as also did young age, leading occupational position, and low safety motivation. Neither gender nor driving skill level had any effect on such self-reported hazards. This study clearly indicates that potential risks of mobile phones are being controlled at many levels, by strategic as well as tactical decisions and, consequently, phone-related accidents have not increased in line with the use of the mobile phones.

**Preece, AW, Iwi, G, Davies-Smith, A, Wesnes, K, Butler, S, Lim, E, Varey, A, Effect of a 915-MHz simulated mobile phone signal on cognitive function in man. Int J Radiat Biol 75(4):447-456, 1999.**

PURPOSE: To examine whether a simulated mobile telephone transmission at 915 MHz has an effect on cognitive function in man. MATERIALS AND METHODS: Thirty-six subjects in two groups were each given two training sessions and then three test sessions in a randomized three-way cross-over design. About 1 W mean power at 915 MHz from a quarter-wave antenna mounted on a physical copy of an analogue phone, as a sine wave, or modulated at 217 Hz with 12.5% duty cycle, or no power, was applied to the left squamous temple region of the subjects while they undertook a series of cognitive function tests lasting approximately 25-30 min. The second group was investigated for sleep, consumption of alcohol and beverages, and any other substances that might affect performance. RESULTS: In both groups, the only test affected was the choice reaction time and this showed as an increase in speed (a decrease in reaction time). There were no changes in word, number or picture recall, or in spatial memory. While an effect of visit-order was evident suggesting a learning effect of repeat tests, the design of the study allowed for this. Additionally, there was no systematic error introduced as a result of consumption of substances or sleep time. CONCLUSIONS: There was evidence of an increase in responsiveness, strongly in the analogue and less in the digital simulation, in choice reaction time. This could be associated with an effect on the angular gyrus that acts as an interface between the visual and speech centres and which lies directly under and on the same side as the antenna. Such an effect could be consistent with mild localized heating, or possibly a non-thermal response, which is nevertheless power-dependent.

**Preece AW, Goodfellow S, Wright MG, Butler SR, Dunn EJ, Johnson Y, Manktelow TC, Wesnes K.Effect of 902 MHz mobile phone transmission on cognitive function in children. Bioelectromagnetics.Suppl 7:S138-43, 2005.**

We examine whether a standard mobile exposure at 902 MHz has a significant effect on cognitive function in 18 children 10-12 years of age. These were in a single group in

which each child was given a single training session and then three test sessions in a randomized, three-way crossover design, using the cognitive drug research (CDR) cognitive assessment system. Exposures were 0, 0.025, or 0.25 W from a standard Nokia 3110 mobile phone handset mounted on a plastic headset in normal use position. The results of testing showed that the baseline (0 W) performance for the reaction time measurements was considerably slower than for the comparable measures in adult. There was a tendency for reaction time to be shorter during exposure to radiation than in the sham (baseline) condition, an effect that was most marked for simple reaction time. However, no effects reached statistical significance after Bonferroni correction. Therefore, we conclude that this study on 18 children did not replicate our earlier finding in adults that exposure to microwave radiation was associated with a reduction in reaction time. It should be noted that the present study investigated the effects of radiation from a GSM handset, whereas in our previous study the effect on reaction time was observed only with a more powerful analogue handset.

**Preece AW, Georgiou AG, Dunn EJ, Farrow S. Health response of two communities to military antennae in Cyprus. Occup Environ Med.64(6):402-8,2007.**

OBJECTIVES: This study investigated concerns that have been raised about past and future health effects caused by high power transmissions of high frequency (7 to 30MHz) radio waves from military antenna systems at Akrotiri, Cyprus. METHODS: A cross-sectional study of three villages (two exposed, one unexposed) collected longitudinal and short-term radiofrequency (RF) measurements. Health data were collected using questionnaires containing information on demographic factors, specific illnesses, general health (SF36 well-being questionnaire), reproductive history, childhood illnesses, risk perception and mortality. Analysis was with SPSS v11.5 using cross tabulations of non-parametric data and tests for significance. Key health outcomes were subjected to logistic regression analysis. RESULTS: Field strengths within the two 'exposed' villages were a maximum of 0.30 Vm-1 from the 17.6 MHz military transmissions and up to 1.4 Vm-1 from unspecified sources, mainly cell-phone frequencies. The corresponding readings in the control village were <0.01 Vm-1. Compared with the control village there were highly significant differences in the reporting of migraine (OR 2.7 p0.0001), headache (3.7 p0.001), and dizziness (2.7 p 0.0001). Residents of the exposed villages showed greater negative views of their health in all eight domains of the SF36. There were also higher levels of perceived risk, particularly to noise and electromagnetic (EM) 'pollution'. All three villages reported higher values of risk perception than a UK population. There was no evidence of birth abnormalities or differences in gynaecological or obstetric history. Numbers of cancers were too small to show differences. CONCLUSION: It was clear that even this close (1-3km) to powerful transmissions, the dominant sources of RF fields were cell-phone and national broadcast systems. There was no excess of cancer, birth defects or obstetric problems. There was heightened risk perception and a considerable excess of migraine, headache and dizziness, which appears to share a gradient with RF exposure. The authors report this association but suggest this is unlikely to be an effect of RF and more likely to be antenna visibility or aircraft noise.

**Prisco MG, Nasta F, Rosado MM, Lovisolo GA, Marino C, Pioli C. Effects of GSM-modulated radiofrequency electromagnetic fields on mouse bone marrow cells.**

**Radiat Res. 170(6):803-810, 2008.**

We examined the effects of in vivo exposure to a GSM-modulated 900 MHz RF field on the ability of bone marrow cells to differentiate, colonize lymphatic organs, and rescue lethally X-irradiated mice from death. X-irradiated mice were injected with medium alone or containing bone marrow cells from either RF-field-exposed (SAR 2 W/kg, 2 h/day, 5 days/ week, 4 weeks) or sham-exposed or cage control donor mice. Whereas all mice injected with medium alone died, mice that received bone marrow cells survived. Three and 6 weeks after bone marrow cell transplantation, no differences in thymus cellularity and in the frequencies of differentiating cell subpopulations (identified by CD4/CD8 expression) were observed among the three transplanted groups. Mitogen-induced thymocyte proliferation yielded comparable levels in all transplanted groups. As to the spleen, no effects of the RF-field exposure on cell number, percentages of B and T (CD4 and CD8) cells, B- and T-cell proliferation, and IFN-gamma production were found in transplanted mice. In conclusion, our results show no effect of in vivo exposure to GSM-modulated RF fields on the ability of bone marrow precursor cells to home and colonize lymphoid organs and differentiate in phenotypically and functionally mature T and B lymphocytes.

**Prochnow N, Gebing T, Ladage K, Krause-Finkeldey D, El Ouardi A, Bitz A, Streckert J, Hansen V, Dermietzel R. Electromagnetic field effect or simply stress? Effects of UMTS exposure on hippocampal longterm plasticity in the context of procedure related hormone release.PLoS One. 6(5):e19437, 2011.**

Harmful effects of electromagnetic fields (EMF) on cognitive and behavioural features of humans and rodents have been controversially discussed and raised persistent concern about adverse effects of EMF on general brain functions. In the present study we applied radio-frequency (RF) signals of the Universal Mobile Telecommunications System (UMTS) to full brain exposed male Wistar rats in order to elaborate putative influences on stress hormone release (corticosteron; CORT and adrenocorticotropic hormone; ACTH) and on hippocampal derived synaptic long-term plasticity (LTP) and depression (LTD) as electrophysiological hallmarks for memory storage and memory consolidation. Exposure was computer controlled providing blind conditions. Nominal brain-averaged specific absorption rates (SAR) as a measure of applied mass-related dissipated RF power were 0, 2, and 10 W/kg over a period of 120 min. Comparison of cage exposed animals revealed, regardless of EMF exposure, significantly increased CORT and ACTH levels which corresponded with generally decreased field potential slopes and amplitudes in hippocampal LTP and LTD. Animals following SAR exposure of 2 W/kg (averaged over the whole brain of 2.3 g tissue mass) did not differ from the sham-exposed group in LTP and LTD experiments. In contrast, a significant reduction in LTP and LTD was observed at the high power rate of SAR (10 W/kg). The results demonstrate that a rate of 2 W/kg displays no adverse impact on LTP and LTD, while 10 W/kg leads to significant effects on the electrophysiological parameters, which can be clearly distinguished from the stress derived background. Our findings suggest that UMTS exposure with SAR in the range of 2 W/kg is not harmful to critical markers for memory storage and

memory consolidation, however, an influence of UMTS at high energy absorption rates (10 W/kg) cannot be excluded.

**Prohofsky EW. RF absorption involving biological macromolecules. Bioelectromagnetics. 25(6):441-451, 2004.**

The fundamental intramolecular frequency of a globular protein can be obtained from the measurements of acoustic velocities of bulk protein matter. This lowest frequency for common size molecules is shown to be above several hundred GHz. All modes below this frequency would then be intermolecular modes or bulk modes of the molecule and surrounding matter or tissue. The lowest frequency modes of an extended DNA double helix are also shown to be bulk modes because of interaction with water. Only DNA modes, whose frequency is well above 4 GHz, can be intrahelical modes, that is, confined to the helix rather than in the helix plus surroundings. Near 4 GHz, they are heavily damped and, therefore, not able to resonantly absorb. Modes that absorb radio frequency (RF) below this frequency are bulk modes of the supporting matter. Bulk modes rapidly thermalize all absorbed energy. The implication of these findings for the possibility of athermal RF effects is considered. The applicability of these findings for other biological molecules is discussed.

**Pu, JS, Chen, J, Yang, YH, Bai, YQ, The effects of 3000 MHz microwave irradiation on electroencephalic energy and energy metabolism in mouse brain. Electro-and Magnetobiology 16:243-247, 1997.**

Mice were exposed to 3000 MHz PW 1h daily for 7 days, with long axes parallel to the magnetic field in an anechoic chamber. The average power density was 5mW/cm$^2$, and the estimated SAR was about 2 W/kg. There was no significant core temperature rise in the mice after exposure. After the last irradiation, mice were euthanized and the whole brain were frozen. Half of each brain were measured for SDH, and the other half for ATP. Results showed that the ATP in the brains and SDH in the hippocampus and hypothalamus in the irradiation group were significantly decreased as compared to the control. The authors suggested that the decrease in SDH caused the decrease in ATP.

**Pyrpasopoulou A, Kotoula V, Cheva A, Hytiroglou P, Nikolakaki E, Magras IN, Xenos TD, Tsiboukis TD, Karkavelas G. Bone morphogenetic protein expression in newborn rat kidneys after prenatal exposure to radiofrequency radiation. Bioelectromagnetics 25(3):216-227, 2004.**

Effects of nonthermal radiofrequency radiation (RFR) of the global system of mobile communication (GSM) cellular phones have been as yet mostly studied at the molecular level in the context of cellular stress and proliferation, as well as neurotransmitter production and localization. In this study, a simulation model was designed for the exposure of pregnant rats to pulsed GSM-like RFR (9.4 GHz), based on the different resonant frequencies of man and rat. The power density applied was 5 microW/cm2, in order to avoid thermal electromagnetic effects as much as possible. Pregnant rats were exposed to RFR during days 1-3 postcoitum (p.c.) (embryogenesis, pre-implantation) and days 4-7 p.c. (early organogenesis, peri-implantation). Relative expression and

localization of bone morphogenetic proteins (BMP) and their receptors (BMPR), members of a molecular family currently considered as major endocrine and autocrine morphogens and known to be involved in renal development, were investigated in newborn kidneys from RFR exposed and sham irradiated (control) rats. Semi-quantitative duplex RT-PCR for BMP-4, -7, BMPR-IA, -IB, and -II showed increased BMP-4 and BMPR-IA, and decreased BMPR-II relative expression in newborn kidneys. These changes were statistically significant for BMP-4, BMPR-IA, and -II after exposure on days 1-3 p.c. (P <.001 each), and for BMP-4 and BMPR-IA after exposure on days 4-7 p.c. (P <.001 and P =.005, respectively). Immunohistochemistry and in situ hybridization (ISH) showed aberrant expression and localization of these molecules at the histological level. Our findings suggest that GSM-like RFR interferes with gene expression during early gestation and results in aberrations of BMP expression in the newborn. These molecular changes do not appear to affect renal organogenesis and may reflect a delay in the development of this organ. The differences of relative BMP expression after different time periods of exposure indicate the importance of timing for GSM-like RFR effects on embryonic development.

**Qiao S, Peng R, Yan H, Gao Y, Wang C, Wang S, Zou Y, Xu X, Zhao L, Dong J, Su Z, Feng X, Wang L, Hu X. Reduction of Phosphorylated Synapsin I (Ser-553) Leads to Spatial Memory Impairment by Attenuating GABA Release after Microwave Exposure in Wistar Rats. PLoS One. 2014 Apr 17;9(4):e95503. doi: 10.1371/journal.pone.0095503. eCollection 2014.**

BACKGROUND: Abnormal release of neurotransmitters after microwave exposure can cause learning and memory deficits. This study investigated the mechanism of this effect by exploring the potential role of phosphorylated synapsin I (p-Syn I). METHODS: Wistar rats, rat hippocampal synaptosomes, and differentiated (neuronal) PC12 cells were exposed to microwave radiation for 5 min at a mean power density of 30 mW/cm2. Sham group rats, synaptosomes, and cells were otherwise identically treated and acted as controls for all of the following post-exposure analyses. Spatial learning and memory in rats was assessed using the Morris Water Maze (MWM) navigation task. The protein expression and presynaptic distribution of p-Syn I and neurotransmitter transporters were examined via western blotting and immunoelectron microscopy, respectively. Levels amino acid neurotransmitter release from rat hippocampal synaptosomes and PC12 cells were measured using high performance liquid chromatograph (HPLC) at 6 hours after exposure, with or without synapsin I silencing via shRNA transfection. RESULTS: In the rat experiments, there was a decrease in spatial memory performance after microwave exposure. The expression of p-Syn I (ser-553) was decreased at 3 days post-exposure and elevated at later time points. Vesicular GABA transporter (VGAT) was significantly elevated after exposure. The GABA release from synaptosomes was attenuated and p-Syn I (ser-553) and VGAT were both enriched in small clear synaptic vesicles, which abnormally assembled in the presynaptic terminal after exposure. In the PC12 cell experiments, the expression of p-Syn I (ser-553) and GABA release were both attenuated at 6 hours after exposure. Both microwave exposure and p-Syn I silencing reduced GABA release and maximal reduction was found for the combination of the two, indicating a synergetic effect. CONCLUSION: p-Syn I (ser-553) was found to play a key

role in the impaired GABA release and cognitive dysfunction that was induced by microwave exposure.

**Qin F, Zhang J, Cao H, Yi C, Li JX, Nie J, Chen LL, Wang J, Tong J.Effects of 1800-MHz radiofrequency fields on circadian rhythm of plasma melatonin and testosterone in male rats. J Toxicol Environ Health A.75(18):1120-1128, 2012.**

Radiofrequency fields (RF) at 1800 MHz are known to affect melatonin (MEL) and testosterone in male rats, but it remains to be determined whether RF affected circadian rhythm of these plasma hormones. Male Sprague-Dawley rats were exposed to 1800-MHz RF at 208 μw/cm² power density (SAR: 0.5762 W/kg) at different zeitgeber (ZT) periods of the day, including 0 (ZT0), 4 (ZT4), 8 (ZT8), 12 (ZT12), 16 (ZT16), and 20 (ZT20) h. RF exposure was 2 h/d for 32 d. From each rat, the concentrations of plasma MEL and testosterone were determined in plasma after RF exposure and compared with controls. The results confirmed the existence of circadian rhythms in the synthesis of MEL and testosterone, but revealed an inverse relationship in peak phase of these rhythms. These rhythms were disturbed after exposure to RF, with the effect being more pronounced on MEL than testosterone. The most pronounced effect of RF exposure on MEL and testosterone appears to be in rats exposed to RF at ZT 16 and ZT0 h, respectively. Data suggest that regulation of testosterone is controlled by MEL and that MEL is more sensitive to RF exposure.

**Qin F, Zhang J, Cao H, Guo W, Chen L, Shen O, Sun J, Yi C, Li J, Wang J, Tong J. Circadian alterations of reproductive functional markers in male rats exposed to 1800-MHz radiofrequency field. Chronobiol Int. 2013 Oct 11. [Epub ahead of print]**

In this study, we explored the circadian effects of daily radiofrequency field (RF) exposure on reproductive functional markers in adult male Sprague-Dawley rats. Animals in circadian rhythm (as indicated by melatonin measurements), were divided into several groups and exposed to 1800 MHz RF at 205 μw/cm$^2$ power density (specific absorption rate 0.0405 W/kg) for 2 h/day for 32 days at different zeitgeber time (ZT) points, namely, ZT0, ZT4, ZT8, ZT12, ZT16 and ZT20. Sham-exposed animals were used as controls in the study. From each rat, testicular and epididymis tissues were collected and assessed for testosterone levels, daily sperm production and sperm motility, testis marker enzymes γ-GT and ACP, cytochrome P450 side-chain cleavage (p450cc) mRNA expression, and steroidogenic acute regulatory protein (StAR) mRNA expression. Via these measurements, we confirmed the existence of circadian rhythms in sham-exposed animals. However, rats exposed to RF exhibited a disruption of circadian rhythms, decreased testosterone levels, lower daily sperm production and sperm motility, down-regulated activity of γ-GT and ACP, as well as altered mRNA expression of cytochrome P450 and StAR. All of these observations were more pronounced when rats were exposed to RF at ZT0. Thus, our findings indicate potential adverse effects of RF exposure on male reproductive functional markers, in terms of both the daily overall levels as well as the circadian rhythmicity.

**Qin F, Yuan H, Nie J, Cao Y, Tong J. [Effects of nano-selenium on cognition performance of mice exposed in 1800 MHz radiofrequency fields]. Wei Sheng Yan Jiu. 43(1):16-21, 2014. [Article in Chinese]**

OBJECTIVE: To study the effects of nano-selenium (NSe) on cognition performance of mice exposed to 1800 MHz radiofrequency fields (RF).METHODS: Male mice were randomly divided into four groups, control and nano-Se low, middle and high dose groups (L, M, H). Each group was sub-divided into three groups, RF 0 min, RF 30 min and RF 120 min. Nano-se solution (2, 4 and 8 microg/ml) were administered to mice of L, M, H groups by intra-gastric injection respectively, 0.5 ml/d for 50 days, the conctral group were administered with distilled water. At the 21st day, the mice in RF subgroup were exposed to 208 microW/cm2 1800 MHz radiofrequency fields (0, 30 and 120 min/d respectively) for 30 days. The cognitive ability of the mice were tested with Y-maze. Further, the levels of MDA, GABA, Glu, Ach and the activities of CAT and GSH-Px in cerebra were measured. RESULTS: Significant impairments in learning and memory ($P < 0.05$) were observed in the RF 120 min group, and with reduction of the Ach level and the activities of CAT and GSH-Px and increase of the content of GABA, Glu and MDA in cerebrum. NSe enhanced cognitive performance of RF mice, decreased GABA, Glu and MDA levels, increased Ach levels, GSH-Px and CAT activities. CONCLUSION: NSe could improve cognitive impairments of mice exposed to RF, the mechanism of which might involve the increasing antioxidation, decreasing free radical content and the changes of cerebra neurotransmitters.

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**Quock RM, Klauenberg BJ, Hurt WD, Merritt JH , Influence of microwave exposure on chlordiazepoxide effects in the mouse staircase test. Pharmacol Biochem Behav 47(4):845-849, 1994.**

To ascertain whether behavioral effects of benzodiazepines are altered by exposure to microwave radiation, we compared the performance of male, Swiss CD1 mice in the staircase test 30 min after pretreatment with chlordiazepoxide (8, 16, and 32 mg/kg, IP) and immediately following a 5-min exposure to microwave radiation (4, 12, and 36 W/kg, continuous wave, 1.8 or 4.7 GHz). In this paradigm, chlordiazepoxide reduction in the number of rears (NR) and number of steps ascended (NSA) is postulated to reflect anxiolytic and sedative drug effects, respectively. In sham-exposed mice, increasing doses of chlordiazepoxide increased NSA without affecting NR, increased NSA and decreased NR, then decreased both NSA and NR. Microwave exposure generally did not alter NSA or NR in mice pretreated with lower doses of chlordiazepoxide. However, in mice pretreated with 32 mg/kg chlordiazepoxide, exposure to 36 W/kg microwave radiation significantly reversed the reductions in NSA and NR at 4.7 GHz but not at 1.8 GHz. These findings indicate that exposure to microwave radiation can selectively alter effects of chlordiazepoxide in this psychopharmacological paradigm.

**Qureshi ST, Memon SA, Abassi AR, Sial MA, Bughio FA. Radiofrequency radiations induced genotoxic and carcinogenic effects on chickpea (Cicer arietinum L.) root tip cells. Saudi J Biol Sci. 24(4):883-891, 2017.**

Present study was under taken to predict the possible DNA damages (genotoxicity) and carcinogenicity caused by radiofrequency radiations (RF) to living tissue. Dry seeds of chickpea were treated with GSM cell phone (900 MHz) and laptop (3.31 GHz) as RF source for 24 and 48 h. Untreated seeds were used as (0 h) negative control and Gamma rays (250 Gray) as positive control. Plant chromosomal aberration assay was used as genotoxicity marker. All the treatment of RF inhibits seed germination percentage. 48 h laptop treatment has the most negative effect as compared to untreated control. A decrease was observed in mitotic index (M.I) and increase in abnormality index (A.I) with the increase in exposure duration and frequency in (Hz). Cell membrane damages were also observed only in 48 h exposure of cell phone and laptop (RF). Maximum nuclear membrane damages and ghost cells were again recorded in 48 h exposure of cell phone and laptop. The radiofrequency radiations (900 MHz and 3.31 GHz) are only genotoxic as they induce micronuclei, bi-nuclei, multi-nuclei and scattered nuclei but could be carcinogenic as 48 h incubation of RF induced fragmentation and ghost cells. Therefore cell phones and laptop should not be used unnecessarily to avoid possible genotoxic and carcinogenic effects.

**Qureshi MRA, Alfadhl Y, Chen X, Peyman A, Maslanyj M, Mann S. Assessment of exposure to radio frequency electromagnetic fields from smart utility meters in GB; part II) numerical assessment of induced SAR within the human body. Bioelectromagnetics. 2017 Nov 16.**

Human body exposure to radiofrequency electromagnetic waves emitted from smart meters was assessed using various exposure configurations. Specific energy absorption rate distributions were determined using three anatomically realistic human models. Each model was assigned with age- and frequency-dependent dielectric properties representing a collection of age groups. Generalized exposure conditions involving standing and sleeping postures were assessed for a home area network operating at 868 and 2,450 MHz. The smart meter antenna was fed with 1 W power input which is an overestimation of what real devices typically emit (15 mW max limit). The highest observed whole body specific energy absorption rate value was 1.87 mW $kg^{-1}$, within the child model at a distance of 15 cm from a 2,450 MHz device. The higher values were attributed to differences in dimension and dielectric properties within the model. Specific absorption rate (SAR) values were also estimated based on power density levels derived from electric field strength measurements made at various distances from smart meter devices. All the calculated SAR values were found to be very small in comparison to International Commission on Non-Ionizing Radiation Protection limits for public exposure.

**Qutob SS, Chauhan V, Bellier PV, Yauk CL, Douglas GR, Berndt L, Williams A, Gajda GB, Lemay E, Thansandote A, McNamee JP. Microarray gene expression profiling of a human glioblastoma cell line exposed in vitro to a 1.9 GHz pulse-modulated radiofrequency field. Radiat Res. 165(6):636-644, 2006.**

The widespread use of mobile phones has led to public concerns about the health effects associated with exposure to radiofrequency (RF) fields. The paramount concern of most persons relates to the potential of these fields to cause cancer. Unlike ionizing radiation,

RF fields used for mobile telecommunications (800-1900 MHz) do not possess sufficient energy to directly damage DNA. Most rodent bioassay and in vitro genotoxicity/mutation studies have reported that RF fields at non-thermal levels have no direct mutagenic, genotoxic or carcinogenic effects. However, some evidence has suggested that RF fields may cause detectable postexposure changes in gene expression. Therefore, the purpose of this study was to assess the ability of exposure to a 1.9 GHz pulse-modulated RF field for 4 h at specific absorption rates (SARs) of 0.1, 1.0 and 10.0 W/kg to affect global gene expression in U87MG glioblastoma cells. We found no evidence that non-thermal RF fields can affect gene expression in cultured U87MG cells relative to the nonirradiated control groups, whereas exposure to heat shock at 43 degrees C for 1 h up-regulated a number of typical stress-responsive genes in the positive control group. Future studies will assess the effect of RF fields on other cell lines and on gene expression in the mouse brain after in vivo exposure.

**Radicheva N, Mileva K, Georgieva B, Kristev I. Long-lasting (fatiguing) activity of isolated muscle fibres influenced by microwave electromagnetic field. Acta Physiol Pharmacol Bulg 26(1-2):37-40, 2001.**

The study aims to clarify the effect of exposure to microwave electromagnetic field (MMW) on muscle fibre fatigue. Repetitive stimulation with interstimulus interval of 200 ms was applied on isolated frog muscle fibre to evoke intracellular action potentials and twitch contractions. After their recording muscle fibre preparation was moved in a Petri dish with radius of 28 mm on open air for one hour exposure to continuous MMW with frequency of 2.45 GHz and power density of 20 mW/cm2. Then it was again moved in the chamber with non irradiated Ringer's solution at controlled temperature for the repeated records. After MMW exposure the changes in amplitude and time parameters characterizing fatigue were attenuated and delayed vs. controls. The twitch amplitude curve described an drastic fall in the first 5 sec followed by an increase and next decrease. MMW (2.45 GHz) have a specific, non-thermal influence on muscle fibre activity resulting in some resistance to fatigue.

**Radon K, Spegel H, Meyer N, Klein J, Brix J, Wiedenhofer A, Eder H, Praml G, Schulze A, Ehrenstein V, von Kries R, Nowak D. Personal dosimetry of exposure to mobile telephone base stations? An epidemiologic feasibility study comparing the Maschek dosimeter prototype and the Antennessa SP-090 system. Bioelectromagnetics.27(1):77-81, 2006.**

The aim of our study was to test the feasibility and reliability of personal dosimetry. Twenty-four hour exposure assessment was carried out in 42 children, 57 adolescents, and 64 adults using the Maschek dosimeter prototype. Self-reported exposure to mobile phone frequencies were compared with the dosimetry results. In addition, dosimetry readings of the Maschek device and those of the Antennessa DSP-090 were compared in 40 subjects. Self-reported exposures were not associated with dosimetry readings. The measurement results of the two dosimeters were in moderate agreement (r(Spearman) = 0.35; P = .03). Personal dosimetry for exposure to mobile phone base station might be feasible in epidemiologic studies. However, the consistency seems to be moderate.

**Radzievsky AA, Gordiienko OV, Szabo I, Alekseev SI, Ziskin MC. Millimeter wave-induced suppression of B16 F10 melanoma growth in mice: involvement of**

**endogenous opioids. Bioelectromagnetics. 25(6):466-473, 2004.**

Millimeter wave treatment (MMWT) is widely used in Eastern European countries, but is virtually unknown in Western medicine. Among reported MMWT effects is suppression of tumor growth. The main aim of the present "blind" and dosimetrically controlled experiments was to evaluate quantitatively the ability of MMWT to influence tumor growth and to assess whether endogenous opioids are involved. The murine experimental model of B16 F10 melanoma subcutaneous growth was used. MMWT characteristics were: frequency, 61.22 GHz; average incident power density, 13.3 x 10(-3) W/cm2; single exposure duration, 15 min; and exposure area, nose. Naloxone (1 mg/kg, intraperitoneally, 30 min prior to MMWT) was used as a nonspecific blocker of opioid receptors. Five daily MMW exposures, if applied starting at the fifth day following B16 melanoma cell injection, suppressed subcutaneous tumor growth. Pretreatment with naloxone completely abolished the MMWT-induced suppression of melanoma growth. The same course of 5 MMW treatments, if started on day 1 or day 10 following tumor inoculations, was ineffective. We concluded that MMWT has an anticancer therapeutic potential and that endogenous opioids are involved in MMWT-induced suppression of melanoma growth in mice. However, appropriate indications and contraindications have to be developed experimentally before recommending MMWT for clinical usage.

**Rağbetli MC, Aydinlioğlu A, Koyun N, Rağbetli C, Karayel M. Effect of prenatal exposure to mobile phone on pyramidal cell numbers in the mouse hippocampus: a stereological study. Int J Neurosci. 119(7):1031-1041, 2009.**

Because of the possible risk factor for the health, World Health Organization (WHO) recommended the study with animals on the developing nervous system concerning the exposure to radiofrequency (RF) field. A few studies related to hippocampal exposure are available, which indicate the impact of RF field in some parameters. The present study investigated the effect of exposure to mobile phone on developing hippocampus. Male and female Swiss albino mice were housed as control and mobile phone exposed groups. The pregnant animals in tested group were exposed to the effects of mobile phone in a room possessing the exposure system. The left hemispheres of the brains were processed by frozen microtome. The sections obtained were stained with Hematoxylin & Eosin. For cell counting by the optical fractionator method, a pilot study was first performed. Hippocampal areas were analyzed using Axiovision software running on a personal computer. The optical dissector, systematically and randomly spaced, was focused to the widest profile of the pyramidal cell nucleus. No significant difference in pyramidal cell number of total Cornu Ammonis (CA) sectors of hippocampus was found between the control and the mobile phone exposed groups ($p > .05$). It was concluded that further study is needed in this field due to popular use of mobile telephones and relatively high exposure to the developing brain.

**Rağbetlı MC, Aydinlioğlu A, Koyun N, Rağbetlı C, Bektas S, Ozdemır S. The effect of mobile phone on the number of Purkinje cells: A stereological study. Int J Radiat Biol.86(7):548-54, 2010**

Purpose: The World Health Organisation proposed an investigation concerning the

exposure of animals to radiofrequency fields because of the possible risk factor for health. At power frequencies there is evidence to associate both childhood leukaemia and brain tumours with magnetic field exposures. There is also evidence of the effect of mobile phone exposure on both cognitive functions and the cerebellum. Purkinje cells of the cerebellum are also sensitive to high dose microwave exposure in rats. The present study investigated the effect of exposure to mobile phone on the number of Purkinje and granule neurons in the developing cerebellum. Material and methods: Male and female Swiss albino mice were housed as control and mobile phone-exposed groups. Pregnant animals in the experimental group were exposed to Global System for Mobile Communication (GSM) mobile phone radiation at 890-915 MHz at 0.95 W/Kg specific absorption rate (SAR). The cerebella were processed by frozen microtome. The sections obtained were stained with Haematoxylin-eosin and cresyl violet. For cell counting by the optical fractionator method, a pilot study was firstly performed. Cerebellar areas were analysed by using Axiovision software running on a personal computer. The optical dissectors were systematically spaced at random, and focused to the widest profile of the neuron cell nucleus. Results: A significant decrease in the number of Purkinje cells and a tendency for granule cells to increase in cerebellum was found. Conclusion: Further studies in this area are needed due to the popular use of mobile telephones and relatively high exposure on developing brain.

**Rago R, Salacone P, Caponecchia L, Sebastianelli A, Marcucci I, Calogero AE, Condorelli R, Vicari E, Morgia G, Favilla V, Cimino S, Arcoria AF, La Vignera S. The semen quality of the mobile phone users. J Endocrinol Invest. 36(11):970-974, 2013.**

BACKGROUND: The increased use of mobile phones, the media's attention for general health, and the increase of idiopathic male infertility suggest to investigate the possible consequences of an excessive use of mobile phones on semen quality. AIM: To evaluate the conventional and some of the main biofunctional sperm parameters in healthy men according to the different use of the mobile phone. SUBJECTS AND METHODS: All the enrolled subjects in this study were divided into four groups according to their active cell phone use: group A= no use (no.=10 subjects); group B= <2 h/day (no.=16); group C= 2-4 h/day (no.=17); and group D= >4 h/day (no.=20). Among the subjects of the group D (>4 h/day), a further evaluation was made between the "trousers users"(no.=12) and "shirt users"(no.=8), and they underwent semen collection to evaluate conventional and biofunctional sperm parameters (density, total count, morphology, progressive motility, apoptosis, mithocondrial membrane potential, chromatin compaction, DNA fragmentation). RESULTS:  None of the conventional sperm parameters examined were significantly altered. However, the group D and the trousers users showed a higher percentage of sperm DNA fragmentation compared to other groups. CONCLUSION: These results suggest that the sperm DNA fragmentation could represent the only parameter significantly altered in the subjects who use the mobile phone for more than 4 h/day and in particular for those who use the device in the pocket of the trousers.

**Ragy MM. Effect of exposure and withdrawal of 900-MHz-electromagnetic waves on brain, kidney and liver oxidative stress and some biochemical parameters in male rats. Electromagn Biol Med. 2014 Apr 8. [Epub ahead of print]**

Increasing use of mobile phones in daily life with increasing adverse effects of electromagnetic radiation (EMR), emitted from mobile on some physiological processes, cause many concerns about their effects on human health. Therefore, this work was designed to study the effects of exposure to mobile phone emits 900-MHz EMR on the brain, liver and kidney of male albino rats. Thirty male adult rats were randomly divided into four groups (10 each) as follows: control group (rats without exposure to EMR), exposure group (exposed to 900-MHz EMR for 1 h/d for 60 d) and withdrawal group (exposed to 900-MHz electromagnetic wave for 1 h/d for 60 d then left for 30 d without exposure). EMR emitted from mobile phone led to a significant increase in malondialdehyde (MDA) levels and significant decrease total antioxidant capacity (TAC) levels in brain, liver and kidneys tissues. The sera activity of alanine transaminase (ALT), aspartate aminotransferase (AST), urea, creatinine and corticosterone were significantly increased ($p < 0.05$), while serum catecholamines were insignificantly higher in the exposed rats. These alterations were corrected by withdrawal. In conclusion, electromagnetic field emitting from mobile phone might produce impairments in some biochemicals changes and oxidative stress in brain, liver and renal tissue of albino rats.

**Ramundo-Orlando A, Liberti M, Mossa G, D'Inzeo G. Effects of 2.45 GHz microwave fields on liposomes entrapping glycoenzyme ascorbate oxidase: evidence for oligosaccharide side chain involvement. Bioelectromagnetics. 25(5):338-345, 2004.**

Previous observations reported by our group indicate that 2.45 GHz microwave fields at specific absorption rate (SAR) of 5.6 W/kg reduce the enzyme activity rate of ascorbate oxidase (AO) trapped in liposomes. In this study, we report dose-response studies on these AO containing liposomes irradiated at different SAR values (1.4, 2.8, 4.2, and 5.6 W/kg). No response was observed for SAR below 5.6 W/kg. Liposomes entrapping functional AO in its deglycated form (AO-D) were also used. In this case, no MW related enzyme activity changes were observed, demonstrating a direct involvement of oligosaccharide chains of AO. Furthermore, the catalytic properties of both AO and AO-D were not impaired by MW irradiation, neither in homogeneous solution nor loaded in liposomes, excluding possible changes in the conformation of enzyme as a mechanism. Our results suggest that the oligosaccharide chains of AO are critical to elicit the microwave observed effects on lipid membrane.

**Rao VS, Titushkin IA, Moros EG, Pickard WF, Thatte HS, Cho MR. Nonthermal effects of radiofrequency-field exposure on calcium dynamics in stem cell-derived neuronal cells: elucidation of calcium pathways. Radiat Res. 169(3):319-329, 2008.**

Intracellular Ca(2+) spikes trigger cell proliferation, differentiation and cytoskeletal reorganization. In addition to Ca(2+) spiking that can be initiated by a ligand binding to its receptor, exposure to electromagnetic stimuli has also been shown to alter Ca(2+) dynamics. Using neuronal cells differentiated from a mouse embryonic stem cell line and a custom-built, frequency-tunable applicator, we examined in real time the altered Ca(2+) dynamics and observed increases in the cytosolic Ca(2+) in

response to nonthermal radiofrequency (RF)-radiation exposure of cells from 700 to 1100 MHz. While about 60% of control cells (not exposed to RF radiation) were observed to exhibit about five spontaneous Ca(2+) spikes per cell in 60 min, exposure of cells to an 800 MHz, 0.5 W/kg RF radiation, for example, significantly increased the number of Ca(2+) spikes to 15.7 +/- 0.8 ($P < 0.05$). The increase in the Ca(2+) spiking activities was dependent on the frequency but not on the SAR between 0.5 to 5 W/kg. Using pharmacological agents, it was found that both the N-type Ca(2+) channels and phospholipase C enzymes appear to be involved in mediating increased Ca(2+) spiking. Interestingly, microfilament disruption also prevented the Ca(2+) spikes. Regulation of Ca(2+) dynamics by external physical stimulation such as RF radiation may provide a noninvasive and useful tool for modulating the Ca(2+)-dependent cellular and molecular activities of cells seeded in a 3D environment for which only a few techniques are currently available to influence the cells.

**Raslear TG, Akyel Y, Bates F, Belt M, Lu ST, Temporal bisection in rats: the effects of high-peak-power pulsed microwave irradiation. Bioelectromagnetics 14(5):459-478, 1993.**

The effects of high-peak-power, pulsed microwaves on a time perception and discrimination task were studied in rats. Exposures were performed with the TEMPO exposure system, which produces an 80 nanosecond pulse with peak-power levels in excess of 700 megawatts. The ability to expose animals to such fields within a controlled environment is unique. As determined by calorimetry, a maximal, whole-body-averaged, specific-absorption rate of 0.072 W/kg was produced. Thus exposures were well below a recommended SAR limit of 0.4 W/kg. Power levels of transmitted microwaves were varied over a 50 dB range to obtain ascending and descending dose-response functions for each of the behavioral measures. Measures of time perception, response bias, and total trials did not change with power level. Dose-response effects were observed for discriminability (ability to distinguish between durations), session time, and trial completions (null responses, failures to respond on a trial). Covarying sound and X-ray exposures produced by TEMPO did not reliably correlate with the observed microwave effects. The observation of repeatable dose-response effects on discriminability and null responses indicates that the microwave exposures were affecting cognitive function in the rats, particularly the decision-making process.

**Ray S, Behari J, Physiological changes in rats after exposure to low levels of microwaves. Radiat Res 123(2):199-202, 1990.**

The effects of exposure to sublethal levels of microwaves were studied. Young albino rats of both sexes were exposed for 60 days to 7.5-GHz microwaves (1.0-KHz square wave modulation, average power 0.6 mW/cm2) for 3 h daily. During and after microwave exposure several physiological parameters were measured in both control and exposed animals. It was found that the animals exposed to microwaves tended to eat and drink less and thus showed a smaller gain in body weight. Some of the hematological parameters and organ weights were also significantly different. It is proposed that a nonspecific stress response due to microwave exposure and mediated through the central nervous system is responsible for the observed physiological changes.

**Razavinasab M, Moazzami K, Shabani M. Maternal mobile phone exposure alters intrinsic electrophysiological properties of CA1 pyramidal neurons in rat offspring. Toxicol Ind Health. 2014 Mar 6. [Epub ahead of print]**

Some studies have shown that exposure to electromagnetic field (EMF) may result in structural damage to neurons. In this study, we have elucidated the alteration in the hippocampal function of offspring Wistar rats (n = 8 rats in each group) that were chronically exposed to mobile phones during their gestational period by applying behavioral, histological, and electrophysiological tests. Rats in the EMF group were exposed to 900 MHz pulsed-EMF irradiation for 6 h/day. Whole cell recordings in hippocampal pyramidal cells in the mobile phone groups did show a decrease in neuronal excitability. Mobile phone exposure was mostly associated with a decrease in the number of action potentials fired in spontaneous activity and in response to current injection in both male and female groups. There was an increase in the amplitude of the afterhyperpolarization (AHP) in mobile phone rats compared with the control. The results of the passive avoidance and Morris water maze assessment of learning and memory performance showed that phone exposure significantly altered learning acquisition and memory retention in male and female rats compared with the control rats. Light microscopy study of brain sections of the control and mobile phone-exposed rats showed normal morphology.Our results suggest that exposure to mobile phones adversely affects the cognitive performance of both female and male offspring rats using behavioral and electrophysiological techniques.

**Redelmeier DA, Tibshirani RJ, Association between cellular-telephone calls and motor vehicle collisions. N Engl J Med 13;336(7):453-458, 1997.**

BACKGROUND: Because of a belief that the use of cellular telephones while driving may cause collisions, several countries have restricted their use in motor vehicles, and others are considering such regulations. We used an epidemiologic method, the case-crossover design, to study whether using a cellular telephone while driving increases the risk of a motor vehicle collision. METHODS: We studied 699 drivers who had cellular telephones and who were involved in motor vehicle collisions resulting in substantial property damage but no personal injury. Each person's cellular-telephone calls on the day of the collision and during the previous week were analyzed through the use of detailed billing records. RESULTS: A total of 26,798 cellular-telephone calls were made during the 14-month study period. The risk of a collision when using a cellular telephone was four times higher than the risk when a cellular telephone was not being used (relative risk, 4.3; 95 percent confidence interval, 3.0 to 6.5). The relative risk was similar for drivers who differed in personal characteristics such as age and driving experience; calls close to the time of the collision were particularly hazardous (relative risk, 4.8 for calls placed within 5 minutes of the accident, as compared with 1.3 for calls placed more than 15 minutes before the accident; P<0.001); and units that allowed the hands to be free (relative risk, 5.9) offered no safety advantage over hand-held units (relative risk, 3.9; P not significant). Thirty-nine percent of the drivers called emergency services after the collision, suggesting that having a cellular telephone may have had advantages in the aftermath of an event. CONCLUSIONS: The use of cellular telephones in motor vehicles is associated with a quadrupling of the risk of a collision during the brief time interval involving a call.

Decisions about regulation of such telephones, however, need to take into account the benefits of the technology and the role of individual responsibility.

**Redmayne M, Inyang I, Dimitriadis C, Benke G, Abramson MJ. Cordless telephone use: implications for mobile phone research. J Environ Monit. 12(4):809-812, 2010.**

Cordless and mobile (cellular) telephone use has increased substantially in recent years causing concerns about possible health effects. This has led to much epidemiological research, but the usual focus is on mobile telephone radiofrequency (RF) exposure only despite cordless RF being very similar. Access to and use of cordless phones were included in the Mobile Radiofrequency Phone Exposed Users Study (MoRPhEUS) of 317 Year 7 students recruited from Melbourne, Australia. Participants completed an exposure questionnaire-87% had a cordless phone at home and 77% owned a mobile phone. There was a statistically significant positive relationship ($r = 0.38$, $p < 0.01$) between cordless and mobile phone use. Taken together, this increases total RF exposure and its ratio in high-to-low mobile users. Therefore, the design and analysis of future epidemiological telecommunication studies need to assess cordless phone exposure to accurately evaluate total RF telephone exposure effects.

**Redmayne M, Smith E, Abramson MJ. Adolescent in-school cellphone habits: a census of rules, survey of their effectiveness, and fertility implications. Reprod Toxicol. 32(3):354-359, 2011.**

We explored school cellphone rules and adolescent exposure to cellphone microwave emissions during school with a census and survey, respectively. The data were used to assess health and policy implications through a review of papers assessing reproductive bio-effects after exposure to cellphone emissions, this being most relevant to students' exposure. All schools banned private use of cellphones in class. However, 43% of student participants admitted breaking this rule. A high-exposure group of risk-takers was identified for whom prohibited in-school use was positively associated with high texting rates, carrying the phone switched-on >10h/day, and in-pocket use. The fertility literature is inconclusive, but increasingly points towards significant time- and dose-dependent deleterious effects from cellphone exposure on sperm. Genotoxic effects have been demonstrated from 'non-thermal' exposures, but not consistently. There is sufficient evidence and expert opinion to warrant an enforced school policy removing cellphones from students during the day.

**Redmayne M, Smith E, Abramson MJ. A forecasting method to reduce estimation bias in self-reported cell phone data. J Expo Sci Environ Epidemiol. 2012 Jul 18. doi: 10.1038/jes.2012.70. [Epub ahead of print]**

There is ongoing concern that extended exposure to cell phone electromagnetic radiation could be related to an increased risk of negative health effects. Epidemiological studies seek to assess this risk, usually relying on participants' recalled use, but recall is notoriously poor. Our objectives were primarily to produce a

forecast method, for use by such studies, to reduce estimation bias in the recalled extent of cell phone use. The method we developed, using Bayes' rule, is modelled with data we collected in a cross-sectional cluster survey exploring cell phone user-habits among New Zealand adolescents. Participants recalled their recent extent of SMS-texting and retrieved from their provider the current month's actual use-to-date. Actual use was taken as the gold standard in the analyses. Estimation bias arose from a large random error, as observed in all cell phone validation studies. We demonstrate that this seriously exaggerates upper-end forecasts of use when used in regression models. This means that calculations using a regression model will lead to underestimation of heavy-users' relative risk. Our Bayesian method substantially reduces estimation bias. In cases where other studies' data conforms to our method's requirements, application should reduce estimation bias, leading to a more accurate relative risk calculation for mid-to-heavy users.

**Redmayne M, Smith E, Abramson MJ. Patterns in wireless phone estimation data from a cross-sectional survey: what are the implications for epidemiology? BMJ Open. 2012 Sep 4;2(5). pii: e000887. doi: 10.1136/bmjopen-2012-000887. Print 2012.**

OBJECTIVE:  Self-reported recall data are often used in wireless phone epidemiological studies, which in turn are used to indicate relative risk of health outcomes from extended radiofrequency exposure. We sought to explain features commonly observed in wireless phone recall data and to improve analytical procedures. SETTING:  Wellington Region, New Zealand. PARTICIPANTS: Each of the 16 schools selected a year 7 and/or 8 class to participate, providing a representative regional sample based on socioeconomic school ratings, school type and urban/rural balance. There was an 85% participation rate (N=373). MAIN OUTCOME MEASURES:  Planned: the distribution of participants' estimated extent of SMS-texting and cordless phone calls, and the extent of rounding to a final zero or five within the full set of recall data and within each order of magnitude. Unplanned: the distribution of the leading digits of these raw data, compared with that of billed data in each order of magnitude. RESULTS: The nature and extent of number-rounding, and the distribution of data across each order in recall data indicated a logarithmic (ratio-based) mental process for assigning values. Responses became less specific as the leading-digit increased from 1 to 9, and 69% of responses for weekly texts sent were rounded by participants to a single non-zero digit (eg, 2, 20 and 200). CONCLUSIONS: Adolescents' estimation of their cellphone use indicated that it was performed on a mental logarithmic scale. This is the first time this phenomenon has been observed in the estimation of recalled, as opposed to observed, numerical quantities. Our findings provide empirical justification for log-transforming data for analysis. We recommend the use of the geometric rather than arithmetic mean when a recalled numerical range is provided. A point of calibration may improve recall.

**Redmayne M. New Zealand adolescents' cellphone and cordless phone user-habits: are they at increased risk of brain tumours already? A cross-sectional study. Environ Health. 12(1):5, 2013.**

**BACKGROUND:** Cellphone and cordless phone use is very prevalent among early adolescents, but the extent and types of use is not well documented. This paper explores how, and to what extent, New Zealand adolescents are typically using and exposed to active cellphones and cordless phones, and considers implications of this in relation to brain tumour risk, with reference to current research findings. **METHODS:** This cross-sectional study recruited 373 Year 7 and 8 school students with a mean age of 12.3 years (range 10.3-13.7 years) from the Wellington region of New Zealand. Participants completed a questionnaire and measured their normal body-to-phone texting distances. Main exposure-metrics included self-reported time spent with an active cellphone close to the body, estimated time and number of calls on both phone types, estimated and actual extent of SMS text-messaging, cellphone functions used and people texted. Statistical analyses used Pearson Chi2 tests and Pearson's correlation coefficient (r). Analyses were undertaken using SPSS version 19.0. **RESULTS:** Both cellphones and cordless phones were used by approximately 90% of students. A third of participants had already used a cordless phone for ≥ 7 years. In 4 years from the survey to mid-2013, the cordless phone use of 6% of participants would equal that of the highest Interphone decile (≥ 1640 hours), at the surveyed rate of use. High cellphone use was related to cellphone location at night, being woken regularly, and being tired at school. More than a third of parents thought cellphones carried a moderate-to-high health risk for their child. **CONCLUSIONS:** While cellphones were very popular for entertainment and social interaction via texting, cordless phones were most popular for calls. If their use continued at the reported rate, many would be at increased risk of specific brain tumours by their mid-teens, based on findings of the Interphone and Hardell-group studies.

**Redmayne M, Smith E, and Abramson MJ. The relationship between adolescents' well-being and their wireless phone use: a cross-sectional study. Environmental Health 12(1):90, 2013.**

Background. The exposure of young people to radiofrequency electromagnetic fields (RF-EMFs) has increased rapidly in recent years with their increased use of cellphones and use of cordless phones and WiFi. We sought to ascertain associations between New Zealand early-adolescents' subjective well-being and self-reported use of, or exposure to, wireless telephone and internet technology. Methods. In this cross-sectional survey, participants completed questionnaires in class about their cellphone and cordless phone use, their self-reported well-being, and possible confounding information such as whether they had had influenza recently or had a television in the bedroom. Parental questionnaires provided data on whether they had WiFi at home and cordless phone ownership and model. Data were analysed with Ordinal Logistic Regression adjusting for common confounders. Odds ratios (OR) and 95% confidence intervals were calculated. Results. The number and duration of cellphone and cordless phone calls were associated with increased risk of headaches (>6 cellphone calls over 10 minutes weekly, adjusted OR 2.4, CI 1.2-4.8; >15 minutes cordless use daily adjusted OR 1.74, CI 1.1-2.9)). Texting and extended use of wireless phones was related to having a painful 'texting' thumb). Using a wired cellphone headset was associated with tinnitus (adjusted OR 1.8, CI 1.0-3.3), while wireless headsets were associated with headache (adjusted OR 2.2, CI 1.1-4.5), feeling down/depressed (adjusted OR 2.0, CI 1.1-3.8), and waking in the night

(adjusted OR 2.4, CI 1.2-4.8). Several cordless phone frequencies bands were related to tinnitus, feeling down/depressed and sleepiness at school, while the last of these was also related to modulation. Waking nightly was less likely for those with WiFi at home (adjusted OR 0.7, CI 0.4-0.99). Being woken at night by a cellphone was strongly related to tiredness at school (OR 4.1, CI 2.2-7.7). Conclusions . There were more statistically significant associations (36%) than could be expected by chance (5%). Several were dose-dependent relationships. To safeguard young people's well-being, we suggest limiting their use of cellphones and cordless phones to less than 15 minutes daily, and employing a speaker-phone device for longer daily use. We recommend parental measures are taken to prevent young people being woken by their cellphones.

**Redmayne M, Smith CL, Benke G, Croft RJ, Dalecki A, Dimitriadis C, Kaufman J, Macleod S, Sim MR, Wolfe R, Abramson MJ. Use of mobile and cordless phones and cognition in Australian primary school children: a prospective cohort study. Environ Health. 15(1):26, 2016.**

BACKGROUND: Use of mobile (MP) and cordless phones (CP) is common among young children, but whether the resulting radiofrequency exposure affects development of cognitive skills is not known. Small changes have been found in older children. This study focused on children's exposures to MP and CP and cognitive development. The hypothesis was that children who used these phones would display differences in cognitive function compared to those who did not. METHODS: We recruited 619 fourth-grade students (8-11 years) from 37 schools around Melbourne and Wollongong, Australia. Participants completed a short questionnaire, a computerised cognitive test battery, and the Stroop colour-word test. Parents completed exposure questionnaires on their child's behalf. Analysis used multiple linear regression. The principal exposure-metrics were the total number of reported MP and CP calls weekly categorised into no use ('None'); use less than or equal to the median amount ('Some'); and use more than the median ('More'). The median number of calls/week was 2.5 for MP and 2.0 for CP. RESULTS: MP and CP use for calls was low; and only 5 of 78 comparisons of phone use with cognitive measures were statistically significant. The reaction time to the response-inhibition task was slower in those who used an MP 'More' compared to the 'Some' use group and non-users. For CP use, the response time to the Stroop interference task was slower in the 'More' group versus the 'Some' group, and accuracy was worse in visual recognition and episodic memory tasks and the identification task. In an additional exploratory analysis, there was some evidence of a gender effect on mean reaction times. The highest users for both phone types were girls. CONCLUSIONS: Overall, there was little evidence cognitive function was associated with CP and MP use in this age group. Although there was some evidence that effects of MP and CP use on cognition may differ by gender, this needs further exploration. CP results may be more reliable as parents estimated children's phone use and the CPs were at home; results for CP use were broadly consistent with our earlier study of older children.

**Reeves GI. Review of extensive workups of 34 patients overexposed to radiofrequency radiation. Aviat Space Environ Med 71(3):206-215, 2000**.

BACKGROUND: The medical records of 34 patients seen at the Aerospace Medicine Directorate, U.S. Air Force Research Laboratory for confirmed exposure to radiofrequency radiation (RFR) exceeding the permitted exposure limits were reviewed to see if RFR overexposure created any detectable clinical or laboratory alterations that could be correlated with power density or the product of power density and time exposed. The goal of this study was to determine which physiological and laboratory parameters required closest attention on work up of future patients with RFR exposure. METHODS: All 34 patients received an extensive history and physical examination, and a large battery of laboratory studies. Clinical findings were also compared with laboratory results. RESULTS: A sensation of warmth was positively associated with power density. A negative correlation was observed between an abnormal tissue destruction screen and power density. Sophisticated neurological tests in 23 patients and extensive psychometric and psychological exams in 30 patients revealed no neurological or ophthalmologic findings attributable to RFR. A few patients reported burning pain that resolved over several weeks; neurological findings were minimal or absent. CONCLUSIONS: Patients with suspected RFR overexposures need to be seen promptly at the nearest medical facility. Based on this study, an extensive evaluation of persons overexposed to non-ionizing radiation should not be routinely performed. However, a careful history and physical examination with laboratory studies as indicated should be performed and the patient's concerns about RFR effects addressed fully.

**Regel SJ, Negovetic S, Roosli M, Berdinas V, Schuderer J, Huss A, Lott U, Kuster N, Achermann P. UMTS Base Station-like Exposure, Well-Being, and Cognitive Performance. Environ Health Perspect. 114(8):1270-1275, 2006.**

Background: Radio-frequency electromagnetic fields (RF EMF) of mobile communication systems are widespread in the living environment, yet their effects on humans are uncertain despite a growing body of literature. Objectives: We investigated the influence of a Universal Mobile Telecommunications System (UMTS) base station-like signal on well-being and cognitive performance in subjects with and without self-reported sensitivity to RF EMF. Methods: We performed a controlled exposure experiment (45 min at an electric field strength of 0, 1, or 10 V/m, incident with a polarization of 45 degrees from the left back side of the subject, weekly intervals) in a randomized, double-blind crossover design. A total of 117 healthy subjects (33 self-reported sensitive, 84 nonsensitive subjects) participated in the study. We assessed well-being, perceived field strength, and cognitive performance with questionnaires and cognitive tasks and conducted statistical analyses using linear mixed models. Organ-specific and brain tissue-specific dosimetry including uncertainty and variation analysis was performed. Results: In both groups, well-being and perceived field strength were not associated with actual exposure levels. We observed no consistent condition-induced changes in cognitive performance except for two marginal effects. At 10 V/m we observed a slight effect on speed in one of six tasks in the sensitive subjects and an effect on accuracy in another task in nonsensitive subjects. Both effects disappeared after multiple end point adjustment. Conclusions: In contrast to a recent Dutch study, we could not confirm a short-term effect of UMTS base station-like exposure on well-being. The reported effects on brain functioning were marginal and may have occurred by chance. Peak spatial

absorption in brain tissue was considerably smaller than during use of a mobile phone. No conclusions can be drawn regarding short-term effects of cell phone exposure or the effects of long-term base station-like exposure on human health. Key words: base station, cognitive function, electromagnetic hypersensitivity, human exposure, mobile phones, RF EMF.

**Regel SJ, Tinguely G, Schuderer J, Adam M, Kuster N, Landolt HP, Achermann P. Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. J Sleep Res. 16(3):253-258, 2007.**

To establish a dose-response relationship between the strength of electromagnetic fields (EMF) and previously reported effects on the brain, we investigated the influence of EMF exposure by varying the signal intensity in three experimental sessions. The head of 15 healthy male subjects was unilaterally exposed for 30 min prior to sleep to a pulse-modulated EMF (GSM handset like signal) with a 10 g-averaged peak spatial specific absorption rate of (1) 0.2 W kg(-1), (2) 5 W kg(-1), or (3) sham exposed in a double-blind, crossover design. During exposure, subjects performed two series of three computerized cognitive tasks, each presented in a fixed order [simple reaction time task, two-choice reaction time task (CRT), 1-, 2-, 3-back task]. Immediately after exposure, night-time sleep was polysomnographically recorded for 8 h. Sleep architecture was not affected by EMF exposure. Analysis of the sleep electroencephalogram (EEG) revealed a dose-dependent increase of power in the spindle frequency range in non-REM sleep. Reaction speed decelerated with increasing field intensity in the 1-back task, while accuracy in the CRT and N-back task were not affected in a dose-dependent manner. In summary, this study reveals first indications of a dose-response relationship between EMF field intensity and its effects on brain physiology as demonstrated by changes in the sleep EEG and in cognitive performance.

**Reiser H, Dimpfel W, Schober F, The influence of electromagnetic fields on human brain activity. Eur J Med Res 1(1):27-32, 1995.**

Possible effects of electromagnetic fields on human brain activity were studied. In a single-blind, cross-over-designed and placebo-controlled study 36 volunteers were exposed firstly to an electromagnetic field originating form a MediLine "MEGA-WAVE 150/1" therapy instrument and secondly to a field originating from a mobile, digital tetlephone as used for wireless telecommunication. All volunteers also underwent a control experiment with no field exposure. Application of the MEGA-WAVE instrument caused an increase in EEG power in the frequency bands Alpha2, Beta1 and Beta2 during and after field exposure. Operation of the mobile telephone caused an increase in the same frequency bands with a delay of approximately 15 minutes after exposure.

**Remondini D, Nylund R, Reivinen J, Poulletier de Gannes F, Veyret B, Lagroye I, Haro E, Trillo MA, Capri M, Franceschi C, Schlatterer K, Gminski R, Fitzner R, Tauber R, Schuderer J, Kuster N, Leszczynski D, Bersani F, Maercker C. Gene expression changes in human cells after exposure to mobile phone microwaves. Proteomics. 6(17):4745-4754, 2006.**

Possible biological effects of mobile phone microwaves were investigated in vitro. In

this study, which was part of the 5FP EU project REFLEX (Risk Evaluation of Potential Environmental Hazards From Low-Energy Electromagnetic Field Exposure Using Sensitive in vitro Methods), six human cell types, immortalized cell lines and primary cells, were exposed to 900 and 1800 MHz. RNA was isolated from exposed and sham-exposed cells and labeled for transcriptome analysis on whole-genome cDNA arrays. The results were evaluated statistically using bioinformatics techniques and examined for biological relevance with the help of different databases. NB69 neuroblastoma cells, T lymphocytes, and CHME5 microglial cells did not show significant changes in gene expression. In EA.hy926 endothelial cells, U937 lymphoblastoma cells, and HL-60 leukemia cells we found between 12 and 34 up- or down-regulated genes. Analysis of the affected gene families does not point towards a stress response. However, following microwave exposure, some but not all human cells might react with an increase in expression of genes encoding ribosomal proteins and therefore up-regulating the cellular metabolism.

**Repacholi, MH, Basten, A, Gebski, V, Noonan, D, Finnie, J, Harris, AW, Lymphomas in E mu-Pim1 transgenic mice exposed to pulsed 900 MHZ electromagnetic fields. Radiat Res 147(5):631-640, 1997.**

Whether radiofrequency (RF) fields are carcinogenic is controversial; epidemiological data have been inconclusive and animal tests limited. The aim of the present study was to determine whether long-term exposure to pulse-modulated RF fields similar to those used in digital mobile telecommunications would increase the incidence of lymphoma in E mu-Pim1 transgenic mice, which are moderately predisposed to develop lymphoma spontaneously. One hundred female E mu-Pim1 mice were sham-exposed and 101 were exposed for two 30-min periods per day for up to 18 months to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms. Incident power densities were 2.6-13 W/m2 and specific absorption rates were 0.008-4.2 W/kg, averaging 0.13-1.4 W/kg. Lymphoma risk was found to be significantly higher in the exposed mice than in the controls (OR = 2.4. P = 0.006, 95% CI = 1.3-4.5). Follicular lymphomas were the major contributor to the increased tumor incidence. Thus long-term intermittent exposure to RF fields can enhance the probability that mice carrying a lymphomagenic oncogene will develop lymphomas. We suggest that such genetically cancer-prone mice provide an experimental system for more detailed assessment of dose-response relationships for risk of cancer after RF-field exposure.

**Rezk AY**, **Abdulqawi K**, **Mustafa RM**, **Abo El-Azm TM**, **Al-Inany H**. **Fetal and neonatal responses following maternal exposure to mobile phones. Saudi Med J. 29(2):218-223, 2008.**

OBJECTIVE: To study fetal and neonatal heart rate (HR) and cardiac output (COP), following acute maternal exposure to electromagnetic fields (EMF) emitted by mobile phones. METHODS: The present study was carried out at Benha University Hospital and El-Shorouq Hospital, Cairo, Egypt, from October 2003 to March 2004. Ninety women with uncomplicated pregnancies aged 18-33 years, and 30 full term healthy newborn infants were included. The pregnant mothers were exposed to EMF emitted by mobile telephones while on telephone-dialing mode for 10 minutes during pregnancy and after birth. The main outcome were measurements of fetal and

neonatal HR and COP. RESULTS: A statistical significant increase in fetal and neonatal HR, and statistical significant decrease in stroke volume and COP before and after use of mobile phone were noted. All these changes are attenuated with increase in gestational age. CONCLUSION: Exposure of pregnant women to mobile phone significantly increase fetal and neonatal HR, and significantly decreased the COP.

**Ribeiro EP, Rhoden EL, Horn MM, Rhoden C, Lima LP, Toniolo L, Effects of Subchronic Exposure to Radio Frequency From a Conventional Cellular Telephone on Testicular Function in Adult Rats. J Urol 177:395-399, 2007.**

Purpose. We investigated the effects of subchronic exposure to radio frequency emitted from a conventional cellular telephone on the testicular function in adult rats. Materials and Methods. A total of 16 male Wistar rats at age 30 days were randomly divided into 2 groups, including experimental and control groups. The experimental group was exposed to radio frequency emitted from a conventional GSM (global system for mobile communications) cellular telephone (1,835 to 1,850 MHz) for 1 hour daily during 11 weeks. Rectal temperature was measured before and after the exposure period. Testicular and epididymal weight, lipid peroxidation levels in these organs, serum total testosterone and the epididymal sperm count were evaluated. Maturation phase spermatid retention at stage IX-X, interstitial infiltration, cellular vacuolation and multinucleate giant cells were among the qualitative testicular histopathological end points analyzed. Each rat had 10 consecutive round seminiferous tubules at stage VII-VIII evaluated for the mean seminiferous tubular diameter measurement, the crude histological count of round spermatids, pachytene spermatocytes and Sertoli’s cells with evident nucleoli, and the true histological count (Abercrombie’s correction factor) of round spermatids and pachytene spermatocytes. Results. Mean rectal temperature did not alter following exposure. There was no statistical difference between the control and experimental groups in any end points evaluated. Conclusions: The current study shows that the low intensity pulsed radio frequency emitted by a conventional cellular telephone does not impair testicular function in adult rats.

**Richter E, Berman T, Ben-Michael E, Laster R, Westin JB, Cancer in Radar Technicians Exposed to Radiofrequency/Microwave Radiation: Sentinel Episodes. Int J Occup Environ Health 6(3):187-193, 2000.**

Controversy exists concerning the health risks from exposures to radiofrequency/microwave irradiation (RF/MW). The authors report exposure-effect relationships in sentinel patients and their co-workers, who were technicians with high levels of exposure to RF/MW radiation. Information about exposures of patients with sentinel tumors was obtained from interviews, medical records, and technical sources. One patient was a member of a cohort of 25 workers with six tumors. The authors estimated relative risks for cancer in this group and latency periods for a larger group of self-reported individuals. Index patients with melanoma of the eye, testicular cancer, nasopharyngioma, non-Hodgkin's lymphoma, and breast cancer were in the 20-37-year age group. Information about work conditions suggested prolonged exposures to high levels of RF/MW radiation that produced risks for the entire body. Clusters involved many

different types of tumors. Latency periods were extremely brief in index patients and a larger self-reported group. The findings suggest that young persons exposed to high levels of RF/MW radiation for long periods in settings where preventive measures were lax were at increased risk for cancer. Very short latency periods suggest high risks from high-level exposures. Calculations derived from a linear model of dose-response suggest the need to prevent exposures in the range of 10-100 muw/cm(2).

**Richter ED, Berman T, Levy O. Brain cancer with induction periods of less than 10 years in young military radar workers. Arch Environ Health 57(4):270-272, 2002.**

The authors have reported on 5 young patients who had brain tumors that appeared within 10 yr of initial occupational exposures to radar. Four of the patients were less than 30 yr of age when the diagnoses were initially made. Brief induction periods that follow high exposures in individual sentinel patients are a recognized indicator of impending group risk, and these periods call attention to the need for precautionary measures. Similarly, reports of short induction periods for brain cancer on the side of the head in which there has been prior use of cell phones may also indicate increased risk.

**Riddervold IS, Pedersen GF, Andersen NT, Pedersen AD, Andersen JB, Zachariae R, Mølhave L, Sigsgaard T, Kjaergaard SK. Cognitive function and symptoms in adults and adolescents in relation to rf radiation from UMTS base stations. Bioelectromagnetics. 29(4):257-267, 2008.**

There is widespread public concern about the potential adverse health effects of mobile phones in general and their associated base stations in particular. This study was designed to investigate the acute effects of radio frequency (RF) electromagnetic fields (EMF) emitted by the Universal Mobile Telecommunication System (UMTS) mobile phone base stations on human cognitive function and symptoms. Forty adolescents (15-16 years) and 40 adults (25-40 years) were exposed to four conditions: (1) sham, (2) a Continuous Wave (CW) at 2140 MHz, (3) a signal at 2140 MHz modulated as UMTS and (4) UMTS at 2140 MHz including all control features in a randomized, double blinded cross-over design. Each exposure lasted 45 min. During exposure the participants performed different cognitive tasks with the Trail Making B (TMB) test as the main outcome and completed a questionnaire measuring self reported subjective symptoms. No statistically significant differences between the UMTS and sham conditions were found for performance on TMB. For the adults, the estimated difference between UMTS and sham was -3.2% (-9.2%; 2.9%) and for the adolescents 5.5% (-1.1%; 12.2%). No significant changes were found in any of the cognitive tasks. An increase in 'headache rating' was observed when data from the adolescents and adults were combined (P = 0.027), an effect that may be due to differences at baseline. In conclusion, the primary hypothesis that UMTS radiation reduces general performance in the TMB test was not confirmed. However, we suggest that the hypothesis of subjective symptoms and EMF exposure needs further research.

**Rittweger J, Lambertz M, Kluge W, Kramer K, Langhorst P, Influence of modulated high-frequency electromagnetic fields on the functional organization and dynamics of the common brainstem system. Bioelectrochem Bioenerg 37(1):31-37, 1995.**

The immediate influence of low-frequency modulated high-frequency electromagnetic fields (MHF) on regulatory patterns in the state of relaxed wakefulness was investigated in five healthy volunteers. The differences in magnetoencephalogram, heart frequency and ventilatory parameters before and after occipital application of MHF indicate that the effects can be explained by an influence on the common brainstem system (CBS). The CBS is part of the central nervous system which organizes and regulates the prerequisites necessary for the execution of meaningful behaviour.

**Riu PJ, Foster KR, Blick DW, Adair ER, A thermal model for human thresholds of microwave-evoked warmth sensations. Bioelectromagnetics 18(8):578-583, 1997.**

Human thresholds for skin sensations of warmth were measured at frequencies from 2.45 to 94 GHz. By solving the one-dimensional bioheat equation, we calculated the temperature increase at the skin surface or at a depth of 175 microm at incident power levels corresponding to the observed thresholds. The thermal analysis suggests that the thresholds correspond to a localized temperature increase of about 0.07 degrees C at and near the surface of the skin. We also found that, even at the highest frequency of irradiation, the depth at which the temperature receptors are located is not a relevant parameter, as long as it is within 0.3 mm of the surface. Over the time range of the simulation, the results of the thermal model are insensitive to blood flow, but sensitive to thermal conduction; and this sensitivity increases strongly with frequency. We conclude with an analysis of the effect of thermal conduction on surface temperature rise, which becomes a dominant factor at microwave frequencies over 10 GHz.

**Rodina A, Lass J, Riipulk J, Bachmann T, Hinrikus H. Study of effects of low level microwave field by method of face masking. Bioelectromagnetics. 26(7):571-577, 2005.**

The aim of this study was to examine experimentally effects of low level, modulated microwaves on human central nervous system function utilizing the phenomenon of visual masking. Ten healthy volunteers, four males and six females, were exposed to electromagnetic field (450 MHz, 0.16 mW/cm2) with 7 Hz modulation frequency. Two photo series (visual stimuli) of unfamiliar, young male faces were presented to the subjects, one picture after another. All the photos were frontal views of unfamiliar faces, which could be recognized only by their unique combinations of features. The task was to identify the pictures from a group of six photos and to decide which order they were presented in. The phenomenon of visual masking is revealed as anamorphosis in subject's perception of two instantaneous visual stimuli presented within a short time interval. When both stimuli were to be recognized correctly and put in the right order, there was a statistically significant difference ($P < 0.05$) between the identification of the stimulus with microwave electromagnetic field and sham exposure. Recognition of both stimuli in a pair was better under the sham exposure conditions but the actual difference was only 5%. It was concluded that early stages of visual information processing are overwhelmingly robust and routine (and adaptively significant) activities, so that the low level 7 Hz modulated electromagnetic field effects exerted upon it are extremely weak.

**Roggeveen S, van Os J, Lousberg R. Does the Brain Detect 3G Mobile Phone Radiation Peaks? An Explorative In-Depth Analysis of an Experimental Study. PLoS One. 2015 May 11;10(5):e0125390. doi: 10.1371/journal.pone.0125390. eCollection 2015.**

This study aimed to investigate whether third generation mobile phone radiation peaks result in event related potentials. Thirty-one healthy females participated. In this single-blind, cross-over design, a 15 minute mobile phone exposure was compared to two 15 minute sham phone conditions, one preceding and one following the exposure condition. Each participant was measured on two separate days, where mobile phone placement was varied between the ear and heart. EEG activity and radiofrequency radiation were recorded jointly. Epochs of 1200ms, starting 200ms before and lasting until 1000ms after the onset of a radiation peak, were extracted from the exposure condition. Control epochs were randomly selected from the two sham phone conditions. The main a-priori hypothesis to be tested concerned an increase of the area in the 240-500ms post-stimulus interval, in the exposure session with ear-placement. Using multilevel regression analyses the placement*exposure interaction effect was significant for the frontal and central cortical regions, indicating that only in the mobile phone exposure with ear-placement an enlarged cortical reactivity was found. Post-hoc analyses based on visual inspection of the ERPs showed a second significantly increased area between 500-1000ms post-stimulus for almost every EEG location measured. It was concluded that, when a dialing mobile phone is placed on the ear, its radiation, although unconsciously, is electrically detected by the brain. The question of whether or not this cortical reactivity results in a negative health outcome has to be answered in future longitudinal experiments.

**Roggeveen S, van Os J, Viechtbauer W, Lousberg R. EEG Changes Due to Experimentally Induced 3G Mobile Phone Radiation. PLoS One. 2015 Jun 8;10(6):e0129496. doi: 10.1371/journal.pone.0129496.**

The aim of this study was to investigate whether a 15-minute placement of a 3G dialing mobile phone causes direct changes in EEG activity compared to the placement of a sham phone. Furthermore, it was investigated whether placement of the mobile phone on the ear or the heart would result in different outcomes. Thirty-one healthy females participated. All subjects were measured twice: on one of the two days the mobile phone was attached to the ear, the other day to the chest. In this single-blind, cross-over design, assessments in the sham phone condition were conducted directly preceding and following the mobile phone exposure. During each assessment, EEG activity and radiofrequency radiation were recorded jointly. Delta, theta, alpha, slowbeta, fastbeta, and gamma activity was computed. The association between radiation exposure and the EEG was tested using multilevel random regression analyses with radiation as predictor of main interest. Significant radiation effects were found for the alpha, slowbeta, fastbeta, and gamma bands. When analyzed separately, ear location of the phone was associated with significant results, while chest placement was not. The results support the notion that EEG alterations are associated with mobile phone usage and that the effect is dependent

on site of placement. Further studies are required to demonstrate the physiological relevance of these findings.

**Roggeveen S, van Os J, Lousberg R. Does the Brain Detect 3G Mobile Phone Radiation Peaks? An Explorative In-Depth Analysis of an Experimental Study. PLoS One. 2015 May 11;10(5):e0125390.**

This study aimed to investigate whether third generation mobile phone radiation peaks result in event related potentials. Thirty-one healthy females participated. In this single-blind, cross-over design, a 15 minute mobile phone exposure was compared to two 15 minute sham phone conditions, one preceding and one following the exposure condition. Each participant was measured on two separate days, where mobile phone placement was varied between the ear and heart. EEG activity and radiofrequency radiation were recorded jointly. Epochs of 1200 ms, starting 200 ms before and lasting until 1000 ms after the onset of a radiation peak, were extracted from the exposure condition. Control epochs were randomly selected from the two sham phone conditions. The main a-priori hypothesis to be tested concerned an increase of the area in the 240-500 ms post-stimulus interval, in the exposure session with ear-placement. Using multilevel regression analyses the placement*exposure interaction effect was significant for the frontal and central cortical regions, indicating that only in the mobile phone exposure with ear-placement an enlarged cortical reactivity was found. Post-hoc analyses based on visual inspection of the ERPs showed a second significantly increased area between 500-1000 ms post-stimulus for almost every EEG location measured. It was concluded that, when a dialing mobile phone is placed on the ear, its radiation, although unconsciously, is electrically detected by the brain. The question of whether or not this cortical reactivity results in a negative health outcome has to be answered in future longitudinal experiments.

**Roivainen P, Eskelinen T, Jokela K, Juutilainen J. Occupational exposure to intermediate frequency and extremely low frequency magnetic fields among personnel working near electronic article surveillance systems. Bioelectromagnetics. 2014 Feb 24. doi: 10.1002/bem.21850. [Epub ahead of print]**

Cashiers are potentially exposed to intermediate frequency (IF) magnetic fields at their workplaces because of the electronic article surveillance (EAS) systems used in stores to protect merchandise against theft. This study aimed at investigating occupational exposure of cashiers to IF magnetic fields in Finnish stores. Exposure to extremely low frequency (ELF) magnetic fields was also evaluated because cashiers work near various devices operating with 50 Hz electric power. The peak magnetic flux density was measured for IF magnetic fields, and was found to vary from 0.2 to 4 μT at the cashier's seat. ELF magnetic fields from 0.03 to 4.5 μT were found at the cashier's seat. These values are much lower than exposure limits. However, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) occupational reference levels for IF magnetic fields (141 μT for the peak field) were exceeded in some cases (maximum 189 μT) for short periods of time when cashiers walked through the EAS gates. As the ICNIRP reference levels do not

define any minimum time for exposure, additional investigations are recommended to determine compliance with basic restrictions. Even if the basic restrictions are not exceeded, persons working near EAS devices represent an exceptional group of workers with respect to exposure to electromagnetic fields. This group could serve as a basis for epidemiological studies addressing possible health effects of IF magnetic fields. Compliance with the reference levels for IF fields was evaluated using both broadband measurement of peak fields and the ICNIRP summation rule for multiple frequencies. The latter was generally more conservative, and the difference between the two methods was large (>10-fold) for EAS systems using a 58 kHz signal with complex waveform. This indicates that the ICNIRP multiple frequency rule can be unnecessarily conservative when measuring complex waveforms.

**Rojavin MA, Ziskin MC, Electromagnetic millimeter waves increase the duration of anaesthesia caused by ketamine and chloral hydrate in mice. Int J Radiat Biol 72(4):475-480, 1997.**

BALB/c mice were injected i.p. with either ketamine 80 mg/kg or chloral hydrate 450 mg/kg. Anaesthetized mice were exposed to unmodulated electromagnetic millimeter waves at the frequency of 61.22 GHz with a peak specific absorption rate of 420 W/kg and corresponding incident power density of 15 mW/cm2 for 15 min or sham-exposed. In combination with either of the anaesthetics used, mm waves increased the duration of anaesthesia by approximately 50% ($p < 0.05$) in a dose (power)-dependent manner. Sham exposure to mm waves did not affect the sleeping time of mice. Pretreatment of mice with naloxone, an opioid antagonist, did not change the duration of anaesthesia caused by the corresponding chemical agent, but completely blocked or decreased the additional effect of mm waves. The data in this study indicates that exposure of mice to mm waves in vivo releases endogenous opioids or enhances the activity of opioid signalling pathway.

**Romano-Spica V, Mucci N, Ursini CL, Ianni A, Bhat NK, Ets1 oncogene induction by ELF-modulated 50 MHz radiofrequency electromagnetic field. Bioelectromagnetics 21(1):8-18, 2000.**

We have analyzed gene expression in hemopoietic and testicular cell types after their exposure to 50 MHz radiofrequency (RF) non-ionizing radiation modulated (80%) with a 16 Hz frequency. The exposure system generates a 0.2 microT magnetic field parallel to the ground and a 60 V/m electric field orthogonal to the earth's magnetic field. Exposure conditions were selected so as to interfere with the calcium ion flow. Under these electromagnetic field (EMF) conditions, we observed an overexpression of the ets1 mRNA in Jurkat T-lymphoblastoid and Leydig TM3 cell lines. This effect was observed only in the presence of the 16 Hz modulation, corresponding to the resonance frequency for calcium ion with a DC magnetic field of 45.7 microT. We have also identified a putative candidate gene repressed after EMF exposure. The experimental model described in this paper may contribute to the understanding of the biological mechanisms involved in EMF effects.

**Röösli M. Radiofrequency electromagnetic field exposure and non-specific symptoms of ill health: A systematic review. Environ Res.107(2):277-287,2008.**

This article is a systematic review of whether everyday exposure to radiofrequency electromagnetic field (RF-EMF) causes symptoms, and whether some individuals are able to detect low-level RF-EMF (below the ICNIRP [International Commission on Non-Ionizing Radiation Protection] guidelines). Peer-reviewed articles published before August 2007 were identified by means of a systematic literature search. Meta-analytic techniques were used to pool the results from studies investigating the ability to discriminate active from sham RF-EMF exposure. RF-EMF discrimination was investigated in seven studies including a total of 182 self-declared electromagnetic hypersensitive (EHS) individuals and 332 non-EHS individuals. The pooled correct field detection rate was 4.2% better than expected by chance (95% CI: -2.1 to 10.5). There was no evidence that EHS individuals could detect presence or absence of RF-EMF better than other persons. There was little evidence that short-term exposure to a mobile phone or base station causes symptoms based on the results of eight randomized trials investigating 194 EHS and 346 non-EHS individuals in a laboratory. Some of the trials provided evidence for the occurrence of nocebo effects. In population based studies an association between symptoms and exposure to RF-EMF in the everyday environment was repeatedly observed. This review showed that the large majority of individuals who claims to be able to detect low level RF-EMF are not able to do so under double-blind conditions. If such individuals exist, they represent a small minority and have not been identified yet. The available observational studies do not allow differentiating between biophysical from EMF and nocebo effects.

**Roosli M, Michel G, Kuehni CE, Spoerri A. Cellular telephone use and time trends in brain tumour mortality in Switzerland from 1969 to 2002.Eur J Cancer Prev. 16(1):77-82. 2007.**

A rising concern exists that with the widespread use of mobile communication technologies, the incidence of brain tumours may increase. On the basis of data from the Swiss national mortality registry from 1969 to 2002, annual age-standardized brain tumour mortality rates per 100 000 person-years were calculated using the European standard population. Time trend analyses were performed by the Poisson regression for six different age groups in men and women separately. The study period was divided into two intervals: before and after 1987, when the analogue mobile technology was introduced in Switzerland. Age-standardized brain tumour mortality rates ranged between 3.7 and 6.7 for men and 2.5 and 4.4 for women per 100 000 person-years. For the whole study period, a significant increase in brain tumour mortality was observed for men and women in the older age groups (60-74 and 75+ years) but not in the younger ones in whom mobile phone use was more prevalent. Time trend analyses restricted to data from 1987 onwards revealed relatively stable brain tumour mortality rates in all age groups. For instance, the annual change in brain tumour mortality rate for the 45-59-year age group was -0.3% (95% confidence interval: -1.7; 1.1) for men and -0.4% (95% confidence interval:-2.2; 1.3) for women. We conclude that after the introduction of mobile phone technology in Switzerland, brain tumour mortality rates remained stable in all age groups. Our results suggest that mobile phone use is not a strong risk factor in the short term for mortality from brain tumours. Ecological analyses like this, however, are limited in

their ability to reveal potentially small increases in risk for diseases with a long latency period.

**Röösli M, Frei P, Mohler E, Hug K. Systematic review on the health effects of exposure to radiofrequency electromagnetic fields from** mobile phonebase **stations. Bull World Health Organ. 88(12):887-896F, 2010.**

OBJECTIVE: to review and evaluate the recent literature on the health effects of exposure to mobile phonebasestation (MPBS) radiation. METHODS: we performed a systematic review of randomized human trials conducted in laboratory settings and of epidemiological studies that investigated the health effects of MPBS radiation in the everyday environment. FINDINGS: we included in the analysis 17 articles that met our basic quality criteria: 5 randomized human laboratory trials and 12 epidemiological studies. The majority of the papers (14) examined self-reported non-specific symptoms of ill-health. Most of the randomized trials did not detect any association between MPBS radiation and the development of acute symptoms during or shortly after exposure. The sporadically observed associations did not show a consistent pattern with regard to symptoms or types of exposure. We also found that the more sophisticated the exposure assessment, the less likely it was that an effect would be reported. Studies on health effects other than non-specific symptoms and studies on MPBS exposure in children were scarce. CONCLUSION: the evidence for a missing relationship between MPBS exposure up to 10 volts per metre and acute symptom development can be considered strong because it is based on randomized, blinded human laboratory trials. At present, there is insufficient data to draw firm conclusions about health effects from long-term low-level exposure typically occurring in the everyday environment.

**Rosaspina S, Salvatorelli G, Anzanel D, Bovolenta R, Effect of microwave radiation on Candida albicans. Microbios 78(314):55-59, 1994.**

Microwave exposure (90 s) provides an effective, rapid sterilization for surgical scalpel blades which have been contaminated with Candida albicans. SEM analysis showed that microwave irradiation induced a morphological modification of the cells. The longer the exposure time the greater such alterations and this micro-organism in effect fractures after 9 min. No evidence was found of morphological alteration of the fungus after being submerged in boiling water for the same amount of time even though cell death was actually achieved.

**Roschke, J, Mann, K, No short-term effects of digital mobile radio telephone on the awake human electroencephalogram. Bioelectromagnetics 18(2):172-176, 1997.**

A recent study reported the results of an exploratory study of alterations of the quantitative sleep profile due to the effects of a digital mobile radio telephone. Rapid eye movement (REM) was suppressed, and the spectral power density in the 8-13 Hz frequency range during REM sleep was altered. The aim of the present study was to illuminate the influence of digital mobile radio telephone on the awake electroencephalogram (EEG) of healthy subjects. For this purpose, we investigated 34 male subjects in a single-blind cross-over design experiment by measuring spontaneous EEGs under closed-eyes condition from scalp positions C3 and C4 and comparing the

effects of an active (0.05 mW/cm2) and an inactive digital mobile radio telephone (GSM) system. During exposure of nearly 3.5 min to the 900 MHz electromagnetic field pulsed at a frequency of 217 Hz and with a pulse width of 580 microseconds, we could not detect any difference in the awake EEGs in terms of spectral power density measures.

**Roser K, Schoeni A, Röösli M. Mobile phone use, behavioural problems and concentration capacity in adolescents: A prospective study. Int J Hyg Environ Health. 219(8):759-769, 2016.**

The aim of this study is to prospectively investigate whether exposure to radiofrequency electromagnetic fields (RF-EMF) emitted by mobile phones and other wireless communication devices is related to behavioural problems or concentration capacity in adolescents. The HERMES (Health Effects Related to Mobile phonE use in adolescentS) study sample consisted of 439 Swiss adolescents aged 12-17 years. Behavioural problems were assessed using the Strengths and Difficulties Questionnaire (SDQ), concentration capacity of the adolescents was measured by means of a standardized computerized cognitive test named FAKT. Cross-sectional and longitudinal (1year of follow-up) analyses were performed to investigate possible associations between behavioural problems and concentration capacity and different exposure measures: self-reported and operator-recorded wireless communication device use, cumulative RF-EMF brain and whole body dose and measured personal RF-EMF exposure. In the cross-sectional analyses behavioural problems were associated with several self-reported wireless device use measures but not operator-recorded mobile phone use measures, concentration capacity was associated with several self-reported and operator-recorded exposures. The longitudinal analyses point towards absence of associations. The lack of consistent exposure-response patterns in the longitudinal analyses suggests that behavioural problems and concentration capacity are not affected by the use of wireless communication devices or RF-EMF exposure. Information bias and reverse causality are likely explanations for the observed cross-sectional findings.

**Roser K, Schoeni A, Struchen B, Zahner M, Eeftens M, Fröhlich J, Röösli M. Personal radiofrequency electromagnetic field exposure measurements in Swiss adolescents. Environ Int. 99:303-314, 2017.**

BACKGROUND: Adolescents belong to the heaviest users of wireless communication devices, but little is known about their personal exposure to radiofrequency electromagnetic fields (RF-EMF). OBJECTIVES: The aim of this paper is to describe personal RF-EMF exposure of Swiss adolescents and evaluate exposure relevant factors. Furthermore, personal measurements were used to estimate average contributions of various sources to the total absorbed RF-EMF dose of the brain and the whole body. METHODS: Personal exposure was measured using a portable RF-EMF measurement device (ExpoM-RF) measuring 13 frequency bands ranging from 470 to 3600MHz. The participants carried the device for three consecutive days and kept a time-activity diary. In total, 90 adolescents aged 13 to 17years participated in the study conducted between May 2013 and April 2014. In addition, personal measurement values were combined with dose calculations for the use of wireless communication devices to

quantify the contribution of various RF-EMF sources to the daily RF-EMF dose of adolescents. RESULTS: Main contributors to the total personal RF-EMF measurements of 63.2μW/$m^2$ (0.15V/m) were exposures from mobile phones (67.2%) and from mobile phone base stations (19.8%). WLAN at school and at home had little impact on the personal measurements (WLAN accounted for 3.5% of total personal measurements). According to the dose calculations, exposure from environmental sources (broadcast transmitters, mobile phone base stations, cordless phone base stations, WLAN access points, and mobile phones in the surroundings) contributed on average 6.0% to the brain dose and 9.0% to the whole-body dose. CONCLUSIONS: RF-EMF exposure of adolescents is dominated by their own mobile phone use. Environmental sources such as mobile phone base stations play a minor role.

**Ros-Llor I, Sanchez-Siles M, Camacho-Alonso F, Lopez-Jornet P. Effect of mobile phones on micronucleus frequency in human exfoliated oral mucosal cells.Oral Dis.18(8):786-792, 2012.**

Objective: In the last two decades, the use of mobile phones has increased enormously all over the world. The controversy regarding whether radiofrequency (RF) fields exert effects upon biological systems is a concern for the general population. An evaluation is made of DNA damage and cytokinetic defects, proliferative potential, and cell death because of RF radiation emitted by mobile phones in healthy young users. Study design: This cohort study was carried out in 50 Caucasian mobile phone users. We collected two cell samples from each subject (a total of 100 cell samples), corresponding to the right and left cheek mucosa, respectively. Case histories and personal information were assessed, including age, gender, body height and weight, history of cancer, smoking and alcohol consumption, exposure to chemical carcinogens or radiation, and dietary habits. Sampling comprised cell collection from both cheeks with a cytobrush, centrifugation, slide preparation, fixation, and staining, followed by fluorescent microscopic analysis. A total of 2000 exfoliated cells were screened for nuclear abnormalities, especially micronucleus. Results: No statistically significant changes were recorded in relation to age, gender, body mass index, or smoking status. A comparison of the results vs the control area according to the side of the face on which the mobile phone was placed, and in relation to the duration of exposure (years) to mobile phone radiation in the total 100 samples, yielded no significant differences. Conclusions: No genotoxic effects because of RF exposure were observed in relation to any of the study parameters.

**Ross A, Barker K. Cell phones, clothing, and sex: first impressions of power using older African Americans as stimuli. Psychol Rep. 93(3 Pt 1): 879-882, 2003.**

Sex, material possessions, and race have long been associated with prestige or status in American society, yet little research has examined this idea. Little is known about the effect of cell phones on first impressions. In a 2 (cell phone: present, absent) x 2 (clothing: jacket, no jacket) x 2 (sex) between-subjects design, 160 women from a predominantly Black college rated stimuli of older, African Americans on 15 items measuring perceived power on three power subscales: expert, legitimate, and coercive. Multivariate analysis of variance showed a 3-way interaction for clothing, cell phone, and sex of stimulus person.

**Rothman KJ, Loughlin JE, Funch DP, Dreyer NA, Overall mortality of cellular telephone customers. Epidemiology 7(3):303-305, 1996.**

Unlike mobile cellular telephones, in which the antenna is not part of the handset, a portable cellular telephone exposes the user's head to radio frequency energy transmitted from the antenna. This exposure has prompted concerns about potential biological effects, including brain cancer. As a first step in a record-based mortality surveillance of cellular telephone customers, we report on overall mortality of a cohort of more than 250,000 portable and mobile telephone customers during 1994. We found age-specific rates to be similar for users of the two types of telephones. For customers with accounts at least 3 years old, the ratio of mortality rates in 1994 for portable telephone users, compared with mobile telephone users, was 0.86 (90% Confidence interval = 0.47-1.53).

**Roti Roti JL , Malyapa RS, Bisht KS, Ahern EW, Moros EG, Pickard WF, Straube WL, Neoplastic Transformation in C3H 10T(1/2) Cells after Exposure to 835.62 MHz FDMA and 847.74 MHz CDMA Radiations. Radiat Res 155(1):239-247, 2001.**

The effect of radiofrequency (RF) radiation in the cellular phone communication range (835.62 MHz frequency division multiple access, FDMA; 847.74 MHz code division multiple access, CDMA) on neoplastic transformation frequency was measured using the in vitro C3H 10T(1/2) cell transformation assay system. To determine if 835.62 MHz FDMA or 847.74 MHz CDMA radiations have any genotoxic effects that induce neoplastic transformation, C3H 10T(1/2) cells were exposed at 37 degrees C to either of the above radiations [each at a specific absorption rate (SAR) of 0.6 W/kg] or sham-exposed at the same time for 7 days. After the culture medium was changed, the cultures were transferred to incubators and refed with fresh growth medium every 7 days. After 42 days, the cells were fixed and stained with Giemsa, and transformed foci were scored. To determine if exposure to 835.62 MHz FDMA or 847.74 MHz CDMA radiation has any epigenetic effects that can promote neoplastic transformation, cells were first exposed to 4.5 Gy of X rays to induce the transformation process and then exposed to the above radiations (SAR = 0.6 W/kg) in temperature-controlled irradiators with weekly refeeding for 42 days. After both the 7-day RF exposure and the 42-day RF exposure after X irradiation, no statistically significant differences in the transformation frequencies were observed between incubator controls, the sham-exposed (maintained in irradiators without power to the antenna), and the 835.62 MHz FDMA or 847.74 MHz CDMA-exposed groups

**Rotkovska D, Bartonickova A, Kautska J, Effects of microwaves on membranes of hematopoietic cells in their structural and functional organization. Bioelectromagnetics 14(1):79-85, 1993.**

The role of cell membranes in stimulating and inhibiting the effects of microwaves was investigated in experiments carried out with a suspension of murine bone marrow cells irradiated with microwaves in vitro [f = 2.45 GHz, CW, specific absorption rate (SAR) = 12 W/kg]. Results obtained by means of a structural probe, 2.4-TNS, indicate that no structural changes occur in the region of the protein-lipid interphase under conditions of short-term irradiation with microwaves that induced temperatures in the range 36-45 degrees C (exposure time 315 and 525 s, respectively). Investigation of one functional parameter--the ability to produce

hematopoietic colonies in the spleen after transplantation of the bone marrow irradiated in vitro by microwaves--indicated the possibility of affecting stimulatory and inhibitory effects of microwaves by using a blocker of cell receptors, Trimepranol. The role of microwaves as a physical factor interfering in the process of cell proliferation at the level of receptor regulation is discussed.

**Rougier C, Prorot A, Chazal P, Leveque P, Leprat P. EFFECT OF DISCONTINUOUS MICROWAVES EXPOSURE (2.45 GHz) ON ESCHERICHIA COLI MEMBRANE: INVESTIGATIONS ON THERMAL VERSUS NON THERMAL EFFECTS. Appl Environ Microbiol. 2014 Jun 6. pii: AEM.00789-14. [Epub ahead of print]**

The aim of this study was to investigate the effects on the cell membranes of Escherichia coli of 2.45 GHz - microwave (MW) treatment under various conditions with an average temperature of the cell suspension maintained at 37°C in order to examine the possible thermal versus non thermal effects of short duration MW exposure. To this purpose, microwave irradiation of bacteria was performed under carefully defined and controlled parameters, resulting in a discontinuous MW exposure in order to maintain the average temperature of the bacterial cell suspensions at 37°C. Escherichia coli cells were exposed to 200 - 2000 W discontinuous microwaves (DW) treatments for different periods of time. For each experiment, conventional heating (CH) in a water bath at 37°C was performed as control. The effects of DW exposure on cell membranes was investigated using flow cytometry (FCM), after propidium iodide (PI) staining of cells in addition to the assessment of intracellular proteins release in bacterial suspensions. No effect was detected when bacteria were exposed to conventional heating or 200 W, whereas cell membrane integrity was slightly altered when cell suspensions were submitted to powers ranging from 400 to 2000 W. The thermal characterization suggested that the temperature reached by the microwave-exposed samples for the contact time studied was not high enough to explain the measured modifications of cell membrane integrity. Because the results indicated that the cell-response is power dependent, the hypothesis of a specific electromagnetic threshold effect, probably related to the temperature increase, can be advanced.

**Roux D, Faure C, Bonnet P, Girard S, Ledoigt G, Davies E, Gendraud M, Paladian F, Vian A. A possible role for extra-cellular ATP in plant responses to high frequency, low amplitude electromagnetic field. to the reports of health hazards among mobile-phone users. Plant Signal Behav. 3(6):383-385, 2008.**

In parallel to evoking the accumulation of stress-related transcripts, exposure to low level 900 MHz EMF affected the levels of ATP, the main energy molecule of the cell. Its concentration dropped rapidly (27% after 30 min) in response to EMF exposure, along with a 18% decrease in the adenylate energy charge (AEC), a good marker of cell energy status. One could interpret this decrease in ATP and AEC in a classical way, i.e., as the result of an increase in cellular energy usage, but recent work brings exciting new insights in pointing out a signalling function for ATP, especially in the stress physiology context where it could trigger both reactive oxygen species and calcium movement (this latter being involved in plant responses to EMF exposure). In this addendum, we discuss our results within this new perspective for ATP function

**Roux D, Vian A, Girard S, Bonnet P, Paladian F, Davies E, Ledoigt G. High frequency (900 MHz) low amplitude (5 V m-1) electromagnetic field: a genuine environmental stimulus that affects transcription, translation, calcium and energy charge in tomato. Planta. 227(4):883-891, 2008.**

Using an especially-designed facility, the Mode Stirred Reverberation Chamber, we exposed tomato plants (Lycopersicon esculentum Mill. VFN8) to low level (900 MHz, 5 V m(-1)) electromagnetic fields for a short period (10 min) and measured changes in abundance of three specific mRNA soon after exposure. Within minutes of electromagnetic stimulation, stress-related mRNA (calmodulin, calcium-dependent protein kinase and proteinase inhibitor) accumulated in a rapid, large and 3-phase manner typical of an environmental stress response. Accumulation of these transcripts into the polysomal RNA also took place (indicating that the encoded proteins were translated) but was delayed (indicating that newly-synthesized mRNA was not immediately recruited into polysomes). Transcript accumulation was maximal at normal Ca(2+) levels and was depressed at higher Ca(2+), especially for those encoding calcium-binding proteins. Removal of Ca(2+) (by addition of chelating agents or Ca(2+) channel blocker) led to total suppression of mRNA accumulation. Finally, 30 min after the electromagnetic treatment, ATP concentration and adenylate energy charge were transiently decreased, while transcript accumulation was totally prevented by application of the uncoupling reagent, CCCP. These responses occur very soon after exposure, strongly suggesting that they are the direct consequence of application of radio-frequency fields and their similarities to wound responses strongly suggests that this radiation is perceived by plants as an injurious stimulus.

**Roux D, Girard S, Paladian F, Bonnet P, Lalléchère S, Gendraud M, Davies E, Vian A. Human keratinocytes in culture exhibit no response when exposed to short duration, low amplitude, high frequency (900 MHz) electromagnetic fields in a reverberation chamber. Bioelectromagnetics. 32(4):302-311, 2011.**

Abstract. We exposed normal human epidermal keratinocytes to short duration, high frequency, and low amplitude electromagnetic fields, similar to that used by mobile phone technologies. We paid particular attention to the control of the characteristics of the electromagnetic environment generated within a mode stirred reverberation chamber (statistical homogeneity and isotropy of the field and SAR distribution). Two non-thermal exposure conditions were tested on the epidermal cells: 10-min exposure with a field amplitude of 8 V/m, and 30 min with 41 V/m. Corresponding specific absorption rates ranged from 2.6 to 73 mW/kg (continuous wave, 900 MHz carrier frequency). We collected RNA from cells subjected to these conditions and used it for a large-scale microarray screening of over 47000 human genes. Under these conditions, exposure of keratinocytes to the electromagnetic field had little effect; only 20 genes displayed significant modulation. The expression ratios were very small (close to 1.5-fold change), and none of them were shared by the two tested conditions. Furthermore, those assayed using polymerase chain reaction did not display significant expression modulation (overall mean of the exposed samples: 1.20 ± 0.18). In conclusion, the data presented here show that cultured keratinocytes are not significantly affected by EMF exposure.

**Rowley JT, Joyner KH. Observations from national Italian fixed radiofrequency monitoring network. Bioelectromagnetics. 37(2):136-139, 2016.**

We analyzed a database of more than 50 million data points from the national Italian fixed radiofrequency (RF) field monitoring network that was operational between June 2002 and November 2006. We applied a modified Regression on Order Statistics approach to reanalyze the database and to deal with the large proportion of entries (39.8%) below detection sensitivity of the probe systems. We found no more than an 18% variation in annual wideband levels during the 2002-2006 period. Mean value for mobile communications band was 0.047 μW/cm(2) for the period 2005-2006. Findings of this analysis are consistent with similar previous studies and we conclude that mean environmental RF levels from cellular mobile communications systems are typically less than 0.1 μW/cm(2) .

**Ruan P, Yong J, Shen H, Zheng X. Monitoring dynamic reactions of red blood cells to UHF electromagnetic waves radiation using a novel micro-imaging technology. Electromagn Biol Med. 31(4):365-374, 2012.**

Multiple state-of-the-art techniques, such as multi-dimensional micro-imaging, fast multi-channel micro-spetrophotometry, and dynamic micro-imaging analysis, were used to dynamically investigate various effects of cell under the 900 MHz electromagnetic radiation. Cell changes in shape, size, and parameters of Hb absorption spectrum under different power density electromagnetic waves radiation were presented in this article. Experimental results indicated that the isolated human red blood cells (RBCs) do not have obviously real-time responses to the ultra-low density (15 μW/cm(2), 31 μW/cm(2)) electromagnetic wave radiation when the radiation time is not more than 30 min; however, the cells do have significant reactions in shape, size, and the like, to the electromagnetic waves radiation with power densities of 1 mW/cm(2) and 5 mW/cm(2). The data also reveal the possible influences and statistical relationships among living human cell functions, radiation amount, and exposure time with high-frequency electromagnetic waves. The results of this study may be significant on protection of human being and other living organisms against possible radiation affections of the high-frequency electromagnetic waves.

**Rubin GJ, Cleare AJ, Wessely S. Psychological factors associated with self-reported sensitivity to mobile phones. J Psychosom Res. 64(1):1-9; discussion 11-12, 2008**

OBJECTIVE: Some people report symptoms associated with mobile phone use. A minority also report "electrosensitivity," experiencing symptoms following exposure to other electrical devices. Research suggests that electromagnetic fields do not trigger these symptoms. In this study, we examined the differences between these two "sensitive" groups and healthy controls. METHODS: Fifty-two people who reported sensitivity to mobile phones, 19 people who reported sensitivity to mobile phones and "electrosensitivity," and 60 nonsensitive controls completed a questionnaire assessing the following: primary reason for using a mobile phone, psychological health, symptoms of

depression, modern health worries (MHW), general health status, symptom severity, and the presence of other medically unexplained syndromes. RESULTS: Perceived sensitivity was associated with an increased likelihood of using a mobile phone predominantly for work (3% of controls, 13% of those sensitive to mobile phones, and 21% of those reporting "electrosensitivity") and greater MHW concerning radiation [mean (S.D.) on a scale of 1-5: 2.0 (1.0), 2.7 (0.9), and 4.0 (0.8), respectively]. Participants who reported "electrosensitivity" also experienced greater depression, greater worries about tainted food and toxic interventions, worse general health on almost every measure, and a greater number of other medically unexplained syndromes compared to participants from the other two groups. No group differences were observed with regards to psychiatric cases. CONCLUSIONS: The data illustrate that patients reporting "electrosensitivity" experience substantially worse health than either healthy individuals or people who report sensitivity to mobile phones but who do not adopt the label "electrosensitivity." Clinicians and researchers would be wise to pay greater attention to this subdivision**.**

**Rufo MM, Paniagua JM, Jiménez A, Antolín A. Exposure to high-frequency electromagnetic fields (100 kHz-2 GHz) in Extremadura (Spain). Health Phys. 101(6):739-745, 2011.**

The last decade has seen a rapid increase in people's exposure to electromagnetic fields. This paper reports the measurements of radiofrequency (RF) total power densities and power density spectra in 35 towns of the region of Extremadura, Spain. The spectra were taken with three antennas covering frequencies from 100 kHz to 2.2 GHz. This frequency range includes AM/FM radio broadcasting, television, and cellular telephone signals. The power density data and transmitting antenna locations were stored in a geographic information system (GIS) as an aid in analyzing and interpreting the results. The results showed the power density levels to be below the reference level guidelines for human exposure and that the power densities are different for different frequency ranges and different size categories of towns.

**Ruigrok HJ, Arnaud-Cormos D, Hurtier A , Poque E, de Gannes FP, Ruffié G, Bonnaudin F, Lagroye I, Sojic N, Arbault S, Lévêque P, Veyret B, Percherancier Y. Activation of the TRPV1 Thermoreceptor Induced by Modulated or Unmodulated 1800 MHz Radiofrequency Field Exposure. Radiat Res. 2017 Oct 23. doi: 10.1667/RR14877.1. [Epub ahead of print]**

The existence of effects of radiofrequency field exposure at environmental levels on living tissues and organisms remains controversial, in particular regarding potential "nonthermal" effects produced in the absence of temperature elevation. Therefore, we investigated whether TRPV1, one of the most studied thermosensitive channels, can be activated by the heat produced by radiofrequency fields and by some specific nonthermal interaction with the fields. We have recently shown that TRPV1 activation can be assessed in real-time on live cells using the bioluminescence resonance energy transfer technique. Taking advantage of this innovative assay, we monitored TRPV1 thermal and chemical modes of activation under radiofrequency exposure at 1800 MHz using different signals (CW, GSM, UMTS, LTE, Wi-Fi and WiMAX) at specific absorption rates between

8 and 32 W/kg. We showed that, as expected, TRPV1 channels were activated by the heat produced by radiofrequency field exposure of transiently-transfected HEK293T cells, but found no evidence of TRPV1 activation in the absence of temperature elevation under radiofrequency field exposure. There was no evidence either that, at fixed temperature, radiofrequency exposure altered the maximal efficacy of the agonist Capsaicin to activate TRPV1.

**Russo R**, **Fox E**, **Cinel C**, **Boldini A**, **Defeyter MA**, **Mirshekar-Syahkal D**, **Mehta A. Does acute exposure to mobile phones affect human attention? Bioelectromagnetics.27(3):215-220, 2006.**

Recent studies have indicated that acute exposure to low level radiofrequency (RF) electromagnetic fields generated by mobile phones affects human cognition. However, the relatively small samples used, in addition to methodological problems, make the outcomes of these studies difficult to interpret. In our study we tested a large sample of volunteers (168) using a series of cognitive tasks apparently sensitive to RF exposure (a simple reaction task, a vigilance task, and a subtraction task). Participants performed those tasks twice, in two different sessions. In one session they were exposed to RFs, with half of subjects exposed to GSM signals and the other half exposed to CW signals, while in the other session they were exposed to sham signals. No significant effects of RF exposure on performance for either GSM or CW were found, independent of whether the phone was positioned on the left or on the right side.

**Ryan KL, Walters TJ, Tehrany MR, Lovelace JD, Jauchem JR.Age does not affect thermal and cardiorespiratory responses to microwave heating in calorically restricted rats. Shock 8(1):55-60, 1997.**

This study sought to determine whether age influences the thermal distribution and cardiorespiratory responses to 35 GHz microwave (MW) heating. Male Sprague-Dawley rats (n = 8/group) 3 to 4 mo old (young), 15 to 16 mo old (middle-aged), and 24 to 25 mo old (old) were used. All animals were restricted to 63% of ad libitum feed. Rats were anesthetized (ketamine) and a catheter was placed into a carotid artery for measurement of mean arterial blood pressure (MAP). Anesthetized rats were then exposed to MWs until death, while measuring MAP, heart rate and temperatures at five sites (colonic, left and right tympanic, subcutaneous, and tail). Before MW exposure, there were no significant ($p < .05$) differences among age groups in measured parameters. MW produced increases in temperature at each of the measured sites; temperatures at death did not differ between groups. Heart rate increased throughout MW exposure, in a statistically identical manner in all age groups. MAP was initially well maintained and then, in the latter phases of heating, precipitously declined until death, with no discernible age-related difference. Respiration rate was not altered by MW exposure in any group. Finally, there were no group differences in the MW exposure time required to induce death. Thus, age does not alter thermal and cardiorespiratory responses to 35 GHz MW heating in food-restricted rats.

**Saalman E, Norden B, Arvidsson L, Hamnerius Y, Hojevik P, Connell KE, Kurucsev T, Effect of 2.45 GHz microwave radiation on permeability of unilamellar liposomes to 5(6)-carboxyfluorescein. Evidence of non-thermal leakage. Biochim Biophys**

**Acta 1064(1):124-130, 1991.**

The influence of 2.45 GHz microwave radiation on the membrane permeability of unilamellar liposomes was studied using the marker 5(6)-carboxyfluorescein trapped in phosphatidylcholine liposomes. The release of the fluorescent marker was followed by spectrofluorimetry after an exposure of 10 minutes to either microwave radiation or to heat alone of the liposome solutions. A significant increase of the permeability of carboxyfluorescein through the membrane was observed for the microwave-exposed samples compared to those exposed to normal heating only. Exposure to 2.45 GHz microwave radiation of liposomes has been previously found to produce increased membrane permeability as compared with heating. However, in contrast to previous studies, the observations reported here were made above the phase transition temperature of the lipid membrane. The experimental setup included monitoring of the temperature during microwave exposure simultaneously at several points in the solution volume using a fiberoptic thermometer. Possible mechanisms to explain the observations are discussed.

**Sadetzki S, Chetrit A, Jarus-Hakak A, Cardis E, Deutch Y, Duvdevani S, Zultan A, Novikov I, Freedman L, Wolf M. Cellular phone use and risk of benign and malignant parotid gland tumors--a nationwide case-control study. Am J Epidemiol. 167(4):457-467, 2008.**

The objective of this nationwide study was to assess the association between cellular phone use and development of parotid gland tumors (PGTs). The methods were based on the international INTERPHONE study that aimed to evaluate possible adverse effects of cellular phone use. The study included 402 benign and 58 malignant incident cases of PGTs diagnosed in Israel at age 18 years or more, in 2001-2003, and 1,266 population individually matched controls. For the entire group, no increased risk of PGTs was observed for ever having been a regular cellular phone user (odds ratio = 0.87; p = 0.3) or for any other measure of exposure investigated. However, analysis restricted to regular users or to conditions that may yield higher levels of exposure (e.g., heavy use in rural areas) showed consistently elevated risks. For ipsilateral use, the odds ratios in the highest category of cumulative number of calls and call time without use of hands-free devices were 1.58 (95% confidence interval: 1.11, 2.24) and 1.49 (95% confidence interval: 1.05, 2.13), respectively. The risk for contralateral use was not significantly different from 1. A positive dose-response trend was found for these measurements. Based on the largest number of benign PGT patients reported to date, our results suggest an association between cellular phone use and PGTs.

**Saffer JD, Profenno LA, Microwave-specific heating affects gene expression. Bioelectromagnetics 13(1):75-78, 1992.**

The effects of low-level microwave radiation on gene expression in Escherichia coli have been examined in a sensitive model. We confirm the previously reported existence of an increase in beta-galactosidase expression by microwave radiation--an increase not duplicated by bulk heating. However, the effect was not frequency dependent and appeared to be due to heating effects peculiar to microwaves. These results indicate that small thermal gradients may be a source of biological effects of non-ionizing radiation.

**Safian F, Khalili MA, Khoradmehr A, Anbari F, Soltani S, Halvaei I. Survival Assessment of Mouse Preimplantation Embryos After Exposure to Cell Phone Radiation. J Reprod Infertil. 17(3):138-143, 2016.**

BACKGROUND: Using cellular phone has rapidly increased all over the world. Also, the concern on the possible health hazards of electromagnetic fields (EMF) induced from cell phones to reproduction has been growing in many countries. The aim of this study was to assess the consequences and effects of exposure to the cell phone radiation on the quality and survival rates of preimplantation embryos in mice. METHODS: A total of 40 mice (20 females and 20 males), 6 weeks old and sexually mature BALB/c, were used for control and experimental groups. The ovary burses were removed and the zygotes were dissected in the morning after mating. Next, 2-cell embryos were divided into two groups of control (n=150) and experimental (n=150). EMF (900-1800 MHz) was used for four days in experimental group for 30 min/day in culture at 37°C in a CO 2 incubator. The quality of embryos was recorded daily and the fluorescent staining was used for identification of viable blastocysts. All data were compared by Student's t-test and Mann-Whitney test ($p<0.05$). RESULTS: The rate of embryo survival to the blastocysts stage was similar in both groups. However, the percentage of dead embryos at the 2-cell stage was significantly higher in EMF-exposed group compared with controls ($p=0.03$). Also, the loss of cell viability significantly increased in experimental blastocysts ($p=0.002$). CONCLUSION: The normal embryonic development up to the blastocyst stage indicates that EMF-exposure commonly did not have adverse effect on embryo development in mice. But, it caused loss of blastocysts cell viability.

**Safronova VG, Gapeev AB, Alovskaia AA, Gabdulkhakova AG, Chemeris NK, Fesenko EE [Millemetre waves inhibit the synergistic effect of calcium ionophore A23187 and phorbol ester in neutrophil respiratory burst]. Biofizika 42(6):1267-1273, 1997.** [Article in Russian]

The effect of extremely high frequency electromagnetic field (mm-waves) on respiratory burst of neutrophils was studied. The peritoneal evoked neutrophils of the mice (NMRI line) were used. The production of reactive oxygen species was estimated by luminol-dependent chemiluminescence technique. Cells were irradiated by the mm-waves of 41. 95 GHz in the far field zone of the channel radiator during 20 min. Absorbed energy flux density was 150 microW/cm2. The irradiation was carried out at different concentrations of calcium ionophore A23187 and then neutrophils were stimulated by phorbol 12-myristate 13-acetate (PMA) 1 microM, activator of PKC. At irradiation of neutrophils the synergistic action of A23187 and PMA was not changed at low concentration of ionophore 10 nM-0.5 microM and was suppressed at high concentrations 0.5-10 microM. The largest inhibition of about 60% was obtained at the concentration of A23187 20 microM. The effect of mm-waves was not found under exposure in Ca(2+)-free medium for all used A23187 concentrations. We suggest that the mm-wave effect on the production of reactive oxygen species by neutrophils is determined by the influx of extracellular Ca2+ and PKC.

**Sage C, Johansson O, Sage SA. Personal digital assistant (PDA) cell phone units**

**produce elevated extremely-low frequency electromagnetic field emissions. Bioelectromagnetics.28(5):386-92,2007.**

Initial tests indicate that personal and occupational use of personal digital assistants (PDAs or palm-held wireless units) produce high intensity bursts of extremely-low frequency electromagnetic fields (ELF-EMF). These emissions could result in comparatively high ELF-EMF exposure in persons that carry a PDA close to the body (i.e., in a pocket or on a belt); or held to the head for cell phone conversations. ELF-EMF emissions of 10 microT were recorded on PDAs during normal office use over a 24 h test period. Results of ELF-EMF measurements show that email transmit and receive functions produce rapid, short-duration ELF-EMF spikes in the 2-10 microT range, each lasting several seconds to over a minute apparently depending on file download size. Some units produced spikes as high as 30-60 microT during email activities. Cell phone activity on PDAs produced continuously elevated ELF-EMF readings in the 0.5-1 microT range, as opposed to the rapid spiking pattern for email receipt and transmission. Switching the PDA unit from "OFF" to "ON" position resulted in single ELF-EMF pulses of over 90 microT on two units. Email downloads into the PDA can occur randomly throughout the day and night when the unit is "ON"; thus the user who wears the PDA may be receiving high-intensity ELF-EMF pulses throughout the day and night. The frequency of email traffic on the PDA, and the power switching unit (battery unit) may affect the frequency and intensity of ELF-EMF emissions.

**Saghiri MA, Orangi J, Asatourian A, Mehriar P, Sheibani N. Effect of mobile phone use on metal ion release from fixed orthodontic appliances. Am J Orthod Dentofacial Orthop. 147(6):719-724, 2015.**

INTRODUCTION: The aim of this study was to evaluate the effect of exposure to radiofrequency electromagnetic fields emitted by mobile phones on the level of nickel in saliva. METHODS: Fifty healthy patients with fixed orthodontic appliances were asked not to use their cell phones for a week, and their saliva samples were taken at the end of the week (control group). The patients recorded their time of mobile phone usage during the next week and returned for a second saliva collection (experimental group). Samples at both times were taken between 8:00 and 10:00 pm, and the nickel levels were measured. Two-tailed paired-samples t test, linear regression, independent t test, and 1-way analysis of variance were used for data analysis. RESULTS: The 2-tailed paired-samples t test showed significant differences between the levels of nickel in the control and experimental groups (t [49] = 9.967; P <0.001). The linear regression test showed a significant relationship between mobile phone usage time and the nickel release (F [1, 48] = 60.263; P <0.001; R(2) = 0.577). CONCLUSIONS: Mobile phone usage has a time-dependent influence on the concentration of nickel in the saliva of patients with orthodontic appliances.

**Sagioglou NE, Manta AK, Giannarakis IK, Skouroliakou AS, Margaritis LH. Apoptotic cell death during Drosophila oogenesis is differentially increased by electromagnetic radiation depending on modulation, intensity and duration of exposure. Electromagn Biol Med. 2014 Oct 21:1-14. [Epub ahead of print]**

Abstract Present generations are being repeatedly exposed to different types and doses of non-ionizing radiation (NIR) from wireless technologies (FM radio, TETRA and TV stations, GSM and UMTS phones/base stations, Wi-Fi networks, DECT phones). Although there is controversy on the published data regarding the non-thermal effects of NIR, studies have convincingly demonstrated bioeffects. Their results indicate that modulation, intensity, exposure duration and model system are important factors determining the biological response to irradiation. Attempting to address the dependence of NIR bioeffectiveness on these factors, apoptosis in the model biological system Drosophila melanogaster was studied under different exposure protocols. A signal generator was used operating alternatively under Continuous Wave (CW) or Frequency Modulation (FM) emission modes, at three power output values (10 dB, 0, -10 dB), under four carrier frequencies (100, 395, 682, 900 MHz). Newly emerged flies were exposed either acutely (6 min or 60 min on the 6th day), or repeatedly (6 min or 60 min daily for the first 6 days of their life). All exposure protocols resulted in an increase of apoptotic cell death (ACD) observed in egg chambers, even at very low electric field strengths. FM waves seem to have a stronger effect in ACD than continuous waves. Regarding intensity and temporal exposure pattern, EMF-biological tissue interaction is not linear in response. Intensity threshold for the induction of biological effects depends on frequency, modulation and temporal exposure pattern with unknown so far mechanisms. Given this complexity, translating such experimental data into possible human exposure guidelines is yet arbitrary.

**Şahin A, Aslan A, Baş O, İkinci A, Özyılmaz C, Fikret Sönmez O, Çolakoğlu S, Odacı E. Deleterious impacts of a 900MHz electromagnetic field on hippocampal pyramidal neurons of 8-week-old Sprague Dawley male rats. Brain Res. 2015 Jul 31. pii: S0006-8993(15)00586-7. doi: 10.1016/j.brainres.2015.07.042. [Epub ahead of print]**

Children are at potential risk due to their intense use of mobile phones. We examined 8-week-old rats because that age is comparable with the preadolescent period in humans. The numbers of pyramidal neurons in the cornu ammonis of the Sprague Dawley male rat (8-weeks old, weighing 180-250g) hippocampus following exposure to a 900MHz (MHz) electromagnetic field (EMF) were examined. The study consisted of control (CN-G), sham exposed (SHM-EG) and EMF exposed (EMF-EG) groups, 6 rats in each. The EMF-EG rats were exposed to 900MHz EMF (1h/day for 30 days) in an EMF jar. The SHM-EG rats were placed in the EMF jar but not exposed to EMF (1h/day for 30 days). The CN-G rats were not placed into the exposure jar and were not exposed to EMF during the study period. All animals were sacrificed at the end of the experiment, and their brains were removed for histopathological and stereological analysis. The number of pyramidal neurons in the cornu ammonis of the hippocampus was estimated on Cresyl violet stained sections of the brain using the optical dissector counting technique. Histopathological evaluations were also performed on these sections. Histopathological observation showed abundant cells with abnormal, black or dark blue cytoplasm and shrunken morphology among the normal pyramidal neurons. The largest lateral ventricles were observed in the EMF-EG sections compared to those from the other groups. Stereological analyses showed that the total number of pyramidal neurons in the cornu

ammonis of the EMF-EG rats was significantly lower than those in CN-G ($p<0.05$) and SHM-EG ($p<0.05$). In conclusion, our results suggest that pyramidal neuron loss and histopathological changes in the cornu ammonis of 8-week-old male rats may be due to 900MHz EMF exposure.

**Şahin D, Özgür E, Güler G, Tomruk A, Ünlü İ, Sepici-Dinçel A, Seyhan N. The 2100MHz radiofrequency radiation of a 3G-mobile phone and the DNA oxidative damage in brain. J Chem Neuroanat. 2016 Jan 8. pii: S0891-0618(16)00004-1. doi: 10.1016/j.jchemneu.2016.01.002. [Epub ahead of print]**

We aimed to evaluate the effect of 2100MHz radiofrequency radiation emitted by a generator, simulating a 3G-mobile phone on the brain of rats during 10 and 40 days of exposure. The female rats were randomly divided into four groups. Group I; exposed to 3G modulated 2100MHz RFR signal for 6h/day, 5 consecutive days/wk for 2 weeks, Group II; control 10 days, were kept in an inactive exposure set-up for 6h/day, 5 consecutive days/wk for 2 weeks, Group III; exposed to 3G modulated 2100MHz RFR signal for 6h/day, 5 consecutive days/wk for 8 weeks and Group IV; control 40 days, were kept in an inactive exposure set-up for 6h/day, 5 consecutive days/wk for 8 weeks. After the genomic DNA content of brain was extracted, oxidative DNA damage (8-hydroxy-2'deoxyguanosine, pg/mL) and malondialdehyde (MDA, nmoL/g tissue) levels were determined. Our main finding was the increased oxidative DNA damage to brain after 10 days of exposure with the decreased oxidative DNA damage following 40 days of exposure compared to their control groups. Besides decreased lipid peroxidation end product, MDA, was observed after 40 days of exposure. The measured decreased quantities of damage during the 40 days of exposure could be the means of adapted and increased DNA repair mechanisms.

**Saikhedkar N, Bhatnagar M, Jain A, Sukhwal P, Sharma C, Jaiswal N. Effects of mobile phone radiation (900 MHz radiofrequency) on structure and functions of rat brain. Neurol Res. 2014 May 26:1743132814Y0000000392. [Epub ahead of print]**

Objectives: The goals of this study were: (1) to obtain basic information about the effects of long-term use of mobile phone on cytological makeup of the hippocampus in rat brain (2) to evaluate the effects on antioxidant status, and (3) to evaluate the effects on cognitive behavior particularly on learning and memory. Methods: Rats (age 30 days, 120 ± 5 g) were exposed to 900 MHz radio waves by means of a mobile hand set for 4 hours per day for 15 days. Effects on anxiety, spatial learning, and memory were studied using open field test, elevated plus maze, Morris water maze (MWM), and classic maze test. Effects on brain antioxidant status were also studied. Cresyl violet staining was done to access the neuronal damage. Result: A significant change in behavior, i.e., more anxiety and poor learning was shown by test animals as compared to controls and sham group. A significant change in level of antioxidant enzymes and non-enzymatic antioxidants, and increase in lipid peroxidation were observed in test rats. Histological examination showed neurodegenerative cells in hippocampal sub regions and cerebral cortex. Discussion: Thus our findings indicate extensive neurodegeneration on exposure to radio waves. Increased production of reactive oxygen species due to exhaustion of enzymatic and

non-enzymatic antioxidants and increased lipid peroxidation are indicating extensive neurodegeneration in selective areas of CA1, CA3, DG, and cerebral cortex. This extensive neuronal damage results in alterations in behavior related to memory and learning.

**Sakakibara Y, Mitsui T, Concerns about sources of electromagnetic interference in patients with pacemakers. Jpn Heart J 40(6):737-743, 1999.**

Electromagnetic noise is rapidly increasing in our environment so electromagnetic interference (EMI) with pacemakers (PM) may become a more important problem despite technological improvements in PM. The aim of this study was to evaluate the kinds of EMI which affect the quality of life of PM patients. The participants (1,942 Japanese Association for Pacemaker Patients: Pacemaker-Tomonokai) were asked to respond to a questionnaire about their major EMI troubles, and 1,567 patients (80.7%) responded by mail. The main concerns were from mobile telephones (MT) (39%), magnetic resonance imaging (MRI) (17%), electronic kitchen appliances, automobile engines and high voltage power lines. If possible, PM implantation sites should be carefully selected not only according to the physician's convenience but also considering information on each patient's habits and physical limitations.

**Sakuma N, Komatsubara Y, Takeda H, Hirose H, Sekijima M, Nojima T, Miyakoshi J.DNA strand breaks are not induced in human cells exposed to 2.1425 GHz band CW and W-CDMA modulated radiofrequency fields allocated to mobile radio base stations. Bioelectromagnetics. 27:51-57, 2006.**

We conducted a large-scale in vitro study focused on the effects of low level radiofrequency (RF) fields from mobile radio base stations employing the International Mobile Telecommunication 2000 (IMT-2000) cellular system in order to test the hypothesis that modulated RF fields may act as a DNA damaging agent. First, we evaluated the responses of human cells to microwave exposure at a specific absorption rate (SAR) of 80 mW/kg, which corresponds to the limit of the average whole body SAR for general public exposure defined as a basic restriction in the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines. Second, we investigated whether continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) modulated signal RF fields at 2.1425 GHz induced different levels of DNA damage. Human glioblastoma A172 cells and normal human IMR-90 fibroblasts from fetal lungs were exposed to mobile communication frequency radiation to investigate whether such exposure produced DNA strand breaks in cell culture. A172 cells were exposed to W-CDMA radiation at SARs of 80, 250, and 800 mW/kg and CW radiation at 80 mW/kg for 2 and 24 h, while IMR-90 cells were exposed to both W-CDMA and CW radiations at a SAR of 80 mW/kg for the same time periods. Under the same RF field exposure conditions, no significant differences in the DNA strand breaks were observed between the test groups exposed to W-CDMA or CW radiation and the sham exposed negative controls, as evaluated immediately after the exposure periods by alkaline comet assays. Our results confirm that low level exposures do not act as a genotoxicant up to a SAR of 800 mW/kg.

**Sakurai T, Kiyokawa T, Narita E, Suzuki Y, Taki M, Miyakoshi J. Analysis of gene**

**expression in a human-derived glial cell line exposed to 2.45 GHz continuous radiofrequency electromagnetic fields.J Radiat Res. 52(2):185-192, 2011.**

The increasing use of mobile phones has aroused public concern regarding the potential health risks of radiofrequency (RF) fields. We investigated the effects of exposure to RF fields (2.45 GHz, continuous wave) at specific absorption rate (SAR) of 1, 5, and 10 W/kg for 1, 4, and 24 h on gene expression in a normal human glial cell line, SVGp12, using DNA microarray. Microarray analysis revealed 23 assigned gene spots and 5 non-assigned gene spots as prospective altered gene spots. Twenty-two genes out of the 23 assigned gene spots were further analyzed by reverse transcription-polymerase chain reaction to validate the results of microarray, and no significant alterations in gene expression were observed. Under the experimental conditions used in this study, we found no evidence that exposure to RF fields affected gene expression in SVGp12 cells.

**Saili L, Hanini A, Smirani C, Azzouz I, Azzouz A, Sakly M, Abdelmelek H, Bouslama Z. Effects of acute exposure to WIFI signals (2.45GHz) on heart variability and blood pressure in Albinos rabbit. Environ Toxicol Pharmacol. 2015 Sep;40(2):600-605, 2015.**

Electrocardiogram and arterial pressure measurements were studied under acute exposures to WIFI (2.45GHz) during one hour in adult male rabbits. Antennas of WIFI were placed at 25cm at the right side near the heart. Acute exposure of rabbits to WIFI increased heart frequency (+22%) and arterial blood pressure (+14%). Moreover, analysis of ECG revealed that WIFI induced a combined increase of PR and QT intervals. By contrast, the same exposure failed to alter maximum amplitude and P waves. After intravenously injection of dopamine (0.50ml/kg) and epinephrine (0.50ml/kg) under acute exposure to RF we found that, WIFI alter catecholamines (dopamine, epinephrine) action on heart variability and blood pressure compared to control. These results suggest for the first time, as far as we know, that exposure to WIFI affect heart rhythm, blood pressure, and catecholamines efficacy on cardiovascular system; indicating that radiofrequency can act directly and/or indirectly on cardiovascular system.

**Salah MB, Abdelmelek H, Abderraba M. Effects of olive leave extract on metabolic disorders and oxidative stress induced by 2.45 GHz WIFI signals. Environ Toxicol Pharmacol. 36(3):826-834, 2013.**

We investigated the effect of olive leaves extract administration on glucose metabolism and oxidative response in liver and kidneys of rats exposed to radio frequency (RF). The exposure of rats to RF (2.45 GHz, 1h/day during 21 consecutive days) induced a diabetes-like status. Moreover, RF decreased the activities of glutathione peroxidase (GPx, -33.33% and -49.40%) catalase (CAT, -43.39% and -39.62%) and the superoxide dismutase (SOD, -59.29% and -68.53%) and groups thiol amount (-62.68% and -34.85%), respectively in liver and kidneys. Indeed, exposure to RF increased the malondialdehyde (MDA, 29.69% and 51.35%) concentration respectively in liver and kidneys. Olive leaves extract administration (100 mg/kg, ip) in RF-exposed rats prevented glucose metabolism disruption and restored the activities of GPx, CAT and SOD and thiol

group amount in liver and kidneys. Moreover, olive leave extract administration was able to bring down the elevated levels of MDA in liver but not in kidneys. Our investigations suggested that RF exposure induced a diabetes-like status through alteration of oxidative response. Olive leaves extract was able to correct glucose metabolism disorder by minimizing oxidative stress induced by RF in rat tissues.

**Salahaldin AH, Bener A. Long-term and frequent cellular phone use and risk of acoustic neuroma. Int Tinnitus J. 12(2):145-148, 2006.**

Human exposure to radio frequency radiation has increased dramatically during recent years from widespread use of mobile phones, and in some studies this exposure has been linked to the development of acoustic neuroma. The aim of our study was to describe the epidemiology of acoustic neuroma in a newly developed country, Qatar. We reviewed all cases of acoustic neuroma registered at the Hamad Medical Corporation during the period 2004-2005. We collected and assessed the sociodemographic information, presenting complaints, audiological evaluation, and laboratory investigations. During the study period, we diagnosed acoustic neuroma in 13 patients (10 women, median age 55 years, and 3 men, median age 49 years). Most of the cell phones were used daily for an average of 14 times per day (range, 8-20 times) and had been used for the duration of more than 5 years, with the exception of 3 patients who had used the cell phone excessively (> 20 minutes per call more than five times daily) owing to the nature of their jobs. The total incidence rate for Qatar was found to be 17.2 per million population. In conclusion, the incidence of acoustic neuroma in Qatar is slightly higher than that in other countries. Despite the presence of facilities in Qatar, no proper screening and management protocol is available. This study highlights the need for the development and implementation of a national registry plan whereby effective care services can be delivered and high-risk groups can be targeted.

**Salama N, Kishimoto T, Kanayama HO. Effects of exposure to a mobile phone on testicular function and structure in adult rabbit. Int J Androl.33(1):88-94, 2010.**

Summary The accumulating effects of exposure to electromagnetic radiation emitted by a conventional mobile phone (standby position) on the testicular function and structure are not yet fully investigated. To study these effects longitudinally, a total of 24 adult male rabbits were randomly and equally divided into three groups. Rabbits in the first (phone) group were exposed, in specially designed cages, to radio frequency emitted from the mobile phone (800 MHz) in a standby position opposite to that of testes for 8 h daily for 12 weeks. The second group consisted of the stress controls which were kept in the same kind of cages to appreciate any cage-induced anxiety. The third group included the ordinary controls which were kept in the conventional roomy cages. Semen analysis and sperm function tests (viability, hypo-osmotic swelling and acridine orange) were conducted weekly. Histological testicular sections and serum total testosterone were also evaluated. A drop in the sperm concentration appeared in the phone group at week 6. This became statistically significant at week 8, compared with the two control (stress and ordinary) groups (133, 339 and 356 x 106/mL, respectively) and to the initial sperm count (341 x 106/mL) of this group. Motile sperm population showed similarity amongst the

three study groups until week 10 when it declined significantly, and thereafter in the phone and stress control groups, with more significant decline in the phone animals (50, 61 and 72.4%, respectively). Histological examination showed also a significant decrease in the diameter of seminiferous tubules in the phone group vs. the stress and ordinary controls (191 mum vs. 206 and 226 mum, respectively). The other study points did not show any difference. In conclusion, low intensity pulsed radio frequency emitted by a conventional mobile phone kept in the standby position could affect the testicular function and structure in the adult rabbit.

**Salama N, Kishimoto T, Kanayama HO, Kagawa S. Effects of exposure to a mobile phone on sexual behavior in adult male rabbit: an observational study. Int J Impot Res.22(2):127-33, 2010.**

The accumulating effects of exposure to electromagnetic radiation emitted by a conventional mobile phone (MP) on male sexual behaviour have not yet been analyzed. Therefore, we studied these effects in 18 male rabbits that were randomly divided into phone and control groups. Six female teasers were taken successively to the male's cage and the copulatory behavior was recorded. Serum total testosterone, dopamine and cortisol were evaluated. The animals of the phone group were exposed to MPs (800 MHz) in a standby position for 8 h daily for 12 weeks. At the end of the study, the copulatory behavior and hormonal assays were re-evaluated. Mounts without ejaculation were the main mounts in the phone group and its duration and frequency increased significantly compared with the controls, whereas the reverse was observed in its mounts with ejaculation. Ejaculation frequency dropped significantly, biting/grasping against teasers increased notably and mounting latency in accumulated means from the first to the fourth teasers were noted in the phone group. The hormonal assays did not show any significant differences between the study groups. Therefore, the pulsed radiofrequency emitted by a conventional MP, which was kept on a standby position, could affect the sexual behavior in the rabbit.

**Salama N, Kishimoto T, Kanayama HO, Kagawa S. The mobile phone decreases fructose but not citrate in rabbit semen: a longitudinal study. Syst Biol Reprod Med. 55(5):181-187, 2009.**

The negative impact of mobile phones on sperm motility has been previously described. Both fructose and citrate are important components in semen that facilitate sperm motility. To date, no studies have investigated the effect of exposure to electromagnetic radiation emitted from the mobile phone on their levels.. Therefore, a longitudinal study using the adult rabbit as a model was undertaken. A total of 30 adult male rabbits were randomly divided into three groups. The first (phone) group was placed in specially designed cages, and exposed to radio frequency emitted from a mobile phone (900 MHz) kept in standby mode and positioned adjacent to the genitalia for 8 h daily for 12 weeks. The other two groups served as controls; the stress group which was housed in the same kind of cages to evaluate any cage-induced anxiety, and the control group which was housed in the conventional roomy cages. Semen samples were retrieved weekly. Sperm motility and viability, semen fructose and citrate, and serum testosterone were measured. Histological sections

from the prostatic complex, ampulla, and vesicular gland were evaluated. A significant drop in both fructose levels (257 +/-11.6 vs. 489 +/- 8.4 mg %, the baseline level) and number of motile sperms (50 vs. 72%) was observedin the phone group at the 10th week. However, no correlation was found between the two values. The stress control animals showed a similar but significantly less decline in motility No significant changes in citrate levels or other study parameters were seen in the three animal groups throughout the study. In conclusion, the pulsed radio frequency emitted by the mobile phone kept in the standby position longitudinally affected sperm motility and fructose but not citrate levels in rabbit semen.

**Salford LG, Brun A, Sturesson K, Eberhardt JL, Persson BR Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz. Microsc Res Tech 27(6):535-542, 1994.**

Biological effects of electromagnetic fields (EMF) on the blood-brain barrier (BBB) can be studied in sensitive and specific models. In a previous investigation of the permeability of the blood-brain barrier after exposure to the various EMF-components of proton magnetic resonance imaging (MRI), we found that the exposure to MRI induced leakage of Evans Blue labeled proteins normally not passing the BBB of rats [Salford et al. (1992), in: Resonance Phenomena in Biology, Oxford University Press, pp. 87-91]. In the present investigation we exposed male and female Fischer 344 rats in a transverse electromagnetic transmission line chamber to microwaves of 915 MHz as continuous wave (CW) and pulse-modulated with repetition rates of 8, 16, 50, and 200 s-1. The specific energy absorption rate (SAR) varied between 0.016 and 5 W/kg. The rats were not anesthetized during the 2-hour exposure. All animals were sacrificed by perfusion-fixation of the brains under chloral hydrate anesthesia about 1 hour after the exposure. The brains were perfused with saline for 3-4 minutes, and thereafter fixed in 4% formaldehyde for 5-6 minutes. Central coronal sections of the brains were dehydrated and embedded in paraffin and sectioned at 5 microns. Albumin and fibrinogen were demonstrated immunohistochemically. The results show albumin leakage in 5 of 62 of the controls and in 56 of 184 of the animals exposed to 915 MHz microwaves. Continuous wave resulted in 14 positive findings of 35, which differ significantly from the controls (P = 0.002).

**Salford LG, Brun A, Persson BRR, Brain tumour development in rats exposed to electromagnetic fields used in wireless cellular communication. Wireless network 3: 463-469, 1997.**

It has been suggested that electromagnetic fields (EMF) act as promoters late in the carcinogenesis process. To date, however, there is no convincing laboratory evidence that EMFs cause tumour promotion at non-thermal exposure levels. Therefore the effects of exposure to electromagnetic fields were investigated in a rat brain glioma model. Some of the exposures correspond to electromagnetic fields used in wireless communication. Microwaves at 915 MHz were used both as continuous waves (1 W), and pulse-modulated at 4, 8, 16 and 217 Hz in 0.57 ms pulses and 50 Hz in 6.67 ms pulses (2 W per pulse). Fischer 344 rats of both sexes were used in the experiments. By stereotaxic technique rat glioma cells (RG2 and N32) were injected into the head of the right caudate

nucleus in 154 pairs of rats, exposed and matched controls. Starting on day 5 after inoculation, the animals were exposed for 7 hours a day, 5 days a week during 2-3 weeks. Exposed animals were kept unanaesthetized in well-ventilated TEM cells producing 915 MHz continuous or modulated microwaves. Their matched controls were kept in identical TEM cells without EMF exposure. All brains were examined histopathologically and the tumour size was estimated as the volume of an ellipsoid. Our study of 154matched pairs of rats does not show any significant difference in tumour size between animals exposed to 915 MHz, and those not exposed. Thus our results do not support that even an extensive daily exposure to EMF promotes tumour growth when given from the fifth day after the start of tumour growth in the rat brain until the sacrifice of the animal after about 16 days.

**Salford LG, Brun AR, Eberhardt JL, Malmgren L, Persson BRR, Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environ Health Persp 111:881-883, 2003.**

The possible risks of radio-frequency electromagnetic fields for the human body is a growing concern for the society. We have earlier shown that weak pulsed microwaves give rise to a significant leakage of albumin through the blood-brain barrier (BBB). Now we have investigated whether a pathological leakage over the BBB might be combined with damage to the neurons. Three groups of each 8 rats were exposed for 2 hours to GSM mobile phone electromagnetic fields of different strengths. We found, and present here for the first time, highly significant ($p < 0.002$) evidence for neuronal damage in both the cortex, the hippocampus and the basal ganglia in the brains of exposed rats.

**Salunke BP, Umathe SN, Chavan JG. Behavioral in-effectiveness of high frequency electromagnetic field in mice. Physiol Behav. 2014 Dec 10;140C:32-37. doi: 10.1016/j.physbeh.2014.12.019. [Epub ahead of print]**

The present investigation was carried out with an objective to study the influence of high frequency electromagnetic field (HF-EMF) on anxiety, obsessive compulsive disorder (OCD) and depression-like behavior. For exposure to HF-EMF, non-magnetic material was used to fabricate the housing. Mice were exposed to HF-EMF (2.45GHz), 60min/day for 7 or 30 or 60 or 90 or 120days. The exposure was carried out by switching-on inbuilt class-I BLUETOOTH device that operates on 2.45GHz frequency in file transfer mode at a peak density of 100mW. Mice were subjected to the assessment of anxiety, OCD and depression-like behavior for 7 or 30 or 60 or 90 or 120days of exposure. The anxiety-like behavior was assessed by elevated plus maze, open field test and social interaction test. OCD-like behavior was assessed by marble burying behavior, whereas depression-like behavior was assessed by forced swim test and tail suspension test. The present experiment demonstrates that up to 120days of exposure to HF-EMF does not produce anxiety, OCD and depression-like behavior in mice.

**Sambucci M, Laudisi F, Nasta F, Pinto R, Lodato R, Altavista P, Lovisolo GA, Marino C, Pioli C. Prenatal exposure to non-ionizing radiation: effects of WiFi signals on pregnancy outcome, peripheral B-cell compartment and antibody production. Radiat Res. 174(6):732-740, 2010.**

During embryogenesis, the development of tissues, organs and systems, including the immune system, is particularly susceptible to the effects of noxious agents. We examined the effects of prenatal (in utero) exposure to WiFi signals on pregnancy outcome and the immune B-cell compartment, including antibody production. Sixteen mated (plug-positive) female mice were assigned to each of the following groups: cage control, sham-exposed and microwave-exposed (WiFi signals at 2.45 GHz, whole body, SAR 4 W/kg, 2 h/day, 14 consecutive days starting 5 days after mating). No effects due to exposure to WiFi signals during pregnancy on mating success, number of newborns/mother and body weight at birth were found. Newborn mice were left to grow until 5 or 26 weeks of age, when immunological analyses were performed. No differences due to exposure were found in spleen cell number, B-cell frequency or antibody serum levels. When challenged in vitro with LPS, B cells from all groups produced comparable amounts of IgM and IgG, and proliferated at a similar level. All these findings were consistently observed in the female and male offspring at both juvenile (5 weeks) and adult (26 weeks) ages. Stress-associated effects as well as age- and/or sex-related differences were observed for several parameters. In conclusion, our results do not show any effect on pregnancy outcome or any early or late effects on B-cell differentiation and function due to prenatal exposure to WiFi signals.

**Sambucci M, Laudisi F, Nasta F, Pinto R, Lodato R, Lopresto V, Altavista P, Marino C, Pioli C. Early life exposure to 2.45GHz WiFi-like signals: effects on development and maturation of the immune system. Prog Biophys Mol Biol. 107(3):393-398, 2011.**

The development of the immune system begins during embryogenesis, continues throughout fetal life, and completes its maturation during infancy. Exposure to immune-toxic compounds at levels producing limited/transient effects in adults, results in long-lasting or permanent immune deficits when it occurs during perinatal life. Potentially harmful radiofrequency (RF) exposure has been investigated mainly in adult animals or with cells from adult subjects, with most of the studies showing no effects. Is the developing immune system more susceptible to the effects of RF exposure? To address this question, newborn mice were exposed to WiFi signals at constant specific absorption rates (SAR) of 0.08 or 4 W/kg, 2h/day, 5 days/week, for 5 consecutive weeks, starting the day after birth. The experiments were performed with a blind procedure using sham-exposed groups as controls. No differences in body weight and development among the groups were found in mice of both sexes. For the immunological analyses, results on female and male newborn mice exposed during early post-natal life did not show any effects on all the investigated parameters with one exception: a reduced IFN-γ production in spleen cells from microwaves (MW)-exposed (SAR 4 W/kg) male (not in female) mice compared with sham-exposed mice. Altogether our findings do not support the hypothesis that early post-natal life exposure to WiFi signals induces detrimental effects on the developing immune system.

**Samkange-Zeeb F, Berg G, Blettner M. Validation of self-reported cellular phone**

**use. J Expo Anal Environ Epidemiol. 14(3):245-248, 2004.**

BACKGROUND: In recent years, concern has been raised over possible adverse health effects of cellular telephone use. In epidemiological studies of cancer risk associated with the use of cellular telephones, the validity of self-reported cellular phone use has been problematic. Up to now there is very little information published on this subject. METHODS: We conducted a study to validate the questionnaire used in an ongoing international case-control study on cellular phone use, the "Interphone study". Self-reported cellular phone use from 68 of 104 participants who took part in our study was compared with information derived from the network providers over a period of 3 months (taken as the gold standard). RESULTS: Using Spearman's rank correlation, the correlation between self-reported phone use and information from the network providers for cellular phone use in terms of the number of calls per day was good (r=0.62, 95% CI: 0.45-0.75), while that of the average duration of each call was rather moderate (r=0.34, 95% CI: 0.11-0.54). Similar results were found when Kappa coefficients were estimated. A value of r=0.56 (Spearman's correlation, CI: 0.38-0.70) was found for cumulative cellular phone use. CONCLUSION: Our study suggests that cellular phone use is easier to recall in terms of number of calls made than in terms of cumulative phone use and should thus be used as the basis for the dose-response analysis.

**Sanchez S, Milochau A, Ruffie G, Poulletier de Gannes F, Lagroye I, Haro E, Surleve-Bazeille JE, Billaudel B, Lassegues M, Veyret B. Human skin cell stress response to GSM-900 mobile phone signals.FEBS J. 273(24):5491-5507, 2006.**

In recent years, possible health hazards due to radiofrequency radiation (RFR) emitted by mobile phones have been investigated. Because several publications have suggested that RFR is stressful, we explored the potential biological effects of Global System for Mobile phone communication at 900 MHz (GSM-900) exposure on cultures of isolated human skin cells and human reconstructed epidermis (hRE) using human keratinocytes. As cell stress markers, we studied Hsc70, Hsp27 and Hsp70 heat shock protein (HSP) expression and epidermis thickness, as well as cell proliferation and apoptosis. Cells were exposed to GSM-900 under optimal culture conditions, for 48 h, using a specific absorption rate (SAR) of 2 W.kg(-1). This SAR level represents the recommended limit for local exposure to a mobile phone. The various biological parameters were analysed immediately after exposure. Apoptosis was not induced in isolated cells and there was no alteration in hRE thickness or proliferation. No change in HSP expression was observed in isolated keratinocytes. By contrast, a slight but significant increase in Hsp70 expression was observed in hREs after 3 and 5 weeks of culture. Moreover, fibroblasts showed a significant decrease in Hsc70, depending on the culture conditions. These results suggest that adaptive cell behaviour in response to RFR exposure, depending on the cell type and culture conditions, is unlikely to have deleterious effects at the skin level.

**Sagar S, Dongus S, Schoeni A, Roser K, Eeftens M, Struchen B, Foerster M, Meier N , Adem S, Röösli M. Radiofrequency electromagnetic field exposure in everyday microenvironments in Europe: A systematic literature review. J Expo Sci Environ Epidemiol. 2017 Aug 2. doi: 10.1038/jes.2017.13. [Epub ahead of print]**

The impact of the introduction and advancement in communication technology in recent years on exposure level of the population is largely unknown. The main aim of this study is to systematically review literature on the distribution of radiofrequency electromagnetic field (RF-EMF) exposure in the everyday environment in Europe and summarize key characteristics of various types of RF-EMF studies conducted in the European countries. We systematically searched the ISI Web of Science for relevant literature published between 1 January 2000 and 30 April 2015, which assessed RF-EMF exposure levels by any of the methods: spot measurements, personal measurement with trained researchers and personal measurement with volunteers. Twenty-one published studies met our eligibility criteria of which 10 were spot measurements studies, 5 were personal measurement studies with trained researchers (microenvironmental), 5 were personal measurement studies with volunteers and 1 was a mixed methods study combining data collected by volunteers and trained researchers. RF-EMF data included in the studies were collected between 2005 and 2013. The mean total RF-EMF exposure for spot measurements in European "Homes" and "Outdoor" microenvironments was 0.29 and 0.54 V/m, respectively. In the personal measurements studies with trained researchers, the mean total RF-EMF exposure was 0.24 V/m in "Home" and 0.76 V/m in "Outdoor". In the personal measurement studies with volunteers, the population weighted mean total RF-EMF exposure was 0.16 V/m in "Homes" and 0.20 V/m in "Outdoor". Among all European microenvironments in "Transportation", the highest mean total RF-EMF 1.96 V/m was found in trains of Belgium during 2007 where more than 95% of exposure was contributed by uplink. Typical RF-EMF exposure levels are substantially below regulatory limits. We found considerable differences between studies according to the type of measurements procedures, which precludes cross-country comparison or evaluating temporal trends. A comparable RF-EMF monitoring concept is needed to accurately identify typical RF-EMF exposure levels in the everyday environment.

**Sanchez S, Masuda H, Billaudel B, Haro E, Anane R, Leveque P, Ruffie G, Lagroye I, Veyret B.Effect of GSM-900 and -1800 signals on the skin of hairless rats. II: 12-week chronic exposures.Int J Radiat Biol. 82(9):675-680, 2006.**

Purpose: The purpose of this work was to determine whether the cellular components of Hairless-rat skin are affected by a chronic local exposure to non-ionizing radiations of Global Mobile Phone System: GSM-900 or -1800 radiations at specific absorption rate (SAR) 2.5 and 5 W/kg.Materials and methods: A selected part of the right back of five-week old female hairless rats was exposed or sham exposed (n = 8) for 2 h per day, 5 days a week, for 12 weeks to GSM-900 or -1800 signals using a loop-antenna. At the end of the experiment, skin biopsies were taken.Results: Analyses of skin sections using hematoxylin eosin saffron (HES) coloration showed no significant difference in skin thickness among the groups. Immunohistochemical analysis of basal lamella cells in radiofrequency radiation (RFR)-exposed epidermis showed that the ratio of the antigen Ki-67 (cellular proliferation marker) positive cells to total lamella cells remained within the range of the normal proliferation ratio. No significant differences in the level of filaggrin, collagen, and elastin were observed among the different groups.Conclusions: The results of this 12-week chronic study do not demonstrate major histological variations in the skin of hairless rats exposed to RFR used in mobile telephony (GSM-900 or -1800).

**Sanchez, S., Haro, E., Ruffie, G., Veyret, B. and Lagroye, I. In Vitro Study of the Stress Response of Human Skin Cells to GSM-1800 Mobile Phone Signals Compared to UVB Radiation and Heat Shock. Radiat. Res. 167, 572-580, 2007.**

The evolution of mobile phone technology is toward an increase of the carrier frequency up to 2.45 GHz. Absorption of radiofrequency (RF) radiation becomes more superficial as the frequency increases. This increasingly superficial absorption of RF radiation by the skin, which is the first organ exposed to RF radiation, may lead to stress responses in skin cells. We thus investigated the expression of three heat-shock proteins (HSP70, HSC70, HSP27) using immunohistochemistry and induction of apoptosis by flow cytometry on human primary keratinocytes and fibroblasts. A well-characterized exposure system, SXC 1800, built by the IT'IS foundation was used at 1800 MHz, with a 217 Hz modulation. We tested a 48-h exposure at an SAR of 2 W/kg (ICNIRP local exposure limit). Skin cells were also irradiated with a 600 mJ/cm(2) single dose of UVB radiation and subjected to heat shock (45 degrees C, 20 min) as positive controls for apoptosis and HSP expression, respectively. The results showed no effect of a 48-h GSM-1800 exposure at 2 W/kg on either keratinocytes or fibroblasts, in contrast to UVB-radiation or heat-shock treatments, which injured cells. We thus conclude that the GSM-1800 signal does not act as a stress factor on human primary skin cells in vitro.

**Sanchez S, Masuda H, Ruffié G, De Gannes FP, Billaudel B, Haro E, Lévêque P, Lagroye I, Veyret B. Effect of GSM-900 and -1800 signals on the skin of hairless rats. III: Expression of heat shock proteins. Int J Radiat Biol.84(1):61-68, 2008.**

Purpose: We previously reported the inability of Global System for Mobile communication (GSM) signals at 900 (GSM-900) and 1800 (GSM-1800) MegaHertz (MHz) to induce morphological and physiological changes in epidermis of Hairless rats. The present work aimed at investigating heat shock proteins (HSP) expression - as a cellular stress marker - in the skin of Hairless rats exposed to GSM-900 and -1800 signals. Materials and methods: We studied the expression of the Heat-shock cognate (Hsc) 70, and the inducible forms of the Heat-shock proteins (Hsp) 25 and 70. Rat skin was locally exposed using loop antenna and restrain rockets to test several Specific Absorption Rates (SAR) and exposure durations: (i) single exposure: 2 hours at 0 and 5 W/kg; (ii) repeated exposure: 2 hours per day, 5 days per week, for 12 weeks, at 0, 2.5, and 5 W/kg. HSP expression was detected on skin slices using immunolabeling in the epidermal area. Results: Our data indicated that neither single nor repeated exposures altered HSP expression in rat skin, irrespective of the GSM signal or SAR considered. Conclusions: Under our experimental conditions (local SAR <5 W/kg), there was no evidence that GSM signals alter HSP expression in rat skin.

**Sandblom J, Theander S, The effect of microwave radiation on the stability and formation of gramicidin-A channels in lipid bilayer membranes. Bioelectromagnetics 12(1):9-20, 1991.**

The effects of microwaves on the single-channel kinetics of gramicidin-A channels in lipid bilayer membranes were examined. Attempts were made to separate thermal and athermal effects by accurate measurements of temperature at the site of the membrane

and by relating the measured parameters to their previously characterized temperature dependence. It was found that microwave radiation does not affect single-channel conductance or channel life time to a degree that is significantly different from that expected of a purely thermal effect. On the other hand, the rate of channel formation is decreased during exposure, which is opposite to that expected of a purely thermal effect. The mechanism of this effect is discussed in terms of the dimerization process of channel formation.

**Sandrini L, Vaccari A, Malacarne C, Cristoforetti L, Pontalti R. RF dosimetry: a comparison between power absorption of female and male numerical models from 0.1 to 4 ghz. Phys Med Biol. 49(22):5185-5201, 2004.**

Realistic numerical models of human subjects and their surrounding environment represent the basic points of radiofrequency (RF) electromagnetic dosimetry. This also involves differentiating the human models in men and women, possibly with different body shapes and postures. In this context, the aims of this paper are, firstly, to propose a female dielectric anatomical model (fDAM) and, secondly, to compare the power absorption distributions of a male and a female model from 0.1 to 4 GHz. For realizing the fDAM, a magnetic resonance imaging tomographer to acquire images and a recent technique which avoids the discrete segmentation of body tissues into different types have been used. Simulations have been performed with the FDTD method by using a novel filtering-based subgridding algorithm. The latter is applied here for the first time to dosimetry, allowing an abrupt mesh refinement by a factor of up to 7. The results show that the whole-body-averaged specific absorption rate (WBA-SAR) of the female model is higher than that of the male counterpart, mainly because of a thicker subcutaneous fat layer. In contrast, the maximum averaged SAR over 1 g (1gA-SAR) and 10 g (10gA-SAR) does not depend on gender, because it occurs in regions where no subcutaneous fat layer is present.

**Sandstrom M, Wilen J, Oftedal G, Hansson Mild K, Mobile phone use and subjective symptoms. Comparison of symptoms experienced by users of analogue and digital mobile phones. Occup Med (Lond) 51(1):25-35, 2001.**

In 1995 many people reported symptoms such as headaches, feelings of discomfort, warmth behind/around or on the ear and difficulties concentrating while using mobile phones. The number of complaints was higher for people using the digital (GSM) system, i.e. with pulse modulated fields, than for those using the analogue (NMT) system. Our main hypothesis was that GSM users experience more symptoms than NMT users. An epidemiological investigation was initiated including 6379 GSM users and 5613 NMT 900 users in Sweden, and 2500 from each category in Norway. The adjusted odds ratio did not indicate any increased risk for symptoms for GSM users compared with NMT 900 users. Our hypothesis was therefore disproved. However, we observed a statistically significant lower risk for sensations of warmth on the ear for GSM users compared with NMT 900 users. The same trend was seen in Norway for sensations of warmth behind/around the ear and in Sweden for headaches and fatigue. Factors distinguishing the two systems (radio frequency emission, phone temperatures and various ergonomic factors) may be responsible for these results, as well as for a secondary finding: a statistically significant association between calling time/number of calls per day and the

prevalence of warmth behind/around or on the ear, headaches and fatigue.

**Sangun O, Dundar B, Darici H, Comlekci S, Doguc DK, Celik S. The effects of long-term exposure to a 2450 MHz electromagnetic field on growth and pubertal development in female Wistar rats. Electromagn Biol Med. 2014 Jan 24. [Epub ahead of print]**

The aim of this study was to investigate the effects of a 2450 MHz electromagnetic field (EMF) (wireless internet frequency) on the growth and development of female Wistar rats. The study was conducted on three groups of rats. The prenatal and postnatal groups were exposed to EMF 1 h/day beginning from intrauterine and postnatal periods, respectively. The third group was the sham-exposed group. Growth, nutrition and vaginal opening (VO) were regularly monitored. Serum and tissue specimens were collected at puberty. Histological examinations, total antioxidant status (TAS), total oxidant status (TOS) and oxidative stress index (OSI) measurements in ovary and brain tissues and also immunohistochemical staining of the hypothalamus were performed besides the determination of serum FSH, LH, E2 and IGF-1 values. Birth masses of the groups were similar ($p > 0.05$). Mass gain per day was significantly lower and the puberty was significantly later in the prenatal group. Brain and ovary TOS and OSI values in the prenatal group were significantly increased ($p < 0.05$) compared to the control group. Serum LH levels of the prenatal and postnatal groups were increased, although serum FSH, and E2 values did not differ among the groups ($p > 0.05$). Histological examinations of the specimens revealed no statistically significant difference between the groups ($p > 0.05$). Exposure to 2450 MHz EMF, particularly in the prenatal period, resulted in postnatal growth restriction and delayed puberty in female Wistar rats. Increased TOS and OSI values in the brain and ovary tissues can be interpreted as a sign of chronic stress induced by EMF. This is the first longitudinal study which investigates the effects of EMF induced by wireless internet on pubertal development beside growth.

**Sanmartin M, Fernandez Lozano I, Marquez J, Antorrena I, Bautista A, Silva L, Ortigosa J, de Artaza M, [The absence of interference between GSM mobile telephones and implantable defibrillators: an in-vivo study. Groupe Systemes Mobiles]. Rev Esp Cardiol 50(10):715-719, 1997.** [Article in Spanish]

Introduction and Objectives: The electromagnetic field created by mobile telephones can cause pacemaker dysfunction. Although implantable cardioverter defibrillators are also susceptible to electromagnetic interference, few studies have addressed this issue and compatibility with the GSM mode has not been tested. This study was developed to detect possible "in vivo" interference between GSM mobile telephones and implantable cardioverter defibrillators. Material and Methods: The study group is composed of 30 patients with 8 different models of defibrillators. Twenty six had endocardial leads and 4 epicardial. Three GSM mobile phones were used: Siemens S3 COM and Motorola 6200 in all cases and Ericsson GA 318 in one. The tests were performed under continuous electrocardiographic monitoring. All therapies were deactivated and sensitivities were set to maximal parameters. The telephones were positioned in close contact to the defibrillator can and precordium, in two different angles. Three situations were evaluated:

calling, established contact for 15 seconds and ringing. The protocol was repeated during pacing to assess the possibility of pacemaker mode inhibition. RESULTS: No cases of electromagnetic interference were observed. One patient presented non-sustained ventricular tachycardia episodes during the tests that were detected by the defibrillator. Conclusions: These results suggest that electromagnetic interference by GSM mobile phones are not a probable cause of implantable defibrillators dysfunction.

**Sannino A, Di Costanzo G, Brescia F, Sarti M, Zeni O, Juutilainen J, Scarfì MR. Human Fibroblasts and 900 MHz Radiofrequency Radiation: Evaluation of DNA Damage after Exposure and Co-exposure to 3-Chloro-4-(dichloromethyl)-5-Hydroxy-2(5h)-furanone (MX). Radiat Res. 171(6):743-751, 2009.**

The aim of this study was to investigate DNA damage in human dermal fibroblasts from a healthy subject and from a subject affected by Turner's syndrome that were exposed for 24 h to radiofrequency (RF) radiation at 900 MHz. The RF-radiation exposure was carried out alone or in combination with 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX), a well-known environmental mutagen and carcinogen produced during the chlorination of drinking water. Turner's syndrome fibroblasts were also exposed for a shorter time (1 h). A signal similar to that emitted by Global System for Mobile Communications (GSM) mobile phones was used at a specific absorption rate of 1 W/kg under strictly controlled conditions of temperature and dosimetry. To evaluate DNA damage after RF-radiation exposure alone, the alkaline comet assay and the cytokinesis-block micronucleus assay were used. In the combined-exposure experiments, MX was given at a concentration of 25 microM for 1 h immediately after the RF-radiation exposure, and the effects were evaluated by the alkaline comet assay. The results revealed no genotoxic and cytotoxic effects from RF radiation alone in either cell line. As expected, MX treatment induced an increase in DNA migration in the comet assay, but no enhancement of the MX-induced DNA damage was observed in the cells exposed to RF radiation.

**Sannino A, Sarti M, Reddy SB, Prihoda TJ, Vijayalaxmi, Scarfì MR. Induction of adaptive response in human blood lymphocytes exposed to radiofrequency radiation. Radiat Res. 171(6):735-742, 2009.**

Abstract Sannino, A., Sarti, M., Reddy, S. B., Prihoda, T. J., Vijayalaxmi and Scarfì, M. R. Induction of Adaptive Response in Human Blood Lymphocytes Exposed to Radiofrequency Radiation. Radiat. Res. 171, 735-742 (2009). The incidence of micronuclei was evaluated to assess the induction of an adaptive response to non-ionizing radiofrequency (RF) radiation in peripheral blood lymphocytes collected from five different human volunteers. After stimulation with phytohemagglutinin for 24 h, the cells were exposed to an adaptive dose of 900 MHz RF radiation used for mobile communications (at a peak specific absorption rate of 10 W/kg) for 20 h and then challenged with a single genotoxic dose of mitomycin C (100 ng/ml) at 48 h. Lymphocytes were collected at 72 h to examine the frequency of micronuclei in cytokinesis-blocked binucleated cells. Cells collected from four donors exhibited the induction of adaptive response (i.e., responders). Lymphocytes that were pre-exposed to 900 MHz RF radiation had a significantly decreased incidence of micronuclei induced by the challenge dose of mitomycin C compared to those that were not pre-exposed to 900 MHz RF

radiation. These preliminary results suggested that the adaptive response can be induced in cells exposed to non-ionizing radiation. A similar phenomenon has been reported in cells as well as in animals exposed to ionizing radiation in several earlier studies. However, induction of adaptive response was not observed in the remaining donor (i.e., non-responder). The incidence of micronuclei induced by the challenge dose of mitomycin C was not significantly different between the cells that were pre-exposed and unexposed to 900 MHz RF radiation. Thus the overall data indicated the existence of heterogeneity in the induction of an adaptive response between individuals exposed to RF radiation and showed that the less time-consuming micronucleus assay can be used to determine whether an individual is a responder or non-responder.

**Sannino A, Zeni O, Sarti M, Romeo S, Reddy SB, Belisario MA, Prihoda TJ, Vijayalaxmi, Scarfi MR. Induction of adaptive response in human blood lymphocytes exposed to 900 MHz radiofrequency fields: influence of cell cycle.Int J Radiat Biol. 87(9):993-999, 2011.**

**PURPOSE:** To investigate the influence of cell cycle on the adaptive response (AR) induced by the exposure of human blood lymphocytes to radiofrequency fields (RF). **MATERIALS AND METHODS:** Human peripheral blood lymphocytes in G(0)-, G(1)- or S-phase of the cell cycle were exposed for 20 hours to an adaptive dose (AD) of 900 MHz RF at an average specific absorption rate of 1.25 W/kg and then treated with a challenge dose (CD) of 100 ng/ml mitomycin C (MMC). Un-exposed and sham-exposed controls as well as cells treated with MMC alone were included in the study. The incidence of micronuclei (MN) was evaluated to determine the induction of AR. **RESULTS:** The results indicated that the cells which were exposed to AD of RF in G(0)- and G(1)-phase of the cell cycle did not exhibit AR while such a response was observed when the cells were exposed to AD of RF in S-phase of the cell cycle. **CONCLUSIONS:** These results confirmed the observations reported in our previous investigation where AR was observed in human blood lymphocytes exposed to AD of RF in S-phase of the cell cycle and further suggested that the timing of AD exposure of RF is important to elicit AR.

**Sannino A, Zeni O, Romeo S, Massa R, Gialanella G, Grossi G, Manti L, Vijayalaxmi, Scarfì MR. Adaptive response in human blood lymphocytes exposed to non-ionizing radiofrequency fields: resistance to ionizing radiation-induced damage. J Radiat Res. 2013 Aug 26. [Epub ahead of print]**

The aim of this preliminary investigation was to assess whether human peripheral blood lymphocytes which have been pre-exposed to non-ionizing radiofrequency fields exhibit an adaptive response (AR) by resisting the induction of genetic damage from subsequent exposure to ionizing radiation. Peripheral blood lymphocytes from four healthy donors were stimulated with phytohemagglutinin for 24 h and then exposed for 20 h to 1950 MHz radiofrequency fields (RF, adaptive dose, AD) at an average specific absorption rate of 0.3 W/kg. At 48 h, the cells were subjected to a challenge dose (CD) of 1.0 or 1.5 Gy X-irradiation (XR, challenge dose, CD). After a 72 h total culture period, cells were collected to examine the incidence of micronuclei (MN). There was a significant decrease in the number of MN in lymphocytes exposed to RF + XR (AD + CD) as compared with those subjected to XR alone (CD). These

observations thus suggested a RF-induced AR and induction of resistance to subsequent damage from XR. There was variability between the donors in RF-induced AR. The data reported in our earlier investigations also indicated a similar induction of AR in human blood lymphocytes that had been pre-exposed to RF (AD) and subsequently treated with a chemical mutagen, mitomycin C (CD). Since XR and mitomycin-C induce different kinds of lesions in cellular DNA, further studies are required to understand the mechanism(s) involved in the RF-induced adaptive response.

**Santini R, Seigne M, Bonhomme-Faivre L, Bouffet S, Defrasne E, Sage M. Symptoms experienced by users of digital cellular phones: a pilot study in a French engineering school. Pathol Biol (Paris) 49(3):222-226, 2001.** [Article in French]

A survey study, using questionnaire, was conducted in 161 students and workers in a French engineering school on symptoms experienced during use of digital cellular phones. A significant increase in concentration difficult ($p < 0.05$) was reported by users of 1800-MHz (DCS) cellular phones compared to 900-MHz (GSM) phone users. In users of cellular phones, women significantly ($p < 0.05$) complained more often of sleep disturbance than men. This sex difference for sleep complaint is not observed between women and men non-users of cellular phone. The use of both cellular phones and VDT significantly (p Ä 0.05) increased concentration difficulty. Digital cellular phone users also significantly ($p < 0.05$) more often complained of discomfort, warmth, and picking on the ear during phone conversation in relation with calling duration per day and number of calls per day. The complaint warmth on the ear might be a signal to users for stopping the call.

**Santini R, Santini P, Danze JM, Le Ruz P, Seigne M.Study of the health of people living in the vicinity of mobile phone base stations: I. Influence of distance and sex. Pathol Biol (Paris) 50(6):369-373, 2002.** [Article in French]

A survey study using questionnaire was conducted in 530 people (270 men, 260 women) living or not in vicinity of cellular phone base stations, on 18 Non Specific Health Symptoms. Comparisons of complaints frequencies (CHI-SQUARE test with Yates correction) in relation with distance from base station and sex, show significant ($p < 0.05$) increase as compared to people living > 300 m or not exposed to base station, till 300 m for tiredness, 200 m for headache, sleep disturbance, discomfort, etc. 100 m for irritability, depression, loss of memory, dizziness, libido decrease, etc. Women significantly more often than men ($p < 0.05$) complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort and visual perturbations. This first study on symptoms experienced by people living in vicinity of base stations shows that, in view of radioprotection, minimal distance of people from cellular phone base stations should not be < 300 m.

**Santini R, Santini P, Le Ruz P, Danze JM, Seigne M, Survey study of people living in the vicinity of cellular phone base stations. Electromag Biol Med 22:41-49, 2003.**

A survey study was conducted, using a questionnaire, on 530 people (270 men, 260 women) living or not in proximity to cellular phone base stations. Eighteen different symptoms (Non Specific Health Symptoms-NSHS), described as radiofrequency

sickness, were studied by means of the chi-square test with Yates correction. The results that were obtained underline that certain complaints are experienced only in the immediate vicinity of base stations (up to 10 m for nausea, loss of appetite, visual disturbances), and other at greater distances from base stations (up to 100 m for irritability, depressive tendencies, lowering of libido, and up to 200 m for headaches, sleep disturbance, feeling of discomfort). In the 200 m to 300 m zone, only the complaint of fatigue is experienced significantly more often when compared with subjects residing at more than 300 m or not exposed (reference group). For seven of the studied symptoms and for the distance up to 300 m, the frequency of reported complaints is significantly higher ($P < 0.05$) for women in comparison to men. Significant differences are also observed in relation to the ages of subjects, and for the location of subjects in relation to the antennas and to other electromagnetic factors.

**Saran A, Pazzaglia S, Mancuso M, Rebessi S, Di Majo V, Tanori M, Lovisolo GA, Pinto R, Marino C. Effects of exposure of newborn patched1 heterozygous mice to GSM, 900 MHz.Radiat Res. 168(6):733-740, 2007.**

Patched1 heterozygous knockout mice (Ptc1+/-), an animal model of multiorgan tumorigenesis in which ionizing radiation dramatically accelerates tumor development, were used to study the potential tumorigenic effects of electromagnetic fields (EMFs) on neonatal mice. Two hundred Ptc1+/- mice and their wild-type siblings were enrolled in this study. Newborn mice were exposed to 900 MHz radiofrequency radiation (average SAR: 0.4 W/kg for 5 days, 0.5 h twice a day) or were sham exposed. We found that RF EMFs simulating the Global System for Mobile Communications (GSM) did not affect the survival of the mice, because no statistically significant differences in survival were found between exposed and sham-exposed animals. Also, no effects attributable to radiofrequency radiation were observed on the incidence and histology of Ptc1-associated cerebellar tumors. Moreover, the skin phenotype was analyzed to look for proliferative effects of RF EMFs on the epidermal basal layer and for acceleration of preneoplastic lesions typical of the basal cell carcinoma phenotype of this model. We found no evidence of proliferative or promotional effects in the skin from neonatal exposure to radiofrequency radiation. Furthermore, no difference in Ptc1-associated rhabdomyosarcomas was detected between sham-exposed and exposed mice. Thus, under the experimental conditions tested, there was no evidence of life shortening or tumorigenic effects of neonatal exposure to GSM RF radiation in a highly tumor-susceptible mouse model.

**Sarapultseva EI, Igolkina JV, Tikhonov VN, Dubrova YE.THE IN VIVO EFFECTS OF LOW-INTENSITY RADIOFREQUENCY FIELDS ON THE MOTOR ACTIVITY OF PROTOZOA. Int J Radiat Biol. 2013 Nov 25. [Epub ahead of print]**

Purpose: To analyze the direct and transgenerational effects of exposure to low-dose 1 GHz (mobile phone/wireless telecommunication range) and 10 GHz (radar/satellite communication range) radiofrequency electromagnetic fields (RF-EMF) on the motility of ciliates Spirostomum ambiguum. Materials and Methods: S. ambiguum were exposed to 1 GHz and 10 GHz RF-EMF with power flux densities (PD) ranging from 0.05 to 0.5 $W/m^2$ over a period of time from 0.05 to 10 h. The motility of directly

exposed ciliates and their non-exposed progeny across 10-15 generations was measured. Results: Exposure to 0.1 W/$m^2$ of either 1 or 10 GHz RF-EMF resulted in a significant decrease in the motility. The dose of exposure capable of altering the mobility of ciliates was inversely correlated with the flux density of RF-EMF. The motility of the non-exposed progeny of ciliates irradiated with 0.1 W/$m^2$ of 10 GHz RF-EMF remained significantly compromised, at least, across 10-15 generations, thus indicating the presence of transgenerational effects. Conclusions: The results of our study show that low-dose exposure to RF-EMF can significantly affect the motility of irradiated ciliates and their non-exposed offspring, thus providing further insights into the unknown mechanisms underlying the in vivo effects of RF-EMF.

**Sarimov, R., Malmgren, L.O.G., Markova, E., Persson, B.R.R.. Belyaev, I.Y. Nonthermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock. IEEE Trans Plasma Sci 32:1600-1608, 2004.**

Here we investigated whether microwaves (MWs) of Global System for Mobile Communication (GSM) induce changes in chromatin conformation in human lymphocytes. Effects of MWs were studied at different frequencies in the range of 895-915 MHz in experiments with lymphocytes from seven healthy persons. Exposure was performed in transverse electromagnetic transmission line cell (TEM-cell) using a GSM test-mobile phone. All standard modulations included 2 W output power in the pulses, specific absorbed rate (SAR) being 5.4 mW/kg. Changes in chromatin conformation, which are indicative of stress response and genotoxic effects, were measured by the method of anomalous viscosity time dependencies (AVTD). Heat shock and treatment with the genotoxic agent camptothecin, were used as positive controls. 30-min exposure to MWs at 900 and 905 MHz resulted in statistically significant condensation of chromatin in lymphocytes from 1 of 3 tested donors. This condensation was similar to effects of heat shock within the temperature window of 40/spl deg/C-44/spl deg/C. Analysis of pooled data from all donors showed statistically significant effect of 30-min exposure to MWs. Stronger effects of MWs was found following 1-h exposure. In replicated experiments, cells from four out of five donors responded to 905 MHz. Responses to 915 MHz were observed in cells from 1 out of 5 donors, $p<0.002$. Dependent on donor, condensation, 3 donors, or decondensation, 1 donor, of chromatin was found in response to 1-h exposure. Analysis of pooled data from all donors showed statistically significant effect of 1-h exposure to MWs. In cells from one donor, this effect was frequency-dependent ($p<0.01$). Effects of MWs correlated statistically significantly with effects of heat shock and initial state of chromatin before exposure. MWs at 895 and 915 MHz affected chromatin conformation in transformed lymphocytes. The conclusion-GSM microwaves under specific conditions of exposure affected human lymphocytes similar to stress response. The data suggested that the MW effects differ at various GSM frequencies and vary between donors.

**Sarkar S, Ali S, Behari J, Effect of low power microwave on the mouse genome: a direct DNA analysis. Mutat Res 320(1-2):141-147, 1994.**

The potential mutagenic effect of low power microwave at the DNA sequence level in the mouse genome was evaluated by direct DNA analysis. Animals were exposed to microwave at a power density of 1 mW/cm2 for 2 h/day at a frequency of 2.45 GHz over a

period of 120, 150 and 200 days. HinfI digested DNA samples from testis and brain of control and exposed animals were hybridized with a synthetic oligo probe (OAT 36) comprising nine repeats of 5'-GACA-3'. As compared to control animals, band patterns in exposed animals were found to be distinctly altered in the range of 7-8 kb which was also substantiated by densitometric analysis. Though the mechanism of this rearrangement is not yet clear, the results obtained at the present dose are of significance. This dose, which has been set as the safe limit for general public exposure by the Non-Ionizing Radiation Committee of the International Radiation Protection Association, may imply a need for (re)evaluation of the mutagenic potential of microwaves at the prescribed safe limit for the personnel and people who are being exposed.

**Sasaki K, Wake K, Watanabe S. Measurement of the dielectric properties of the epidermis and dermis at frequencies from 0.5 GHz to 110 GHz. Phys Med Biol. 59(16):4739-4747, 2014.**

Numerous studies have reported the measurements of the dielectric properties of the skin. Clarifying the manner in which the human body interacts with electromagnetic waves is essential for medical research and development, as well as for the safety assessment of electromagnetic wave exposure. The skin comprises several layers: the epidermis, the dermis, and the subcutaneous fat. Each of these skin layers has a different constitution; however, the previous measurements of their dielectric properties were typically conducted on tissue which included all three layers of the skin. This study presents novel dielectric property data for the epidermis and dermis with in vitro measurement at frequencies ranging from 0.5 GHz to 110 GHz. Measured data was compared with literature values; in particular, the findings were compared with Gabriel's widely used data on skin dielectric properties. The experimental results agreed with the data reported by Gabriel for the dermis of up to 20 GHz, which is the upper limit of the range of frequencies at which Gabriel reported measurements. For frequencies of 20-100 GHz, the experimental results indicated larger values than those extrapolated from Gabriel's data using parametric expansion. For frequencies over 20 GHz, the dielectric properties provided by the parametric model tend toward the experimental results for the epidermis with increasing frequency.

**Sato Y, Kiyohara K, Kojimahara N, Yamaguchi N. Time trend in incidence of malignant neoplasms of the central nervous system in relation to mobile phone use among young people in Japan. Bioelectromagnetics. 2016 May 19. doi: 10.1002/bem.21982. [Epub ahead of print]**

The aim of this study was to examine whether incidence of malignant neoplasms of the central nervous system from 1993 to 2010 has increased among young people in Japan, and whether the increase could be explained by increase in mobile phone use. Joinpoint regression analysis of incidence data was performed. Subsequently, the expected incidence rate was calculated assuming that the relative risk was 1.4 for those who used mobile phones more than 1640 h cumulatively. Annual percent change was 3.9% (95% confidence interval [CI], 1.6-6.3) for men in their 20s from 1993 to 2010, 12.3% (95% CI, 3.3-22.1) for women in their 20s from 2002 to 2010, 2.7% (95% CI, 1.3-4.1) for men in their 30s from 1993 to 2010, and 3.0% (95% CI, 1.4-4.7) for women in their 30s from

1993 to 2010. Change in incidence rates from 1993 to 2010 was 0.92 per 100,000 people for men in their 20s, 0.83 for women in their 20s, 0.89 for men in their 30s, and 0.74 for women in their 30s. Change in expected incidence rates from 1993 to 2010 was 0.08 per 100,000 people for men in their 20s, 0.03 for women in their 20s, 0.15 for men in their 30s, and 0.05 for women in their 30s. Patterns in sex-, age-, and period-specific incidence increases are inconsistent with sex-, age-, and period-specific prevalence trends, suggesting the overall incidence increase cannot be explained by heavy mobile phone use.

**Sato Y, Kojimahara N, Yamaguchi N. Analysis of mobile phone use among young patients with brain tumors in Japan. Bioelectromagnetics. 38(5):349-355, 2017.**

The purpose of this study was to clarify ownership and usage of mobile phones among young patients with brain tumors in Japan. The subjects of this study were patients with brain tumors diagnosed between 2006 and 2010 who were between the ages of 6 and 18 years. The target population for the analysis was 82 patients. Patients were divided into two groups: 16 patients who were mobile phone owners 1 year before diagnosis, and 66 patients who did not own mobile phones (non-owners). Using data on the mobile phone ownership rate obtained from three general-population surveys, we calculated the expected number of mobile phone owners. The three age-adjusted standardized ownership ratios were 0.83 (95% confidence interval [CI]: 0.56-1.22), 0.51 (95% CI: 0.24-1.04), and 0.75 (95% CI: 0.42-1.32). The mobile phone ownership prevalence among the young Japanese patients with brain tumors in the current study does not differ from available estimates for the general population of corresponding age. However, since the use of mobile phones among children is increasing annually, investigations into the health effects of mobile phone use among children should continue.

**Sato Y, Kojimahara N, Taki M, Yamaguchi N. Analysis of ear side of mobile phone use in the general population of Japan. Bioelectromagnetics. 2017 Nov 24. doi: 10.1002/bem.22098. [Epub ahead of print]**

This study aimed to clarify the distribution of the ear side of mobile phone use in the general population of Japan and clarify what factors are associated with the ear side of mobile phone use. Children at elementary and junior high schools (n = 2,518) and adults aged ≥20 years (n = 1,529) completed an Internet-based survey. Data were subjected to a logistic regression analysis. In children, due to the tendency to use the dominant hand, we analyzed the factors associated with the use of right ear in right-handed people. Statistically significant differences were observed only in talk time per call (odds ratio (OR) = 2.17; 95% confidence interval (CI): 1.22-3.99). In adults, due to the tendency to use the left ear, we analyzed factors associated with the use of left ear in right-handed people. Significant differences were observed in those aged 30-39 years (OR = 2.55; 95% CI: 1.79-3.68), those aged 40-49 years (OR = 3.08; 95% CI: 2.15-4.43), those aged >50 years (OR = 1.85; 95% CI: 1.20-2.85), and in those with a percentage of total talk time when using mobile phones at work of 51-100% (OR = 1.75; 95% CI: 1.21-2.55). We believe that future epidemiological studies on

mobile phone use can be improved by considering the trends in mobile phone use identified in this study.

**Sauter C, Dorn H, Bahr A, Hansen ML, Peter A, Bajbouj M, Danker-Hopfe H. Effects of exposure to electromagnetic fields emitted by GSM 900 and WCDMA mobile phones on cognitive function in young male subjects.Bioelectromagnetics. 32(3):179-190, 2011.**

Results of studies on the possible effects of electromagnetic fields emitted by mobile phones on cognitive functions are contradictory, therefore, possible effects of long-term (7 h 15 min) electromagnetic field (EMF) exposure to handset-like signals of Global System for Mobile Communications (GSM) 900 and Wideband Code-Division Multiple Access (WCDMA) on attention and working memory were studied. The sample comprised 30 healthy male subjects (mean ± SD: 25.3 ± 2.6 years), who were tested on nine study days in which they were exposed to three exposure conditions (sham, GSM 900 and WCDMA) in a randomly assigned and balanced order. All tests were presented twice (morning and afternoon) on each study day within a fixed timeframe. Univariate comparisons revealed significant changes when subjects were exposed to GSM 900 compared to sham, only in the vigilance test. In the WCDMA exposure condition, one parameter in the vigilance and one in the test on divided attention were altered compared to sham. Performance in the selective attention test and the n-back task was not affected by GSM 900 or WCDMA exposure. Time-of-day effects were evident for the tests on divided and selective attention, as well as for working memory. After correction for multiple testing, only time-of-day effects remained significant in two tests, resulting in faster reactions in the afternoon trials. The results of the present study do not provide any evidence of an EMF effect on human cognition, but they underline the necessity to control for time of day.

**Sauter C, Eggert T, Dorn H, Schmid G, Bolz T, Marasanov A, Hansen ML, Peter A, Danker-Hopfe H. Do signals of a hand-held TETRA transmitter affect cognitive performance, well-being, mood or somatic complaints in healthy young men? Results of a randomized double-blind cross-over provocation study. Environ Res. 140:85-94, 2015.**

BACKGROUND: TETRA (terrestrial trunked radio) is a digital radio communication standard, which has been implemented in several European countries and is used by public executives, transportation services, and by private companies. Studies on possible impacts on the users' health considering different exposure conditions are missing. OBJECTIVES: To investigate possible acute effects of electromagnetic fields (EMF) of two different levels of TETRA hand-held transmitter signals on cognitive function and well-being in healthy young males. METHODS: In the present double-blind cross-over study possible effects of short-term (2.5h) EMF exposure of handset-like signals of TETRA (385MHz) were studied in 30 healthy male participants (mean±SD: 25.4±2.6 years). Individuals were tested on nine study days, on which they were exposed to three different exposure conditions (Sham, TETRA 1.5W/kg and TETRA 6.0W/kg) in a randomly assigned and balanced order. Participants were tested in the afternoon at a fixed timeframe. RESULTS:  Attention remained unchanged in two out of three tasks. In the

working memory significant changes were observed in two out of four subtasks. Significant results were found in 5 out of 35 tested parameters, four of them led to an improvement in performance. Mood, well-being and subjective somatic complaints were not affected by TETRA exposure. CONCLUSIONS: The results of the present study do not indicate a negative impact of a short-term EMF-effect of TETRA on cognitive function and well-being in healthy young men.

**Saygin M, Caliskan S, Karahan N, Koyu A, Gumral N, Uguz A. Testicular apoptosis and histopathological changes induced by a 2.45 GHz electromagnetic field. Toxicol Ind Health. 27(5):455-463, 2011.**

There is a growing public concern about the potential human health hazard caused by exposure to electromagnetic radiation (EMR). The objective of this study is to investigate the effects of 2450 mhz electromagnetic field on apoptosis and histopathological changes on rat testis tissue. Twelve-week-old male Wistar Albino rats were used in this study. Eighteen rats equally divided into three different groups which were named group I, II and III. Cage control (group I), sham control (group II) and 2.45 GHz EMR (group III) groups were formed. Group III were exposed to 2.45 GHz EMR, at 3.21 W/kg specific absorption rate for 60 minutes/ day for 28 days. There was no difference among the groups for the diameter of the seminiferous tubules, pyknotic, karyolectic and karyotic cells. However, the number of Leydig cells of testis tissue of the rats in group III was significantly reduced comparing with the group I ($p < 0.05$). Estimation of spermatogenesis using the Johnsen testicular biopsy score revealed that the difference between groups is statistically significant. The level of TNF-α, Caspase-3 and Bcl-2 were compared, and no significant difference was found between the groups. When Bax apoptosis genes and Caspase-8 apoptosis enzyme were compared, there were significant differences between the groups ($p < 0.05$). Electromagnetic field affects spermatogenesis and causes to apoptosis due to the heat and other stress-related events in testis tissue.

**Saygin M, Asci H, Ozmen O, Cankara FN, Dincoglu D, Ilhan I. Impact of 2.45 GHz microwave radiation on the testicular inflammatory pathway biomarkers in young rats: The role of gallic acid. Environ Toxicol. 2015 Aug 13. doi: 10.1002/tox.22179. [Epub ahead of print]**

The aim of this study was to investigate electromagnetic radiation (EMR) transmitted by wireless devices (2.45 GHz), which may cause physiopathological or ultrastructural changes, in the testes of rats. We addressed if the supplemental gallic acid (GA) may reduce these adverse effects. Six-week-old male Sprague Dawley rats were used in this study. Forty eight rats were equally divided into four groups, which were named: Sham, EMR only (EMR, 3 h $day^{-1}$ for 30 days), EMR + GA (30 mg/kg/daily), and GA (30 mg/kg/daily) groups. Malondialdehyde (MDA) and total oxidant status (TOS) levels increased ($p = 0.001$ for both) in EMR only group. TOS and oxidative stress index (OSI) levels decreased in GA treated group significantly ($p = 0.001$ and $p = 0.045$, respectively). Total antioxidant status (TAS) activities decreased in EMR only group and increased in GA treatment group ($p = 0.001$ and $p = 0.029$, respectively). Testosterone and vascular endothelial growth factor (VEGF) levels decreased in EMR only group, but this was not statistically significant.

Testosterone and VEGF levels increased in EMR+GA group, compared with EMR only group ($p = 0.002$), and also increased in GA group compared with the control and EMR only group ($p = 0.044$ and $p = 0.032$, respectively). Prostaglandin $E_2$ ($PGE_2$ ) and calcitonin gene releated peptide (CGRP) staining increased in tubules of the testes in EMR only group ($p < 0.001$ for both) and decreased in tubules of the testes in EMR+GA group ($p < 0.001$ for all parameters). In EMR only group, most of the tubules contained less spermatozoa, and the spermatozoon counts decreased in tubules of the testes. All these findings and the regenerative reaction, characterized by mitotic activity, increased in seminiferous tubules cells of the testes in EMR+GA group ($p < 0.001$). Long term EMR exposure resulted in testicular physiopathology via oxidative damage and inflammation. GA may have ameliorative effects on the prepubertal rat testes physiopathology.

**Scarfi MR, Fresegna AM, Villani P, Pinto R, Marino C, Sarti M, Altavista P, Sannino A, Lovisolo GA. Exposure to radiofrequency radiation (900 MHz, GSM signal) does not affect micronucleus frequency and cell proliferation in human peripheral blood lymphocytes: an interlaboratory study. Radiat Res. 165(6):655-663, 2006.**

The objective of this study was to investigate whether 24 h exposure to radiofrequency electromagnetic fields similar to those emitted by mobile phones induces genotoxic effects and/or effects on cell cycle kinetics in cultured human peripheral blood lymphocytes. The effect of 900 MHz exposure (GSM signal) was evaluated at four specific absorption rates (SARs, 0, 1, 5 and 10 W/kg peak values). The exposures were carried out in wire patch cells under strictly controlled conditions of both temperature and dosimetry, and the induction of genotoxic effects was evaluated in lymphocyte cultures from 10 healthy donors by applying the cytokinesis-block micronucleus assay. Positive controls were provided by using mitomycin C. Two research groups were involved in the study, one at ENEA, Rome, and the other at CNR-IREA, Naples. Each laboratory tested five donors, and the resulting slides were scored by both laboratories. Following this experimental scheme, it was also possible to compare the results obtained by cross-scoring of slides. The results obtained provided no evidence for the existence of genotoxic or cytotoxic effects in the range of SARs investigated. These findings were confirmed in the two groups of five donors examined in the two laboratories and when the same slides were scored by two operators.

**Schauer I, Mohamad Al-Ali B.Combined effects of varicocele and cell phones on semen and hormonal parameters. Wien Klin Wochenschr. 2017 Oct 13. doi: 10.1007/s00508-017-1277-9. [Epub ahead of print]**

BACKGROUND: The objective of this study was to evaluate if there is a combined effect of varicocele and **cell phone** storage in trousers pockets on semen and hormonal parameters. METHODS: A retrospective analysis of 468 men attending an infertility clinic from 1993-2007 was performed. Varicoceles were determined by clinical examination and patients were questioned on **cell phone** usage and storage fashion. Semen samples were analyzed according to the World Health Organization (WHO) guidelines of 1999. Serum testosterone, luteinizing hormone (LH) and follicle stimulating hormone (FSH) were assessed. RESULTS: There was a significant effect of **cell phone** storage in trousers pockets and varicocele in multivariate analysis (both $p < 0.001$). Varicocele

showed an effect on sperm concentration (p = 0.003), LH (p = 0.014) and testosterone (p = 0.003). Compared to grade 1, grade 2 varicoceles showed a difference in sperm concentration (p = 0.004). Regarding testosterone differences were shown for grade 3 versus grade 1 (p = 0.002) and grade 3 compared to grade 2 (p = 0.003). **Cell phone** storage in trousers pockets showed an influence on the percentage of normal sperm morphology and LH (both p < 0.001). Varicocele and **cell phone** storage in trousers pockets did not show a combined effect (p = 0.76).CONCLUSIONS: This analysis showed an inverse relation between sperm concentration and degree of varicocele, with lower concentrations in higher grade varicoceles. Testosterone was significantly higher in higher grade varicoceles, which could reflect a compensatory mechanism to the impaired testicular function. **Cell phone** storage in trousers pockets showed an effect on LH and sperm morphology. A combined effect of varicocele and **cell phone** storage in trousers pockets was not detected.

**Schilling, CJ, Effects of acute exposure to ultrahigh radiofrequency radiation on three antenna engineers. Occup Environ Med 54(4):281-284, 1997.**

Three men were accidentally exposed to high levels of ultrahigh frequency radiofrequency radiation (785 MHz mean frequency) while working on a television mast. They experienced an immediate sensation of intense heating of the parts of the body in the electromagnetic field followed by a variety of symptoms and signs which included pain, headache, numbness, and parasthesiae, malaise, diarrhoea, and skin erythema. The most notable problem was that of acute then chronic headache involving the part of the head which was most exposed.

**Schilling CJ, Effects of exposure to very high frequency radiofrequency radiation on six antenna engineers in two separate incidents. Occup Med 60:49-56, 2000.**

Six men are likely to have been accidentally exposed to high levels of very high frequency (VHF) radiofrequency radiation (100 MHz) while working on transmission masts; four men in one incident and two in another. They experienced symptoms and signs which included headache, parasthesiae, diarrhoea, malaise and lassitude. The condition of four men, two men from each incident likely to have had the highest exposure, has shown no significant improvement. The first incident occurred in 1995 and the second in 1996.

**Schirmacher A, Winters S, Fischer S, Goeke J, Galla H, Kullnick U, Ringelstein EB, Stogbauer F, Electromagnetic fields (1.8 GHz) increase the permeability to sucrose of the blood-brain barrier in vitro. Bioelectromagnetics 21(5):338-345, 2000.**

We report an investigation on the influence of high frequency electromagnetic fields (EMF) on the permeability of an in vitro model of the blood-brain barrier (BBB). Our model was a co-culture consisting of rat astrocytes and porcine brain capillary endothelial cells (BCEC). Samples were characterized morphologically by scanning electron microscopy and immunocytochemistry. The BBB phenotype of the BCEC was shown by the presence of zona occludens protein (ZO-1) as a marker for tight junctions and the close contact of the cells together with the absence of intercellular clefts. Permeability measurements using (14)C-sucrose indicated a physiological tightness which correlated with the morphological findings and verified the usefulness of our in vitro model. Samples

were exposed to EMF conforming to the GSM1800-standard used in mobile telephones (1.8 GHz). The permeability of the samples was monitored over four days and compared with results of samples that were cultured identically but not exposed to EMF. Exposure to EMF increased permeability for (14)C-sucrose significantly compared to unexposed samples. The underlying pathophysiological mechanism remains to be investigated.

**Schlegel RE, Grant FH, Raman S, Reynolds D Electromagnetic compatibility study of the in-vitro interaction of wireless phones with cardiac pacemakers. Biomed Instrum Technol 32(6):645-655, 1998.**

This large-scale in-vitro investigation of the interaction between hand-held wireless phones and cardiac pacemakers tested 29 pacemaker models with five different phone standards. The phones were operational and suspended on a grid above a torso simulator filled with a saline bath with the pacemaker submerged at 0.5 cm. Testing consisted of 8,296 runs, during which any interactions detected were classified by type and regularity. Only a few pacemakers were responsible for a disproportionately large number of interactions. Likewise, interactions occurred during 21% of the tests using one particular phone technology, with little or no interaction resulting from use of the other standards. Other significant factors included the relative orientation of the phone and the pacemaker case, as well as the presence or absence of an injected ECG signal. The ECG signal facilitated observation of certain forms of interaction to the extent that this study indicates the importance of including an injected ECG signal in all testing. The study also supports the recommendation to maintain a separation distance of at least 6 inches between pacemakers and wireless phones. Each pacemaker reverted to its normal operation when the phone creating an interaction was turned off. This study may be useful in ongoing efforts to define test protocols, evaluate pacemaker designs, and mitigate interactions, perhaps providing the basis for future certification and screening efforts.

**Schmid G, Sauter C, Stepansky R, Lobentanz IS, Zeitlhofer J. No influence on selected parameters of human visual perception of 1970 MHz UMTS-like exposure. Bioelectromagnetics. 26(4):243-250, 2005.**

In recent years several studies regarding possible effects of radio frequency (RF) electromagnetic fields (EMFs) on cognitive brain function were reported. In many of these studies on awake humans the working tasks were presented visually to the test subjects, e.g., on a computer screen. Therefore, the question of where in the chain of visual perception, brain processing and response a possible effect could be induced seems to be of interest. In this study, possible effects of exposure to a generic 1.97 GHz UMTS-like signal on human visual perception were investigated in a double blinded, crossover study including 58 healthy volunteer subjects (29 male, 29 female), aged 29 +/- 5.1 years (mean +/- SD). Each test subject underwent a battery of four different clinical tests three times (two different exposure levels and sham exposure) to assess selected parameters of visual perception. The generic signals applied to the subjects' head represented the RF emissions of an UMTS mobile phone under constant receiving conditions and the under condition of strongly varying transmit power, i.e., the signal envelope contained low frequency components. In the high exposure condition the resulting average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (1 g

averaged SAR) and 0.37 W/kg (10 g averaged SAR). Low exposure condition was one tenth of high exposure and sham was at least 50 dB (corresponding to a factor of 100 000) below low exposure. Statistical evaluation of the obtained test results revealed no statistically significant differences in the investigated parameters of visual perception between the exposure conditions and sham exposure.

**Schmid G, Uberbacher R, Samaras T, Jappel A, Baumgartner WD, Tschabitscher M, Mazal PR. High-resolution numerical model of the middle and inner ear for a detailed analysis of radio frequency absorption. Phys Med Biol. 52(7):1771-1781, 2007.**

In order to enable a detailed analysis of radio frequency (RF) absorption in the human middle and inner ear organs, a numerical model of these organs was developed at a spatial resolution of 0.1 mm, based on a real human tissue sample. The dielectric properties of the liquids (perilymph and endolymph) inside the bony labyrinth were measured on samples of ten freshly deceased humans. After inserting this model into a commercially available numerical head model, FDTD-based computations for exposure scenarios with generic models of handheld devices operated close to the head in the frequency range 400-3700 MHz were carried out. For typical output power values of real handheld mobile communication devices the obtained results showed only very small amounts of absorbed RF power in the middle and inner ear organs. Highest absorption in the middle and inner ear was found for the 400 MHz irradiation. In this case, the RF power absorbed inside the labyrinth and the vestibulocochlear nerve was as low as 166 microW and 12 microW, respectively, when considering a device of 500 mW output power operated close to the ear. For typical mobile phone frequencies (900 MHz and 1850 MHz) and output power values (250 mW and 125 mW) the corresponding values of absorbed RF power were found to be more than one order of magnitude lower than the values given above. These results indicate that temperature-related biologically relevant effects on the middle and inner ear, induced by the RF emissions of typical handheld mobile communication devices, are unlikely.

**Schmid G, Uberbacher R, Samaras T, Tschabitscher M, Mazal PR. The dielectric properties of human pineal gland tissue and RF absorption due to wireless communication devices in the frequency range 400-1850 MHz. Phys Med Biol. 52(17):5457-5468, 2007.**

In order to enable a detailed analysis of radio frequency (RF) absorption in the human pineal gland, the dielectric properties of a sample of 20 freshly removed pineal glands were measured less than 20 h after death. Furthermore, a corresponding high resolution numerical model of the brain region surrounding the pineal gland was developed, based on a real human tissue sample. After inserting this model into a commercially available numerical head model, FDTD-based computations for exposure scenarios with generic models of handheld devices operated close to the head in the frequency range 400-1850 MHz were carried out. For typical output power values of real handheld mobile communication devices, the obtained results showed only very small amounts of absorbed RF power in the pineal gland when compared to SAR limits according to international safety standards. The

highest absorption was found for the 400 MHz irradiation. In this case the RF power absorbed inside the pineal gland (organ mass 96 mg) was as low as 11 microW, when considering a device of 500 mW output power operated close to the ear. For typical mobile phone frequencies (900 MHz and 1850 MHz) and output power values (250 mW and 125 mW) the corresponding values of absorbed RF power in the pineal gland were found to be lower by a factor of 4.2 and 36, respectively. These results indicate that temperature-related biologically relevant effects on the pineal gland induced by the RF emissions of typical handheld mobile communication devices are unlikely.

**Schmid MR, Loughran SP, Regel SJ, Murbach M, Bratic Grunauer A, Rusterholz T, Bersagliere A, Kuster N, Achermann P. Sleep EEG alterations: effects of different pulse-modulated radio frequency electromagnetic fields.J Sleep Res. 21(1):50-58, 2012.**

Previous studies have observed increases in electroencephalographic power during sleep in the spindle frequency range (approximately 11-15 Hz) after exposure to mobile phone-like radio frequency electromagnetic fields (RF EMF). Results also suggest that pulse modulation of the signal is crucial to induce these effects. Nevertheless, it remains unclear which specific elements of the field are responsible for the observed changes. We investigated whether pulse-modulation frequency components in the range of sleep spindles may be involved in mediating these effects. Thirty young healthy men were exposed, at weekly intervals, to three different conditions for 30 min directly prior to an 8-h sleep period. Exposure consisted of a 900-MHz RF EMF, pulse modulated at 14 Hz or 217 Hz, and a sham control condition. Both active conditions had a peak spatial specific absorption rate of 2 W kg(-1) . During exposure subjects performed three different cognitive tasks (measuring attention, reaction speed and working memory), which were presented in a fixed order. Electroencephalographic power in the spindle frequency range was increased during non-rapid eye movement sleep (2nd episode) following the 14-Hz pulse-modulated condition. A similar but non-significant increase was also observed following the 217-Hz pulse-modulated condition. Importantly, this exposure-induced effect showed considerable individual variability. Regarding cognitive performance, no clear exposure-related effects were seen. Consistent with previous findings, our results provide further evidence that pulse-modulated RF EMF alter brain physiology, although the time-course of the effect remains variable across studies. Additionally, we demonstrated that modulation frequency components within a physiological range may be sufficient to induce these effects.

**Schmid MR, Murbach M, Lustenberger C, Maire M, Kuster N, Achermann P, Loughran SP. Sleep EEG alterations: effects of pulsed magnetic fields versus pulse-modulated radio frequency electromagnetic fields.J Sleep Res.21(6):620-629, 2012.**

Studies have repeatedly shown that electroencephalographic power during sleep is enhanced in the spindle frequency range following radio frequency electromagnetic field exposures pulse-modulated with fundamental frequency components of 2, 8, 14 or 217 Hz and combinations of these. However, signals used in previous studies also had

significant harmonic components above 20 Hz. The current study aimed: (i) to determine if modulation components above 20 Hz, in combination with radio frequency, are necessary to alter the electroencephalogram; and (ii) to test the demodulation hypothesis, if the same effects occur after magnetic field exposure with the same pulse sequence used in the pulse-modulated radio frequency exposure. In a randomized double-blind crossover design, 25 young healthy men were exposed at weekly intervals to three different conditions for 30 min before sleep. Cognitive tasks were also performed during exposure. The conditions were a 2-Hz pulse-modulated radio frequency field, a 2-Hz pulsed magnetic field, and sham. Radio frequency exposure increased electroencephalogram power in the spindle frequency range. Furthermore, delta and theta activity (non-rapid eye movement sleep), and alpha and delta activity (rapid eye movement sleep) were affected following both exposure conditions. No effect on sleep architecture and no clear impact of exposure on cognition was observed. These results demonstrate that both pulse-modulated radio frequency and pulsed magnetic fields affect brain physiology, and the presence of significant frequency components above 20 Hz are not fundamental for these effects to occur. Because responses were not identical for all exposures, the study does not support the hypothesis that effects of radio frequency exposure are based on demodulation of the signal only.

**Schneider J, Stangassinger M. Nonthermal Effects of Lifelong High-Frequency Electromagnetic Field Exposure on Social Memory Performance in Rats. Behav Neurosci. 2014 Jul 7. [Epub ahead of print]**

We are today surrounded almost constantly by high-frequency electromagnetic fields (EMFs) from mobile communications base stations. To date, however, there has been little concern regarding nonthermal effects of EMFs on cognition. In the present study, male and female rats were subjected to continuous far-field exposure to a frequency of 900-MHz (Global System for Mobile Communications [GSM]) or 1.966-GHz (Universal Mobile Telecommunications System [UMTS]) at 0.4 W/kg. Memory performance of adult EMF-exposed and sham-exposed female rats (at 6 months of age) and male rats (at 3 and 6 months of age) was tested using a social discrimination procedure. For this procedure, a target juvenile male was introduced to the subject's home cage for 4 min (Trial 1). After 30 min, the same target animal and a novel juvenile male were simultaneously presented to the subject for 4 min (Trial 2). Differences in sniffing duration to the familiar and novel target rats during Trial 2 were used to assess memory performance. EMF-exposed females exhibited no differences in sniffing duration compared with controls. In contrast, the sniffing durations of EMF-exposed males at 3 months of age were significantly affected. At 6 months of age, GSM-, but not UMTS-, exposed male adults showed a memory performance deficit. These findings provide new insight into the nonthermal effects of long-term high-frequency EMF exposure on memory.

**Schoemaker MJ, Swerdlow AJ, Ahlbom A, Auvinen A, Blaasaas KG, Cardis E, Collatz Christensen H, Feychting M, Hepworth SJ, Johansen C, Klæboe L, Lönn S, McKinney PA, Muir K, Raitanen J, Salminen T, Thomsen J, Tynes T. Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in**

**five North European countries. Br J Cancer 93:842-848, 2005.**

There is public concern that use of mobile phones could increase the risk of brain tumours. If such an effect exists, acoustic neuroma would be of particular concern because of the proximity of the acoustic nerve to the handset. We conducted, to a shared protocol, six population-based case-control studies in four Nordic countries and the UK to assess the risk of acoustic neuroma in relation to mobile phone use. Data were collected by personal interview from 678 cases of acoustic neuroma and 3553 controls. The risk of acoustic neuroma in relation to regular mobile phone use in the pooled data set was not raised (odds ratio (OR)=0.9, 95% confidence interval (CI): 0.7-1.1). There was no association of risk with duration of use, lifetime cumulative hours of use or number of calls, for phone use overall or for analogue or digital phones separately. Risk of a tumour on the same side of the head as reported phone use was raised for use for 10 years or longer (OR=1.8, 95% CI: 1.1-3.1). The study suggests that there is no substantial risk of acoustic neuroma in the first decade after starting mobile phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out.

**Schoemaker MJ, Swerdlow AJ. Risk of pituitary tumors in cellular phone users: a case-control study. Epidemiology. 20(3):348-54, 2009.**

BACKGROUND:: There is public concern and scientific interest regarding a potential effect of cellular phone use on the risk of developing intracranial tumors. Tumors of the pituitary gland have barely been investigated in this context, but are of interest because of their intracranial location. METHODS:: We conducted a population-based case-control study between 2001 and 2005 of the risk of developing pituitary tumors in relation to cellular phone use in Southeast England, with 291 cases and 630 controls. Detailed information on cellular phone use was collected by personal interview. RESULTS:: Tumor risk was not associated with cellular phone use overall (adjusted odds ratio = 0.9, 95% confidence interval = 0.7-1.3), and was not appreciably increased 10 or more years after first use (1.0; 0.5-1.9), or after 10 or more years of cumulative use (1.1; 0.5-2.4). Odds ratios were 1.2 (0.7-1.9) for users in the highest quartile of cumulative number of calls and 1.1 (0.7-1.7) in the highest quartile of hours of use. Separate analyses of analog and digital phone use showed no associations with tumor risk. CONCLUSIONS:: We found no evidence that the risk of developing pituitary tumors is associated with cellular phone use for the induction time periods and intensities of use observed.

**Schoeni A, Roser K, Röösli M. Memory performance, wireless communication and exposure to radiofrequency electromagnetic fields: A prospective cohort study in adolescents. Environ Int. 85:343-351, 2015.**

BACKGROUND: The aim of this study is to investigate whether memory performance in adolescents is affected by radiofrequency electromagnetic fields (RF-EMF) from wireless device use or by the wireless device use itself due to non-radiation related factors in that context. METHODS: We conducted a prospective cohort study with 439 adolescents. Verbal and figural memory tasks at baseline and after one year were completed using a standardized, computerized cognitive test battery. Use of wireless devices was inquired by questionnaire and operator recorded mobile phone use data was obtained for a

subgroup of 234 adolescents. RF-EMF dose measures considering various factors affecting RF-EMF exposure were computed for the brain and the whole body. Data were analysed using a longitudinal approach, to investigate whether cumulative exposure over one year was related to changes in memory performance. All analyses were adjusted for relevant confounders. RESULTS: The kappa coefficients between cumulative mobile phone call duration and RF-EMF brain and whole body dose were 0.62 and 0.67, respectively for the whole sample and 0.48 and 0.28, respectively for the sample with operator data. In linear exposure-response models an interquartile increase in cumulative operator recorded mobile phone call duration was associated with a decrease in figural memory performance score by -0.15 (95% CI: -0.33, 0.03) units. For cumulative RF-EMF brain and whole body dose corresponding decreases in figural memory scores were -0.26 (95% CI: -0.42, -0.10) and -0.40 (95% CI: -0.79, -0.01), respectively. No exposure-response associations were observed for sending text messages and duration of gaming, which produces tiny RF-EMF emissions. CONCLUSIONS:  A change in memory performance over one year was negatively associated with cumulative duration of wireless phone use and more strongly with RF-EMF dose. This may indicate that RF-EMF exposure affects memory performance.

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**Schoeni A, Roser K, Röösli M. Symptoms and Cognitive Functions in Adolescents in Relation to Mobile Phone Use during Night. PLoS One. 2015 Jul 29;10(7):e0133528. doi: 10.1371/journal.pone.0133528. eCollection 2015.**

Many adolescents tend to leave their mobile phones turned on during night, accepting that they may be awakened by an incoming text message or call. Using self-reported and objective operator recorded mobile phone use data, we thus aimed to analyze how being awakened during night by mobile phone affects adolescents' perceived health and cognitive functions. In this cross-sectional study, 439 adolescents completed questionnaires about their mobile phone use during night, health related quality of life and possible confounding factors. Standardized computerized cognitive tests were performed to assess memory and concentration capacity. Objective operator recorded mobile phone use data was further collected for 233 study participants. Data were analyzed by multivariable regression models adjusted for relevant confounders including amount of mobile phone use. For adolescents reporting to be awakened by a mobile phone during night at least once a month the odds ratio for daytime tiredness and rapid exhaustibility were 1.86 (95% CI: 1.02-3.39) and 2.28 (95% CI: 0.97-5.34), respectively. Similar results were found when analyzing objective operator recorded mobile phone use data (tiredness: 1.63, 95% CI: 0.94-2.82 and rapid exhaustibility: 2.32, 95% CI: 1.01-5.36). The cognitive tests on memory and concentration capacity were not related to mobile phone use during night. Overall, being awakened during night by mobile phone was associated with an increase in health symptom reports such as tiredness, rapid exhaustibility, headache and physical ill-being, but not with memory and concentration capacity. Prevention strategies should focus on helping adolescents set limits for their accessibility by mobile phone, especially during night.

**Schoeni A, Roser K, Röösli M. Symptoms and the use of wireless communication devices: A prospective cohort study in Swiss adolescents. Environ Res. 154:275-283, 2017.**

BACKGROUND: We investigated whether radiofrequency electromagnetic fields (RF-EMF) from mobile phones and other wireless devices or by the wireless device use itself due to non-radiation related factors in that context are associated with an increase in health symptom reports of adolescents in Central Switzerland. METHODS: In a prospective cohort study, 439 study participants (participation rate: 36.8%) aged 12-17 years, completed questionnaires about their mobile and cordless phone use, their self-reported symptoms and possible confounding factors at baseline (2012/2013) and one year later (2013/2014). Operator recorded mobile phone data was obtained for a subgroup of 234 adolescents. RF-EMF dose measures considering various factors affecting RF-EMF exposure were computed for the brain and the whole body. Data were analysed using a mixed-logistic cross-sectional model and a cohort approach, where we investigated whether cumulative dose over one year was related to a new onset of a symptom between baseline and follow-up. All analyses were adjusted for relevant confounders. RESULTS: Participation rate in the follow-up was 97% (425 participants). In both analyses, cross-sectional and cohort, various symptoms tended to be mostly associated with usage measures that are only marginally related to RF-EMF exposure such as the number of text messages sent per day (e.g. tiredness: OR:1.81; 95%CI:1.20-2.74 for cross-sectional analyses and OR:1.87; 95%CI:1.04-3.38 for cohort analyses). Outcomes were generally less strongly or not associated with mobile phone call duration and RF-EMF dose measures. CONCLUSIONS: Stronger associations between symptoms of ill health and wireless communication device use than for RF-EMF dose measures were observed. Such a result pattern does not support a causal association between RF-EMF exposure and health symptoms of adolescents but rather suggests that other aspects of extensive media use are related to symptoms.

**Schonborn F, Burkhardt M, Kuster N, Differences in energy absorption between heads of adults and children in the near field of sources. Health Phys 74(2):160-168, 1998.**

This paper was motivated by a recent article in which the levels of electromagnetic energy absorbed in the heads of mobile phone users were compared for children and adults at the frequencies of 835 MHz and 1,900 MHz. Significant differences were found, in particular substantially greater absorption in children's heads at 835 MHz. These findings contradict other studies in which no significant changes had been postulated. The clarification of this issue is crucial to the mobile communications industry since current SAR evaluations as required by the FCC are only performed with phantoms based on the heads of adults. In order to investigate the differences in absorption between adults and children due to their differing anatomies, simulations have been performed using head phantoms based on MRI scans of an adult (voxel size 2 x 2 x 1 mm3) and two children (voxel size 2 x 2 x 1.1 mm3) of the ages of 3 and 7 y. Ten different tissue types were distinguished. The differences in absorption were investigated for the frequencies of 900 MHz and 1,800 MHz using 0.45 lambda dipoles instead of actual mobile phones. These well-defined sources simplified the investigation and facilitated the comparison to

previously published data obtained from several numerical and experimental studies on phantoms based on adults. All simulations were performed using a commercial code based on the finite integration technique. The results revealed no significant differences in the absorption of electromagnetic radiation in the near field of sources between adults and children. The same conclusion holds when children are approximated as scaled adults.

**Schrader, SM, Langford, RE, Turner, TW, Breitenstein, MJ, Clark, JC, Jenkins, BL, Lundyl DO, Simonl SD, Weyandtl TBl, Reproductive function in relation to duty assignments among military personnel. Reprod Toxicol 12(4):465-468, 1998.**

As a follow-up to the pilot study of semen quality of soldiers with various military assignments a larger, more complete study was conducted. Soldiers were recruited at Fort Hood, Texas. Thirty-three men were exposed to radar as part of their duty assignment in the Signal Corps, 57 men were involved with firing the 155 mm howitzer (potential lead exposure), and 103 soldiers had neither lead nor radar exposure and served as the comparison control group. Both serum and urinary follicle-stimulating hormone and luteinizing hormone and serum, salivary, and urine testosterone levels were determined in all men. A complete semen analysis was conducted on each soldier. For statistical analysis, the primary study variables were: sperm concentration, sperm/ejaculate, semen volume, percent normal morphology, percent motile, percent viable (both vital stain and hypoosmotic swelling), curvilinear velocity,straight-line velocity, linearity, sperm head length, width, area, and perimeter. Variables were adjusted for significant confounders (e.g., abstinence, sample age, race). No statistical differences ($P < 0.05$) were observed in any measurement. While these results are in agreement with two previous studies assessing soldiers firing the 155-mm howitzer, they contradict our previous report indicating that radar exposure caused a significant decrease in sperm numbers. A possible explanation is that the radar exposure in this study was that used in Signal Corps operations while the men in the previous study were using different radar as part of military intelligence operations. The data presented here in men firing the 155-mm howitzer combined with the results from the previous studies confirms that there are no deficits in semen quality in these men. The contradiction between the results of the radar exposure studies indicates that more data are needed to evaluate the relationship of military radar and male reproductive health.

**Schuz J, Mann S, A discussion of potential exposure metrics for use in epidemiological studies on human exposure to radiowaves from mobile phone base stations. J Expo Anal Environ Epidemiol 10(6 Pt 1):600-605, 2000.**

There is currently a high level of concern in many countries that exposure to radiowaves from mobile phone base stations may be hazardous to health. When investigating such suggested risks, epidemiologists need to define an exposure metric that can reliably discriminate between exposed and unexposed groups of people. We conducted a feasibility study to investigate if either short-term measurements of electric field strength, calculations of electric field strength, or distance from nearby mobile phone base stations could be used to develop a metric reflecting an individual's exposure to radiowaves. With electric field strengths in the range of 0.012-0.343 V/m, radiowaves from mobile phone base stations were found to give a material contribution to total exposure; however,

stronger signals were frequently measured from other sources such as broadcast radio and television transmitters. Theoretical considerations and the measurements made during this work demonstrated that studies at the population level on suggested adverse effects of radiowaves from mobile phone base stations are not feasible since no valid metric for estimating historical exposures is currently available. The pace of radio infrastructure development is also such that today's measurements are unlikely to be good proxies for either past or future exposures. The complex propagation characteristics affecting the beams from base station antennas include shielding effects and multiple reflections from house walls and other buildings. These factors, combined with the presence of other environmental sources of radiowaves, cause distance from a base station to be a poor proxy for exposure to radiowaves indoors. It may be possible to adapt computer models developed by network providers to predict network coverage for epidemiological purposes; however, this has yet to be investigated. Furthermore, there is little evidence that presently justifies epidemiological studies being restricted to adverse effects of radiowaves from mobile phone base stations while neglecting radiowaves at other frequencies produced by different transmitters.

**Schuz J. Mobile phone use and exposures in children. Bioelectromagnetics. Suppl 7:S45-50,2005.**

The main difference concerning the use of mobile phones (MPs) between today's children and adults is the longer lifetime exposure of children when they grow older, due to starting to use MPs at an early age. Additionally, recent trends lead to a higher frequency of use among children, including higher popularity of MPs and features specifically designed to attract children. The prevalence of MP users is already very high and reaches >90% among adolescents in some countries. In a German study, 6% of 9-10 years old children used a MP for making calls daily; 35% owned their own MP. For children, MPs are dominant sources of radio wave exposures and relevant sources of extremely low frequency magnetic fields. For very young children, however, environmental exposure to radio waves may be of concern. In conclusion, children will have a much higher cumulative exposure to radio waves than today's adults when they are at the same age. Radio wave exposure of children may be estimated more easily, because the variety of exposure sources is smaller than for adults. As long as adverse health effects cannot be ruled out with some degree of certainty, it appears to be appropriate to instruct children and their parents about a prudent use of MPs.

**Schuz J, Bohler E, Berg G, Schlehofer B, Hettinger I, Schlaefer K, Wahrendorf J, Kunna-Grass K, Blettner M. Cellular phones, cordless phones, and the risks of glioma and meningioma (Interphone Study Group, Germany). Am J Epidemiol. 163(6):512-520, 2006**

The widespread use of cellular telephones has generated concern about possible adverse health effects, particularly brain tumors. In this population-based case-control study carried out in three regions of Germany, all incident cases of glioma and meningioma among patients aged 30-69 years were ascertained during 2000-2003. Controls matched on age, gender, and region were randomly drawn from population registries. In total, 366 glioma cases, 381 meningioma cases, and 1,494 controls were interviewed. Overall use of a cellular phone was not associated with brain tumor risk; the

respective odds ratios were 0.98 (95% confidence interval (CI): 0.74, 1.29) for glioma and 0.84 (95% CI: 0.62, 1.13) for meningioma. Among persons who had used cellular phones for 10 or more years, increased risk was found for glioma (odds ratio = 2.20, 95% CI: 0.94, 5.11) but not for meningioma (odds ratio = 1.09, 95% CI: 0.35, 3.37). No excess of temporal glioma (p = 0.41) or meningioma (p = 0.43) was observed in cellular phone users as compared with nonusers. Cordless phone use was not related to either glioma risk or meningioma risk. In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn.

**Schuz J, Bohler E, Schlehofer B, Berg G, Schlaefer K, Hettinger I, Kunna-Grass K, Wahrendorf J, Blettner M. Radiofrequency Electromagnetic Fields Emitted from Base Stations of DECT Cordless Phones and the Risk of Glioma and Meningioma (Interphone Study Group, Germany). Radiat Res. 166(1):116-119, 2006.**

The objective of this study was to test the hypothesis that exposure to continuous low-level radiofrequency electromagnetic fields (RF EMFs) increases the risk of glioma and meningioma. Participants in a population-based case-control study in Germany on the risk of brain tumors in relation to cellular phone use were 747 incident brain tumor cases between the ages of 30 and 69 years and 1494 matched controls. The exposure measure of this analysis was the location of a base station of a DECT (Digital Enhanced Cordless Telecommunications) cordless phone close to the bed, which was used as a proxy for continuous low-level exposure to RF EMFs during the night. Estimated odds ratios were 0.82 (95% confidence interval: 0.29-2.33) for glioma and 0.83 (0.29-2.36) for meningioma. There was also no increasing risk observed with duration of exposure to DECT cordless phone base stations. Although the study was limited due to the small number of exposed subjects, it is still a first indication that residential low-level exposure to RF EMFs may not pose a higher risk of brain tumors.

**Schüz J, Jacobsen R, Olsen JH, Boice, JD Jr, McLaughlin JK, Johansen C. Cellular Telephone Use and Cancer Risk: Update of a nationwide Danish cohort. J Natl Cancer Inst 98:1707-1713, 2006.**

Background: The widespread use of cellular telephones has heightenedconcerns about possible adverse health effects. The objectiveof this study was to investigate cancer risk among Danish cellulartelephone users who were followed for up to 21 years. Methods:This study is an extended follow-up of a large nationwide cohortof 420 095 persons whose first cellular telephone subscriptionwas between 1982 and 1995 and who were followed through 2002for cancer incidence. Standardized incidence ratios (SIRs) werecalculated by dividing the number of observed cancer cases inthe cohort by the number expected in the Danish population.Results: A total of 14 249 cancers were observed (SIR = 0.95;95% confidence interval [CI] = 0.93 to 0.97) for men and womencombined. Cellular telephone use was not associated with increasedrisk for brain tumors (SIR = 0.97), acoustic neuromas (SIR =0.73), salivary gland tumors (SIR = 0.77), eye tumors (SIR =0.96), or leukemias (SIR = 1.00). Among long-term subscribersof 10 years or more, cellular telephone use was not associatedwith increased risk for brain tumors (SIR = 0.66, 95% CI = 0.44to 0.95), and there was no trend with time since first subscription.The risk for smoking-related

cancers was decreased among men(SIR = 0.88, 95% CI = 0.86 to 0.91) but increased among women(SIR = 1.11, 95% CI = 1.02 to 1.21). Additional data on incomeand smoking prevalence, primarily among men, indicated thatcellular telephone users who started subscriptions in the mid-1980sappeared to have a higher income and to smoke less than thegeneral population. Conclusions: We found no evidence for anassociation between tumor risk and cellular telephone use amongeither short-term or long-term users. Moreover, the narrow confidenceintervals provide evidence that any large association of riskof cancer and cellular telephone use can be excluded.

**Schüz J, Waldemar G, Olsen JH, Johansen C. Risks for central nervous system diseases among mobile phone subscribers: a Danish retrospective cohort study. PLoS One. 4(2):e4389, 2009**

The aim of this study was to investigate a possible link between cellular telephone use and risks for various diseases of the central nervous system (CNS). We conducted a large nationwide cohort study of 420 095 persons whose first cellular telephone subscription was between 1982 and 1995, who were followed through 2003 for hospital contacts for a diagnosis of a CNS disorder. Standardized hospitalization ratios (SHRs) were derived by dividing the number of hospital contacts in the cohort by the number expected in the Danish population. The SHRs were increased by 10-20% for migraine and vertigo. No associations were seen for amyotrophic lateral sclerosis, multiple sclerosis or epilepsy in women. SHRs decreased by 30-40% were observed for dementia (Alzheimer disease, vascular and other dementia), Parkinson disease and epilepsy among men. In analyses restricted to subscribers of 10 years or more, the SHRs remained similarly increased for migraine and vertigo and similarly decreased for Alzheimer disease and other dementia and epilepsy (in men); the other SHRs were close to unity. In conclusion, the excesses of migraine and vertigo observed in this first study on cellular telephones and CNS disease deserve further attention. An interplay of a healthy cohort effect and reversed causation bias due to prodromal symptoms impedes detection of a possible association with dementia and Parkinson disease. Identification of the factors that result in a healthy cohort might be of interest for elucidation of the etiology of these diseases.

**Schwartz JL, House DE, Mealing GA, Exposure of frog hearts to CW or amplitude-modulated VHF fields: selective efflux of calcium ions at 16 Hz. Bioelectromagnetics 11(4):349-358, 1990.**

Isolated frog hearts were exposed for 30-min periods in a Crawford cell to a 240-MHz electromagnetic field, either continuous-wave or sinusoidally modulated at 0.5 or 16 Hz. Radiolabeled with calcium (45Ca), the hearts were observed for movement of Ca2+ at calculated SARs of 0.15, 0.24, 0.30, 0.36, 1.50, or 3.00 mW/kg. Neither CW radiation nor radiation at 0.5 Hz, which is close to the beating frequency of the frog's heart, affected movement of calcium ions. When the VHF field was modulated at 16 Hz, a field-intensity-dependent change in the efflux of calcium ions was observed. Relative to control values, ionic effluxes increased by about 18% at 0.3 mW/kg (P less than .01) and by 21% at 0.15 mW/kg (P less than .05), but movement of ions did not change significantly at other rates

of energy deposition. These data indicate that the intact myocardium of the frog, akin to brain tissue of neonatal chicken, exhibits movement of calcium ions in response to a weak VHF field that is modulated at 16 Hz.

**Schwartz JL, Mealing GA, Calcium-ion movement and contractility in atrial strips of frog heart are not affected by low-frequency-modulated, 1 GHz electromagnetic radiation. Bioelectromagnetics 14(6):521-533, 1993.**

Calcium efflux from electrically stimulated, 45Ca(2+)-preloaded atrial strips of the frog heart was measured from samples of the rinsing perfusate collected at 2-min intervals for 32 min in a continuous perfusion chamber. Contractile force was simultaneously monitored. The specimen chamber was located in a stripline apparatus in which the atrial strips were exposed for 32 min to constant (CW) or amplitude-modulated (AM), 1 GHz electromagnetic (EM) fields at specific absorption rates (SAR) ranging from 3.2 microW/kg to 1.6 W/kg. Amplitude modulation was either at 0.5 Hz, in synchrony with the electrical stimulus applied to the preparation, or at 16 Hz. Neither unmodulated nor 0.5 Hz or 16 Hz modulated 1 GHz waves affected the movement of calcium ions or the contractile force in isolated atrial strips of the frog heart.

**Schwarz C, Kratochvil E, Pilger A, Kuster N, Adlkofer F, Rüdiger HW. Radiofrequency electromagnetic fields (UMTS, 1,950 MHz) induce genotoxic effects in vitro in human fibroblasts but not in lymphocytes. Int Arch Occup Environ Health. 81(6):755-767, 2008.**

OBJECTIVE: Universal Mobile Telecommunication System (UMTS) was recently introduced as the third generation mobile communication standard in Europe. This was done without any information on biological effects and genotoxic properties of these particular high-frequency electromagnetic fields. This is discomforting, because genotoxic effects of the second generation standard Global System for Mobile Communication have been reported after exposure of human cells in vitro. METHODS: Human cultured fibroblasts of three different donors and three different short-term human lymphocyte cultures were exposed to 1,950 MHz UMTS below the specific absorption rate (SAR) safety limit of 2 W/kg. The alkaline comet assay and the micronucleus assay were used to ascertain dose and time-dependent genotoxic effects. Five hundred cells per slide were visually evaluated in the comet assay and comet tail factor (CTF) was calculated. In the micronucleus assay 1,000 binucleated cells were evaluated per assay. The origin of the micronuclei was determined by fluorescence labeled anticentromere antibodies. All evaluations were performed under blinded conditions. RESULTS: UMTS exposure increased the CTF and induced centromere-negative micronuclei (MN) in human cultured fibroblasts in a dose and time-dependent way. Incubation for 24 h at a SAR of 0.05 W/kg generated a statistically significant rise in both CTF and MN (P = 0.02). At a SAR of 0.1 W/kg the CTF was significantly increased after 8 h of incubation (P = 0.02), the number of MN after 12 h (P = 0.02). No UMTS effect was obtained with lymphocytes, either unstimulated or stimulated with Phytohemagglutinin. CONCLUSION: UMTS exposure may cause genetic alterations in some but not in all human cells in vitro.

**Schwarze S, Schneider NL, Reichl T, Dreyer D, Lefeldt N, Engels S, Baker N, Hore PJ, Mouritsen H. Weak Broadband Electromagnetic Fields are More Disruptive to Magnetic Compass Orientation in a Night-Migratory Songbird (Erithacus rubecula) than Strong Narrow-Band Fields.Front Behav Neurosci. 2016 Mar 22;10:55.**

Magnetic compass orientation in night-migratory songbirds is embedded in the visual system and seems to be based on a light-dependent radical pair mechanism. Recent findings suggest that both broadband electromagnetic fields ranging from ~2 kHz to ~9 MHz and narrow-band fields at the so-called Larmor frequency for a free electron in the Earth's magnetic field can disrupt this mechanism. However, due to local magnetic fields generated by nuclear spins, effects specific to the Larmor frequency are difficult to understand considering that the primary sensory molecule should be organic and probably a protein. We therefore constructed a purpose-built laboratory and tested the orientation capabilities of European robins in an electromagnetically silent environment, under the specific influence of four different oscillating narrow-band electromagnetic fields, at the Larmor frequency, double the Larmor frequency, 1.315 MHz or 50 Hz, and in the presence of broadband electromagnetic noise covering the range from ~2 kHz to ~9 MHz. Our results indicated that the magnetic compass orientation of European robins could not be disrupted by any of the relatively strong narrow-band electromagnetic fields employed here, but that the weak broadband field very efficiently disrupted their orientation.

**Seaman RL, Beblo DA, Modification of acoustic startle by microwave pulses in the rat: a preliminary report. Bioelectromagnetics 13(4):323-328, 1992.**

Single, 1.25-GHz microwave pulses of 0.8- to 1.0-microseconds duration were presented to each of four rats 100 ms before presentation of a startle-inducing acoustic stimulus. This sequential pairing of microwave pulse and acoustic stimulus was found to modify the startle response. At an energy dose to the head of 22-43 mJ/kg per pulse (peak SAR, 23-48 kW/kg), the mean latency to the startle response was longer and the mean amplitude of the response was smaller with respect to control responses that occurred to acoustic stimuli alone. However, at a higher energy dose per microwave pulse in the range of 59-107 mJ/kg (peak SAR, 63-111 kW/kg), the mean latency and amplitude of the startle response were not statistically different from the respective means of control responses.

**Seaman RL, DeHaan RL, Inter-beat intervals of cardiac-cell aggregates during exposure to 2.45 GHz CW, pulsed, and square-wave-modulated microwaves. Bioelectromagnetics 14(1):41-55, 1993.**

Inter-beat intervals of aggregated cardiac cells from chicken embryos were studied during 190 s exposures to 2.45 GHz microwaves in an open-ended coaxial device. Averaged specific-absorption rates (SARs) and modulation conditions were 1.2-86.9 W/kg continuous-wave (CW), 1.2-12.2 W/kg pulse modulation (PW, duty cycle approximately 11%), and 12.0-43.5 W/kg square-wave modulation (duty cycle = 50%). The inter-beat interval decreased during microwave exposures at 42.0 W/kg and higher when CW or square-wave modulation was used, which is consistent with established effects of elevated temperatures. However, increases in the inter-beat

interval during CW exposures at 1.2-12.2 W/kg, and decreases in the inter-beat interval after PW exposures at 8.4-12.2 W/kg, are not consistent with simple thermal effects. Analysis of variance indicated that SAR, modulation, and the modulation-SAR interaction were all significant factors in altering the inter-beat interval. The latter two factors indicated that the cardiac cells were affected by athermal as well as thermal effects of microwave exposure.

**Seaman RL, Belt ML, Doyle JM, Mathur SP, Ultra-wideband electromagnetic pulses and morphine-induced changes in nociception and activity in mice. Physiol Behav 65(2):263-270, 1998.**

Mice were exposed to ultra-wideband (UWB) electromagnetic pulses averaging 99-105 kV/m peak amplitude, 0.97-1.03 ns duration, and 155-174 ps rise time, after intraperitoneal administration of saline or morphine sulfate. They were then tested for thermal nociception on a 50 degrees C surface and for spontaneous locomotor activity and its time profile over 5 min. Analysis of results showed no effect of UWB exposure on nociception and activity measures in CF-1 mice after 15-, 30-, or 45-min exposure to pulses at 600/s or after 30-min exposure to UWB pulses at 60/s. Similarly, no effect was seen in C57BL/6 mice after 30-min exposure to pulses at 60/s or 600/s. Although trends in morphine-modified measures seen with UWB pulse repetition frequency could be expected because of increased levels of low-frequency energy, no significant change was seen in normal or morphine-modified nociception or activity after UWB exposure. This indicated lack of effect of the UWB pulses used in these experiments on nervous system components, including endogenous opioids, involved in these behaviors.

**Seaman RL, Belt ML, Doyle JM, Mathur SP, Hyperactivity caused by a nitric oxide synthase inhibitor is countered by ultra-wideband pulses. Bioelectromagnetics 20(7):431-439, 1999.**

Potential action of ultra-wideband (UWB) electromagnetic field pulses on effects of N(G)-nitro- L-arginine methyl ester (L-NAME), an inhibitor of nitric oxide synthase (NOS), on nociception and locomotor activity was investigated in CF-1 mice. Animals were injected IP with saline or 50 mg/kg L-NAME and exposed for 30 min to no pulses (sham exposure) or UWB pulses with electric field parameters of 102+/-1 kV/m peak amplitude, 0.90+/-0.05 ns duration, and 160+/-5 ps rise time (mean+/-S.D.) at 600/s. Animals were tested for thermal nociceptive responses on a 50 degrees C surface and for spontaneous locomotor activity for 5 min. L-NAME by itself increased mean first-response (paw lift, shake, or lick; jump) and back-paw-lick response latencies and mean locomotor activity. Exposure to UWB pulses reduced the L-NAME-induced increase in back-paw-lick latency by 22%, but this change was not statistically significant. The L-NAME-induced hyperactivity was not present after UWB exposure. Reduction and cancellation of effects of L-NAME suggest activation of opposing mechanism(s) by the UWB pulses, possibly including increase of nitric oxide production by NOS. The action, or actions, of UWB pulses appears to be more effective on locomotor activity than on thermal nociception in CF-1 mice.

**Seaman RL, Phelix CF. Acute effects of pulsed microwaves and 3-nitropropionic acid on neuronal ultrastructure in the rat caudate-putamen. Bioelectromagnetics. 26(2):82-101, 2005.**

Ultrastructure of the medium sized "spiny" neuron in rat dorsal-lateral caudate-putamen was assessed after administration of 3-nitropropionic acid (3-NP) and exposure to pulsed microwaves. Sprague-Dawley male rats were given two daily intraperitoneal doses of 0 or 10 mg/kg 3-NP and 1.5 h after each dose were exposed to microwave radiation at a whole body averaged specific absorption rate (SAR) of 0 (sham exposure), 0.6, or 6 W/kg for 30 min. Microwave exposure consisted of 1.25 GHz radiation delivered as 5.9 mus pulses with repetition frequency 10 Hz. Tissue samples taken 2-3 h after the second sham or microwave exposure showed no injury with light microscope methods. Blinded qualitative assessment of ultrastructure of randomly selected neurons from the same samples did reveal differences. Subsequent detailed, quantitative measurements showed that, when followed by sham exposure, administration of 3-NP significantly increased endoplasmic reticulum (ER) intracisternal width, ER area density, and nuclear envelope thickness. Microwave exposure at 6 W/kg alone also significantly increased these measures. Exposure of 3-NP treated animals at 6 W/kg significantly increased effects of 3-NP on ultrastructure. Although exposure at 0.6 W/kg alone did not affect ultrastructure measures, exposure of 3-NP treated animals at 0.6 W/kg reduced the effects of 3-NP. We concluded that 3-NP changed neuronal ultrastructure and that the microwave exposures used here changed neuronal ultrastructure in ways that depended on microwave SAR and neuron metabolic status. The apparent cancellation of 3-NP induced changes by exposure to pulsed microwaves at 0.6 W/kg indicated the possibility that such exposure can protect against the effects of mitochondrial toxins on the nervous system.

**Sebastian JL, Munoz S, Sancho M, Miranda JM, Analysis of the influence of the cell geometry, orientation and cell proximity effects on the electric field distribution from direct RF exposure. Phys Med Biol 46(1):213-225, 2001.**

This paper shows the importance of using a cell model with the proper geometry, orientation and internal structure to study possible cellular effects from direct radiofrequency exposure. For this purpose, the electric field intensity is calculated, using the finite element numerical technique, in single- and multilayer spherical, cylindrical and ellipsoidal mammalian cell models exposed to linearly polarized electromagnetic plane waves of frequencies 900 and 2450 MHz. An extensive analysis is performed on the influence that the cell geometry and orientation with respect to the external field have in the value of the electric field induced in the membrane and cytoplasm. We also show the significant role that the cytoplasmic and extracellular bound water layers play in determining the electric field intensity for the cylindrical and ellipsoidal cell models. Finally, a study of the mutual interactions between cells shows that polarizing effects between cells significantly modify the values of field intensity within the cell.

**Seckin E, Suren Basar F, Atmaca S, Kaymaz FF, Suzer A, Akar A, Sunan E, Koyuncu M.The effect of radiofrequency radiation generated by a Global System for Mobile Communications source on cochlear development in a rat model. J Laryngol Otol. 2014 May 1:1-6. [Epub ahead of print]**

Objective: This study aimed to determine the effect of radiofrequency radiation generated by 900 and 1800 MHz Global System for Mobile Communications sources on cochlear development in the rat model. Methods: Eight pregnant albino Wistar rats were divided

into three groups: control, 900 MHz and 1800 MHz. The latter two groups of pregnant rats were exposed to radiofrequency radiation for 1 hour per day starting on the 12th day of pregnancy until delivery. The rats in the control, 900 MHz and 1800 MHz groups gave birth to 24, 31 and 26 newborn rats respectively. Newborn rats in the 900 MHz and 1800 MHz groups were exposed to radiofrequency radiation for 1 hour per day for 21 days after delivery. Hearing evaluations of newborn rats were carried out using distortion product otoacoustic emissions testing. Eight newborn rats were randomly selected from each group for electron microscopic evaluation. Results: Distortion product otoacoustic emission tests revealed no significant difference among the groups, but electron microscopic evaluation revealed significant differences among the groups with regard to the number of normal, apoptotic and necrotic cells. Conclusion: The findings indicated cellular structural damage in the cochlea caused by radiofrequency radiation exposure during cochlear development in the rat model.

**Sefidbakht Y, Hosseinkhani S, Mortazavi M, Tavakkolnia I, Khellat MR, Shakiba-Herfeh M, Saviz M, Faraji-Dana R, Saboury AA, Sheibani N, Moosavi-Movahedi AA. Effects of 940 MHz EMF on Luciferase Solution: Structure, Function, and Dielectric Studies. Bioelectromagnetics. 2013 Apr 30. doi: 10.1002/bem.21792. [Epub ahead of print]**

We designed a rectangular waveguide exposure system to study the effects of mobile phone frequency (940 MHz) electromagnetic fields (EMF) on luciferase structure and activity. The luciferase activity of exposed samples was significantly higher than that of unexposed samples. Dynamic light scattering of the exposed samples showed smaller hydrodynamic radii compared to unexposed samples (20 nm vs. 47 nm ± 5%). The exposed samples also showed less tendency to form aggregates, monitored by turbidity measurements at $\lambda = 360$ nm. A microwave dielectric measurement was performed to study the hydration properties of luciferase solutions with a precision network analyzer over frequency ranges from 0.2 to 20 GHz before and after exposure. The change in the dielectric properties of the exposed luciferase solution was related to the disaggregation potency of the applied field. Together, our results suggested that direct interactions with luciferase molecules and its dipole moment were responsible for the reduced aggregation and enhanced luciferase activity upon exposure to the EMF.

**Sefidbakht Y, Moosavi-Movahedi AA, Hosseinkhani S, Khodagholi F, Torkzadeh-Mahani M, Foolad F, Faraji-Dana R. Effects of 940 MHz EMF on bioluminescence and oxidative response of stable luciferase producing HEK cells. Photochem Photobiol Sci. 2014 Jun 2. [Epub ahead of print]**

The effects of mobile phone frequency electromagnetic field (RF-EMF, 940 MHz) on a stable cell line (HEK293T) harbouring the firefly luciferase gene were evaluated. A waveguide exposure system with 1 W input power provided the mean specific absorption rate of ≈0.09 W $kg^{-1}$ in 35 mm Petri dishes. The effects of exposure duration (15, 30, 45, 60 and 90 min) on luciferase activity and oxidative response elements were investigated. Endogenous luciferase activity was reduced after 30 and 45 min of continuous exposure,

while after 60 min, the exposed cell lysate showed higher luciferase activity compared with the non-exposed control. Reactive oxygen species (ROS) generation was highest in the 30 min exposed cells as studied by 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA) fluorescence. The observed boost in ROS was then followed by a sharp rise in catalase (CAT) and superoxide dismutase (SOD) activity and elevation of glutathione (GSH) during the 45 min exposure. Decrease in lipid peroxidation (malondialdehyde, MDA) was meaningful for the 45 and 60 min exposed cells. Therefore, it appears that an increase in the activity of luciferase after 60 min of continuous exposure could be associated with a decrease in ROS level caused by activation of the oxidative response. This ability in cells to overcome oxidative stress and compensate the luciferase activity could also be responsible for the adaptive response mechanism detected in ionizing radiation studies with RF-EMF pre-treatments.

**Sehitoglu I, Tumkaya L, Kalkan Y, Bedir R, Cure MC, Zorba OU, Cure E, Yuce S. Biochemical and histopathological effects on the rat testis after exposure to electromagnetic field during fetal period. Arch Esp Urol. 68(6):562-568, 2015.**

OBJECTIVES: Electromagnetic radiation (ER) emitted from cell phones may exert a detrimental influence on human health and may affect the man reproductive system. We aimed to study the biological and morphological effects on the testes of 60-day-old male rats after ER exposure (900 MHz), which was applied continuously throughout embryogenesis. METHODS: A total of six pregnant Sprague Dawley rats were included in the study. Three pregnant rats (experimental group) were exposed to radiation from a cell phone set to talking mode for 24 hours a day for 20 days, and the other 3 pregnant rats (control group) were not to exposed to radiation. Newborn male rats were included from the experimental group (n=7) and the control group (n=7). At the end of 60 days, the rats' testes were excised, and testis length, width, depth, and weight were measured. Histopathological examinations were compared and serum testosterone (T) levels were assayed biochemically. RESULTS: While serum T level (3.51±0.21 ng/ml) of ER Exposed group was significantly lower than the control group (4.04±0.47 ng/ml, p=0.018), Caspase-3 enzyme activity (2.00±0.88) was significantly higher than the control group control (1.00±0.63, p=0.026). Johnsen score (8.4±0.5) of ER group was fairly lower than the control group (9.4±0.5, p= 0.010). CONCLUSION: Our study demonstrated that ER exposure throughout embryogenesis may cause reductions in serum total T levels and in the size and weight of the testes of male rats, while causing modest increase in apoptosis.

**Seishima M, Oyama Z, Oda M. Cellular phone dermatitis with chromate allergy. Dermatology. 207(1):48-50, 2003.**

BACKGROUND: A patient with allergic contact dermatitis caused by hexavalent chromium plating on a cellular phone has already been reported. OBJECTIVES: This study described the clinical characteristics and results of patch tests in 8 patients with contact dermatitis possibly caused by handling a cellular phone. PATIENTS: The 8 patients were 4 males and 4 females aged from 14 to 54 years. They each noticed skin eruptions after 9-25 days of using a cellular phone. All patients had erythema, and 7 had papules on the hemilateral auricle or in the preauricular region. Three of 8 patients had a

history of metal allergy. Chromate, aluminium and acrylnitrile-butadiene-styrene copolymer were used as plating on the cellular phones used by these patients. METHODS: Closed patch tests and photopatch tests were performed using metal standard antigens. RESULTS: The patch test was positive for 0.5, 0.1 and 0.05% potassium dichromate in all 8 patients. The photopatch test showed the same results. One patient was positive for 2% cobalt chloride and one for 5% nickel sulfate. CONCLUSION: It is important to consider the possibility of contact dermatitis due to a cellular phone, possibly caused by chromate, when the patients have erythema and papules on the hemilateral auricle or in the preauricular region.

**Seitz H, Stinner D, Eikmann T, Herr C, Röösli M. Electromagnetic hypersensitivity (EHS) and subjective health complaints associated with electromagnetic fields of mobile phone communication--a literature review published between 2000 and 2004. Sci Total Environ. 349(1-3):45-55, 2005.**

Literature published between 2000 to 2004 concerning electromagnetic fields (EMF) of mobile communication and electromagnetic hypersensitivity (EHS) or unspecific symptoms of ill health, respectively, is reviewed. Basically, literature from established databases was systematically searched for. For each study, the design and quality were evaluated by means of a criteria list in order to judge evidence for causality of exposures on effects. Finally, 13 studies of sufficient quality were considered for this review. In only one provocation study, individuals with self-reported electromagnetic hypersensitivity were exposed to EMF. Their perception of field status was no better than would have been expected by chance. Results of five randomised cross-over studies on impaired well-being due to mobile phone exposure were contradictory. Even though these studies would allow more reliable exposure assessment, they are limited due to short exposure period and the small study size. No firm conclusion could be drawn from a few observational epidemiological studies finding a positive association between exposure and unspecific symptoms of ill health due to methodological limitations. Causality of exposure and effect was not derivable from these cross-sectional studies as field status and health complaints were assessed at the same time. In addition, exposure assessment has not been validated. In conclusion, based on the limited studies available, there is no valid evidence for an association between impaired well-being and exposure to mobile phone radiation presently. However, the limited quantity and quality of research in this area do not allow to exclude long-term health effects definitely.

**Sekeroğlu V, Akar A, Sekeroğlu ZA. Cytotoxic and genotoxic effects of high-frequency electromagnetic fields (GSM 1800 MHz) on immature and mature rats. Ecotoxicol Environ Saf. 80:140-144, 2012.**

We investigated the cytogenotoxic effects of high frequency electromagnetic fields (HF-EMF) for 45 day and the effect of a recovery period of 15 day after exposure to EMF on bone marrow cells of immature and mature rats. The animals in treatment groups were exposed to 1800 MHz EMF at SAR of 0.37 W/kg and 0.49 W/kg for 2h/day for 45 day. Two recovery groups were kept for a recovery period of 15 day without EMF after exposure to HF-EMF. Two control groups for both immature and

mature rats were also included. Significant differences were also observed in chromosome aberrations (CA), micronucleus (MN) frequency, mitotic index (MI) and ratio of polychromatic erythrocytes (PCEs) in all treatment groups. The cytogenotoxic damage was more remarkable in immature rats and, the recovery period did not improve this damage in immature rats. Because much higher and irreversible cytogenotoxic damage was observed in immature rats than in mature rats, further studies are needed to understand effects of EMF on DNA damage and DNA repair, and to determine safe limits for environment and human, especially for children.

**Sekijima M, Takeda H, Yasunaga K, Sakuma N, Hirose H, Nojima T, Miyakoshi J. 2-GHz band CW and W-CDMA modulated radiofrequency fields have no significant effect on cell proliferation and gene expression profile in human cells. J Radiat Res. 51(3):277-284, 2010.**

We investigated the mechanisms by which radiofrequency (RF) fields exert their activity, and the changes in both cell proliferation and the gene expression profile in the human cell lines, A172 (glioblastoma), H4 (neuroglioma), and IMR-90 (fibroblasts from normal fetal lung) following exposure to 2.1425 GHz continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) RF fields at three field levels. During the incubation phase, cells were exposed at the specific absorption rates (SARs) of 80, 250, or 800 mW/kg with both CW and W-CDMA RF fields for up to 96 h. Heat shock treatment was used as the positive control. No significant differences in cell growth or viability were observed between any test group exposed to W-CDMA or CW radiation and the sham-exposed negative controls. Using the Affymetrix Human Genome Array, only a very small (< 1%) number of available genes (ca. 16,000 to 19,000) exhibited altered expression in each experiment. The results confirm that low-level exposure to 2.1425 GHz CW and W-CDMA RF fields for up to 96 h did not act as an acute cytotoxicant in either cell proliferation or the gene expression profile.These results suggest that RF exposure up to the limit of whole-body average SAR levels as specified in the ICNIRP guidelines is unlikely to elicit a general stress response in the tested cell lines under these conditions.

**Senavirathna MD, Asaeda T, Thilakarathne BL, Kadono H. Nanometer-scale elongation rate fluctuations in the Myriophyllum aquaticum (Parrot feather) stem were altered by radio-frequency electromagnetic radiation. Plant Signal Behav. 2014 Apr;9(4):e28590. doi: 10.4161/psb.28590.**

The emission of radio-frequency electromagnetic radiation (EMR) by various wireless communication base stations has increased in recent years. While there is wide concern about the effects of EMR on humans and animals, the influence of EMR on plants is not well understood. In this study, we investigated the effect of EMR on the growth dynamics of Myriophyllum aquaticum (Parrot feather) by measuring the nanometric elongation rate fluctuation (NERF) using a statistical interferometry technique. Plants were exposed to 2 GHz EMR at a maximum of 1.42 Wm(-2) for 1 h. After continuous exposure to EMR, M. aquaticum plants exhibited a statistically significant 51 ± 16% reduction in NERF standard deviation. Temperature observations revealed that EMR exposure did not cause dielectric heating of the plants. Therefore, the reduced NERF was due to a non-thermal effect

caused by EMR exposure. The alteration in NERF continued for at least 2.5 h after EMR exposure and no significant recovery was found in post-EMR NERF during the experimental period.

**Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S. Analysis of rat testicular proteome following 30-days exposure to 900 MHz electromagnetic field radiation. Electrophoresis. 2014 Aug 21. doi: 10.1002/elps.201400273. [Epub ahead of print]**

The use of electromagnetic field (EMF) generating apparatuses such as cell phones is increasing, and has caused an interest in the investigations of its effects on human health. We analyzed proteome in preparations from the whole testis in adult male Sprague-Dawley rats exposed for 1, 2 or 4 h/d for 30 consecutive days to 900 MHz EMF radiation, simulating a range of possible human cell phone use. Subjects were sacrificed immediately after the end of the experiment and testes fractions were solubilized and separated via high resolution 2-dimensional electrophoresis, and gel patterns were scanned, digitized and processed. Thirteen of the proteins which found only in sham or in exposure groups were identified by MALDI-TOF/TOF-MS. Among them, heat shock proteins, superoxide dismutase, peroxiredoxin-1 and other proteins related to misfolding of proteins and/or stress were identified. These results demonstrate significant effects of radio-frequency modulated electromagnetic fields (RF-EMF) exposure on proteome, particularly in protein species in the rodent testis, and suggest that a 30 d exposure to EMF radiation induces non-thermal stress in testicular tissue. The functional implication of the identified proteins was discussed.

**Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S, Davis DL. Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. Environ Sci Pollut Res Int. 24(15):13666-13673, 2017.**

Although cell phones have been used worldwide, some adverse and toxic effects were reported for this communication technology apparatus. To analyze in vivo effects of exposure to radiofrequency-electromagnetic field (RF-EMF) on protein expression in rat testicular proteome, 20 Sprague-Dawley rats were exposed to 900 MHz RF-EMF for 0, 1, 2, or 4 h/day for 30 consecutive days. Protein content of rat testes was separated by high-resolution two-dimensional electrophoresis using immobilized pH gradient (pI 4-7, 7 cm) and 12% acrylamide and identified by MALDI-TOF/TOF-MS. Two protein spots were found differentially overexpressed ($P < 0.05$) in intensity and volume with induction factors 1.7 times greater after RF-EMF exposure. After 4 h of daily exposure for 30 consecutive days, ATP synthase beta subunit (ASBS) and hypoxia up-regulated protein 1 precursor (HYOU1) were found to be significantly up-regulated. These proteins affect signaling pathways in rat testes and spermatogenesis and play a critical role in protein folding and secretion in the endoplasmic reticulum. Our results indicate that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage. In light of the widespread practice of men carrying phones in their pockets near their gonads, where exposures can exceed as-tested guidelines, further study of these effects should be a high priority.

**Shahbazi-Gahrouei D, Hashemi-Beni B, Ahmadi Z. Effects of RF-EMF Exposure from GSM Mobile Phones on Proliferation Rate of Human Adipose-derived Stem Cells: An In-vitro Study. Biomed Phys Eng. 6(4):243-252, 2016.**

BACKGROUND: As the use of mobile phones is increasing, public concern about the harmful effects of radiation emitted by these devices is also growing. In addition, protection questions and biological effects are among growing concerns which have remained largely unanswered. Stem cells are useful models to assess the effects of radiofrequency electromagnetic fields (RF-EMF) on other cell lines. Stem cells are undifferentiated biological cells that can differentiate into specialized cells. Adipose tissue represents an abundant and accessible source of adult stem cells. The aim of this study is to investigate the effects of GSM 900 MHz on growth and proliferation of mesenchymal stem cells derived from adipose tissue within the specific distance and intensity. MATERIALS AND METHODS: ADSCs were exposed to GSM mobile phones 900 MHz with intensity of 354.6 μW/cm$^2$ square waves (217 Hz pulse frequency, 50% duty cycle), during different exposure times ranging from 6 to 21 min/day for 5 days at 20 cm distance from the antenna. MTT assay was used to determine the growth and metabolism of cells and trypan blue test was also done for cell viability. Statistical analyses were carried out using analysis of one way ANOVA. $P<0.05$ was considered to be statistically significant. RESULTS: The proliferation rates of human ADSCs in all exposure groups were significantly lower than control groups ($P<0.05$) except in the group of 6 minutes/day which did not show any significant difference with control groups. CONCLUSION: The results show that 900 MHz RF signal radiation from antenna can reduce cell viability and proliferation rates of human ADSCs regarding the duration of exposure.

**Shahin S, Singh SP, Chaturvedi CM. Mobile phone (1800MHz) radiation impairs female reproduction in mice, Mus musculus, through stress induced inhibition of ovarian and uterine activity. Reprod Toxicol. 73:41-60, 2017.**

Present study investigated the long-term effects of mobile phone (1800MHz) radiation in stand-by, dialing and receiving modes on the female reproductive function (ovarian and uterine histo-architecture, and steroidogenesis) and stress responses (oxidative and nitrosative stress). We observed that mobile phone radiation induces significant elevation in ROS, NO, lipid peroxidation, total carbonyl content and serum corticosterone coupled with significant decrease in antioxidant enzymes in hypothalamus, ovary and uterus of mice. Compared to control group, exposed mice exhibited reduced number of developing and mature follicles as well as corpus lutea. Significantly decreased serum levels of pituitary gonadotrophins (LH, FSH), sex steroids (E2 and P4) and expression of SF-1, StAR, P-450scc, 3β-HSD, 17β-HSD, cytochrome P-450 aromatase, ER-α and ER-β were observed in all the exposed groups of mice, compared to control. These findings suggest that mobile phone radiation induces oxidative and nitrosative stress, which affects the reproductive performance of female mice.

**Solomentsev GY, English NJ, Mooney DA.Hydrogen bond perturbation in hen egg white lysozyme by external electromagnetic fields: a nonequilibrium molecular dynamics study.J Chem Phys. 133(23):235102, 2010.**

Nonequilibrium molecular dynamics simulations of a charge-neutral mutant of hen egg white lysozyme have been performed at 300 K and 1 bar in the presence of external microwave fields (2.45 to 100 GHz) of an rms electric field intensity of 0.05 V Å(-1). A systematic study was carried out of the distributions of persistence times and energies of each intraprotein hydrogen bond in between breakage and reformation, in addition to overall persistence over 20 ns simulations, vis-á-vis equilibrium, zero-field conditions. It was found that localized translational motion for formally charged residues led to greater disruption of associated hydrogen bonds, although induced rotational motion of strongly dipolar residues also led to a degree of hydrogen bond perturbation. These effects were most apparent in the solvent exposed exterior of hen egg white lysozyme, in which the intraprotein hydrogen bonds tend to be weaker.

**Semin IuA, Shvartsburg LK, Dubovik BV. [Changes in the secondary structure of DNA under the influence of external low-intensity electromagnetic field] Radiats Biol Radioecol 35(1):36-41, 1995.** [Article in Russian]

The effect of weak RF on the stability of DNA secondary structure was studied in vitro. DNA was exposed in the presence of glycine and formaldehyde. Aminomethynol compounds, which form in this medium, react with DNA bases at single-strand sites, which prevents recovery from damage to the DNA secondary structure. The damage accumulates during the incubation, and its amount canbe estimated from the dynamics of thermal DNA denaturalization after RF or sha exposure. Samples were exposed in an anechoic chamber at 18$^{o}$C at 10 different microwave frequencies simultaneously (4- to 8 GHz, 25 ms pulses, 0.4 to 0.7 mW/cm2 peak power, 1- to 6-Hz repetition rate, no heating). Parallel control samples were sham exposed in a shielded area in the same chamber. The experiments established that irradiation at 3 or 4 Hz and 0.6 mW/cm2 peak power clearly increased the accumulated damage to the DNA secondary structure (P< .00001). However, changing the pulse repetition rate to 1, 5, 6 Hz, as well as changing the peak power to 0.4 or 0.7 mW/cm2, eliminated the effect entirely. Thus, the effect occurred only within narrow ‘windows’ of the peak intensities and modulation frequencies.

**Senavirathna MD, Asaeda T, Thilakarathne BL, Kadono H. Nanometer-scale elongation rate fluctuations in the Myriophyllum aquaticum (Parrot feather) stem were altered by radio-frequency electromagnetic radiation. Plant Signal Behav. 2014 Mar 26;9(3). pii: e28590. [Epub ahead of print]**

The emission of radio-frequency electromagnetic radiation (EMR) by various wireless communication base stations has increased in recent years. While there is wide concern about the effects of EMR on humans and animals, the influence of EMR on plants is not well understood. In this study, we investigated the effect of EMR on the growth dynamics of Myriophyllum aquaticum (Parrot feather) by measuring the nanometric elongation rate fluctuation (NERF) using a statistical interferometry technique. Plants were exposed to 2 GHz EMR at a maximum of 1.42 Wm-2 for 1 h. After continuous exposure to EMR, M. aquaticum plants exhibited a statistically significant 51 ± 16% reduction in NERF standard deviation. Temperature observations revealed that EMR exposure did not cause dielectric heating of the plants. Therefore, the reduced NERF was due to a non-thermal effect caused by EMR exposure. The alteration in NERF continued for at least 2.5 h after EMR

exposure and no significant recovery was found in post-EMR NERF during the experimental period.

**Sepehrimanesh M, Saeb M, Nazifi S, Kazemipour N, Jelodar G, Saeb S. Impact of 900 MHz electromagnetic field exposure on main male reproductive hormone levels: a Rattus norvegicus model. Int J Biometeorol. 2013 Dec 20. [Epub ahead of print]**

This work analyzes the effects of radiofrequency-electromagnetic field (RF-EMF) exposure on the reproductive system of male rats, assessed by measuring circulating levels of FSH, LH, inhibin B, activin B, prolactin, and testosterone. Twenty adult male Sprague-Dawley rats (180 ± 10 g) were exposed to 900 MHz RF-EMF in four equal separated groups. The duration of exposure was 1, 2, and 4 h/day over a period of 30 days and sham-exposed animals were kept under the same environmental conditions as the exposed group except with no RF-EMF exposure. Before the exposure, at 15 and 30 days of exposure, determination of the abovementioned hormone levels was performed using ELISA. At the end of the experiment, FSH and LH values of the long time exposure (LTE) group were significantly higher than the sham-exposed group ($p < 0.05$). Serum activin B and prolactin in the LTE group showed significant increase and inhibin B showed significant decrease than sham and short time exposed (STE) groups after 30 days RF-EMF exposure ($p < 0.05$). Also, a significant decrease in serum testosterone levels in the LTE group was found compared to short and moderate time exposed (MTE) groups after 30 days RF-EMF exposure ($p < 0.05$). Results suggest that reproductive hormone levels are disturbed as a result of RF-EMF exposure and it may possibly affect reproductive functions. However, testosterone and inhibin B concentrations as a fertility marker and spermatogenesis were decreased significantly.

**Sepehrimanesh M, Kazemipour N, Saeb M, Nazifi S, Davis DL. Proteomic analysis of continuous 900-MHz radiofrequency electromagnetic field exposure in testicular tissue: a rat model of human cell phone exposure. Environ Sci Pollut Res Int. 24(15):13666-13673, 2017.**

Although cell phones have been used worldwide, some adverse and toxic effects were reported for this communication technology apparatus. To analyze in vivo effects of exposure to radiofrequency-electromagnetic field (RF-EMF) on protein expression in rat testicular proteome, 20 Sprague-Dawley rats were exposed to 900 MHz RF-EMF for 0, 1, 2, or 4 h/day for 30 consecutive days. Protein content of rat testes was separated by high-resolution two-dimensional electrophoresis using immobilized pH gradient (pI 4-7, 7 cm) and 12% acrylamide and identified by MALDI-TOF/TOF-MS. Two protein spots were found differentially overexpressed ($P < 0.05$) in intensity and volume with induction factors 1.7 times greater after RF-EMF exposure. After 4 h of daily exposure for 30 consecutive days, ATP synthase beta subunit (ASBS) and hypoxia up-regulated protein 1 precursor (HYOU1) were found to be significantly up-regulated. These proteins affect signaling pathways in rat testes and spermatogenesis and play a critical role in protein folding and

secretion in the endoplasmic reticulum. Our results indicate that exposure to RF-EMF produces increases in testicular proteins in adults that are related to carcinogenic risk and reproductive damage. In light of the widespread practice of men carrying phones in their pockets near their gonads, where exposures can exceed as-tested guidelines, further study of these effects should be a high priority.

**Shahbazi-Gahrouei D, Mortazavi SM, Nasri H, Baradaran A, Baradaran-Ghahfarokhi M, Baradaran-Ghahfarokhi HR. Mobile phone radiation interferes laboratory immunoenzymometric assays: Example chorionic gonadotropin assays. Pathophysiology. 19(1):43-47, 2012.**

The radiofrequency radiation is of concern in hospital laboratories as the microwaves have many health effects even on immune functions. The aim of this study was, however, to evaluate the effects of cell phone radiation on chorionic gonadotropin immunoassays of human serum. Two cell phones with 0.69 and 1.09W/kg (head SAR) emitting 900MHz radiation were used. Sixty wells with five human serum concentrations (0, 10, 100, 250, 500mIU/mL) were used in three batches. The well heads in each batch were exposed to 900MHz emitted from these phones, and the 0.69, 1.09W/kg exposed batches were compared with the unexposed controls. Radiation exposure from mobile phones altered the measured serum levels especially in the wells with 100, 250, 500mIU/mL hormone concentrations. Exposure at 1.09W/kg SAR caused a significant loss compared to 0.69W/kg SAR exposure. In conclusion, the microwave exposures may require attention in laboratories using immunoassays.

**Shahbazi-Gahrouei D, Hashemi-Beni B, Ahmadi Z. Effects of RF-EMF Exposure from GSM** Mobile Phones **on Proliferation Rate of Human Adipose-derived Stem Cells: An In-vitro Study. J Biomed Phys Eng. 6(4):243-252, 2016.**

BACKGROUND: As the use of **mobile phones** is increasing, public concern about the harmful effects of radiation emitted by these devices is also growing. In addition, protection questions and biological effects are among growing concerns which have remained largely unanswered. Stem cells are useful models to assess the effects of radiofrequency electromagnetic fields (RF-EMF) on other **cell** lines. Stem cells are undifferentiated biological cells that can differentiate into specialized cells. Adipose tissue represents an abundant and accessible source of adult stem cells. The aim of this study is to investigate the effects of GSM 900 MHz on growth and proliferation of mesenchymal stem cells derived from adipose tissue within the specific distance and intensity. MATERIALS AND METHODS: ADSCs were exposed to GSM **mobile phones** 900 MHz with intensity of 354.6 $\mu W/cm^2$ square waves (217 Hz pulse frequency, 50% duty cycle), during different exposure times ranging from 6 to 21 min/day for 5 days at 20 cm distance from the antenna. MTT assay was used to determine the growth and metabolism of cells and trypan blue test was also done for **cell** viability. Statistical analyses were carried out using analysis of one way ANOVA. $P<0.05$ was considered to be statistically significant. RESULTS: The proliferation rates of human ADSCs in all exposure groups were significantly lower than control groups ($P<0.05$) except in the group of 6 minutes/day which did not show any significant difference with control groups. CONCLUSION: The

results show that 900 MHz RF signal radiation from antenna can reduce **cell** viability and proliferation rates of human ADSCs regarding the duration of exposure.

**Shahin S, Mishra V, Singh SP, Chaturvedi CM. 2.45-GHz microwave irradiation adversely affects reproductive function in male mouse, Mus musculus by inducing oxidative and nitrosative stress. Free Radic Res. 48(5):511-525, 2014.**

Electromagnetic radiations are reported to produce long-term and short-term biological effects, which are of great concern to human health due to increasing use of devices emitting EMR especially microwave (MW) radiation in our daily life. In view of the unavoidable use of MW emitting devices (microwaves oven, mobile phones, Wi-Fi, etc.) and their harmful effects on biological system, it was thought worthwhile to investigate the long-term effects of low-level MW irradiation on the reproductive function of male Swiss strain mice and its mechanism of action. Twelve-week-old mice were exposed to non-thermal low-level 2.45-GHz MW radiation (CW for 2 h/day for 30 days, power density = 0.029812 mW/cm(2) and SAR = 0.018 W/Kg). Sperm count and sperm viability test were done as well as vital organs were processed to study different stress parameters. Plasma was used for testosterone and testis for 3β HSD assay. Immunohistochemistry of 3β HSD and nitric oxide synthase (i-NOS) was also performed in testis. We observed that MW irradiation induced a significant decrease in sperm count and sperm viability along with the decrease in seminiferous tubule diameter and degeneration of seminiferous tubules. Reduction in testicular 3β HSD activity and plasma testosterone levels was also noted in the exposed group of mice. Increased expression of testicular i-NOS was observed in the MW-irradiated group of mice. Further, these adverse reproductive effects suggest that chronic exposure to nonionizing MW radiation may lead to infertility via free radical species-mediated pathway.

**Shahin S, Singh VP, Shukla RK, Dhawan A, Gangwar RK, Singh SP, Chaturvedi CM. 2.45 GHz microwave irradiation-induced oxidative stress affects implantation or pregnancy in mice, Mus musculus. Appl Biochem Biotechnol. 169(5):1727-1751, 2013.**

The present experiment was designed to study the 2.45 GHz low-level microwave (MW) irradiation-induced stress response and its effect on implantation or pregnancy in female mice. Twelve-week-old mice were exposed to MW radiation (continuous wave for 2 h/day for 45 days, frequency 2.45 GHz, power density=0.033549 mW/cm(2), and specific absorption rate=0.023023 W/kg). At the end of a total of 45 days of exposure, mice were sacrificed, implantation sites were monitored, blood was processed to study stress parameters (hemoglobin, RBC and WBC count, and neutrophil/lymphocyte (N/L) ratio), the brain was processed for comet assay, and plasma was used for nitric oxide (NO), progesterone and estradiol estimation. Reactive oxygen species (ROS) and the activities of ROS-scavenging enzymes- superoxide dismutase, catalase, and glutathione peroxidase-were determined in the liver, kidney and ovary. We observed that implantation sites were affected significantly in MW-irradiated mice as compared to control. Further, in addition to a significant increase in ROS, hemoglobin ($p<0.001$), RBC and WBC counts ($p<0.001$), N/L ratio ($p<0.01$), DNA damage ($p<0.001$) in brain cells, and plasma estradiol

concentration ($p<0.05$), a significant decrease was observed in NO level ($p<0.05$) and antioxidant enzyme activities of MW-exposed mice. Our findings led us to conclude that a low level of MW irradiation-induced oxidative stress not only suppresses implantation, but it may also lead to deformity of the embryo in case pregnancy continues. We also suggest that MW radiation-induced oxidative stress by increasing ROS production in the body may lead to DNA strand breakage in the brain cells and implantation failure/resorption or abnormal pregnancy in mice.

**Shallom JM, Di Carlo AL, Ko D, Penafiel LM, Nakai A, Litovitz TA. Microwave exposure induces Hsp70 and confers protection against hypoxia in chick embryos. J Cell Biochem 86(3):490-496, 2002.**

To determine if microwave exposure could elicit a biological effect in the absence of thermal stress, studies were designed in which chick embryos were exposed to athermal microwave radiation (915 MHz) to look for induction of Hsp70, a protein produced during times of cellular stress that aids in the protection of cellular components. Levels of Hsp70 were found to increase within 2 h, with maximum expression (approximately 30% higher than controls) typically occurring by 3 h from the start of exposure. Other embryos were exposed to microwave radiation prior to being subjected to hypoxic stress, and were found to have significantly higher survival ($P < 0.05$) following re-oxygenation than non-exposed controls. The results of these studies indicate that not only can athermal microwave exposures activate the stress protein response pathway; they can also enhance survivability following exposure to a subsequent, potentially lethal stress. From a public health standpoint, it is important that more studies be performed to determine if repeated exposures, a condition likely to be found in cell phone use, are still beneficial.

**Sharma A, Sisodia R, Bhatnagar D, Saxena VK. Spatial memory and learning performance and its relationship to protein synthesis of Swiss albino mice exposed to 10 GHz microwaves. Int J Radiat Biol. 2013 Aug 19. [Epub ahead of print]**

Purpose: To study the possible role of microwave (MW) exposure on spatial memory of Swiss albino mice and its relationship to protein concentration in whole brain. Materials and methods: Mice were exposed to 10 GHz (Giga Hertz) microwaves with the power density of 0.25 $mW/cm^2$ (milliwatt per centimeter square) with average whole body specific absorption rate (SAR) 0.1790 W/kg daily for 2 hours per day (h/day) for 30 days. After exposure mice were tested for spatial memory performance using Morris water maze test (MWT). For this purpose mice (6-8 weeks old) were divided into two groups (i) sham exposed and, (ii) microwaves exposed. After initial training for two days, MWT was performed for another 6 days. Protein was estimated 48 hours after exposure and immediately after completion of MWT. Results: Both sham exposed and microwave exposed animals showed a significant decrease in escape time with training. Microwave exposed animals had statistically significant higher mean latency to reach the target quadrant compared to sham exposed. A concurrent decrease in protein levels was estimated in whole brain of the exposed mice compared to sham exposed mice. Conclusions: It can be concluded from the current study that exposure to microwave radiation caused decrements in the ability

of mice to learn the special memory task, this may be due to simultaneous decrease in protein levels in the brain of mice.

**Sharma A, Kesari KK, Saxena VK, Sisodia R. Ten gigahertz microwave radiation impairs spatial memory, enzymes activity, and histopathology of developing mice brain. Mol Cell Biochem. 2017 May 3. doi: 10.1007/s11010-017-3051-8. [Epub ahead of print]**

For decades, there has been an increasing concern about the potential hazards of non-ionizing electromagnetic fields that are present in the environment and alarming as a major pollutant or electro-pollutant for health risk and neuronal diseases. Therefore, the objective of the present study was to explore the effects of 10 GHz microwave radiation on developing mice brain. Two weeks old mice were selected and divided into two groups (i) sham-exposed and (ii) microwave-exposed groups. Animals were exposed for 2 h/day for 15 consecutive days. After the completion of exposure, within an hour, half of the animals were autopsied immediately and others were allowed to attain 6 weeks of age for the follow-up study. Thereafter results were recorded in terms of various biochemical, behavioral, and histopathological parameters. Body weight result showed significant changes immediately after treatment, whereas non-significant changes were observed in mice attaining 6 weeks of age. Several other endpoints like brain weight, lipid peroxidation, glutathione, protein, catalase, and superoxide dismutase were also found significantly ($p < 0.05$) altered in mice whole brain. These significant differences were found immediately after exposure and also in follow-up on attaining 6 weeks of age in microwave exposure group. Moreover, statistically significant ($p < 0.001$) effect was investigated in spatial memory of the animals, in learning to locate the position of platform in Morris water maze test. Although in probe trial test, sham-exposed animals spent more time in searching for platform into the target quadrant than in opposite or other quadrants. Significant alteration in histopathological parameters (qualitative and quantitative) was also observed in CA1 region of the hippocampus, cerebral cortex, and ansiform lobule of cerebellum. Results from the present study concludes that the brain of 2 weeks aged mice was very sensitive to microwave exposure as observed immediately after exposure and during follow-up study at 6 weeks of age

**Sharma VP, Singh HP, Batish DR, Kohli RK. Cell phone radiations affect early growth of Vigna radiata (mung bean) through biochemical alterations. Z Naturforsch C. 65(1-2):66-72, 2010.**

The indiscriminate use of wireless technologies, particularly of cell phones, has increased the health risks among living organisms including plants. We investigated the impact of cell phone electromagentic field (EMF) radiations (power density, 8.55 microW cm(-2)) on germination, early growth, proteins and carbohydrate contents, and activities of some enzymes in Vigna radiata. Cell phone EMF radiations significantly reduced the seedling length and dry weight of V radiata after exposure for 0.5, 1, 2, and 4 h. Furthermore, the contents of proteins and carbohydrates were reduced in EMF-exposed plants. However, the activities of proteases, alpha-amylases, beta-amylases, polyphenol oxidases, and peroxidases were enhanced in

EMF-exposed radicles indicating their role in providing protection against EMF-induced stress. The study concludes that cell phone EMFs impair early growth of V radiata seedlings by inducing biochemical changes.

**Sharma VP, Singh HP, Kohli RK, Batish DR. Mobile phone radiation inhibits Vigna radiata (mung bean) root growth by inducing oxidative stress. Sci Total Environ. 407(21):5543-7, 2009.**

During the last couple of decades, there has been a tremendous increase in the use of cell phones. It has significantly added to the rapidly increasing EMF smog, an unprecedented type of pollution consisting of radiation in the environment, thereby prompting the scientists to study the effects on humans. However, not many studies have been conducted to explore the effects of cell **phone** EMFr on growth and biochemical changes in plants. We investigated whether EMFr from cell phones inhibit growth of Vigna radiata (mung bean) through induction of conventional stress responses. Effects of cell **phone** EMFr (power density: 8.55 microW cm(-2); 900 MHz band width; for 1/2, 1, 2, and 4 h) were determined by measuring the generation of reactive oxygen species (ROS) in terms of malondialdehyde and hydrogen peroxide (H(2)O(2)) content, root oxidizability and changes in levels of antioxidant enzymes. Our results showed that cell **phone** EMFr significantly inhibited the germination (at > or =2 h), and radicle and plumule growths (> or =1 h) in mung bean in a time-dependent manner. Further, cell **phone** EMFr enhanced MDA content (indicating lipid peroxidation), and increased H(2)O(2) accumulation and root oxidizability in mung bean roots, thereby inducing oxidative stress and **cellular** damage. In response to EMFr, there was a significant upregulation in the activities of scavenging enzymes, such as superoxide dismutases, ascorbate peroxidases, guaiacol peroxidases, catalases and glutathione reductases, in mung bean roots. The study concluded that cell **phone** EMFr inhibit root growth of mung bean by inducing ROS-generated oxidative stress despite increased activities of antioxidant enzymes.

**Shcheglov VS, Alipov ED, Belyaev IY. Cell-to-cell communication in response of E. coli cells at different phases of growth to low-intensity microwaves. Biochim Biophys Acta 1572(1):101-106, 2002.**

Effects of millimeter waves (MMW) at the frequency of 51.755 GHz were studied in logarithmic and stationary E. coli cells at various cell densities. The changes in the genome conformational state (GCS) were analyzed by the method of anomalous viscosity time dependence (AVTD). Before lysis, the cells were adjusted to the cell density of 4x10(7) cells/ml and all AVTD measurements were run at this cell density. Stationary cells responded to MMW by increase in AVTD, while the same MMW exposure decreased AVTD in logarithmic cells. MMW effects depended on cell density during exposure and were stronger for stationary cells. The observed dependence on cell density suggested a cell-to-cell communication between cells during exposure to microwaves. Decrease in power density (PD) resulted in more striking differences between responses at different cell densities. The data provided evidence that intercellular communication in response to MMW depended on cell status and PD of microwaves. The MMW effects were studied in more detail at low intensity of 10(-17) W/cm(2) in the range of cell densities 4x10(7) to 8x10(8) cells/ml. The obtained sigmoid-

like dependence of MMW effect on cell density saturated at approximately 5x10(8) cells/ml. The dependence of MMW effect on cell density was very similar in this study and in previous studies with weak extremely low frequency (ELF) electromagnetic fields (EMF). The data suggested that cell-to-cell communication might be involved in response of cells to weak EMF of various frequency ranges.

**Shckorbatov YG, Grigoryeva NN, Shakhbazov VG, Grabina VA, Bogoslavsky AM, Microwave irradiation influences on the state of human cell nuclei. Bioelectromagnetics 19(7):414-419, 1998.**

Changes of electrokinetic properties of cell nuclei and the quantity of granules of heterochromatin located near the nuclear envelope in nuclei of human buccal epithelium cells were studied under the influence of electromagnetic fields in vitro. Irradiation of cells was realized by means of a semiconductor generator of millimeter radiation (wavelength 7.1 mm, frequency 42.2 GHz), the Yav-1 apparatus for extremely high frequency therapy. It was shown that irradiation of cells induced a decrease in electric charge of native human buccal epithelium cell nuclei and an increase in chromatin condensation in nuclei. The observed effects depend on irradiation dose and individual peculiarities of donors.

**Shckorbatov YG, Shakhbazov VG, Navrotskaya VV, Grabina VA, Sirenko SP, Fisun AI, Gorobets NN, Kiyko VI. Application of intracellular microelectrophoresis to analysis of the influence of the low-level microwave radiation on electrokinetic properties of nuclei in human epithelial cells. Electrophoresis 23(13):2074-2079, 2002.**

Intracellular microelectrophoresis was applied to investigate the electrokinetic properties of human buccal epithelium cell nuclei after exposure of cells to microwaves of wavelengths of 8 mm (f = 37.5 GHz) and 16 mm (f = 18.75 GHz) at a surface power density of 0.2 mW/cm(2). Irradiated or nonirradiated cells were suspended in a flat microelectrophoretic chamber and exposed to an electric field of 15 V/cm at a current flow of 0.1 mA. The cells, whose nuclei altered their intracellular location towards the anode of the externally applied electric field, were considered to have negatively charged nuclei. The percentage of cells with electrophoretically movable nuclei was determined as the value of electronegativity of cell nuclei (ENN). Microwaves induced changes of ENN during irradiation of 15-60 s. If cells of a donor had an elevated initial level of ENN, it decreased during irradiation. On the contrary, if cells of another donor had a low initial ENN level, irradiation induced ENN increase. No significant difference between the action of microwaves of wavelengths of 8 mm and 16 mm was found. However, microwave irradiation caused an increase in membrane permeability for the in vivo dye indigo Carmine in cells of all donors irrespectively of the initial levels they showed. This suggests that electrokinetic properties of nuclei in cells do not only depend on cell membrane permeability.

**Shehu A, Mohammed A, Magaji RA, Muhammad MS. Exposure to mobile phone electromagnetic field radiation, ringtone and vibration affects anxiety-like behaviour and oxidative stress biomarkers in albino wistar rats. Metab Brain Dis. 2015 Nov 7. [Epub ahead of print]**

Research on the effects of Mobile phone radio frequency emissions on biological systems has been focused on noise and vibrations as auditory stressors. This study investigated the potential effects of exposure to mobile phone electromagnetic field radiation, ringtone and vibration on anxiety-like behaviour and oxidative stress biomarkers in albino wistar rats. Twenty five male wistar rats were randomly divided into five groups of 5 animals each: group I: exposed to mobile phone in switched off mode (control), group II: exposed to mobile phone in silent mode, group III: exposed to mobile phone in vibration mode, group IV: exposed to mobile phone in ringtone mode, group V: exposed to mobile phone in vibration and ringtone mode. The animals in group II to V were exposed to 10 min call (30 missed calls for 20 s each) per day for 4 weeks. Neurobehavioural studies for assessing anxiety were carried out 24 h after the last exposure and the animals were sacrificed. Brain samples were collected for biochemical evaluation immediately. Results obtained showed a significant decrease ($P < 0.05$) in open arm duration in all the experimental groups when compared to the control. A significant decrease ($P < 0.05$) was also observed in catalase activity in group IV and V when compared to the control. In conclusion, the results of the present study indicates that 4 weeks exposure to electromagnetic radiation, vibration, ringtone or both produced a significant effect on anxiety-like behavior and oxidative stress in young wistar rats.

**Shekoohi Shooli F, Mortazavi SA, Jarideh S, Nematollahii S, Yousefi F, Haghani M, Mortazavi SM, Shojaei-Fard MB. Short-Term Exposure to Electromagnetic Fields Generated by Mobile Phone Jammers Decreases the Fasting Blood Sugar in Adult Male Rats. J Biomed Phys Eng. 6(1):27-32, 2016.**

**BACKGROUND:** Substantial evidence indicates that exposure to electromagnetic fields (EMF) above certain levels can affect human health through triggering some biological responses. According to WHO, short-term exposure to EMF at the levels present in the home/environment do not cause any apparent detrimental effects in healthy individuals. However, now, there is a debate on whether long-term exposure to low level EMF can evoke detrimental biological responses. Although based on the Communications Act of 1934, selling, advertising, using, or importing mobile jammers which block cell phone calls and text messages are illegal acts, in some countries these devices are being used for security purpose and for prevention of cheating during examinations. **METHODS:** In this study 30 male Wistar rats were randomly divided into 3 groups of 10 each. The control group received no radiation. The sham exposure group was exposed to a switched-off jammer device. After fasting for 12 hours, the exposure group was exposed to EMFs at a distance of 50 cm from the jammer. Blood samples were collected from the tail vein after 24, 48 and72 hours and fasting blood sugar was measured by using a common blood glucose monitor (BIONIME GM110, Taiwan). The significance level was considered 5% and SPSS Ver. 21 was used for statistical analysis. The data were analyzed by ANOVA followed by Tukey's test. **RESULTS:** A statistically significant difference was observed between blood sugar level in the control and exposure groups after 24, 48 and 72 hours of continuous irradiation (p values were <0.001, <0.001 and 0.002, respectively). No significant difference was found between the level of fasting blood sugar in control and sham groups. **CONCLUSION:** Short-term exposure to electromagnetic field

generated by mobile phone jammer can reduce blood sugar level in adult male rats. These findings, in contrast with our previous results, lead us to this conclusion that the use of these signal blocking devices in very specific circumstances may have some therapeutic effects. However, further studies have to be performed to find out the exact mechanism by which Jammer EMFs reduce fasting blood sugar.

**Shen YH, Yu D, Fu YT, Chiang H. [Effects of mobile-phone microwave on dimethylbenz (a) anthracene induced mammary carcinoma development in rats.] Zhonghua Yu Fang Yi Xue Za Zhi. 40(3):164-167, 2006.** [Article in Chinese]

OBJECTIVE: To investigate whether exposure to 900 MHz GSM wireless communication signals enhances mammary tumor development and growth induced by low dose dimethylbenz (a) anthracene (DMBA). METHODS: Five hundred female Sprague Dawley (SD) rats were treated with a single dose of 35 mg/kg. DMBA and then divided into 5 groups: one control group without exposure, and 4 groups with exposure in blinded fashion. The specific absorption rates (SAR) were 0, 0.44, 1.33 and 4.00 W/kg for the 4 exposure groups, respectively. Exposure started on the next day after DMBA administration and lasted 4 hours/day, 5 days/week for 26 weeks. Rats were weighted and palpated weekly for the presence of tumors, and killed at the end of 26-week exposure period. All mammary glands were examined histopathologically. RESULTS: The incidence of mammary carcinoma in sham-exposure group was 37% (37/100). And mammary carcinoma incidences in the other groups of the exposure dose (0.44, 1.33 and 4.00 W/kg) were 25% (25/100), 34% (34/99) and 38% (38/100) respectively. There were no statistically significant differences between sham- and mobile phone microwave-exposed groups. In addition, the histopathological morphology of mammary tumor model in SD rats was observed. By microscopical examination two types of mammary tumor in this model were found, that was malignant or benign one. The former included adenocarcinoma and squamous cell carcinoma, and the latter included adenoma, fibroadenoma and cyst. Sometimes the histopathological morphology of mammary tumor appeared various since several kinds of histopathological features existed in the same individual. CONCLUSION: This study does not provide the evidence that 900 MHz GSM microwave exposure might promote DMBA-induced mammary tumor development in rats.

**Sherry CJ, Blick DW, Walters TJ, Brown GC, Murphy MR, Lack of behavioral effects in non-human primates after exposure to ultrawideband electromagnetic radiation in the microwave frequency range. Radiat Res 143(1):93-97, 1995.**

The effect of acute exposure to ultrawideband (UWB) electromagnetic radiation on the Primate Equilibrium Platform (PEP) task, where the monkey's task is to manipulate a joystick control to compensate for the random perturbations in the pitch plane that are generated by a computer at unpredictable intervals, was examined. The duration of the UWB exposure was 2 min at a pulse repetition rate of 60 Hz (total of 7200 pulses). The bandwidth of the pulse was 100 MHz to 1.5 GHz (peak power between 250-500 MHz) with a peak E-field strength of 250 kV/m. Each monkey was exposed twice. The interval between exposures was 6 days. The exposure to UWB electromagnetic radiation had no effect on PEP performance when tested immediately after exposure.

**Shinar D, Tractinsky N, Compton R. Effects of practice, age, and task demands, on interference from a phone task while driving. Accid Anal Prev. 37(2):315-326, 2005.**

Experimental research on the effects of cellular phone conversations on driving indicates that the phone task interferes with many driving-related functions, especially with older drivers. Unfortunately in past research (1) the dual task conditions were not repeated in order to test for learning, (2) the 'phone tasks' were not representative of real conversations, and (3) most often both the driving and the phone tasks were experimenter-paced. In real driving drivers learn to time-share various tasks, they can pace their driving to accommodate the demands of a phone conversation, and they can even partially pace the phone conversation to accommodate the driving demands. The present study was designed to better simulate real driving conditions by providing a simulated driving environment with repeated experiences of driving while carrying two different hands-free 'phone' tasks with different proximities to real conversations. In the course of five sessions of driving and using the phone, there was a learning effect on most of the driving measures. In addition, the interference from the phone task on many of the driving tasks diminished over time as expected. Finally, the interference effects were greater when the phone task was the often-used artificial math operations task than when it was an emotionally involving conversation, when the driving demands were greater, and when the drivers were older. Thus, the deleterious effects of conversing on the phone are very real initially, but may not be as severe with continued practice at the dual task, especially for drivers who are not old.

**Shirai T, Kawabe M, Ichihara T, Fujiwara O, Taki M, Watanabe SI, Wake K, Yamanaka Y, Imaida K, Asamoto M, Tamano S. Chronic exposure to a 1.439 GHz electromagnetic field used for cellular phones does not promote N-ethylnitrosourea induced central nervous system tumors in F344 rats. Bioelectromagnetics 26:59-68, 2005.**

The present study was designed to evaluate whether a 2 year exposure to an electromagnetic field (EMF) equivalent to that generated by cellular phones can accelerate tumor development in the central nervous system (CNS) of rats. Brain tumorigenesis was initiated by an intrauterine exposure to N-ethylnitrosourea (ENU) on gestational day 18. A total of 500 pups were divided into five groups, each composed of 50 males and 50 females: Group 1, untreated control; Group 2, ENU alone; Groups 3-5, ENU + EMF (sham exposure and 2 exposure levels). A 1.439 GHz time division multiple access (TDMA) signal for the Personal Digital Cellular (PDC), Japanese standard cellular system was used for the exposure of the rat head starting from 5 weeks of age, 90 min a day, 5 days a week, for 104 weeks. Brain average specific absorption rate (SAR) was 0.67 and 2.0 W/kg for low and high exposures, respectively: whole body average SAR was less than 0.4 W/kg. There were no inter-group differences in body weights, food consumption, and survival rates. No increase in the incidences or numbers per group of brain and/or spinal cord tumors, either in the males or females, was detected in the EMF exposed groups. In addition, no clear changes in tumor types were evident. Thus, under the present experimental conditions, 1.439 GHz EMF exposure to the heads of rats for a 2 year period was not demonstrated to accelerate or affect ENU initiated brain tumorigenesis.

**Shirai T, Ichihara T, Wake K, Watanabe SI, Yamanaka Y, Kawabe M, Taki M, Fujiwara O, Wang J, Takahashi S, Tamano S. Lack of promoting effects of chronic exposure to 1.95-GHz W-CDMA signals for IMT-2000 cellular system on development of N-ethylnitrosourea-induced central nervous system tumors in F344 rats. Bioelectromagnetics.28(7):562-572, 2007.**

The present study was performed to evaluate effects of a 2-year exposure to an electromagnetic near-field (EMF) equivalent to that generated by cellular phones on tumor development in the central nervous system (CNS) of rats. For this purpose, pregnant F344 rats were given a single administration of N-ethylnitrosourea (ENU) on gestational day 18. A total of 500 pups were divided into five groups, each composed of 50 males and 50 females: Group 1, untreated controls; Group 2, ENU alone; Groups 3 to 5, ENU + EMF (sham exposure and two exposure levels). A 1.95-GHz wide-band code division multiple access (W-CDMA) signal, which is a feature of the International Mobile Telecommunication 2000 (IMT-2000) cellular system was employed for exposure of the rat head starting from 5 weeks of age, 90 min a day, 5 days a week, for 104 weeks. Brain average specific absorption rates (SARs) were designed to be .67 and 2.0 W/kg for low and high exposures, respectively. The incidence and numbers of brain tumors in female rats exposed to 1.95-GHz W-CDMA signals showed tendencies to increase but without statistical significance. Overall, no significant increase in incidences or numbers, either in the males or females, was detected in the EMF-exposed groups. In addition, no clear changes in tumor types in the brain were evident. Thus, under the present experimental conditions, exposure of heads of rats to 1.95-GHz W-CDMA signals for IMT-2000 for a 2-year period was not demonstrated to accelerate or otherwise affect ENU-initiated brain tumorigenesis.

**Shirai T, Imai N, Wang J, Takahashi S, Kawabe M, Wake K, Kawai H, Watanabe S-I, Furukawa F, Fujiwara O. Multigenerational effects of whole body exposure to 2.14 GHz W-CDMA cellular phone signals on brain function in rats. Bioelectromagnetics 35(7):497-511, 2014.**

The present experimental study was carried out with rats to evaluate the effects of whole body exposure to 2.14 GHz band code division multiple access (W-CDMA) signals for 20 h a day, over three generations. The average specific absorption rate (SAR, in unit of W/kg) for dams was designed at three levels: high (<0.24 W/kg), low (<0.08 W/kg), and 0 (sham exposure). Pregnant mothers (4 rats/group) were exposed from gestational day (GD) 7 to weaning and then their offspring ($F_1$ generation, 4 males and 4 females/dam, respectively) were continuously exposed until 6 weeks of age. The $F_1$ females were mated with $F_1$ males at 11 weeks old, and then starting from GD 7, they were exposed continuously to the electromagnetic field (EMF; one half of the F1 offspring was used for mating, that is, two of each sex per dam and 8 males and 8 females/group, except for all offspring for the functional development tests). This protocol was repeated in the same manner on pregnant $F_2$ females and $F_3$ pups; the latter were killed at 10 weeks of age. No abnormalities were observed in the mother rats ($F_0$, $F_1$, and $F_2$) and in the offspring ($F_1$, $F_2$, and $F_3$) in any biological parameters, including neurobehavioral function. Thus, it was concluded that under the experimental conditions applied, multigenerational whole body exposure to

2.14 GHz W-CDMA signals for 20 h/day did not cause any adverse effects on the $F_1$, $F_2$, and $F_3$ offspring.

**Shirai T, Wang J, Kawabe M, Wake K, Watanabe SI, Takahashi S, Fujiwara O. No adverse effects detected for simultaneous whole-body exposure to multiple-frequency radiofrequency electromagnetic fields for rats in the intrauterine and pre- and post-weaning periods. J Radiat Res. 58(1):48-58, 2017.**

In everyday life, people are exposed to radiofrequency (RF) electromagnetic fields (EMFs) with multiple frequencies. To evaluate the possible adverse effects of multifrequency RF EMFs, we performed an experiment in which pregnant rats and their delivered offspring were simultaneously exposed to eight different communication signal EMFs (two of 800 MHz band, two of 2 GHz band, one of 2.4 GHz band, two of 2.5 GHz band and one of 5.2 GHz band). Thirty six pregnant Sprague-Dawley (SD) 10-week-old rats were divided into three groups of 12 rats: one control (sham exposure) group and two experimental (low- and high-level RF EMF exposure) groups. The whole body of the mother rats was exposed to the RF EMFs for 20 h per day from Gestational Day 7 to weaning, and $F_1$ offspring rats (46-48 F1 pups per group) were then exposed up to 6 weeks of age also for 20 h per day. The parameters evaluated included the growth, gestational condition and organ weights of the dams; the survival rates, development, growth, physical and functional development, memory function, and reproductive ability of the $F_1$ offspring; and the embryotoxicity and teratogenicity in the $F_2$ rats. No abnormal findings were observed in the dams or $F_1$ offspring exposed to the RF EMFs or to the $F_2$ offspring for any of the parameters evaluated. Thus, under the conditions of the present experiment, simultaneous whole-body exposure to eight different communication signal EMFs at frequencies between 800 MHz and 5.2 GHz did not show any adverse effects on pregnancy or on the development of rats.

**Shivashankara AR, Joy J, Sunitha V, Rai MP, Rao S, Nambranathayil S, Baliga MS. Effect of cell phone use on salivary total protein, enzymes and oxidative stress markers in young adults: a pilot study. J Clin Diagn Res. 9(2):BC19-22, 2015.**

INTRODUCTION: The present study aimed to assess the levels of salivary enzymes, protein and oxidant-antioxidant system in young college-going cell phone users. MATERIALS AND METHODS: The cell users (students) were categorized in to two groups - less mobile users and high mobile users, based on the duration and frequency of cell use. Unstimulated whole saliva samples of the volunteers were analysed for amylase, lactate dehydrogenase (LDH), malondialdehdye (MDA) and glutathione (GSH). RESULTS: High mobile users had significantly higher levels of amylase ($p = 0.001$), LDH ($p = 0.002$) and MDA ($p = 0.002$) in saliva, when compared to less mobile users. The marginal decrease in salivary total proteins, GSH and flow rate were statistically not significant ($p > 0.05$). CONCLUSION: Significant changes in salivary enzymes and MDA suggest adverse effect of high use of cell phones on cell health.

**Shokri S, Soltani A, Kazemi M, Sardari D, Mofrad FB. Effects of Wi-Fi (2.45 GHz) Exposure on Apoptosis, Sperm Parameters and Testicular Histomorphometry in**

**Rats: A Time Course Study. Cell J. 17(2):322-331, 2015.**

OBJECTIVE: In today's world, 2.45-GHz radio-frequency radiation (RFR) from industrial, scientific, medical, military and domestic applications is the main part of indoor-outdoor electromagnetic field exposure. Long-term effects of 2.45-GHz Wi-Fi radiation on male reproductive system was not known completely. Therefore, this study aimed to investigate the major cause of male infertility during short- and long-term exposure of Wi-Fi radiation. MATERIALS AND METHODS: This is an animal experimental study, which was conducted in the Department of Anatomical Sciences, Faculty of Medicine, Zanjan University of Medical Sciences, Zanjan, IRAN, from June to August 2014. Three-month-old male Wistar rats (n=27) were exposed to the 2.45 GHz radiation in a chamber with two Wi-Fi antennas on opposite walls. Animals were divided into the three following groups: I. control group (n=9) including healthy animals without any exposure to the antenna, II. 1-hour group (n=9) exposed to the 2.45 GHz Wi-Fi radiation for 1 hour per day during two months and III.7-hour group (n=9) exposed to the 2.45 GHz Wi-Fi radiation for 7 hours per day during 2 months. Sperm parameters, caspase-3 concentrations, histomorphometric changes of testis in addition to the apoptotic indexes were evaluated in the exposed and control animals. RESULTS: Both 1-hour and 7-hour groups showed a decrease in sperm parameters in a time dependent pattern. In parallel, the number of apoptosis-positive cells and caspase-3 activity increased in the seminiferous tubules of exposed rats. The seminal vesicle weight reduced significantly in both1-hour or 7-hour groups in comparison to the control group. CONCLUSION: Regarding the progressive privilege of 2.45 GHz wireless networks in our environment, we concluded that there should be a major concern regarding the time-dependent exposure of whole-body to the higher frequencies of Wi-Fi networks existing in the vicinity of our living places.

**Shrestha M, Raitanen J, Salminen T, Lahkola A, Auvinen A. Pituitary tumor risk in relation to** mobile phone **use: A case-control study. Acta Oncol. 2015 May 18:1-7. [Epub ahead of print]**

BACKGROUND: The number of **mobile phone** users has grown rapidly, which has generated mounting public concern regarding possible health hazards. This study aims to assess pituitary tumor risk, as it has rarely been investigated. MATERIAL AND METHODS: A case-control study was conducted with 80 eligible cases identified from all five university hospitals in Finland and frequency-matched 240 controls from the national population register. Controls were matched to cases by age, sex, region of residence and date of interview. A detailed history of **mobile phone** use was obtained using a structured interview. Several indicators of **mobile phone** use were assessed using conditional logistic regression. RESULTS: A reduced odds ratio was seen among regular **mobile phone** users [OR 0.39, 95% confidence interval (CI) 0.21, 0.72] relative to never/non-regular users, possibly reflecting methodological limitations. Pituitary tumor risk was not increased after 10 or more years since first use (OR 0.69, 95% CI 0.25, 1.89). The risk was not increased in relation to duration, cumulative hours of use, or cumulative number of calls. The results were similar for analog and digital **phones**. CONCLUSIONS: We found no excess risk associated with self-reported short- or medium-term use of **mobile phones**. This is consistent with most of the published studies. However, uncertainties

remained for longer duration of use, as a very small proportion of study participants reported use beyond 10 years.

**Shtemberg AS, Uzbekov MG, Shikhov SN, Bazian AS, Cherniakov GM, [Species specificity, age factors, and various neurochemical correlates of the animal spontaneous behavior after exposure to electromagnetic field of the ultralow intensity]. Zh Vyssh Nerv Deiat Im I P Pavlova 50(4):703-715, 2000.** [Article in Russian]

Behavioral and neurochemical reactions of small laboratory animals (mice and rats of different age) under exposure to ultralow-intensity electromagnetic fields (EMF, frequency of 4200 and 970 MHz, modulated by a quasistochastic signal in the range of 20-20,000 Hz, power density 15 microW/cm2, specific body absorption rate up to 4.5 mJ/kg) were studied. The EMF basically inhibited the locomotor and exploratory activity in the "open-field" test. The species- and age-specific features rather than radiation conditions dominated. However, decrease in the EMF frequency considerably intensified the observed effect. Change in animal behavior was accompanied by shifts in neurochemical processes, i.e., sharp activation of serotoninergic and inhibition of morepinephrinergic system.

**Sidorenko AV, The analysis of animal bioelectric brain activity influenced by microwaves or by the introduction of strychnine. Bioelectrochem Bioenerg 48(1):223-226, 1999.**

The widespread impact made by technology has raised concerns about the safety of human exposure to electromagnetic radiation in the environment. The brain is especially sensitive to the influence of microwaves. The most effective method for estimation of the organism's functional states is an analysis of electroencephalograms. The statistical and spectral methods are usually used for analysis of animal electrocorticograms. The information obtained in such way is the integrated character and it is sometimes insufficient for identification of the brain state charging caused by various factors, especially microwaves altering the ecological situation. The nonlinear dynamics method is used in our work concurrent with the spectral correlation method for animal electrocorticogram processing. The correlation dimensionality represents a numerical criterion allowing for comparative investigation of various dynamic states of the system. In the process of investigation, it has been found that the nonlinear dynamics method may be used to analyze the electrocorticograms of experimental animal in different functional states being confirmed by increasing parameter of the correlation dimensionality in electrocorticograms of animal irradiated by microwaves or subjected to the introduction of strychnine.

**Sidorenko A, Tsaryuk V, Effects of microwave radiation and strychnine on cerebral biopotentials in narcotized rats. Bull Exp Biol Med 130(9):835-837, 2000.**

Strychnine and microwave radiation produced changes in spectral parameters of electrocorticogram, correlation dimension, and Kolmogorov entropy, parameters calculated by the methods of nonlinear dynamics opposite to those induced by urethane. The modulatory effect of microwaves on bioelectric cerebral activity in narcotized animals

was similar to the effect of strychnine and probably related to enhanced excitability of brain structures and complication of bioelectric processes.

**Sienkiewicz ZJ, Blackwell RP, Haylock RG, Saunders RD, Cobb BL, Low-level exposure to pulsed 900 MHz microwave radiation does not cause deficits in the performance of a spatial learning task in mice. Bioelectromagnetics 21(3):151-158, 2000.**

There is some concern that short-term memory loss or other cognitive effects may be associated with the use of mobile cellular telephones. In this experiment, the effect of repeated, acute exposure to a low intensity 900 MHz radiofrequency (RF) field pulsed at 217 Hz was explored using an appetitively-motivated spatial learning and working memory task. Adult male C57BL/6J mice were exposed under far field conditions in a GTEM cell for 45 min each day for 10 days at an average whole-body specific energy absorption rate (SAR) of 0.05 W/kg. Their performance in an 8-arm radial maze was compared to that of sham-exposed control animals. All behavioral assessments were performed without handlers having knowledge of the exposure status of the animals. Animals were tested in the maze immediately following exposure or after a delay of 15 or 30 min. No significant field-dependent effects on performance were observed in choice accuracy or in total times to complete the task across the experiment. These results suggest that exposure to RF radiation simulating a digital wireless telephone (GSM) signal under the conditions of this experiment does not affect the acquisition of the learned response. Further studies are planned to explore the effects of other SARs on learned behavior.

**Sieroń-Stołtny K, Teister Ł, Cieślar G, Sieroń D, Śliwinski Z, Kucharzewski M, Sieroń A. The influence of electromagnetic radiation generated by a mobile phone on the skeletal system of rats. Biomed Res Int. 2015;2015:896019. doi: 10.1155/2015/896019. Epub 2015 Feb 1.**

The study was focused on the influence of electromagnetic field generated by mobile phone on the skeletal system of rats, assessed by measuring the macrometric parameters of bones, mechanical properties of long bones, calcium and phosphorus content in bones, and the concentration of osteogenesis (osteocalcin) and bone resorption (NTX, pyridinoline) markers in blood serum. The study was carried out on male rats divided into two groups: experimental group subjected to 28-day cycle of exposures in electromagnetic field of 900 MHz frequency generated by mobile phone and a control, sham-exposed one. The mobile phone-generated electromagnetic field did not influence the macrometric parameters of long bones and L4 vertebra, it altered mechanical properties of bones (stress and energy at maximum bending force, stress at fracture), it decreased the content of calcium in long bones and L4 vertebra, and it altered the concentration of osteogenesis and bone resorption markers in rats. On the basis of obtained results, it was concluded that electromagnetic field generated by 900 MHz mobile phone does not have a direct impact on macrometric parameters of bones; however, it alters the processes of bone mineralization and the intensity of bone turnover processes and thus influences the mechanical strength of bones.

**Sievert U, Eggert S, Pau HW. Can mobile phone emissions affect auditory functions of cochlea or brain stem? Otolaryngol Head Neck Surg. 132(3):451-455, 2005.**

Problems addressed Despite their abundant spread, mobile phones are suspected by a major share of the population to cause adverse effects on health and welfare. The ear as the sense organ next to the individual device has rarely been investigated for short-term effects in this regard. In a previous article, we could not prove any impact on the vestibular part of the inner ear. Our present examinations are concerned with the question whether mobile phone emissions could affect cochlear or auditory brain stem functions. Methods and measures In 12 healthy test persons with normal hearing, auditory brain stem reflexes recordings were performed before, during, and after exposure to electromagnetic emissions by standardized mobile phone devices. Two modes of electromagnetic emissions fields were administered: pulsed and continuous. For acoustic stimulation simultaneous to field exposure, special "plug-in" earphones had to be used. Results No impact on auditory brain stem reflexes recordings in terms of absolute and interpeak latencies could be found. Clinical significance Together with the results of a previous article concerned with the vestibular part of the inner ear, we can state that there are no adverse effects of mobile phone emissions on the ear function, at least on a short-term range. Of course, any long-term effects cannot be excluded by our study.

**Silva V, Hilly O, Strenov Y, Tzabari C, Hauptman Y, Feinmesser R. Effect of cell phone-like electromagnetic radiation on primary human thyroid cells. Int J Radiat Biol. 2015 Dec 21:1-9. [Epub ahead of print]**

Purpose To evaluate the potential carcinogenic effects of radiofrequency energy (RFE) emitted by cell phones on human thyroid primary cells. Materials and methods Primary thyroid cell culture was prepared from normal thyroid tissue obtained from patients who underwent surgery at our department. Subconfluent thyroid cells were irradiated under different conditions inside a cell incubator using a device that simulates cell phone-RFE. Proliferation of control and irradiated cells was assessed by the immunohistochemical staining of antigen Kiel clone-67 (Ki-67) and tumor suppressor p53 (p53) expression. DNA ploidy and the stress biomarkers heat shock protein 70 (HSP70) and reactive oxygen species (ROS) was evaluated by fluorescence-activated cell sorting (FACS). Results Our cells highly expressed thyroglobulin (Tg) and sodium-iodide symporter (NIS) confirming the origin of the tissue. None of the irradiation conditions evaluated here had an effect neither on the proliferation marker Ki-67 nor on p53 expression. DNA ploidy was also not affected by RFE, as well as the expression of the biomarkers HSP70 and ROS. Conclusion Our conditions of RFE exposure seem to have no potential carcinogenic effect on human thyroid cells. Moreover, common biomarkers usually associated to environmental stress also remained unchanged. We failed to find an association between cell phone-RFE and thyroid cancer. Additional studies are recommended.

**Silvi A M, Zari A, Licitra G. Assessment of the temporal trend of the exposure of people to electromagnetic fields produced by base stations for mobile telephones. Radiat Prot Dosimetry 97(4):387-390, 2001.**

Monitoring of electric field levels produced by base stations (BSs) for mobile telephones

of different typologies (TACS. GSM, DCS) has been carried out. Results show that BSs can be classified as 'business' or 'residential'. The mean value of six minutes averaged E-field value measured between 10 a.m. and 1 p.m. corresponds to the 84% of the maximum daily six minutes averaged value. Comparison between electromagnetic field levels produced by BSs and their phone traffic data, supplied by companies, is shown. Finally, on an hourly average basis, a daily curve has been constructed of the exposure trend produced by such installations.

**Silva V, Hilly O, Strenov Y, Tzabari C, Hauptman Y, Feinmesser R. Effect of cell phone-like electromagnetic radiation on primary human thyroid cells. Int J Radiat Biol. 2015 Dec 21:1-9. [Epub ahead of print]**

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**Simko M, Hartwig C, Lantow M, Lupke M, Mattsson MO, Rahman Q, Rollwitz J. Hsp70 expression and free radical release after exposure to non-thermal radio-frequency electromagnetic fields and ultrafine particles in human Mono Mac 6 cells. Toxicol Lett. 161(1):73-82, 2006.**

The contemporary urban environment has become increasingly complex in its composition, leading to discussions regarding possible novel health effects. Two factors that recently have received considerable attention are ultrafine particles (UFP; <0.1mum) produced by combustion processes and emissions from wireless communication devices like mobile phones that emit in the radio-frequency (RF) part of the spectrum. Several studies have shown biological effects of both these exposures in various cell systems. Here we investigate if exposure to UFP (12-14nm, 100mug/ml) and RF-electromagnetic fields (EMF; 2W/kg specific absorption rate (SAR); continuous wave (CW) or modulated (217Hz or GSM-nonDTX)), alone or in combination influences levels of the superoxide radical anion or the stress protein heat-shock protein (Hsp70) in the human monocyte cell line Mono Mac 6. Heat treatment (42-43 degrees C, 1h) was used as positive control for both stress reaction and for heat development in the RF exposure setup. Our results

clearly show that Mono Mac 6 cells are capable to internalise UFP, and that this phagocytic activity is connected to an increased release of free radicals. This increase (40-45% above negative control) is stronger than the effect of heat treatment. On the other hand, none of the employed RF exposures showed any effects on free radical levels. Co-exposure of RF and UFP did not potentiate the UFP effect either. Our investigations showed a significantly increased Hsp70 expression level by heat treatment in a time-dependent manner, whereas UFP, RF, or UFP+RF were without any effect. Therefore, we conclude that in the investigated Mono Mac 6 cells, RF exposure alone or in combination with UFP cannot influence stress-related responses.

**Simon D, Daubos A, Pain C, Fitoussi R, Vié K, Taieb A, de Benetti L, Cario-André M.Exposure to acute electromagnetic radiation of mobile phone exposure range alters transiently skin homeostasis of a model of pigmented reconstructed epidermis.Int J Cosmet Sci. 35(1):27-34, 2013.**

Exposure to electromagnetic radiations (EMR) produced by mobile phone concerns half the world's population and raises the problem of their impact on human health. In this study, we looked at the effects of mobile phone exposure (GSM basic, 900MHz, SAR 2 mW g(-1) , 6 h) on a model of pigmented skin. We have analysed the expression and localization of various markers of keratinocyte and melanocyte differentiation 2, 6, 18 and 24 h after EMR exposure of reconstructed epidermis containing either only keratinocytes or a combination of keratinocytes and melanocytes grown on dead de-epidermized dermis, using histology, immunohistochemistry and Western blot. No changes were found in epidermal architecture, localization of epidermal markers, presence of apoptotic cells and the induction of p53 in both types of epidermis (with or without melanocytes) after exposure to EMR. In pigmented reconstructs, no change in the location and dendricity of melanocytes and in melanin transfer to neighbouring keratinocytes was detected after EMR exposure. Loricrin, cytokeratin 14 were significantly decreased at 6 h. The level of all markers increased at 24 h as compared to 6 h post-EMR exposure, associated with a significant decrease of the 20S proteasome activity. Our data indicate that exposure to 900MHz frequency induces a transient alteration of epidermal homoeostasis, which may alter the protective capacity of the skin against external factors. Presence or absence of melanocytes did not modify the behaviour of reconstructs after EMR exposure.

**Simsek V, Sahin H, Akay AF, Kaya H, Bircan MK. The effects of cellular telephone use on serum PSA levels in men. Int Urol Nephrol. 35(2):193-196, 2003.**

BACKGROUND: The increasing use of cellular telephones is known to have harmful effects on human health. The aim of this prospective study was to determine whether cellular telephone use affected serum PSA levels in men. METHODS: Participants included 20 men with ages ranging from 22 to 65 years who had never previously used cellular telephones. Blood samples were taken prior to and 30 days after the beginning of cellular telephone use. Serum was separated from the blood samples and stored in a deep freezer until the end of the study, at which time serum free and total PSA levels were determined by tandem radioimmunoassay. The results were statistically analyzed by the Wilcoxon Paired Signed Rank Test. RESULTS: Average free and total PSA values were 2.070 ng/ml and 0.500 ng/ml before the study, and 2.0 ng/ml and 0.505 ng/ml at the

end of the study, respectively. No significant difference was determined between the initial and final values ($p > 0.05$). CONCLUSIONS: The results indicate that cellular telephone use does not significantly affect PSA values in the short term. Nevertheless, we think that there is a need for longer-term studies on this subject.

**Singh B, Bate LA, Responses of pulmonary intravascular macrophages to 915-MHz microwave radiation: ultrastructural and cytochemical study. Anat Rec 246(3):343-355, 1996.**

BACKGROUND: Microwave (MW) radiation is being increasingly used as a source of heat supplementation during early postnatal development of pigs. Although MW radiation does not cause deleterious physiological effects, no specific information exists regarding its impact on immune cells such as macrophages. Pulmonary intravascular macrophages (PIMs) are emerging as important inflammatory cells due to their endocytic and secretory potential. An in vivo study was conducted to evaluate the effects of infrared, and low and high power MW radiation on the PIMs of pigs. METHODS: Pigs were exposed to infrared (IR), low MW (LMW; 6.1mW cm-2), and high MW (HMW; 11.4mW cm-2) radiation at 915 MHz (n = 2 for each treatment) for 24 hr. The controls (n = 2) were exposed to natural light for the same period of time. Lung tissues were processed for ultrastructural examination and acid phosphatase (AcPase) cytochemistry. In addition, rough endoplasmic reticulum (RER) as a fraction of cytosol of the PIMs was counted. RESULTS: Ultrastructural and numerical data suggested enhanced secretory activity in the PIMs of LMW-treated pigs as indicated by the increased RER:cytoplasm ratio, prominent Golgi complex profiles, and accumulation of secretory vesicles in conjunction with microtubules as compared with the control, IR, and HMW-exposed pigs. High MW treatment induced some damage to pulmonary interstitium as deduced from the presence of extracellular AcPase precipitates and disrupted collagen matrix. Intracellular globules were noticed in the PIMs of IR and LMW-treated pigs but not in the control and HMW-radiated animals. CONCLUSIONS: Elaboration of structural signs of secretory activity in the PIMs by LMW radiation in the absence of pulmonary pathological changes indicates its potential for cell activation in addition to the already established role of LMW in heat supplementation. This activation could be due to either increased core body temperature or initiation of intracellular signaling by the LMW radiation. This study also shows that the HMW radiation is capable of inducing pathology in the form of changes in the pulmonary interstitial matrix and may not be a good source of supplementary heat.

**Singh HP, Sharma VP, Batish DR, Kohli RK. Cell phone electromagnetic field radiations affect rhizogenesis through impairment of biochemical processes. Environ Monit Assess. 184(4):1813-1821, 2012.**

Indiscriminate adoption and use of cell phone technology has tremendously increased the levels of electromagnetic field radiations (EMFr) in the natural environment. It has raised the concerns among the scientists regarding the possible risks of EMFr to living organisms. However, not much has been done to assess the damage caused to plants that are continuously exposed to EMFr present in the environment. The present study investigated the biochemical mechanism of

interference of 900 MHz cell phone EMFr with root formation in mung bean (Vigna radiata syn. Phaseolus aureus) hypocotyls, a model system to study rhizogenesis in plants. Cell phone EMFr enhanced the activities of proteases (by 1.52 to 2.33 times), polyphenol oxidases (by 1.5 to 4.3 times), and peroxidases (by 1.5 to 2.0 times) in mung bean hypocotyls over control. Further, EMFr enhanced malondialdehyde (an indicator of lipid peroxidation), hydrogen peroxide, and proline content, indicating a reactive oxygen species-mediated oxidative damage in hypocotyls. It was confirmed by the upregulation in the activities of antioxidant enzymes (superoxide dismutase, ascorbate peroxidase, guaiacol peroxidase, catalase, and glutathione reductase) suggesting their possible role in providing protection against EMFr-induced oxidative damage. The study concluded that cell phone radiations affect the process of rhizogenesis through biochemical alterations that manifest as oxidative damage resulting in root impairment.

**Singh K, Nagaraj A, Yousuf A, Ganta S, Pareek S, Vishnani P. Effect of electromagnetic radiations from mobile phone base stations on general health and salivary function. J Int Soc Prevent Communit Dent 6:54-59, 2016.**

Objective: Cell phones use electromagnetic, nonionizing radiations in the microwave range, which some believe may be harmful to human health. The present study aimed to determine the effect of electromagnetic radiations (EMRs) on unstimulated/stimulated salivary flow rate and other health-related problems between the general populations residing in proximity to and far away from mobile phone base stations. Materials and Methods: A total of four mobile base stations were randomly selected from four zones of Jaipur, Rajasthan, India. Twenty individuals who were residing in proximity to the selected mobile phone towers were taken as the case group and the other 20 individuals (control group) who were living nearly 1 km away in the periphery were selected for salivary analysis. Questions related to sleep disturbances were measured using Pittsburgh Sleep Quality Index (PSQI) and other health problems were included in the questionnaire. Chi-square test was used for statistical analysis. Results: It was unveiled that a majority of the subjects who were residing near the mobile base station complained of sleep disturbances, headache, dizziness, irritability, concentration difficulties, and hypertension. A majority of the study subjects had significantly lesser stimulated salivary secretion ($P < 0.01$) as compared to the control subjects. Conclusions: The effects of prolonged exposure to EMRs from mobile phone base stations on the health and well-being of the general population cannot be ruled out. Further studies are warranted to evaluate the effect of electromagnetic fields (EMFs) on general health and more specifically on oral health.

**Singh N, Rudra N, Bansal P, Mathur R, Behari J, Nayar U, Poly ADP ribosylation as a possible mechanism of microwave--biointeraction. Indian J Physiol Pharmacol 38(3):181-184, 1994.**

Electromagnetic fields (EMFs) affect the metabolism of the body including the nervous, endocrine, cardiovascular, hematological as well as the reproductive system. EMFs are environmental pollutants, thus posing a health hazard which can cause steric changes in the molecule located at the cell surface. Microwaves are

known to cause chromosomal abberations and act as tumor promoters. The process involves a stream of signals from cell membrane to nucleus and other organelles. The present investigations aim to understand the mechanism of biological effects of microwaves (2.45 GHz). The effect was studied on poly ADP-ribosylation, which is a post translational modification of chromatin protein catalysed by the enzyme poly ADPR polymerase using NAD+ as the substrate. Poly ADP-ribosylation has been shown to be involved in several aspects of chromatin structure and function. Twenty-three days old rats weighing 42-48 gms were exposed at a microwave dose level of 1.0 mW/cm2. After exposure for sixty days the animals were sacrificed and an estimation of poly ADPR polymerase activity was undertaken in different organs of these animals. There was an increase of 20% in its activity in liver, 35% in testis, whereas brain showed a 53% decrease in diencephalon and 20% decrease in the cortex in the exposed animals as compared to their respective controls. There was no change in enzyme activity in spleen and kidney. This was accompanied by concomitant changes in NAD+ levels. The above results may be cited as important events in carcinogenesis and tumor promotion related to microwave exposure and the signal transduction mechanism involved. The goal is to shed light on complex ecogenetic interactions leading to cancer modulation of gene expression by epigenetic mechanism.

**Sinha RK. Chronic non-thermal exposure of modulated 2450 MHz microwave radiation alters thyroid hormones and behavior of male rats. Int J Radiat Biol. 84(6):505-513, 2008.**

Purpose: The purpose of this investigation was to analyze the effects of leakage microwave (2450 MHz) irradiation on thyroid hormones and behavior of male rats. Materials and methods: Experiments were carried out on two groups of male rats (exposure and control, respectively). Radio-immuno assay (RIA) methods were used for estimation of 3,5,3'-triiodothyronine (T(3)), thyroxine (T(4)) and thyrotrophin or thyroid stimulating hormone (TSH). The assessments of behavioral changes were performed in Open-Field (OF) and Elevated Plus-Maze (EPM) apparatuses. Results: Following chronic microwave exposure, rats were found hyperactive and aggressive on the 16th and 21st days. Behavioral changes in OF were analyzed and found to be significantly changed from controls ($p < 0.05$) for immobilization, rearing and ambulation behavior. In EPM, rats showed increased activity with decreased time spent in the open arm and more time spent in the center on the 11th ($p < 0.05$), 16th ($p < 0.05$) and 21st day ($p < 0.01$) after irradiation. Changes in behavioral parameters are also correlated with the trend of changes, compared to control animals, in hormonal blood levels of T3 (decreased on the 16th day, $p < 0.05$ and 21st day, $p < 0.01$) and T4 (increased on the 21st day, $p < 0.05$). Conclusion: Low energy microwave irradiation may be harmful as it is sufficient to alter the levels of thyroid hormones as well as the emotional reactivity of the irradiated compared to control animals.

**Singh S, Mani KV, Kapoor N. Effect of occupational EMF exposure from radar at two different frequency bands on plasma melatonin and serotonin levels. Int J Radiat Biol. 2015 Jan 7:1-39. [Epub ahead of print].**

Objective: The purpose of the present study was to delineate the effect of chronic electromagnetic field (EMF) exposure from radar on plasma melatonin and serotonin levels in occupationally exposed military personnel. Subjects and Methods: 166 male military personnel participated in the study out of which only 155 joined for blood draw. They were divided into three sets viz control group (n=68), exposure group I (n=40) exposed to 8-12GHz and exposure group II (n=58) working with radar at 12.5-18GHz frequency. All the three groups were further split into two groups according to their years of service (up to 10 years and > 10 years) in order to investigate the effect of years of exposure from radar. Melatonin and serotonin levels were estimated by enzyme immunoassay in fasting blood samples collected during 0600-0700h. EMF measurements were recorded at different locations using Satimo EME Guard 'Personal Exposure Meter' and Narda 'Broad Band Field Meter'. Results: The group I exposed population registered a minor though not significant decrease in plasma melatonin concentration while the other group II exposed population registered statistically significant decline in melatonin concentration when compared with controls. Highly significant increase in plasma serotonin levels was found in exposure group II when compared to control whereas marginal non-significant rise was also registered in exposure group I in comparison to control. Exposure in terms of length of service up to 10 years did not produce any significant effect in the indoleamine levels in both the exposure groups when they were compared with their respective control groups. Whereas, length of service greater than 10 years was observed to decrease and increase respectively the melatonin and serotonin concentration significantly in exposure group II but not in exposure group I. However, correlation test did not yield any significant association between years of service and melatonin or serotonin levels respectively in both the exposure sets I and II. No significant association was observed between melatonin and serotonin levels as well. Conclusion: The study shows the EMF ability to influence plasma melatonin and serotonin concentration in radar workers, significantly in 12.5-18GHz range with service period greater than 10 years.

**Siqueira EC, de Souza FT, Ferreira E, Souza RP, Macedo SC, Friedman E, Gomez MV, Gomes CC, Gomez RS. Cell phone use is associated with an inflammatory cytokine profile of parotid gland saliva. J Oral Pathol Med. 2016 Feb 14. doi: 10.1111/jop.12434. [Epub ahead of print]**

BACKGROUND: There is controversy on the effects of the non-ionizing radiation emitted by cell phones on cellular processes and the impact of such radiation exposure on health. The purpose of this study was to investigate whether cell phone use alters cytokine expression in the saliva produced by the parotid glands. METHODS: Cytokine expression profile was determined by enzyme linked immuno sorbent assay (ELISA) in the saliva produced by the parotid glands in healthy volunteers, and correlated with self-reported cell phone use and laterality. RESULTS: The following parameters were determined, in 83 Brazilian individuals in saliva produced by the parotid glands comparing the saliva from the gland exposed to cell phone radiation (ipsilateral) to that from the contralateral parotid: salivary flow, total protein concentration, interleukin 1 β (IL-1 β), interleukin 6 (IL-6), interleukin 10 (IL-10), interferon γ (IFN-γ), and tumor necrosis factor α (TNF-α) salivary levels by ELISA. After multiple testing correction, decreased IL-10 and increased IL-1β

salivary levels in the ipsilateral side compared with the contralateral side ($P < 0.05$) were detected. Subjects who used cell phones for more than 10 years presented higher differences between IL-10 levels in ipsilateral versus contralateral parotids ($P = 0.0012$). No difference was observed in any of the tested parameters in correlation with cell phone monthly usage in minutes. CONCLUSION: The exposure of parotid glands to cell phones can alter salivary IL-10 and IL-1β levels, consistent with a pro-inflammatory microenvironment that may be related to heat production.

**Sirav B, Seyhan N. Radio frequency radiation (RFR) from TV and radio transmitters at a pilot region in Turkey. Radiat Prot Dosimetry. 136(2):114-117. 2009.**

For the last 30 y, the biological effects of non-ionising radiation (NIR: 0-300 GHz) have been a major topic in bioelectromagnetism. Since the number of radiofrequency (RF) systems operating in this frequency range has shown an incredible increase over the last few decades, the dangers of exposure to the fields generated thereby has become an important public health issue. In this study, the aim was to evaluate the level of RF electromagnetic radiation in Yenimahalle Sentepe Dededoruk Hill in Ankara, Turkey that is a multiple-transmitter site hosting 64 different TV and radio towers and one base station for mobile phone communication. The site has been of interest as it is nearby a residential community. Within the technical input data available on 31 of the radio and TV transmitters, the calculated radiation level in this particular region was found to be approximately four times higher than the permitted standards of Turkey, which are the same as the ICNIRP standards. Electromagnetic field measurement is needed in the site.

**Sirav B, Seyhan N.Effects of radiofrequency radiation exposure on blood-brain barrier permeability in male and female rats.Electromagn Biol Med. 30(4):253-260, 2011.**

During the last several decades, numerous studies have been performed aiming at the question of whether or not exposure to radiofrequency radiation (RFR) influences the permeability of the blood-brain barrier (BBB). The objective of this study was to investigate the effect of RFR on the permeability of BBB in male and female Wistar albino rats. Right brain, left brain, cerebellum, and total brain were analyzed separately in the study. Rats were exposed to 0.9 and 1.8 GHz continuous-wave (CW) RFR for 20 min (at SARs of 4.26 mW/kg and 1.46 mW/kg, respectively) while under anesthesia. Control rats were sham-exposed. Disruption of BBB integrity was detected spectrophotometrically using the Evans-blue dye, which has been used as a BBB tracer and is known to be bound to serum albumin. Right brain, left brain, cerebellum, and total brain were evaluated for BBB permeability. In female rats, no albumin extravasation was found in in the brain after RFR exposure. A significant increase in albumin was found in the brains of the RF-exposed male rats when compared to sham-exposed male brains. These results suggest that exposure to 0.9 and 1.8 GHz CW RFR at levels below the international limits can affect the vascular permeability in the brain of male rats. The possible risk of RFR exposure in humans is a major concern for the society. Thus, this topic should be investigated more thoroughly in the future.

**Sırav B, Seyhan N. Effects of GSM modulated radio-frequency electromagnetic radiation on permeability of blood-brain barrier in male & female rats. J Chem Neuroanat. 2015 Dec 23. pii: S0891-0618(15)00106-4. doi: 10.1016/j.jchemneu.2015.12.010. [Epub ahead of print]**

With the increased use of mobile phones, their biological and health effects have become more important. Usage of mobile phones near the head increases the possibility of effects on brain tissue. This study was designed to investigate the possible effects of pulse modulated 900MHz and 1800MHz radio-frequency radiation on the permeability of blood-brain barrier of rats. Study was performed with 6 groups of young adult male and female wistar albino rats. The permeability of blood-brain barrier to intravenously injected evans blue dye was quantitatively examined for both control and radio-frequency radiarion exposed groups. For male groups; Evans blue content in the whole brain was found to be 0.08±0.01mg% in the control, 0.13±0.03mg% in 900MHz exposed and 0.26±0.05mg% in 1800MHz exposed animals. In both male radio-frequency radiation exposed groups, the permeability of blood-brain barrier found to be increased with respect to the controls ($p<0.01$). 1800MHz pulse modulated radio-frequency radiation exposure was found more effective on the male animals ($p<0.01$). For female groups; dye contents in the whole brains were 0.14±0.01mg% in the control, 0.24±0.03mg% in 900MHz exposed and 0.14±0.02mg% in 1800MHz exposed animals. No statistical variance found between the control and 1800MHz exposed animals ($p>0.01$). However 900MHz pulse modulated radio-frequency exposure was found effective on the permeability of blood-brain barrier of female animals. Results have shown that 20minutes pulse modulated radio-frequency radiation exposure of 900MHz and 1800MHz induces an effect and increases the permeability of blood-brain barrier of male rats. For females, 900MHz was found effective and it could be concluded that this result may due to the physiological differences between female and male animals. The results of this study suggest that mobile phone radation could lead to increase the permeability of blood-brain barrier under non-thermal exposure levels. More studies are needed to demonstrate the mechanisms of that breakdown.

**Smith P, Kuster N, Ebert S, Chevalier HJ. GSM and DCS wireless communication signals: combined chronic toxicity/carcinogenicity study in the Wistar Rat. Radiat Res. 168(4):480-492, 2007.**

.A total of 1170 rats comprised of 65 male and 65 female Han Wistar rats per group were exposed for 2 h/day, 5 days/ week for up to 104 weeks to GSM or DCS wireless communication signals at three nominal SARs of 0.44, 1.33 and 4.0 W/kg. A preliminary study confirmed that the highest exposure level was below that which was capable of causing a measurable increase in the core temperature of the rat. Additional groups for each modulation were sham exposed, and there was also an unrestrained, unexposed (cage) control group. Fifteen male and 15 female rats per group were killed after 52 weeks. From the remaining 50 male and 50 female rats per group, surviving animals were killed after 104 weeks. Evaluations during the study included mortality rate, clinical signs, recording of palpable masses, body weight, food consumption, ophthalmoscopic examination, and clinical pathological investigations. Terminal investigations included organ weight measurement and

macroscopic and microscopic pathology examinations. There was no adverse response to the wireless communication signals. In particular, there were no significant differences in the incidence of primary neoplasms, the number of rats with more than one primary neoplasm, the multiplicity and latency of neoplasms, the number of rats with metastases, and the number of benign and malignant neoplasms between the rats exposed to wireless communication signals and rats that were sham exposed.

**Smythe JW, Costall B. Mobile phone use facilitates memory in male, but not female, subjects. Neuroreport 14(2):243-246, 2003.**

In the present study we report on the effects of mobile phone exposure on short- and long-term memory in male and female subjects. Subjects were university undergraduate students, and consisted of right-handed, males ( = 33) and females ( = 29). Individuals were randomly assigned to one of three experimental conditions: no phone exposure; inactive phone exposure; and active phone exposure. They were provided with a series of words to learn, structured in a two-dimensional shape, and given 3 min to memorise the words. After a 12 min distraction task, they were then asked to draw the shape (spatial) and place the correct words (semantic) into the appropriate boxes. One week later the same subjects were brought back to again redraw the shape and words. Error scores were determined and analysed by non-parametric techniques. The results show that males exposed to an active phone made fewer spatial errors than those exposed to an active phone condition, while females were largely unaffected. These results further indicate that mobile phone exposure has functional consequences for human subjects, and these effects appear to be sex-dependent.

**Soderqvist F, Carlberg M, Hardell L. Use of wireless telephones and self-reported health symptoms: a population-based study among Swedish adolescents aged 15-19 years. Environ Health. 7(1):18, 2008.**

ABSTRACT: BACKGROUND: Despite the last years of rapid increase in use of wireless phones little data on the use of these devices has been systematically assessed among young persons. The aim of this descriptive cross-sectional study was to assess use of wireless phones and to study such use in relation to explanatory factors and self-reported health symptoms. METHODS: A postal questionnaire comprising 8 pages of 27 questions with 75 items in total was sent to 2000 Swedish adolescents aged 15-19 years and selected from the population registry using a stratified sampling scheme. RESULTS: The questionnaire was answered by 63.5 % of the study subjects. Most participants reported access to a mobile phone (99.6%) and use increased with age; 55.6% of the 15-year-olds and 82.2% of the 19-year-olds were regular users. Girls generally reported more frequent use than boys. Use of wired hands-free equipment 'anytime' was reported by 17.4%. Cordless phones were used by 81.9%, and 67.3% were regular users. Watching TV increased the odds ratio for use of wireless phones, adjusted for age and gender. Some of the most frequently reported health complaints were tiredness, stress, headache, anxiety, concentration difficulties and sleep disturbances. Regular users of wireless phones had health symptoms more often and reported poorer perceived health than less frequent users. CONCLUSIONS: Almost all adolescence in this

study used a wireless phone, girls more than boys. The most frequent use was seen among the older adolescents and those who watched TV extensively. The study further showed that perceived health and certain health symptoms seemed to be related to the use of wireless phones. However, this part of the investigation was explorative and should therefore be interpreted with caution since bias and chance findings due to multiple testing might have influenced the results. Potentially this study will stimulate more sophisticated studies that may also investigate directions of associations and whether, or to what degree, any mediation factors are involved.

**Söderqvist F, Carlberg M, Hardell L. Use of wireless telephones and serum S100B levels: A descriptive cross-sectional study among healthy Swedish adults aged 18-65 years. Sci Total Environ. 407(2):798-805, 2009**

BACKGROUND: Since the late 1970s, experimental animal studies have been carried out on the possible effects of low-intensive radiofrequency fields on the blood-brain barrier (BBB), but no epidemiological study has been published to date. OBJECTIVE: Using serum S100B as a putative marker of BBB dysfunction we performed a descriptive cross-sectional study to investigate whether protein levels were higher among frequent than non-frequent users of mobile and cordless desktop phones. METHOD: One thousand subjects, 500 of each sex aged 18-65 years, were randomly recruited using the population registry. Data on wireless phone use were assessed by a postal questionnaire and blood samples were analyzed for S100B. RESULTS: The response rate was 31.4%. The results from logistic and linear regression analyses were statistically insignificant, with one exception: the linear regression analysis of latency for UMTS use, which after stratifying on gender remained significant only for men ($p = 0.01$; $n = 31$). A low p-value (0.052) was obtained for use of cordless phone ($n = 98$) prior to giving the blood samples indicating a weak negative association. Total use of mobile and cordless phones over time yielded odds ratio (OR) 0.8 and 95% confidence interval (CI) 0.3-2.0 and use on the same day as giving blood yielded OR=1.1, CI=0.4-2.8. CONCLUSIONS: This study failed to show that long- or short-term use of wireless telephones was associated with elevated levels of serum S100B as a marker of BBB integrity. The finding regarding latency of UMTS use may be interesting but it is based on small numbers. Generally, S100B levels were low and to determine whether this association - if causal - is clinically relevant, larger studies with sufficient follow-up are needed.

**Söderqvist F, Carlberg M, Hansson Mild K, Hardell L. Exposure to an 890-MHz mobile phone-like signal and serum levels of S100B and transthyretin in volunteers. Toxicol Lett. 189(1):63-66, 2009.**

Whether low-intensity non-thermal microwave radiation alters the integrity of the blood-brain barrier has been debated since the late 1970s, yet no experimental study has been carried out on humans. The aim of this study was to test, using peripheral markers, whether exposure to a mobile phone-like signal alters the integrity of the human blood-brain and blood-cerebrospinal fluid barriers. A provocation study was carried out that exposed 41 volunteers to a 30 min GSM 890 MHz signal with an average specific energy absorption rate distribution of 1.0 W/kg in the temporal area

of the head as measured over any 1g of contiguous tissue. The outcome was assessed by changes in serum concentrations of two putative markers of brain barrier integrity, S100B and transthyretin. Repeated blood sampling before and after the provocation showed no statistically significant increase in the serum levels of S100B, while for transthyretin a statistically significant increase was seen in the final blood sample 60 min after the end of the provocation as compared to the prior sample taken immediately after provocation (p=0.02). The clinical significance of this finding, if any, is unknown. Further randomized studies with use of additional more brain specific markers are needed.

**Soderqvist F, Carlberg M, Hardell L. Mobile and cordless telephones, serum transthyretin and the blood-cerebrospinal fluid barrier: a cross-sectional study. Environ Health. 8(1):19, 2009.**

BACKGROUND: Whether low-intensity radiofrequency radiation damages the blood-brain barrier has long been debated, but little or no consideration has been given to the blood-cerebrospinal fluid barrier. In this cross-sectional study we tested whether long-term and/or short-term use of wireless telephones was associated with changes in the serum transthyretin level, indicating altered transthyretin concentration in the cerebrospinal fluid, possibly reflecting an effect of radiation. METHODS: One thousand subjects, 500 of each sex aged 18-65 years, were randomly recruited using the population registry. Data on wireless telephone use were assessed by a postal questionnaire and blood samples were analyzed for serum transthyretin concentrations determined by standard immunonephelometric techniques on a BN Prospec(R) instrument. RESULTS: The response rate was 31.4%. Logistic regression of dichotomized TTR serum levels with a cut-point of 0.31 g/l on wireless telephone use yielded increased odds ratios that were statistically not significant. Linear regression of time since first use overall and on the day that blood was withdrawn gave different results for males and females: for men significantly higher serum concentrations of TTR were seen the longer an analogue telephone or a mobile and cordless desktop telephone combined had been used, and in contrast, significantly lower serum levels were seen the longer an UMTS telephone had been used. Adjustment for fractions of use of the different telephone types did not modify the effect for cumulative use or years since first use for mobile telephone and DECT, combined. For women, linear regression gave a significant association for short-term use of mobile and cordless telephones combined, indicating that the sooner blood was withdrawn after the most recent telephone call, the higher the expected transthyretin concentration. CONCLUSIONS: In this hypothesis-generating descriptive study time since first use of mobile telephones and DECT combined was significantly associated with higher TTR levels regardless of how much each telephone type had been used. Regarding short-term use, significantly higher TTR concentrations were seen in women the sooner blood was withdrawn after the most recent telephone call on that day.

**Söderqvist F, Hardell L, Carlberg M, Mild KH. Radiofrequency fields, transthyretin, and Alzheimer's disease.J Alzheimers Dis. 20(2):599-606, 2010.**

Radiofrequency field (RF) exposure provided cognitive benefits in an animal study. In Alzheimer's disease (AD) mice, exposure reduced brain amyloid-beta (Abeta) deposition through decreased aggregation of Abeta and increase in soluble Abeta levels. Based on our studies on humans on RF from wireless phones, we propose that transthyretin (TTR) might explain the findings. In a cross-sectional study on 313 subjects, we used serum TTR as a marker of cerebrospinal fluid TTR. We found a statistically significantly positive beta coefficient for TTR for time since first use of mobile phones and desktop cordless phones combined (P=0.03). The electromagnetic field parameters were similar for the phone types. In a provocation study on 41 persons exposed for 30 min to an 890-MHz GSM signal with specific absorption rate of 1.0 Watt/kg to the temporal area of the brain, we found statistically significantly increased serum TTR 60 min after exposure. In our cross-sectional study, use of oral snuff also yielded statistically significantly increased serum TTR concentrations and nicotine has been associated with decreased risk for AD and to upregulate the TTR gene in choroid plexus but not in the liver, another source of serum TTR. TTR sequesters Abeta, thereby preventing the formation of Abeta plaques in the brain. Studies have shown that patients with AD have lowered TTR concentrations in the cerebrospinal fluid and have attributed the onset of AD to insufficient sequestering of Abeta by TTR. We propose that TTR might be involved in the findings of RF exposure benefit in AD mice.

**Söderqvist F, Carlberg M, Hardell L. Use of wireless phones and the risk of salivary gland tumours: a case-control study. Eur J Cancer Prev.21(6):576-579, 2012.**

The last decades of increasing use of wireless phones, including mobile as well as cordless desktop phones, have led to concerns about the potential carcinogenic effects of radiofrequency electromagnetic fields. Among the most exposed areas of the body when the phone is used for talking are the salivary glands, mainly the parotid gland, located in front of the ear. The objective of this case-control study was to assess whether the use of wireless phones is associated with an increased risk of tumour at this site. Sixty-nine patients with salivary gland tumours (63 with a parotid gland tumour) and 262 randomly recruited controls were included. Unconditional logistic regression - adjusted for age at diagnosis, sex, year of diagnosis and socioeconomic index - was used to produce odds ratios and 95% confidence intervals. The use of wireless phones was not associated with an overall increased risk of salivary gland tumours, odds ratio 0.8, 95% confidence interval 0.4-1.5. Neither was there an increased risk for the different phone types when calculated separately nor was there an increased risk for different latencies or when cumulative use was divided into three groups (1-1000, 1001-2000 and >2000 h). The overall results were similar for the risk of parotid gland tumours. In conclusion, our data add to the evidence against there being an increased risk for parotid gland tumours associated with light-to-moderate use of wireless phones and for less than 10 years of use but offers little information on risk related to more prolonged and/or heavy use.

**Söderqvist F, Carlberg M, Zetterberg H, Hardell L. Use of wireless phones and serum β-trace protein in randomly recruited persons aged 18-65 years: a cross-sectional study. Electromagn Biol Med.31(4):416-424, 2012.**

Background: There are studies suggesting effects on sleep from pulse-modulated radiofrequency fields used in mobile and cordless phones. So far, reports of adverse effects in observational studies are of limited value for risk assessment while effects from experimental studies seem to be more consistent but unclear as to their importance for health. The aim of this study was to investigate whether use of wireless phones is associated with lower concentrations of β-trace protein (lipocalin-type prostaglandin D synthase), a key enzyme in the synthesis of prostaglandin D(2), an endogenous sleep-promoting neurohormone. Methods: Three hundred and fourteen people, aged 18-65 years and living in the municipality of Örebro, Sweden, were recruited randomly using the population registry. Total and age-specific linear regression analyses adjusted for known covariates were used to calculate associations between levels of β-trace protein and short- and long-term use of wireless phones. Results: Overall, no statistically significant association between use of wireless phones and the serum concentration of β-trace protein was found, neither with respect to short-term nor long-term use. Age-specific analyses, however, yielded negative associations for long-term use (cumulative hours of use) and β-trace protein in the youngest age group (18-30 years). Conclusion: This study provided no overall evidence of an association between wireless phone use and serum concentrations of β-trace protein. While the findings in the 18-30 year age group indicating lower concentrations with more cumulative hours of use should be further investigated, no causal inferences can be made from the results of the present study.

**Söderqvist F, Carlberg M, Hardell L. Biomarkers in volunteers exposed to mobile phone radiation. Toxicol Lett. 2015 Mar 31. pii: S0378-4274(15)00119-8. doi: 10.1016/j.toxlet.2015.03.016. [Epub ahead of print]**

For some time it has been investigated whether low-intensity non-thermal microwave radiation from mobile phones adversely affects the mammalian blood-brain barrier (BBB). All such studies except one have been either in vitro or experimental animal studies. The one carried out on humans showed a statistically significant increase in serum transthyretin (TTR) 60min after finishing of a 30-min microwave exposure session. The aim of the present study was to follow up on the finding of the previous one using a better study design. Using biomarkers analyzed in blood serum before and after the exposure this single blinded randomized counterbalanced study, including 24 healthy subjects aged 18-30 years that all underwent three exposure conditions ($SAR_{10G}$=2W/kg, $SAR_{10G}$=0.2W/kg, sham), tested whether microwaves from an 890-MHz phone-like signal give acute effects on the integrity of brain-shielding barriers. Over time, statistically significant variations were found for two of the three biomarkers (TTR; β-trace protein); however, no such difference was found between the different exposure conditions nor was there any interaction between exposure condition and time of blood sampling. In conclusion this study failed to show any acute clinically or statistically significant effect of short term microwave exposure on the serum levels of S100β, TTR and β-trace protein with a follow up limited to two hours. The study was hampered by the fact that all study persons were regular wireless phone users and thus not naïve as to microwave exposure.

**Sokolovic D, Djindjic B, Nikolic J, Bjelakovic G, Pavlovic D, Kocic G, Krstic D, Cvetkovic T, Pavlovic V. Melatonin reduces oxidative stress induced by chronic exposure of microwave radiation from mobile phones in rat brain. J Radiat Res (Tokyo). 49(6):579-586, 2008.**

PURPOSE: The aim of the study was to evaluate the intensity of oxidative stress in the brain of animals chronically exposed to mobile phones and potential protective effects of melatonin in reducing oxidative stress and brain injury. MATERIALS AND METHODS: Experiments were performed on Wistar rats exposed to microwave radiation during 20, 40 and 60 days. Four groups were formed: I group (control)- animals treated by saline, intraperitoneally (i.p.) applied daily during follow up, II group (Mel)- rats treated daily with melatonin (2 mg kg(-1) body weight i.p.), III group (MWs)- microwave exposed rats, IV group (MWs + Mel)- MWs exposed rats treated with melatonin (2 mg kg(-1) body weight i.p.). The microwave radiation was produced by a mobile test phone (SAR = 0.043-0.135 W/kg). RESULTS: A significant increase in the brain tissue malondialdehyde (MDA) and carbonyl group concentration was registered during exposure. Decreased activity of catalase (CAT) and increased activity of xanthine oxidase (XO) remained after 40 and 60 days of exposure to mobile phones. Melatonin treatment significantly prevented the increase in the MDA content and XO activity in the brain tissue after 40 days of exposure while it was unable to prevent the decrease of CAT activity and increase of carbonyl group contents. CONCLUSION: We demonstrated two important findings; that mobile phones caused oxidative damage biochemically by increasing the levels of MDA, carbonyl groups, XO activity and decreasing CAT activity; and that treatment with the melatonin significantly prevented oxidative damage in the brain.

**Sokolovic D, Djordjevic B, Kocic G, Babovic P, Ristic G, Stanojkovic Z, Sokolovic DM, Veljkovic A, Jankovic A, Radovanovic Z. The effect of melatonin on body mass and behaviour of rats during an exposure to microwave radiation from mobile phone. Bratisl Lek Listy. 113(5):265-269, 2012.**

BACKGROUND: Microwave radiation (MW) produced by wireless telecommunications and a number of electrical devices used in household or in healthcare institutions may cause various disorders in human organism. On the other hand, melatonin is a potent antioxidant, immunostimulator and neuromodulator. The aim of this research was to determine body mass and behaviour changes in rats after a chronic microwave exposure, as well as to determine the effects of melatonin on body mass and behaviour in irradiated rats. METHODS: Wistar rats were divided into the four experimental groups: I group (control) - rats treated with 0,9 % saline, II group (Mel) - rats treated with melatonin (2 mg/kg), III group (MW) - rats exposed to MW radiation (4 h/day), IV group (MW+Mel) - rats, which were both exposed to MW radiation and received melatonin premedication (2 mg/kg). RESULTS: A significant body mass reduction was noted in animals exposed to MW radiation when compared to controls after 20, 40 and 60 days ($p<0.001$). Furthermore, body weight was significantly increased ($p<0.05$) in irradiated rats, which received melatonin pretreatment (MW+Mel) in comparison to irradiated group (MW) after 20 days. Microwave radiation exposed animals showed an anxiety related behaviour

(agitation, irritability) after 10 days of exposure. After the radiation source removal, changes in behaviour were less noticeable. Melatonin administration to irradiated rats caused a decrease in the stress induced behaviour. CONCLUSION: Microwave radiation causes body mass decrease and anxiety related behaviour in rats, however melatonin causes a reverse of those effects on both body weight and behaviour of irradiated animals (Fig. 2, Ref. 32).

**Sokolovic D, Djordjevic B, Kocic G, Stoimenov TJ, Stanojkovic Z, Sokolovic DM, et al. The Effects of Melatonin on Oxidative Stress Parameters and DNA Fragmentation in Testicular Tissue of Rats Exposed to Microwave Radiation. Adv Clin Exp Med. 24(3):429-436, 2015.**

BACKGROUND: Microwaves from mobile phones are one of the environmental toxicants that are capable of compromising male fertility by inducing oxidative stress and apoptosis in the testes. Melatonin is a lipophilic tryptophan indole amine and a potent antioxidant. OBJECTIVES: The aim of the study was to evaluate the effect of melatonin treatment on oxidative stress parameters and DNA fragmentation in the testicular tissue of rats exposed to microwave radiation (4 h/day). MATERIAL AND METHODS: Adult Wistar rats were divided in 4 groups: I - treated with saline; II - treated with melatonin; III - exposed to microwaves; IV - exposed to microwaves and treated with melatonin. The melatonin (2 mg/kg ip) was administered daily. The animals were sacrificed after 20, 40 and 60 days. RESULTS: Melatonin treatment prevented previously registered increases in malondialdehyde after only 20 days. Furthermore, it reversed the effects of microwave exposure on xanthine oxidase (after 40 days) and acid-DNase activity (after 20 days). However, neither protein carbonyl content nor catalase and alkaline Dnase activity were changed due to melatonin treatment. CONCLUSIONS: Melatonin exerts potent antioxidant effects in the testes of rats exposed to microwaves by decreasing the intensity of oxidative stress; it also reduces DNA fragmentation.

**Solomentsev GY, English NJ, Mooney DA. Effects of external electromagnetic fields on the conformational sampling of a short alanine peptide. J Comput Chem. 33(9):917-923, 2012.**

Non-equilibrium molecular dynamics simulations of a solvated 21-residue polyalanine (A21) peptide, featuring a high propensity for helix formation, have been performed at 300 K and 1 bar in the presence of external electromagnetic (e/m) fields in the microwave region (2.45 GHz) and an r.m.s. electric field intensity range of 0.01-0.05 V/Å. To investigate how the field presence affects transitions between the conformational states of a protein, we report 16 independent 40 ns-trajectories of A21 starting from both extended and fully folded states. We observe folding-behavior of the peptide consistent with prior simulation and experimental studies. The peptide displays a natural tendency to form stable elements of secondary structure which are stabilized by tertiary interactions with proximate regions of the peptide. Consistent with our earlier work, the presence of external e/m fields disrupts this behavior, involving a mechanism of localized dipolar alignment which serves to enhance intra-protein perturbations in hydrogen bonds

(English, et al., J. Chem. Phys. 2010, 133, 091105), leading to more frequent transitions between shorter-lifetime states.

**Sommer AM, Streckert J, Bitz AK, Hansen VW, Lerchl A. No effects of GSM-modulated 900 MHz electromagnetic fields on survival rate and spontaneous development of lymphoma in female AKR/J mice. BMC Cancer. 4(1):77, 2004.**

BACKGROUND: There are several reports that indicate that non-thermal electromagnetic radiation such as from mobile phones and base stations may promote cancer. Therefore, it was investigated experimentally, whether 900 MHz electromagnetic field exposure influences lymphoma development in a mouse strain that is genetically predisposed to this disease. The AKR/J mice genome carries the AK-virus, which leads within one year to spontaneous development of thymic lymphoblastic lymphoma. METHODS: 48 groups of 6-7 unrestrained female mice were sham-exposed or exposed (each n = 160 animals) to GSM like 900 MHz electromagnetic fields for 24 hours per day, 7 days per week, at an average whole body specific absorption rates (SAR) values of 0.4 W/Kg. Animals were visually checked daily and were weighed and palpated weekly. Starting with an age of 6 months, blood samples were taken monthly from the tail. Animals with signs of disease or with an age of about 42 weeks were sacrificed and a gross necropsy was performed. RESULTS: There was no effect of electromagnetic field exposure on body weight gain or survival rate, and lymphoma incidence did not differ between exposed and sham-exposed animals. CONCLUSION: These data do not support the hypothesis that exposure to 900 MHz electromagnetic fields is a significant risk factor for developing lymphoma in a genetically predisposed species, even at a relatively high exposure level.

**Sommer AM, Bitz AK, Streckert J, Hansen VW, Lerchl A. Lymphoma development in mice chronically exposed to UMTS-modulated radiofrequency electromagnetic fields. Radiat Res. 168(1):72-80, 2007.**

There are public concerns regarding possible carcinogenic or cancer-promoting effects of electromagnetic fields (EMFs) from mobile phones and base stations. The objective of the present study was to investigate whether chronic exposure to EMFs of the UMTS (Universal Mobile Telecommunication System) influences the development of lymphoma in a lymphoma animal model, the AKR/J mouse. Unrestrained mice were chronically sham-exposed (n = 160) or exposed (n = 160) in identical exposure systems (radial waveguides) to a generic UMTS test signal (24 h per day, 7 days per week, 0.4 W/kg SAR). Additionally, 30 animals were kept as cage controls. Animals were checked visually each day and were weighed and palpated weekly to detect swollen lymph nodes. Starting at the age of 6 months, blood samples were taken from the tail every 2 weeks to perform differential leukocyte counts and to measure the hematocrit. Visibly diseased animals or those older than 43 weeks were killed humanely, and tissue slices were examined for metastatic infiltrations and lymphoma type. The study was performed in a blinded way. Cage control animals had a significantly lower growth rate than those kept in the radial waveguides. The number of ill animals, the mean survival time, and the severity code of the disease did not differ between the experimental groups. Therefore, the data

show no negative effects from exposure and corroborate earlier findings in AKR/J mice exposed to GSM EMF (Sommer et al., BMC Cancer 4, 77-90, 2004).

**Sommer, A. M., Grote, K., Reinhardt, T., Streckert, J., Hansen, V. and Lerchl, A. Effects of radiofrequency electromagnetic fields (UMTS) on reproduction and development of mice: A Multi-generation Study. Radiat. Res. 171: 89-95, 2009.**

Male and female mice (C57BL) were chronically exposed (life-long, 24 h/day) to mobile phone communication electromagnetic fields at approximately 1966 MHz (UMTS). Their development and fertility were monitored over four generations by investigating histological, physiological, reproductive and behavioral functions. The mean whole-body SARs, calculated for adult animals at the time of mating, were 0 (sham), 0.08, 0.4 and 1.3 W/kg. Power densities were kept constant for each group (0, 1.35, 6.8 and 22 W/m(2)), resulting in varying SARs due to the different numbers of adults and pups over the course of the experiment. The experiment was done in a blind fashion. The results show no harmful effects of exposure on the fertility and development of the animals. The number and the development of pups were not affected by exposure. Some data, albeit without a clear dose-response relationship, indicate effects of exposure on food consumption that is in accordance with some data published previously. In summary, the results of this study do not indicate harmful effects of long-term exposure of mice to UMTS over several generations.

**Somosy Z, Thuroczy G, Koteles GJ, Kovacs J, Effects of modulated microwave and X-ray irradiation on the activity and distribution of Ca(2+)-ATPase in small intestine epithelial cells. Scanning Microsc 8(3):613-619; discussion 619-620, 1994.**

The distribution and activity of Ca(2+)-ATPase were investigated by histochemical methods in small intestine epithelial cells of mice following total body 2450 MHz low frequency (16 Hz) microwave and X-ray irradiation. In the control animals, enzyme activities were found in the brush border and on lateral membranes, including junctional areas of the cells. The enzyme activity of lateral membranes was inhibited by quercetin, a specific inhibitor of Ca(2+)-ATPase. Immediately after square modulated (16 Hz) 2450 MHz microwave irradiation at 1 mW/cm2 power densities, we observed a decreased activity of Ca(2+)-ATPase on the lateral membrane regions. The X-ray irradiation (1 Gy) induced a similar decrease of Ca(2+)-ATPase activity which was reversible within 24 hours. "5 Gy" doses resulted in a decrease of enzyme activities on both apical and lateral membrane areas persisting up to 24 hours following irradiation

**Somosy Z, Thuroczy G, Kovacs J, Effects of modulated and continuous microwave irradiation on pyroantimonate precipitable calcium content in junctional complex of mouse small intestine. Scanning Microsc 7(4):1255-1261, 1993.**

The pyroantimonate precipitable calcium content of intestinal epithelial cells was investigated in mice following total body irradiation with 2450 MHz continuous and low frequency (16 Hz) square modulated waves. In the control animals the reaction products appeared in the intercellular space of adjacent cells including intermediate junctions and desmosomes and were absent in the area of tight junctions. Immediately after low frequency modulated microwave irradiation at 0.5 and 1 mW/cm2 power densities, a rapid distribution of pyroantimonate precipitable calcium content was observed. The

pyroantimonate deposits were located on the cytoplasmic side of lateral membrane, in the area of junctional complex, including tight junction, and in other parts of lateral plasma membrane. These changes were reversible and 24 hours after the irradiation the distribution of pyroantimonate deposits was similar to the control. Continuous waves with same energy not altered the distribution of precipitable calcium. We conclude the low frequency modulated microwave irradiation can modify the calcium distribution without heat effects.

**Somosy Z, Thuroczy G, Kubasova T, Kovacs J, Szabo LD, Effects of modulated and continuous microwave irradiation on the morphology and cell surface negative charge of 3T3 fibroblasts. Scanning Microsc 5(4):1145-1155, 1991**

Mouse embryo 3T3 cells were irradiated with 2450 MHz continuous and low frequency (16 Hz) square modulated waves of absorbed energy ranging from 0.0024 to 2.4 mW/g. The low frequency modulated microwave irradiation yielded more morphological cell changes than did the continuous microwave fields of the same intensity. The amount of free negative charges (cationized ferritin binding) on cell surfaces decreased following irradiation by modulated waves but remained unchanged under the effect of a continuous field of the same dose. Modulated waves of 0.024 mW/g dose increased the ruffling activity of the cells, and caused ultrastructural alteration in the cytoplasm. Similar effects were experienced by continuous waves at higher (0.24 and 2.4 mW/g) doses.

**Son Y, Jeong YJ, Kwon JH, Choi HD, Pack JK, Kim N, Lee YS, Lee HJ. 1950 MHz radiofrequency electromagnetic fields do not aggravate memory deficits in 5xFAD mice. Bioelectromagnetics. 37(6):391-399, 2016.**

The increased use of mobile phones has generated public concern about the impact of radiofrequency electromagnetic fields (RF-EMF) on health. In the present study, we investigated whether RF-EMFs induce molecular changes in amyloid precursor protein (APP) processing and amyloid beta (Aβ)-related memory impairment in the 5xFAD mouse, which is a widely used amyloid animal model. The 5xFAD mice at the age of 1.5 months were assigned to two groups (RF-EMF- and sham-exposed groups, eight mice per group). The RF-EMF group was placed in a reverberation chamber and exposed to 1950 MHz electromagnetic fields for 3 months (SAR 5 W/kg, 2 h/day, 5 days/week). The Y-maze, Morris water maze, and novel object recognition memory test were used to evaluate spatial and non-spatial memory following 3-month RF-EMF exposure. Furthermore, Aβ deposition and APP and carboxyl-terminal fragment β (CTFβ) levels were evaluated in the hippocampus and cortex of 5xFAD mice, and plasma levels of Aβ peptides were also investigated. In behavioral tests, mice that were exposed to RF-EMF for 3 months did not exhibit differences in spatial and non-spatial memory compared to the sham-exposed group, and no apparent change was evident in locomotor activity. Consistent with behavioral data, RF-EMF did not alter APP and CTFβ levels or Aβ deposition in the brains of the 5xFAD mice. These findings indicate that 3-month RF-EMF exposure did not affect Aβ-related memory impairment or Aβ accumulation in the 5xFAD Alzheimer's disease model.

**Sonmez OF, Odaci E, Bas O, Kaplan S. Purkinje cell number decreases in the adult female rat cerebellum following exposure to 900 MHz electromagnetic field. Brain**

**Res. 1356:95-101, 2010.**

The biological effects of electromagnetic field (EMF) exposure from mobile phones have growing concern among scientists since there are some reports showing increased risk for human health, especially in the use of mobile phones for a long duration. In the presented study, the effects on the number of Purkinje cells in the cerebellum of 16-week (16 weeks) old female rats were investigated following exposure to 900 MHz EMF. Three groups of rats, a control group (CG), sham exposed group (SG) and an electromagnetic field exposed group (EMFG) were used in this study. While EMFG group rats were exposed to 900 MHz EMF (1h/day for 28 days) in an exposure tube, SG was placed in the exposure tube but not exposed to EMF (1h/day for 28 days). The specific energy absorption rate (SAR) varied between 0.016 (whole body) and 2 W/kg (locally in the head). The CG was not placed into the exposure tube nor was it exposed to EMF during the study period. At the end of the experiment, all of the female rats were sacrificed and the number of Purkinje cells was estimated using a stereological counting technique. Histopathological evaluations were also done on sections of the cerebellum. Results showed that the total number of Purkinje cells in the cerebellum of the EMFG was significantly lower than those of CG ($p<0.004$) and SG ($p<0.002$). In addition, there was no significant difference at the 0.05 level between the rats' body and brain weights in the EMFG and CG or SG. Therefore, it is suggested that long duration exposure to 900 MHz EMF leads to decreases of Purkinje cell numbers in the female rat cerebellum.

**Soran ML, Stan M, Niinemets U, Copolovici L. Influence of microwave frequency electromagnetic radiation on terpene emission and content in aromatic plants.J Plant Physiol. 171(15):1436-1443, 2014**

Influence of environmental stress factors on both crop and wild plants of nutritional value is an important research topic. The past research has focused on rising temperatures, drought, soil salinity and toxicity, but the potential effects of increased environmental contamination by human-generated electromagnetic radiation on plants have little been studied. Here we studied the influence of microwave irradiation at bands corresponding to wireless router (WLAN) and mobile devices (GSM) on leaf anatomy, essential oil content and volatile emissions in Petroselinum crispum, Apium graveolens and Anethum graveolens. Microwave irradiation resulted in thinner cell walls, smaller chloroplasts and mitochondria, and enhanced emissions of volatile compounds, in particular, monoterpenes and green leaf volatiles (GLV). These effects were stronger for WLAN-frequency microwaves. Essential oil content was enhanced by GSM-frequency microwaves, but the effect of WLAN-frequency microwaves was inhibitory. There was a direct relationship between microwave-induced structural and chemical modifications of the three plant species studied. These data collectively demonstrate that human-generated microwave pollution can potentially constitute a stress to the plants.

**Sorri MJ, Huttunen KH, Valimaa TT, Karinen PJ, Lopponen HJ, Cochllear implants and GSM phone. Scand Audiol Suppl (52):54-56, 2001.**

Use of a telephone and GSM phones, in particular, was assessed by means of a postal interview sent to all adult Finnish implantees. The response rate was very high (87%). Fifty-one of the 61 respondents used a telephone and 27/61 also used a mobile phone, usually a digital phone. Two GSM phone models from Nokia (3110 and 6110) were tested with three different cochlear implant systems used by nine patients. Definite differences between the processors were found. Nucleus Spectra (two implantees) could not be used with any of the GSM phones under any test condition. Nucleus SPrint was incompatible with both GSM phone models in a poor field, while GSM phone model 6110 could be used in a good field. The Med-El Combi 40+ processor was compatible with both GSM models tested under any condition.

**Souza LD, Cerqueira ED, Meireles JR. Assessment of nuclear abnormalities in exfoliated cells from the oral epithelium of mobile phone users. Electromagn Biol Med. 2013 May 28. [Epub ahead of print]**

Transmission and reception of mobile telephony signals take place through electromagnetic wave radiation, or electromagnetic radiofrequency fields, between the mobile terminal and the radio base station. Based on reports in the literature on adverse effects from exposure to this type of radiation, the objective of this study was to evaluate the genotoxic and cytotoxic potential of such exposure, by means of the micronucleus test on exfoliated cells from the oral epithelium. The sample included 45 individuals distributed in 3 groups according to the amount of time in hours per week (t) spent using mobile phones: group I, $t > 5$ h; group II, $t > 1$ h and $\leq 5$ h; and group III, $t \leq 1$ h. Cells from the oral mucosa were analyzed to assess the numbers of micronuclei, broken egg structures and degenerative nuclear abnormalities indicative of apoptosis (condensed chromatin, karyorrhexis and pyknosis) or necrosis (karyolysis in addition to these changes). The occurrences of micronuclei and degenerative nuclear abnormalities did not differ between the groups, but the number of broken egg (structures that may be associated with gene amplification) was significantly greater in the individuals in group I ($p < 0.05$).

**Sparks PB, Mond HG, Joyner KH, Wood MP, The safety of digital mobile cellular telephones with minute ventilation rate adaptive pacemakers. Pacing Clin Electrophysiol 19(10):1451-1455, 1996.**

In vitro tests suggest that rate adaptive pacemakers using changes in transthoracic impedance to vary pacing rate may be affected by digital mobile telephones. Electromagnetic fields generated by digital mobile telephones (Global System for Mobile [GSM]) represent a potential source of electromagnetic interference (EMI) for the Telectronics META rate adaptive pacemakers, which use transthoracic impedance as a sensor to determine changes in minute ventilation. Sixteen implanted Telectronics META pulse generators were exposed to 25-W simulated GSM transmissions (900-MHz carrier pulsed at 2, 8, and 217 Hz with a pulse width of 0.6 ms) and the antenna of a 2-W digital mobile telephone (900-MHz, 217-Hz pulse, 0.6-ms pulse width). The 12 dual and four single chamber devices were programmed to maximum sensitivity and assessed in unipolar and bipolar settings and rate adaptive and nonrate adaptive modes. In all cases of EMI, testing was repeated at lower, more routinely set bipolar sensitivity levels. At

maximum sensitivity, 11 of 16 devices displayed no evidence of EMI. Brief ventricular triggering occurred in 2, a brief pause in 1, a combination of both in 1, and a brief episode of pacemaker-mediated tachycardia in 1. With pulse generators programmed to more routine sensitivities, only one device displayed rare single beat ventricular triggering. No changes in minute ventilation rate adaptive pacing were observed. At maximum unipolar sensitivities, the META series of rate adaptive pacemakers are resistant to clinically important EMI from digital mobile telephones. Set at routine sensitivities, these devices perform reliably in the presence of digital mobile telephones.

**Speit G, Schütz P, Hoffmann H. Genotoxic effects of exposure to radiofrequencyelectromagnetic fields (RF-EMF) in cultured mammalian cells are not independently reproducible. Mutat Res. 626(1-2):42-47, 2007.**

Conflicting results have been published regarding the induction of genotoxic effects by exposure to radiofrequencyelectromagnetic fields (RF-EMF). Using the comet assay, the micronucleus test and the chromosome aberration test with human fibroblasts (ES1 cells), the EU-funded "REFLEX" project (Risk Evaluation of Potential Environmental Hazards From Low Energy Electromagnetic Field Exposure Using Sensitive in vitro Methods) reported clearly positive effects for various exposure conditions. Because of the ongoing discussion on the biological significance of the effects observed, it was the aim of the present study to independently repeat the results using the same cells, the same equipment and the same exposure conditions. We therefore exposed ES1 cells to RF-EMF (1800 MHz; SAR 2 W/kg, continuous wave with intermittent exposure) for different time periods and then performed the alkaline (pH>13) comet assay and the micronucleus test (MNT). For both tests, clearly negative results were obtained in independently repeated experiments. We also performed these experiments with V79 cells, a sensitive Chinese hamster cell line that is frequently used in genotoxicity testing, and also did not measure any genotoxic effect in the comet assay and the MNT. Appropriate measures of quality control were considered to exclude variations in the test performance, failure of the RF-EMF exposure or an evaluation bias. The reasons for the difference between the results reported by the REFLEX project and our experiments remain unclear.

**Spichtig S, Scholkmann F, Chin L, Lehmann H, Wolf M. Assessment of intermittent UMTS electromagnetic field effects on blood circulation in the human auditory region using a near-infrared system.Bioelectromagnetics. 33(1):40-54, 2012.**

The aim of the present study was to assess the potential effects of intermittent Universal Mobile Telecommunications System electromagnetic fields (UMTS-EMF) on blood circulation in the human head (auditory region) using near-infrared spectroscopy (NIRS) on two different timescales: short-term (effects occurring within 80 s) and medium-term (effects occurring within 80 s to 30 min). For the first time, we measured potential immediate effects of UMTS-EMF in real-time without any interference during exposure. Three different exposures (sham, 0.18 W/kg, and 1.8 W/kg) were applied in a controlled, randomized, crossover, and double-blind paradigm on 16 healthy volunteers. In addition to oxy-, deoxy-, and total haemoglobin concentrations ([O(2) Hb], [HHb], and [tHb], respectively), the heart rate (HR), subjective well-being, tiredness, and counting speed

were recorded. During exposure to 0.18 W/kg, we found a significant short-term increase in Δ[O(2) Hb] and Δ[tHb], which is small (≈17%) compared to a functional brain activation. A significant decrease in the medium-term response of Δ[HHb] at 0.18 and 1.8 W/kg exposures was detected, which is in the range of physiological fluctuations. The medium-term ΔHR was significantly higher (+1.84 bpm) at 1.8 W/kg than for sham exposure. The other parameters showed no significant effects. Our results suggest that intermittent exposure to UMTS-EMF has small short- and medium-term effects on cerebral blood circulation and HR.

**Spiers DE, Baummer SC, Thermal and metabolic responsiveness of Japanese quail embryos following periodic exposure to 2,450 MHz microwaves. Bioelectromagnetics 12(4):225-239, 1991.**

Two studies were performed to determine if repeated exposure of the avian egg to microwaves can alter metabolism, temperature, and growth rate of embryos. Another aim was to supplement conventional heating with microwave heating and provide an optimal temperature for growth. Japanese quail (Coturnix coturnix japonica) eggs were exposed from day 1 through 15 of incubation (8 h/day) to sham or microwave (2,450 MHz) irradiation. Microwave exposures were at two power densities, 5 or 20 mW/cm2, and at three ambient temperatures (Tas), 30.0, 33.1, or 35.4 degrees C. Specific absorption rates for unincubated and 15-day-old incubated eggs were, respectively, 0.76 and 0.66 W kg-1 mW-1 cm-2 (i.e., 3.8 and 3.3 W/kg at 5 mW/cm2 and 15.2 and 13.2 W/kg at 20 mW/cm2). Eggs were concurrently sham exposed at each of five Tas, ranging from 27.9 to 37.5 degrees C. Tests were conducted during the 16th day of incubation (i.e., 1 day post-treatment), in the absence of microwaves, to determine metabolic rate of embryos and internal and external egg temperatures at different Tas. Repeated exposures to microwaves at 5 and 20 mW/cm2 at the same Ta (30 degrees C) increased wet-embryo mass on the 16th day by an average, respectively, of 9% and 61% when compared with predicted masses for embryos exposed at the same Ta in the absence of microwave radiation. There was no reliable indication, from post-treatment tests and comparisons with control embryos of similar mass, that repeated exposure to microwave radiation resulted in abnormal physiological development. Microwave radiation can be used to increase egg temperature and embryonic growth rate at Tas below normal incubation level without altering basic metabolic and thermal characteristics of the developing bird.

**Stagg RB, Thomas WJ, Jones RA, Adey WR, DNA synthesis and cell proliferation in C6 glioma and primary glial cells exposed to a 836.55 MHz modulated radiofrequency field. Bioelectromagnetics 18(3):230-236, 1997.**

We have tested the hypothesis that modulated radiofrequency (RF) fields may act as a tumor-promoting agent by altering DNA synthesis, leading to increased cell proliferation. In vitro tissue cultures of transformed and normal rat glial cells were exposed to an 836.55 MHz, packet-modulated RF field at three power densities: 0.09, 0.9, and 9 mW/cm2, resulting in specific absorption rates (SARs) ranging from 0.15 to 59 muW/g. TEM-mode transmission-line cells were powered by a prototype time-domain multiple-access (TDMA) transmitter that conforms to the North American digital cellular telephone standard. One sham and one energized TEM cell were placed in standard incubators

maintained at 37 degrees C and 5% CO2. DNA synthesis experiments at 0.59-59 muW/g SAR were performed on log-phase and serum-starved semiquiescent cultures after 24 h exposure. Cell growth at 0.15-15 muW/g SAR was determined by cell counts of log-phase cultures on days 0, 1, 5, 7, 9, 12, and 14 of a 2 week protocol. Results from the DNA synthesis assays differed for the two cell types. Sham-exposed and RF-exposed cultures of primary rat glial cells showed no significant differences for either log-phase or serum-starved condition. C6 glioma cells exposed to RF at 5.9 muW/g SAR (0.9 mW/cm2) exhibited small (20-40%) significant increases in 38% of [3H]thymidine incorporation experiments. Growth curves of sham and RF-exposed cultures showed no differences in either normal or transformed glial cells at any of the power densities tested. Cell doubling times of C6 glioma cells [sham (21.9 +/- 1.4 h) vs. field (22.7 +/- 3.2 h)] also demonstrated no significant differences that could be attributed to altered DNA synthesis rates. Under these conditions, this modulated RF field did not increase cell proliferation of normal or transformed cultures of glial origin.

**Stagg RB, Hawel LH III, Pastorian K, Cain C, Adey WR, Byus CV, Effect of immobilization and concurrent exposure to a pulse-modulated microwave field on core body temperature, plasma ACTH and corticosteroid, and brain ornithine decarboxylase, Fos and Jun mRNA. Radiat Res 155(4):584-592, 2001.**

Effect of Immobilization and Concurrent Exposure to a Pulse-Modulated Microwave Field on Core Body Temperature, Plasma ACTH and Corticosteroid, and Brain Ornithine Decarboxylase, Fos and Jun mRNA. Exposure of humans and rodents to radiofrequency (RF) cell phone fields has been reported to alter a number of stress- related parameters. To study this potential relationship in more detail, tube-restrained immobilized Fischer 344 rats were exposed in the near field in a dose-dependent manner to pulse-modulated (11 packets/s) digital cell phone microwave fields at 1.6 GHz in accordance with the Iridium protocol. Core body temperatures, plasma levels of the stress-induced hormones adrenocorticotrophic hormone (ACTH) and corticosterone, and brain levels of ornithine decarboxylase (Odc), Fos and Jun mRNAs were measured as potential markers of stress responses mediated by RF radiation. We tested the effects of the loose-tube immobilization with and without prior conditioning throughout a 2-h period (required for near-field head exposure to RF fields), on core body temperature, plasma ACTH and corticosteroids. Core body temperature increased transiently (+/-0.3 degrees C) during the initial 30 min of loose- tube restraint in conditioned animals. When conditioned/tube-trained animals were followed as a function of time after immobilization, both the ACTH and corticosterone levels were increased by nearly 10-fold. For example, within 2-3 min, ACTH increased to 83.2 +/- 31.0 pg/dl, compared to 28.1 +/- 7.7 pg/dl for cage controls, reaching a maximum at 15-30 min (254.6 +/- 46.8 pg/dl) before returning to near resting levels by 120 min (31.2 +/- 10.2 pg/dl). However, when non-tube-trained animals were submitted to loose-tube immobilization, these animals demonstrated significantly higher (3-10-fold greater) hormone levels at 120 min than their tube-trained counterparts (313.5 +/- 54.8 compared to 31.2 +/- 10.2 pg/dl; corticosterone, 12.2 +/- 6.2 ?g/dl compared to 37.1 +/- 6.4 ?g/dl). Hormone levels in exposed animals were also compared to those in swim-stressed animals. Swimming stress also resulted in marked elevation in both ACTH and corticosterone levels, which were 10-20 fold higher (541.8 compared to 27.2-59.1 pg/dl for ACTH) and 2-5 fold higher (45.7 compared to 8.4- 20.0 ?g/dl for corticosteroids)

than the cage control animals. Three time-averaged brain SAR levels of 0.16, 1.6 and 5 W/ kg were tested in a single 2-h RF-field exposure to the Iridium cell phone field. When RF-exposed and sham-exposed (immobilized) animals were compared, no differences were seen in core body temperature, corticosterone or ACTH that could be attributed to near-field RF radiation. Levels of Odc, Fos and Jun mRNA were also monitored in brains of animals exposed to the RF field for 2 h, and they showed no differences from sham-exposed (loose-tube immobilized) animals that were due to RF-field exposure. These data suggest that a significant stress response, indicated by a transient increase in core body temperature, ACTH and corticosterone, occurred in animals placed in even the mild loose-tube immobilization required for near-field RF exposure employed here and in our other studies. Failure to adequately characterize and control this immobilization response with appropriate cage control animals, as described previously, could significantly mask any potential effects mediated by the RF field on these and other stress-related parameters. We conclude that the pulse-modulated digital Iridium RF field at SARs up to 5 W/kg is incapable of altering these stress-related responses. This conclusion is further supported by our use of an RF-field exposure apparatus that minimized immobilization stress; the use of conditioned/tube-trained animals and the measurement of hormonal and molecular markers after 2 h RF-field exposure when the stress-mediated effects were complete further support our conclusion.

**Stang A, Anastassiou G, Ahrens W, Bromen K, Bornfeld N, Jockel KH, The possible role of radiofrequency radiation in the development of uveal melanoma. Epidemiology 12(1):7-12, 2001.**

There are few epidemiologic studies dealing with electromagnetic radiation and uveal melanoma. The majority of these studies are exploratory and are based on job and industry titles only. We conducted a hospital-based and population-based case-control study of uveal melanoma and occupational exposures to different sources of electromagnetic radiation, including radiofrequency radiation. We then pooled these results. We interviewed a total of 118 female and male cases with uveal melanoma and 475 controls matching on sex, age, and study regions. Exposure to radiofrequency-transmitting devices was rated as (a) no radiofrequency radiation exposure, (b) possible exposure to mobile phones, or (c) probable/certain exposure to mobile phones. Exposures were rated independently by two of the authors who did not know case or control status. We used conditional logistic regression to calculate odds ratios (ORs) and 95% confidence intervals (95% CIs). We found an elevated risk for exposure to radiofrequency-transmitting devices (exposure to radio sets, OR = 3.0, 95% CI = 1.4-6.3; probable/certain exposure to mobile phones, OR = 4.2, 95% CI = 1.2-14.5). Other sources of electromagnetic radiation such as high-voltage lines, electrical machines, complex electrical environments, visual display terminals, or radar units were not associated with uveal melanoma. This is the first study describing an association between radiofrequency radiation exposure and uveal melanoma. Several methodologic limitations prevent our results from providing clear evidence on the hypothesized association.

**Stang A, Schmidt-Pokrzywniak A, Lash TL, Lommatzsch PK, Taubert G, Bornfeld N, Jöckel KH. Mobile phone use and risk of uveal melanoma: results of the risk factors for uveal melanoma Case-control study. J Natl Cancer Inst. 101(2):120-123, 2009.**

We recently reported an increased risk of uveal melanoma among mobile phone users. Here, we present the results of a case-control study that assessed the association between mobile phone use and risk of uveal melanoma. We recruited 459 uveal melanoma case patients at the University of Duisburg-Essen and matched 455 case patients with 827 population control subjects, 133 with 180 ophthalmologist control subjects, and 187 with 187 sibling control subjects. We used a questionnaire to assess mobile phone use and estimated odds ratios (ORs) and 95% confidence intervals (95% CIs) of risk for uveal melanoma using conditional logistic regression. Risk of uveal melanoma was not associated with regular mobile phone use (OR = 0.7, 95% CI = 0.5 to 1.0 vs population control subjects; OR = 1.1, 95% CI = 0.6 to 2.3 vs ophthalmologist control subjects; and OR = 1.2, 95% CI = 0.5 to 2.6 vs sibling control subjects), and we observed no trend for cumulative measures of exposure. We did not corroborate our previous results that showed an increased risk of uveal melanoma among regular mobile phone users.

**Stankiewicz W, Dąbrowski MP, Kubacki R, Sobiczewska E, Szmigielski S Immunotropic influence of 900 MHz microwave GSM signal on human blood immune cells activated in vitro. Electromag Biol Med 25(1): 45-51, 2006.**

In an earlier study we reported that $G_o$ phase peripheral blood mononulclear cells (PBMC) exposed to low-level (SAR = 0.18 W/kg) pulse-modulated 1300 MHz microwaves and subsequently cultured, demonstrate changed immune activity (Dabrowski et al., 2003). We investigated whether cultured immune cells induced into the active phases of cell cycle ($G_1$, S) and then exposed to microwaves will also be sensitive to electromagnetic field. An anechoic chamber of our design containing a microplate with cultured cells and an antenna emitting microwaves (900 MHz simulated GSM signal, 27 V/m, SAR 0.024 W/kg) was placed inside the ASSAB incubator. The microcultures of PBMC exposed to microwaves demonstrated significantly higher response to mitogens and higher immunogenic activity of monocytes (LM index) than control cultures. LM index, described in detail elsewhere (Dabrowski et al., 2001), represents the monokine influence on lymphocyte mitogenic response. The results suggest that immune activity of responding lymphocytes and monocytes can be additionally intensified by 900 MHz microwaves.

**Stark KD, Krebs T, Altpeter E, Manz B, Griot C, Abelin T, Absence of chronic effect of exposure to short-wave radio broadcast signal on salivary melatonin concentrations in dairy cattle. J Pineal Res 22(4):171-176, 1997.**

A pilot study was conducted to investigate the influence of electromagnetic fields in the short-wave range (3-30 MHz) radio transmitter signals on salivary melatonin concentration in dairy cattle. The hypothesis to be tested was whether EMF exposure would lower salivary melatonin concentrations, and whether removal of the EMF source would be followed by higher concentration levels. For this pilot study, a controlled intervention trial was designed. Two commercial dairy herds at two farms were compared, one located at a distance of 500 m (exposed), the other at a distance of 4,000 m (unexposed) from the transmitter. At each farm, five cows were monitored with respect to their salivary melatonin concentrations over a period of ten consecutive days. Saliva samples were collected at two-hour intervals during the dark phase of the night. As an

additional intervention, the short-wave transmitter was switched off during three of the ten days (off phase). The samples were analyzed using a radioimmunoassay. The average nightly field strength readings were 21-fold greater on the exposed farm (1.59 mA/m) than on the control farm (0.076 mA/m). The mean values of the two initial nights did not show a statistically significant difference between exposed and unexposed cows. Therefore, a chronic melatonin reduction effect seemed unlikely. However, on the first night of re-exposure after the transmitter had been off for three days, the difference in salivary melatonin concentration between the two farms (3.89 pg/ml, CI: 2.04, 7.41) was statistically significant, indicating a two- to seven-fold increase of melatonin concentration. Thus, a delayed acute effect of EMF on melatonin concentration cannot completely be excluded. However, results should be interpreted with caution and further trials are required in order to confirm the results.

**Stasinopoulou M, Fragopoulou AF, Stamatakis A, Mantziaras G, Skouroliakou K, Papassideri IS, Stylianopoulou F, Lai H, Kostomitsopoulos N, Margaritis LH. Effects of pre- and postnatal exposure to 1880-1900MHz DECT base radiation on development in the rat. Reprod Toxicol. 65:248-262, 2016.**

In the present study, to evaluate the effects of wireless 1880-1900MHz Digital Enhanced Communication Telephony (DECT) base radiation on fetal and postnatal development, Wistar rats were exposed at an average electric field intensity of 3.7V/m, 12h/day, during pregnancy. After parturition, a group of dams and offspring were similarly exposed for another 22days. Controls were sham-exposed. The data showed that DECT base radiation exposure caused heart rate increase in the embryos on the 17th day of pregnancy. Moreover, significant changes on the newborns' somatometric characteristics were noticed. Pyramidal cell loss and glia fibrilliary acidic protein (GFAP) over-expression were detected in the CA4 region of the hippocampus of the 22-day old pups that were irradiated either during prenatal life or both pre- and postnatally. Changes in the integrity of the brain in the 22-day old pups could potentially be related to developmental behavioral changes during the fetal period.

**Stefanics G, Kellenyi L, Molnar F, Kubinyi G, Thuroczy G, Hernadi I. Short GSM mobile phone exposure does not alter human auditory brainstem response. BMC Public Health.7:325,2007.**

ABSTRACT: BACKGROUND: There are about 1.6 billion GSM cellular phones in use throughout the world today. Numerous papers have reported various biological effects in humans exposed to electromagnetic fields emitted by mobile phones. The aim of the present study was to advance our understanding of potential adverse effects of the GSM mobile phones on the human hearing system. METHODS: Auditory Brainstem Response (ABR) was recorded with three non-polarizing Ag-AgCl scalp electrodes in thirty young and healthy volunteers (age 18-26 years) with normal hearing. ABR data were collected before, and immediately after a 10 minute exposure to 900 MHz pulsed electromagnetic field (EMF) emitted by a commercial Nokia 6310 mobile phone. Fifteen subjects were exposed to genuine EMF and fifteen to sham EMF in a double blind and counterbalanced order. Possible effects of irradiation was analyzed by comparing the latency of ABR waves I, III and V before

and after genuine/sham EMF exposure. RESULTS: Paired sample t-test was conducted for statistical analysis. Results revealed no significant differences in the latency of ABR waves I, III and V before and after 10 minutes of genuine/sham EMF exposure. CONCLUSIONS: The present results suggest that, in our experimental conditions, a single 10 minute exposure of 900 MHz EMF emitted by a commercial mobile phone does not produce measurable immediate effects in the latency of auditory brainstem waves I, III and V.

**Stefanics G, Thuróczy G, Kellényi L, Hernádi I. Effects of twenty-minute 3G mobile phone irradiation on event related potential components and early gamma synchronization in auditory oddball paradigm. Neuroscience. 157(2):453-462, 2008.**

We investigated the potential effects of 20 min irradiation from a new generation Universal Mobile Telecommunication System (UMTS) 3G mobile phone on human event related potentials (ERPs) in an auditory oddball paradigm. In a double-blind task design, subjects were exposed to either genuine or sham irradiation in two separate sessions. Before and after irradiation subjects were presented with a random series of 50 ms tone burst (frequent standards: 1 kHz, P=0.8, rare deviants: 1.5 kHz, P=0.2) at a mean repetition rate of 1500 ms while electroencephalogram (EEG) was recorded. The subjects' task was to silently count the appearance of targets. The amplitude and latency of the N100, N200, P200 and P300 components for targets and standards were analyzed in 29 subjects. We found no significant effects of electromagnetic field (EMF) irradiation on the amplitude and latency of the above ERP components. In order to study possible effects of EMF on attentional processes, we applied a wavelet-based time-frequency method to analyze the early gamma component of brain responses to auditory stimuli. We found that the early evoked gamma activity was insensitive to UMTS RF exposition. Our results support the notion, that a single 20 min irradiation from new generation 3G mobile phones does not induce measurable changes in latency or amplitude of ERP components or in oscillatory gamma-band activity in an auditory oddball paradigm.

**Stewart A, Rao JN, Middleton JD, Pearmain P, Evans T. Mobile telecommunications and health: report of an investigation into an alleged cancer cluster in Sandwell, West Midlands.Perspect Public Health. 132(6):299-304, 2012.**

Aims: Residents of one street expressed concern about the number of incident cancers, following the installation of a nearby mobile phone base station. The investigation explored whether the base station could be responsible for the cancers. Methods: Data were collected from residents' medical records. GPs and oncologists provided further information. Results: Ward-level cancer incidence and mortality data were also obtained, over four three-year time periods. A total of 19 residents had developed cancer. The collection of cancers did not fulfil the criteria for a cancer cluster. Standardized mortality ratios (SMRs) for all malignant neoplasms (excluding non-melanoma skin cancers) in females (1.38 (95% CI, 1.08-1.74)) and all persons (1.27 (CI, 1.06-1.51)) were significantly higher than in the West Midlands during 2001-3. There were no significant differences for colorectal, female breast and prostate cancers, for any time period. Standardized incidence ratios (SIRs) for non-melanoma skin cancers in males and all persons was significantly lower than in the West Midlands during 1999-2001, and

significantly lower in males, females and all persons during 2002-4. Conclusions: We cannot conclude that the base station was responsible for the cancers. It is unlikely that information around a single base station can either demonstrate or exclude causality.

**Stopczyk D, Gnitecki W, Buczynski A, Markuszewski L, Buczynski J. Med Pr 53(4):311-314, 2002.** [Article in Polish]

The aim of the study was to assess in vitro the effect of electromagnetic field produced by mobile phones on the activity of superoxide dismutase (SOD-1) and the level of malonyldialdehyde (MDA) in human blood platelets. The suspension of blood platelets was exposed to the electromagnetic field with the frequency of 900 MHz for 1, 3, 5, and 7 min. Our studies demonstrated that microwaves produced by mobiles significantly depleted SOD-1 activity after 1, 5, and 7 min of exposure and increased after 3 min in comparison with the control test. There was a significant increase in the concentration of MDA after 1, 5, and 7 min and decrease after 3 min of exposure as compared with the control test. On the grounds of our results we conclude that oxidative stress after exposure to microwaves may be the reason for many adverse changes in cells and may cause a number of systemic disturbances in the human body.

**Stovner LJ, Oftedal G, Straume A, Johnsson A. Nocebo as headache trigger: evidence from a sham-controlled provocation study with RF fields. Acta Neurol Scand Suppl. 188:67-71, 2008.**

BACKGROUND: A large proportion of the population in Norway has experienced headache in connection with mobile phone use, but several double-blind provocation studies with radiofrequency (RF) and sham exposures have shown no relation between headache and mobile phone RF fields. AIMS: To investigate the type and location of headache experienced by participants in one provocation study in order to gain insight into possible causes and mechanisms of the headaches. METHOD: Questionnaire about headache, indication on figure of location of headache after exposure, interview with neurologist about headache features to make headache diagnoses. RESULTS: The 17 participants went through 130 trials (sham or RF exposure). No significant difference existed in headache type, laterality or location between the headaches experienced with the two exposures types. In most participants, the headache was compatible with tension-type headache. DISCUSSION: As participants experienced their typical 'mobile phone headache' both with and without RF exposure, and since the experiment did not involve the stress or the arm/head position of mobile phone use, the most likely explanation is that the headache in this situation is caused by negative expectations (nocebo). CONCLUSION: This and other similar studies indicate that headache occurring in connection with mobile phone use is not related to RF fields, and that a nocebo effect is important for this and possibly other headache triggers.

**Straume A, Oftedal G, Johnsson A. Skin temperature increase caused by a mobile phone: A methodological infrared camera study. Bioelectromagnetics. 26(6):510-519, 2005.**

Mobile phone users often complain about burning sensations or a heating of the ear region. The increase in temperature may be due to thermal insulation by the phone,

heating of the mobile phone resulting from its electrical power dissipation, and radio frequency (RF) exposure. The main objective of this study was to use infrared (IR) camera techniques to find how much each of these factors contributes to the increase in skin temperature resulting from the use of one GSM 900 phone. One subject, a healthy male took part in the study. He was holding the phone in a normal position when the phone was switched off, when it was switched on but with the antenna replaced by a 50 Omega load to eliminate the RF exposure, and when it was transmitting RF fields. The output power could be fixed, and the minimal and the maximal power levels of the phone were used. The study was designed as a double blind experiment. The changes in temperature after 15 and 30 min of mobile phone use were calculated on the exposed side of the head relative to the unexposed side. The insulation and the electrical power dissipation lead to statistically significant rises in the skin temperature, while the RF exposure did not.

**Straume A, Johnsson A, Oftedal G, Wilén J. Frequency spectra from current vs. magnetic flux density measurements for mobile phones and other electrical appliances. Health Phys. 93(4):279-287, 2007.**

The frequency spectra of electromagnetic fields have to be determined to evaluate human exposure in accordance to ICNIRP guidelines. In the literature, comparisons with magnetic field guidelines have been performed by using the frequency distribution of the current drawn from the battery. In the present study we compared the frequency spectrum in the range 217 Hz to 2.4 kHz of the magnetic flux density measured near the surface of a mobile phone with the frequency spectrum of the supply current. By using the multiple frequency rule, recommended in the ICNIRP guidelines, we estimated the magnetic field exposure in the two cases. Similar measurements and estimations were done for an electric drill, a hair dryer, and a fluorescent desk lamp. All the devices have a basic frequency of 50 Hz, and the frequency spectra were evaluated up to 550 Hz. We also mapped the magnetic field in 3D around three mobile phones. The frequency distributions obtained from the two measurement methods are not equal. The frequency content of the current leads to an overestimation of the magnetic field exposure by a factor up to 2.2 for the mobile phone. For the drill, the hair dryer, and the fluorescent lamp, the supply current signal underestimated the exposure by a factor up to 2.3. In conclusion, an accurate exposure evaluation requires the magnetic flux density spectrum of the device to be measured directly. There was no indication that the devices studied would exceed the reference levels at the working distances normally used.

**Strayer DL, Johnston WA. Driven to distraction: dual-Task studies of simulated driving and conversing on a cellular telephone. Psychol Sci 12(6):462-466, 2001.**

Dual-task studies assessed the effects of cellular-phone conversations on performance of a simulated driving task. Performance was not disrupted by listening to radio broadcasts or listening to a book on tape. Nor was it disrupted by a continuous shadowing task using a handheld phone, ruling out, in this case, dual-task interpretations associated with holding the phone, listening, or speaking, However significant interference was observed in a word-generation variant of the shadowing task, and this deficit increased with the difficulty of driving. Moreover unconstrained conversations using either a handheld or a hands-free cell phone resulted in a twofold increase in the failure to detect simulated

traffic signals and slower reactions to those signals that were detected. We suggest that cellular-phone use disrupts performance by diverting attention to an engaging cognitive context other than the one immediately associated with driving.

**Strayer DL, Drews FA, Johnston WA. Cell phone-induced failures of visual attention during simulated driving. J Exp Psychol Appl 9(1):23-32, 2003.**

This research examined the effects of hands-free cell phone conversations on simulated driving. The authors found that these conversations impaired driver's reactions to vehicles braking in front of them. The authors assessed whether this impairment could be attributed to a withdrawal of attention from the visual scene, yielding a form of inattention blindness. Cell phone conversations impaired explicit recognition memory for roadside billboards. Eye-tracking data indicated that this was due to reduced attention to foveal information. This interpretation was bolstered by data showing that cell phone conversations impaired implicit perceptual memory for items presented at fixation. The data suggest that the impairment of driving performance produced by cell phone conversations is mediated, at least in part, by reduced attention to visual inputs.

**Strayer DL, Drews FA. Profiles in driver distraction: effects of cell phone conversations on younger and older drivers. Hum Factors. 46(4):640-649, 2004.**

Our research examined the effects of hands-free cell phone conversations on simulated driving. We found that driving performance of both younger and older adults was influenced by cell phone conversations. Compared with single-task (i.e., driving-only) conditions, when drivers used cell phones their reactions were 18% slower, their following distance was 12% greater, and they took 17% longer to recover the speed that was lost following braking. There was also a twofold increase in the number of rear-end collisions when drivers were conversing on a cell phone. These cell-phone-induced effects were equivalent for younger and older adults, suggesting that older adults do not suffer a significantly greater penalty for talking on a cell phone while driving than compared with their younger counterparts. Interestingly, the net effect of having younger drivers converse on a cell phone was to make their average reactions equivalent to those of older drivers who were not using a cell phone. Actual or potential applications of this research include providing guidance for recommendations and regulations concerning the use of mobile technology while driving.

**Strobos MA, Coenraads PJ, De Jongste MJ, Ubels FL. Dermatitis caused by radio-frequency electromagnetic radiation. Contact Dermatitis 44(5):309, 2001.**

A case report of a woman who developed dermatitis to a transmitter placed on the abdomen that sent radio waves to an implanted neurostimulatory receiver for angina. Patch tests with the plastic, rubber and glue of the transmitter were negative, as well as those with various components of the device from the manufacturer. She had skin symptoms only after starting stimulation, with spontaneous improvement in between times.

**Stronati L, Testa A, Moquet J, Edwards A, Cordelli E, Villani P, Marino C, Fresegna AM, Appolloni M, Lloyd D. 935 MHz cellular phone radiation. An in vitro study of genotoxicity in human lymphocytes. Int J Radiat Biol. 82(5):339-346, 2006.**

Purpose: The possibility of genotoxicity of radiofrequency radiation (RFR) applied alone or in combination with x-rays was investigated in vitro using several assays on human lymphocytes. The chosen specific absorption rate (SAR) values are near the upper limit of actual energy absorption in localized tissue when persons use some cellular telephones. The purpose of the combined exposures was to examine whether RFR might act epigenetically by reducing the fidelity of repair of DNA damage caused by a well-characterized and established mutagen.Methods: Blood specimens from 14 donors were exposed continuously for 24 h to a Global System for Mobile Communications (GSM) basic 935 MHz signal. The signal was applied at two SAR; 1 and 2 W/Kg, alone or combined with a 1-min exposure to 1.0 Gy of 250 kVp x-rays given immediately before or after the RFR. The assays employed were the alkaline comet technique to detect DNA strand breakage, metaphase analyses to detect unstable chromosomal aberrations and sister chromatid exchanges, micronuclei in cytokinesis-blocked binucleate lymphocytes and the nuclear division index to detect alterations in the speed of in vitro cell cycling.Results: By comparison with appropriate sham-exposed and control samples, no effect of RFR alone could be found for any of the assay endpoints. In addition RFR did not modify any measured effects of the x-radiation.Conclusions: This study has used several standard in vitro tests for chromosomal and DNA damage in Go human lymphocytes exposed in vitro to a combination of x-rays and RFR. It has comprehensively examined whether a 24-h continuous exposure to a 935 MHz GSM basic signal delivering SAR of 1 or 2 W/Kg is genotoxic per se or whether, it can influence the genotoxicity of the well-established clastogenic agent; x-radiation. Within the experimental parameters of the study in all instances no effect from the RFR signal was observed.

**Stutts J, Feaganes J, Rodgman E, Hamlett C, Reinfurt D, Gish K, Mercadante M, Staplin L. The causes and consequences of distraction in everyday driving. Annu Proc Assoc Adv Automot Med. 47:235-251, 2003.**

ABSTRACT To document drivers' exposure to potential distractions and the effects of these distractions on driving performance, inconspicuous video camera units were mounted in the vehicles of 70 volunteer subjects. The camera units automatically recorded a closeup view of the driver's face, a broader view of the interior of the vehicle, and the roadway immediately ahead of the vehicle whenever it was powered on. Three hours of randomly selected data per subject were coded based on a taxonomy of driver distractions (talking on cell phone, eating, tuning radio, etc.), contextual variables (whether vehicle stopped or moving, road type, traffic level, etc.) and observable measures of driver performance (eyes directed inside or outside vehicle, hands on or off steering wheel, and vehicle position in travel lane). Results were analyzed descriptively and using nonparametric bootstrap analysis techniques. The most common distractions in terms of overall event durations were eating and drinking (including preparations to eat or drink), distractions inside the vehicle (reaching or looking for an object, manipulating vehicle controls, etc.), and distractions outside the vehicle (often unidentified). Although many of the distractions were also associated with negative driving performance outcomes, further research is needed to clarify their impact on driving safety.

**Su L, Wei X, Xu Z, Chen G. RF-EMF exposure at 1800 MHz did not elicit DNA damage or abnormal cellular behaviors in different neurogenic cells. Bioelectromagnetics. 38(3):175-185, 2017.**

Despite many years of studies, the debate on genotoxic effects of radiofrequency electromagnetic fields (RF-EMF) continues. To systematically evaluate genotoxicity of RF-EMF, this study examined effects of RF-EMF on DNA damage and cellular behavior in different neurogenic cells. Neurogenic A172, U251, and SH-SY5Y cells were intermittently (5 min on/10 min off) exposed to 1800 MHz RF-EMF at an average specific absorption rate (SAR) of 4.0 W/kg for 1, 6, or 24 h. DNA damage was evaluated by quantification of γH2AX foci, an early marker of DNA double-strand breaks. Cell cycle progression, cell proliferation, and cell viability were examined by flow cytometry, hemocytometer, and cell counting kit-8 assay, respectively. Results showed that exposure to RF-EMF at an SAR of 4.0 W/kg neither significantly induced γH2AX foci formation in A172, U251, or SH-SY5Y cells, nor resulted in abnormal cell cycle progression, cell proliferation, or cell viability. Furthermore, prolonged incubation of these cells for up to 48 h after exposure did not significantly affect cellular behavior. Our data suggest that 1800 MHz RF-EMF exposure at 4.0 W/kg is unlikely to elicit DNA damage or abnormal cellular behaviors in neurogenic cells.[1]

**Sudan M, Kheifets L, Arah O, Olsen J, Zeltzer L. Prenatal and Postnatal Cell Phone Exposures and Headaches in Children. Open Pediatr Med Journal. 6(2012):46-52, 2012.**

OBJECTIVE: Children today are exposed to cell phones early in life, and may be at the greatest risk if exposure is harmful to health. We investigated associations between cell phone exposures and headaches in children. STUDY DESIGN: The Danish National Birth Cohort enrolled pregnant women between 1996 and 2002. When their children reached age seven years, mothers completed a questionnaire regarding the child's health, behaviors, and exposures. We used multivariable adjusted models to relate prenatal only, postnatal only, or both prenatal and postnatal cell phone exposure to whether the child had migraines and headache-related symptoms. RESULTS: Our analyses included data from 52,680 children. Children with cell phone exposure had higher odds of migraines and headache-related symptoms than children with no exposure. The odds ratio for migraines was 1.30 (95% confidence interval: 1.01-1.68) and for headache-related symptoms was 1.32 (95% confidence interval: 1.23-1.40) for children with both prenatal and postnatal exposure. CONCLUSIONS: In this study, cell phone exposures were associated with headaches in children, but the associations may not be causal given the potential for uncontrolled confounding and misclassification in observational studies such as this. However, given the widespread use of cell phones, if a causal effect exists it would have great public health impact.

**Sudan M, Kheifets L, Arah OA, Olsen J. Cell phone exposures and hearing loss in children in the danish national birth cohort. Paediatr Perinat Epidemiol. 27(3):247-257, 2013.**

**BACKGROUND:** Children today are exposed to cell phones early in life, and may be the most vulnerable if exposure is harmful to health. We investigated the association between

cell phone use and hearing loss in children. **METHODS:** The Danish National Birth Cohort (DNBC) enrolled pregnant women between 1996 and 2002. Detailed interviews were conducted during gestation, and when the children were 6 months, 18 months and 7 years of age. We used multivariable-adjusted logistic regression, marginal structural models (MSM) with inverse-probability weighting, and doubly robust estimation (DRE) to relate hearing loss at age 18 months to cell phone use at age 7 years, and to investigate cell phone use reported at age 7 in relation to hearing loss at age 7. **RESULTS:** Our analyses included data from 52 680 children. We observed weak associations between cell phone use and hearing loss at age 7, with odds ratios and 95% confidence intervals from the traditional logistic regression, MSM and DRE models being 1.21 [95% confidence interval [CI] 0.99, 1.46], 1.23 [95% CI 1.01, 1.49] and 1.22 [95% CI 1.00, 1.49], respectively. **CONCLUSIONS:** Our findings could have been affected by various biases and are not sufficient to conclude that cell phone exposures have an effect on hearing. This is the first large-scale epidemiologic study to investigate this potentially important association among children, and replication of these findings is needed.

**Sudan M, Kheifets LI, Arah OA, Divan HA, Olsen J. Complexities of sibling analysis when exposures and outcomes change with time and birth order. Expo Sci Environ Epidemiol. 2013 Sep 25. doi: 10.1038/jes.2013.56. [Epub ahead of print]**

In this study, we demonstrate the complexities of performing a sibling analysis with a re-examination of associations between cell phone exposures and behavioral problems observed previously in the Danish National Birth Cohort. Children (52,680; including 5441 siblings) followed up to age 7 were included. We examined differences in exposures and behavioral problems between siblings and non-siblings and by birth order and birth year. We estimated associations between cell phone exposures and behavioral problems while accounting for the random family effect among siblings. The association of behavioral problems with both prenatal and postnatal exposure differed between siblings (odds ratio (OR): 1.07; 95% confidence interval (CI): 0.69-1.66) and non-siblings (OR: 1.54; 95% CI: 1.36-1.74) and within siblings by birth order; the association was strongest for first-born siblings (OR: 1.72; 95% CI: 0.86-3.42) and negative for later-born siblings (OR: 0.63; 95% CI: 0.31-1.25), which may be because of increases in cell phone use with later birth year. Sibling analysis can be a powerful tool for (partially) accounting for confounding by invariant unmeasured within-family factors, but it cannot account for uncontrolled confounding by varying family-level factors, such as those that vary with time and birth order.

**Sukhotina I, Streckert JR, Bitz AK, Hansen VW, Lerchl A. 1800 MHz electromagnetic field effects on melatonin release from isolated pineal glands. J Pineal Res. 40(1):86-91, 2006.**

Isolated pineal glands of Djungarian hamsters (Phodopus sungorus) were continuously perifused by Krebs-Ringer buffer, stimulated with the beta-adrenergic receptor agonist isoproterenol to induce melatonin synthesis, and exposed for 7 hr to a 1800 MHz continuous wave (CW) or pulsed GSM (Global System for Mobile Communications)-modulated electromagnetic signal at specific absorption rate (SAR) rates of 8, 80, 800, and 2700 mW/kg. Experiments were performed in a blind fashion. Perifusate samples

were collected every hour, and melatonin concentrations were measured by a specific radioimmunoassay. Both types of signal significantly enhanced melatonin release at 800 mW/kg SAR, while at 2700 mW/kg SAR, melatonin levels were elevated in the CW, but suppressed in the GSM-exposed pineal glands. As a temperature rise of approximately 1.2 degrees C was measured at 2700 mW/kg SAR, effects at this level are thermal. With regard to radiofrequency electromagnetic fields, the data do not support the 'melatonin hypothesis,' according to which nonthermal exposure suppresses melatonin synthesis.

**Sun C, Wei X, Fei Y, Su L, Zhao X, Chen G, Xu Z. Mobile phone signal exposure triggers a hormesis-like effect in Atm+/+ and Atm-/- mouse embryonic fibroblasts. Sci Rep. 2016 Nov 18;6:37423. doi: 10.1038/srep37423.**

Radiofrequency electromagnetic fields (RF-EMFs) have been classified by the International Agency for Research on Cancer as possible carcinogens to humans; however, this conclusion is based on limited epidemiological findings and lacks solid support from experimental studies. In particular, there are no consistent data regarding the genotoxicity of RF-EMFs. Ataxia telangiectasia mutated (ATM) is recognised as a chief guardian of genomic stability. To address the debate on whether RF-EMFs are genotoxic, we compared the effects of 1,800 MHz RF-EMF exposure on genomic DNA in mouse embryonic fibroblasts (MEFs) with proficient ($Atm^{+/+}$) or deficient ($Atm^{-/-}$) ATM. In $Atm^{+/+}$ MEFs, RF-EMF exposure for 1 h at an average special absorption rate of 4.0 W/kg induced significant DNA single-strand breaks (SSBs) and activated the SSB repair mechanism. This effect reduced the DNA damage to less than that of the background level after 36 hours of exposure. In the $Atm^{-/-}$ MEFs, the same RF-EMF exposure for 12 h induced both SSBs and double-strand breaks and activated the two repair processes, which also reduced the DNA damage to less than the control level after prolonged exposure. The observed phenomenon is similar to the hormesis of a toxic substance at a low dose. To the best of our knowledge, this study is the first to report a hormesis-like effect of an RF-EMF.

**Sun LX, Yao K, He JL, Lu DQ, Wang KJ, Li HW. [Effect of acute exposure to microwave from mobile phone on DNA damage and repair of cultured human lens epithelial cells in vitro.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 24(8):465-467, 2006.** [Article in Chinese]

OBJECTIVE: To investigate the DNA damage of human lens epithelial cells (LECs) caused by acute exposure to low-power 217 Hz modulated 1.8 GHz microwave radiation and DNA repair. METHODS: Cultured LECs were exposed to 217 Hz modulated 1.8 GHz microwave radiation at SAR (specific absorption rate) of 0, 1, 2, 3 and 4 W/kg for 2 hours in an sXc-1800 incubator and irradiate system. The DNA single strand breaks were detected with comet assay in sham-irradiated cells and irradiated cells incubated for varying periods: 0, 30, 60, 120 and 240 min after irradiation. Images of comets were digitized and analyzed using an Imagine-pro plus software, and the indexes used in this study were tail length (TL) and tail moment (TM). RESULTS: The difference in DNA-breaks between the exposure and sham exposure groups induced by 1 and 2 W/kg irradiation was not significant at every detect time ($P > 0.05$). As for the dosage of 3 and 4 W/kg there was difference in both

group immediately after irradiation (P < 0.01). At the time of 30 min after irradiation the difference went on at both group (P < 0.01). However, the difference disappeared after one hour's incubation in 3 W/kg group (P > 0.05), and existed in 4 W/kg group. CONCLUSION: No or repairable DNA damage was observed after 2 hour irradiation of 1.8 GHz microwave on LECs when SAR </= 3 W/kg. The DNA damages caused by 4 W/kg irradiation were irreversible.

**Sun LX, Yao K, Jiang H, He JL, Lu DQ, Wang KJ, Li HW [DNA damage and repair induced by acute exposure of microwave from mobile phone on cultured human lens epithelial cells] Zhonghua Yan Ke Za Zhi. 42(12):1084-1088, 2006.** [Article in Chinese]

OBJECTIVE: To investigate the effects of acute exposure of low-power 217 Hz modulated 1. 8 GHz microwave radiation on the DNA damage of human lens epithelial cells (hLECs) and repair. METHODS: Cultured hLECs were exposed to 217 Hz modulated 1. 8 GHz microwave radiation at SAR (specific absorption rate) of 1. 0, 2. 0, 3. O0 and 4. 0 W/kg for 2 hours in an sXc-1800 incubator and irradiate system, the DNA single strand breaks were detected with comet assay ( single-cell gel electrophoresis) in sham-irradiated cells and irradiated cells incubated for varying periods: 0, 30 and 60 minutes after irradiation. Images of comets were digitized and analyzed using an Imagine-pro plus software, and the indexes used in this study were tail length (TL) and tail moment (TM). BrdU was added into the medium with additional one hour incubation after radiation, the cell proliferation rate was determined using a BrdU-kit. RESULTS: The difference of DNA-breaks between the exposure and sham exposure groups induced by 1.0 and 2.0 W/kg irradiation were not significant in each time points (P > 0.05) ; there were significant difference in both groups at the exposure dose of 3. 0 and 4. 0 W/kg immediately and at the time of 30 minutes after irradiation (P <0. 01) ; if the radiation exposure time was beyond one hour no differences were be able to detected in 3.0 W/kg group (P > 0. 05) compared with control, but the evidence of significant DNA damage still existed in 4. 0 W/kg group at the same time point. Cell proliferation rate had no significant difference when the application of SAR was < or = 3. 0 W/kg (P >0. 05) , however the cell proliferation was decreased significantly at the dose of 4. 0 W/kg irradiation ( P < 0. 01). CONCLUSIONS: No effective DNA damage was induced using comet assay after 2 hours irradiation of 1. 8 GHz microwave on hLECs at the dose SAR < or = 3.0 W/kg. 4.0 W/kg irradiation caused significantly DNA damage and inhibition of hLECs proliferation.

**Sun W, Shen X, Lu D, Lu D, Chiang H. Superposition of an incoherent magnetic field inhibited EGF receptor clustering and phosphorylation induced by a 1.8 GHz pulse-modulated radiofrequency radiation. Int J Radiat Biol. 89:378-383, 2013.**

Purpose: The present study was conducted to investigate the effect of a temporally incoherent ('noise') magnetic field (MF) on radiofrequency radiation (RFR)-induced epidermal growth factor (EGF) receptor clustering and phosporylation in cultured cells. Materials and methods: Human amniotic epithelial (FL) cells were exposed for 15 min to either a 1.8 GHz RFR (modulated at 217 Hz), a 2 μT incoherent MF, or concurrently to the RFR and incoherent MF. Epidermal growth factor treatment severed as the positive control. Epidermal growth factor receptor clustering on cellular membrane surface was analyzed using confocal microscopy after indirect

immunofluorescence staining, and phosphorylation of EGF receptors was measured by western blot technology. Results: Exposure of FL cells to the 1.8 GHz RFR at SAR (specific absorption rate) of 0.5, 1.0, 2.0, or 4.0 W/kg for 15 min induced EGF receptor clustering and enhanced phosphorylation on tyrosine-1173 residue, whereas exposure to RFR at SAR of 0.1 W/kg for 15 min did not significantly cause these effects. Exposure to a 2 μT incoherent MF for 15 min did not significantly affect clustering and phosphorylation of EGF receptor in FL cells. When superimposed, the incoherent MF completely inhibited EGF receptor clustering and phosphorylation induced by RFR at SAR of 0.5, 1.0, and 2.0 W/kg, but did not inhibit the effects induced at SAR of 4.0 W/kg. Conclusion: Based on the data of the experiment, it is suggested that membrane receptors could be one of the main targets by which RFR interacts with cells. An incoherent MF could block the interaction to a certain extent

**Sun W, Shen X, Lu D, Fu Y, Lu D, Chiang H. A 1.8-GHz radiofrequency radiation induces EGF receptor clustering and phosphorylation in cultured human amniotic (FL) cells. Int J Radiat Biol. 88(3):239-244, 2012.**

PURPOSE: Many studies have shown that exposure to radiofrequency radiation (RFR) could activate cellular signal transduction pathways. In the present research, we investigated the effects of exposure to a 1.8-GHz RFR at different intensities on epidermal growth factor (EGF) receptor clustering and phosphorylation in human amniotic (FL) cells.MATERIALS AND METHODS: Receptor clustering on cellular membrane surface was analyzed using immunofluorescence assessed by confocal microscopy, and phosphorylation of EGF receptors was measured by western blot technology. EGF treatment served as a positive control.RESULTS: The results showed that, compared with sham exposure, exposure to RFR at specific absorption rate (SAR) of 0.5, 1.0, 2.0, or 4.0 W/kg for 15 min significantly induced EGF receptor clustering and enhanced phosphorylation on the tyrosine-1173 residue in FL cells, whereas exposure to a SAR 0.1 W/kg radiation for 15 min did not cause a significant effect.CONCLUSION: Based on the results of this experiment, we conclude that membrane receptors could be one of the main targets that RFR interacts with cells, and the dose-rate threshold, in the case of EGF receptors, is between SAR of 0.1 and 0.5 W/kg. The results indicate a sigmoid dependence of RFR effects on intensity.

**Sun Y, Zong L, Gao Z, Zhu S, Tong J, Cao Y. Mitochondrial DNA damage and oxidative damage in HL-60 cells exposed to 900MHz radiofrequency fields. Mutat Res. 797-799:7-14, 2017.**

HL-60 cells, derived from human promyelocytic leukemia, were exposed to continuous wave 900MHz radiofrequency fields (RF) at 120μW/cm2 power intensity for 4h/day for 5 consecutive days to examine whether such exposure is capable damaging the mitochondrial DNA (mtDNA) mediated through the production of reactive oxygen species (ROS). In addition, the effect of RF exposure was examined on 8-hydroxy-2'-dexoyguanosine (8-OHdG) which is a biomarker for oxidative damage and on the mitochondrial synthesis of adenosine triphosphate (ATP) which is the energy required for cellular functions. The results indicated a significant increase in ROS and significant

decreases in mitochondrial transcription factor A, mtDNA polymerase gamma, mtDNA transcripts and mtDNA copy number in RF-exposed cells compared with those in sham-exposed control cells. In addition, there was a significant increase in 8-OHdG and a significant decrease in ATP in RF-exposed cells. The response in positive control cells exposed to gamma radiation (GR, which is also known to induce ROS) was similar to those in RF-exposed cells. Thus, the overall data indicated that RF exposure was capable of inducing mtDNA damage mediated through ROS pathway which also induced oxidative damage. Prior-treatment of RF- and GR-exposed the cells with melatonin, a well-known free radical scavenger, reversed the effects observed in RF-exposed cells.

**Sunohara T, Hirata A, Laakso I, Onishi T. Analysis of in situ electric field and specific absorption rate in human models for wireless power transfer system with induction coupling.Phys Med Biol. 59(14):3721-3735, 2014.**

This study investigates the specific absorption rate (SAR) and the in situ electric field in anatomically based human models for the magnetic field from an inductive wireless power transfer system developed on the basis of the specifications of the wireless power consortium. The transfer system consists of two induction coils covered by magnetic sheets. Both the waiting and charging conditions are considered. The transfer frequency considered in this study is 140 kHz, which is within the range where the magneto-quasi-static approximation is valid. The SAR and in situ electric field in the chest and arm of the models are calculated by numerically solving the scalar potential finite difference equation. The electromagnetic modelling of the coils in the wireless power transfer system is verified by comparing the computed and measured magnetic field distributions. The results indicate that the peak value of the SAR averaged over a 10 g of tissue and that of the in situ electric field are 72 nW $kg^{-1}$ and 91 mV $m^{-1}$ for a transmitted power of 1 W, Consequently, the maximum allowable transmitted powers satisfying the exposure limits of the SAR (2 W $kg^{-1}$) and the in situ electric field (18.9 V $m^{-1}$) are found to be 28 MW and 43 kW. The computational results show that the in situ electric field in the chest is the most restrictive factor when compliance with the wireless power transfer system is evaluated according to international guidelines.

**Suresh S, Sabanayagam C, Kalidindi S, Shankar A. Cell-phone use and self-reported hypertension: national health interview survey 2008.Int J Hypertens.2011:360415, 2011.**

Background. Cell-phone usage has increased dramatically over the last decade, along with a rising public concern over the health effects of using this device. The association between cell-phone usage and hypertension has not been examined before. Methods. We analysed data from 21,135 adults aged ≥18 years who participated in the 2008 National Health Interview Survey. Based on reported cell-phone use, participants were categorized as cell-phone nonusers, predominantly landline users, dual users of cell phone and landline, and predominantly cell-phone users. The main outcome of interest was self-reported physician-diagnosed hypertension (n = 6,793). Results. 43.5% of the participants were cell-phone nonusers, while 13.8% were predominantly cell-phone users. We found that cell-phone use was inversely associated with hypertension,

independent of age, sex, race/ethnicity, smoking, alcohol consumption, education, body mass index (BMI), and physical activity. Compared to cell-phone nonusers, the multivariable odds ratio (95% confidence interval) of hypertension was 0.86 (0.75-0.98, P trend = .005) among predominantly cell-phone users. This inverse association between cell-phone use and hypertension was stronger in women, those aged <60 years, whites, and those with BMI <25 kg/m(2). Conclusion. We found that cell-phone usage was protectively associated with self-reported hypertension in a nationally representative sample of US adults.

**Susa M, Pavicić I. Djelovanje Radiofrekvencijskog Elektromagnetskog Zracenja na Spermatogenez u Sisavaca. Arh Hig Rada Toksikol. 58(4):449-459, 2007.**

This article reviews studies about the effects of radiofrequency electromagnetic (RF EM) fields on male reproductive system and reproductive health in mammals. According to current data, there are almost 4 million active mobile phone lines in Croatia while this number has risen to 2 billion in the world. Increased use of mobile technology raises scientific and public concern about possible hazardous effects of RF fields on human health. The effects of radiofrequencies on reproductive health and consequences for the offspring are still mainly unknown. A number of in vivo and in vitro studies indicated that RF fields could interact with charged intracellular macromolecular structures. Results of several laboratory studies on animal models showed how the RF fields could affect the mammalian reproductive system and sperm cells. Inasmuch as, in normal physiological conditions spermatogenesis is a balanced process of division, maturation and storage of cells, it is particularly vulnerable to the chemical and physical environmental stimuli. Especially sensitive could be the cytoskeleton, composed of charged proteins; actin, intermedial filaments and microtubules. Cytoskeleton is a functional and structural part of the cell that has important role in the sperm motility, and is actively involved in the morphologic changes that occur during mammalian spermiogenesis.

**Suzuki S, Okutsu M, Suganuma R, Komiya H, Nakatani-Enomoto S, Kobayashi S, Ugawa YTateno H, Fujimori K. Influence of radiofrequency-electromagnetic waves from 3rd-generation cellular phones on fertilization and embryo development in mice. Bioelectromagnetics. 38(6):466-473, 2017.**

The purpose of this study was to evaluate the effects of 3rd-generation (3G) cellular phone radiofrequency-electromagnetic wave (RF-EMW) exposure on fertilization and embryogenesis in mice. Oocytes and spermatozoa were exposed to 3G cellular phone RF-EMWs, 1.95 GHz wideband code division multiple access, at a specific absorption rate of 2 mW/g for 60 min, or to sham exposure. After RF-EMW exposure, in vitro fertilization and intracytoplasmic sperm injection were performed. Rates of fertilization, embryogenesis (8-cell embryo, blastocyst), and chromosome aberration were compared between the combined spermatozoa and oocyte groups: both exposed, both non-exposed, one exposed, and the other non-exposed. Rates of fertilization, embryogenesis, and blastocyst formation did not change significantly across the four groups. Considering that the degree of exposure in the present study was ≥100 times greater than daily

exposure of human spermatozoa and even greater than daily exposure of oocytes, the present results indicate safety of RF-EMW exposure in humans.

**Sykes PJ, McCallum BD, Bangay MJ, Hooker AM, Morley AA. Effect of Exposure to 900 MHz Radiofrequency Radiation on Intrachromosomal Recombination in pKZ1 Mice. Radiat Res 156(5):495-502, 2001.**

Radiofrequency (RF) radiation emitted from mobile phones is not considered to be directly genotoxic, but it may have downstream effects on cellular DNA. We studied the effect of 4 W/kg pulsed 900 MHz RF radiation on somatic intrachromosomal recombination in the spleen in the pKZ1 recombination mutagenesis model. Somatic intrachromosomal recombination inversion events were detected in spleen tissue of pKZ1 mice by histochemical staining for E. coli beta-galactosidase protein in cells in which the lacZ transgene has undergone an inversion event. pKZ1 mice were exposed daily for 30 min to plane-wave fields of 900 MHz with a pulse repetition frequency of 217 Hz and a pulse width of 0.6 ms for 1, 5 or 25 days. Three days after the last exposure, spleen sections were screened for DNA inversion events. There was no significant difference between the control and treated groups in the 1- and 5-day exposure groups, but there was a significant reduction in inversions below the spontaneous frequency in the 25-day exposure group. This observation suggests that exposure to RF radiation can lead to a perturbation in recombination frequency which may have implications for recombination repair of DNA. The biological significance of a reduction below the spontaneous frequency is not known. The number of mice in each treatment group in this study was small (n = 10 or n = 20). Therefore, repetition of this study with a larger number of animals is required to confirm these observations.

**Szmigielski, S, Cancer morbidity in subjects occupationally exposed to high frequency (radiofrequency and microwave) electromagnetic radiation. Sci Total Environ 180(1):9-17, 1996.**

Cancer morbidity was registered in the whole population of military career personnel in Poland during a period of 15 years (1971-1985). Subjects exposed occupationally to radiofrequencies (RF) and microwaves (MW) were selected from the population on the basis of their service records and documented exposures at service posts. The population size varied slightly from year to year with a mean count of about 128,000 persons each year; each year about 3700 of them (2.98%) were considered as occupationally exposed to RF/MW. All subjects (exposed and non-exposed to RF/MW) were divided into age groups (20-29, 30-39, 40-49 and 50-59). All newly registered cases of cancer were divided into 12 types based on localisation of the malignancy; for neoplasms of the haemopoietic system and lymphatic organs an additional analysis based on diagnosis was performed. Morbidity rates (per 100,000 subjects annually) were calculated for all of the above localisations and types of malignancies both for the whole population and for the age groups. The mean value of 15 annual rates during 1971-1985 represented the respective morbidity rate for the whole period. Morbidity rates in the non-exposed groups of personnel were used as 'expected' (E) rates for the exposed subjects, while the real morbidity rates counted in the RF/MW-exposed personnel served as 'observed' (O) rates. This allowed the calculation of the observed/expected ratio (OER)

representing the odds ratio for the exposed groups. The cancer morbidity rate for RF/MW-exposed personnel for all age groups (20-59 years) reached 119.1 per 100,000 annually (57.6 in non-exposed) with an OER of 2.07, significant at $P < 0.05$. The difference between observed and expected values results from higher morbidity rates due to neoplasms of the alimentary tract (OER = 3.19-3.24), brain tumours (OER = 1.91) and malignancies of the haemopoietic system and lymphatic organs (OER = 6.31). Among malignancies of the haemopoietic/lymphatic systems, the largest differences in morbidity rates between exposed and non-exposed personnel were found for chronic myelocytic leukaemia (OER = 13.9), acute myeloblastic leukaemia (OER = 8.62) and non-Hodgkin lymphomas (OER = 5.82).

**Szmigielski, S, Bortkiewicz, A, Gadzicka, E, Zmyslony, M, Kubacki, R, Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields. Blood Press Monit 3(6):323-330, 1998.**

BACKGROUND: In previous studies we found measurable effects on variability of heart rate and on blood-pressure parameters of workers exposed to radiofrequency electromagnetic fields (EMF)compared with a control population, but none of the effects could be assigned clinical significance. In general, the obtained results strongly suggested that dysregulation of the autonomic control of the circulatory system was occurring. Therefore, it seemed logical that analysis of diurnal rhythms of blood pressure and heart rate, on the basis of data from 24 h recordings, might further support the above hypothesis. OBJECTIVE: The aim of this study was to determine the course of diurnal rhythms of blood pressure and heart rate in a group of workers exposed to various intensities of radiofrequency electromagnetic fields. METHODS: In the study we used 61 healthy workers (aged 30-50 years) who had been exposed to radiofrequency EMF of 0.738-1.503 Mhz and 42 healthy workers at radio-line stations (aged 28-49 years), who had not been exposed to EMF occupationally. The work patterns of these two groups were identical (12 h day working shift, 24 h interval, 12 h night shift and then 48 h rest). During the second day of the rest period 24 h ambulatory blood pressure (ABP) was recorded. For analysis of diurnal rhythms the group of exposed workers was divided into two subgroups: group A of 38 subjects exposed to low intensities of radiofrequency EMF (20-180 V/m) and group B of 23 subjects exposed to high intensities of radiofrequency EMF (200-550 V/m). Parameters of diurnal rhythms of blood pressure and heart rate (acrophase, amplitude and mean) were calculated by performing a least-square fit of a 24 h cosinor (single cosinor analysis) at $P < 0.05$. RESULTS: Healthy men aged 28-49 years, working on a pattern of 12-24-12-48 h, exhibited typical, well-preserved diurnal rhythms of blood pressure and heart rate with two maxima (at about 1400 and 1700-1800 h) and one minimum (at about 0200-0400 h). For workers exposed to radiofrequency EMF we noted a significant lowering of the amplitudes of rhythms of blood pressure and heart rate ($P < 0.01$) and a shift of the acrophase to an earlier time (1100-1200 h; $P < 0.05$). These changes were more pronounced among workers exposed to high intensities of radiofrequency EMF. CONCLUSIONS: Occupational exposure to radiofrequency EMF can result in changes of the diurnal rhythms of blood pressure and heart rate with lowering of their amplitudes and a shift of the acrophase. The clinical relevance of the present finding needs to be investigated in further studies.

**Szyjkowska A, Bortkiewicz A, Szymczak W, Makowiec-Dabrowska T. [Subjective**

**symptoms related to mobile phone use--a pilot study] Pol Merkuriusz Lek. 19(112):529-532, 2005.** [Article in Polish]

Research findings indicate that the use of mobile phones may lead to a number of symptoms such as headache, impaired concentration and memory, fatigue. In Poland this problem has not as yet been addressed by scientific studies. THE AIM: The present project was undertaken to investigate whether the symptoms of ill health reported by young people may be associated with the use of mobile phone. MATERIAL AND METHODS: A survey using a self-reported questionnaire was conducted among randomly selected university students in Lodz, Central Poland. The questionnaire was designed specifically for this study and contained items on health condition and complaints as well as on frequency of mobile phone use. The number of questionnaires necessary for the study was assessed using the simple random sample method. Out of the 160 copies distributed among the students, 140 (87.5%) were completed. Eventually, 117 questionnaires were subject to analysis; the data from respondents who reported health problems (neck trauma in a car accident, chronic sinusitis and arterial hypertension) were excluded. The following statistical methods were used to analyse questionnaire data: t-Student test for equal and unequal variances or F-Snedecor test for comparing parameters in two study groups, Fisher exact test for comparing frequency, and single and multiple logistic regression models for quantitative risk assessment of negative health outcomes in relation to exposure level and with control for confounders. The subjects were 61 (52.1%) males and 56 females (47.9%). RESULTS: Most of the subjects (62%) assessed their health condition as good, 31% as very good and 7% as fair. 70% complained of headache and 20% of dizziness. Impaired concentration occurred in 56% of respondents. Facial dermatitis was reported by 11%. The most prevalent symptom related to mobile phone use was the thermal sensation within the auricle and behind/around the ear. This was reported by 33 subjects (28.2%). Out of 82 subjects who complained of headache, only 8 (6.8%) related this symptom to mobile phone use. Only 10 subjects of 65 reporting impaired concentration thought it could be associated with their using a mobile phone. The symptoms and health complaints reported by the respondents in no case were the reason for a medical check-up or taking any medication. CONCLUSIONS: The large number of young people complaining of headache and impaired concentration calls for further research to investigate the underlying reasons. It cannot be excluded that one of them may be exposure to EMF emitted by mobile phone. The explanation should be sought through further experimental and epidemiologic studies.

**Szyjkowska A, Gadzicka E, Szymczak W, Bortkiewicz A. The risk of subjective symptoms in mobile phone users in Poland - An epidemiological study. Int J Occup Med Environ Health. 2014 Apr 1. [Epub ahead of print]**

**OBJECTIVES:** To assess the type and incidence of subjective symptoms related to the use of mobile phones in Polish users. **MATERIAL AND METHODS:** The study was conducted in 2005 using a questionnaire survey. Although it has been quite a long time, up to now, no such data have been published for Poland. The questionnaire consisted of 53 questions concerning sex, age, education, general health, characteristics of a mobile phone (hand-held, loud-speaking unit) as well as the habits associated with its use

(frequency and duration of calls, text messages, etc.) and complaints associated with using a mobile phone. **RESULTS:** As many as 1800 questionnaires were sent. The response was obtained from 587 subjects aged 32.6±11.3 (48.9% women, 51.1% men); the age did not differ significantly between men and women. The subjects owned a cell phone for an average of 3 years. Majority of the respondents used the phone intensively, i.e. daily (74%) or almost daily (20%). Headaches were reported significantly more often by the people who talked frequently and long in comparison with other users (63.2% of the subjects, p = 0.0029), just like the symptoms of fatigue (45%, p = 0.013). Also, the feeling of warmth around the ear and directly to the auricle was reported significantly more frequently by the intensive mobile phone users, compared with other mobile phone users (47.3%, p = 0.00004 vs. 44.6%, p = 0.00063, respectively). Most symptoms appeared during or immediately after a call and disappeared within 2 h after the call. Continuous headache, persisting for longer than 6 h since the end of a call, was reported by 26% of the subjects. **CONCLUSIONS:** Our results show that the mobile phone users may experience subjective symptoms, the intensity of which depends on the intensity of use of mobile phones.

**Taberski K, Klose M, Grote K, El Ouardi A, Streckert J, Hansen VW, Lerchl A. Noninvasive Assessment of Metabolic Effects of Exposure to 900 MHz Electromagnetic Fields on Djungarian Hamsters ( Phodopus sungorus). Radiat Res. 181(6):617-622, 2014.**

Sixteen male Djungarian hamsters, serving as their own controls, were individually exposed to RF-EMF (900 MHz, GSM modulation) at 0 (sham), 0.08, 0.4 or 4 W/kg specific absorption rate (SAR) in specially constructed rectangular waveguides. Exposure duration was one week per condition, followed by one week without exposure. Once per day, the temperatures of the hamsters' back fur (a surrogate for skin temperature) and the cornea of the eye (a surrogate for body temperature), were measured by infrared thermography. Oxygen, carbon dioxide and humidity were measured continuously in the ambient and exhaled air. Food and water consumption, as well as body weight were recorded once per week. Only at the highest SAR level were the following effects observed: fur temperatures were elevated by approximately 0.5°C ($P < 0.001$), while the temperatures of the eyes' surface were not affected; food consumption was lowered ($P < 0.05$), while water consumption and body weight were not affected; the production of carbon dioxide was lowered during the day ($P < 0.01$) and unaffected during the night, while oxygen consumption levels remained unaffected and finally the respiratory quotient (carbon dioxide production divided by oxygen consumption) was lower during the day ($P < 0.05$) and also somewhat lower during the night (not significant). The results demonstrate the usefulness of our methods for experiments dealing with metabolic effects of RF-EMF exposure in rodents. They also confirm the assumption that even though the metabolism is reduced at high SAR levels, the body core temperature is being kept constant by the energy uptake from the RF-EMF exposure which is able to physiologically compensate for the reduced metabolism.

**Tafforeau M, Verdus MC, Norris V, White GJ, Cole M, Demarty M, Thellier M, Ripoll C.Plant sensitivity to low intensity 105 GHz electromagnetic radiation.**

**Bioelectromagnetics. 25(6):403-407, 2004.**

Exposing seedlings of the flax, Linum usitatissimum L., to a variety of weak environmental stresses followed by a 2 day calcium deprivation, triggers the common response of production of epidermal meristems (actively dividing groups of cells) in the hypocotyl, which is the part of the stem between the root and the cotyledons (the pre-existing leaves in the embryo). This production reaches a plateau of 10-20 meristems after a month in the case of mechanical stimulation and cold shock. Recently, we have shown that radiation from a global system for mobile communication (GSM) telephone also triggers production of meristems with a plateau of around six meristems. Here, we show that a single 2 h exposure to radiation emitted at 105 GHz at non-thermal levels by a Gunn oscillator induces meristem production with kinetics similar to that induced by weak environmental stimuli and radiation from GSM telephone.

**Tafforeau M, Verdus M-C, Norris V, White G, Demarty M, Thellier M, Ripoll C. SIMS study of the calcium-deprivation step related to epidermal meristem production induced in flax by cold shock or radiation from a GSM telephone. J Trace Microprobe Tech 20(4):611-623, 2002.**

Exposing seedlings of the flax, Linum usitatissimum L., to a variety of weak environmental stresses plus a 2-day calcium deprivation triggers the common response of production of epidermal meristems in the hypocotyls. Here, we show that the same response was induced by a 1 min cold shock. Epidemal meristem production was also induced by a single 2-h exposure to radiation emitted at 0.9 GHz at non-thermal levels by a GSM telephone. This flax-based system is therefore well suited to studying the effects of low intensity stimuli, including those of electromagnetic radiation. To begin to determine the underlying mechanisms, in which calcium is implicated, it is desirable to analyse the changes in ions in the tissues affected. We therefore performed a Secondary Ion Mass Spectrometry (SIMS) study of the distribution of the main inorganic cations in the hypocotl of control and calcium-deprived seedlings. This showed decreases in calcium, sodium and potassium and an increase in magnesium that did not alter substantially the overall ratio of divalent to monovalent cations.

**Taheri M, Mortazavi SM, Moradi M, Mansouri S, Hatam GR, Nouri F. Evaluation of the Effect of Radiofrequency Radiation Emitted From Wi-Fi Router and Mobile Phone Simulator on the Antibacterial Susceptibility of Pathogenic Bacteria Listeria monocytogenes and Escherichia coli. Dose Response. 2017 Jan 23;15(1):1559325816688527.**

Mobile phones and Wi-Fi radiofrequency radiation are among the main sources of the exposure of the general population to radiofrequency electromagnetic fields (RF-EMF). Previous studies have shown that exposure of microorganisms to RF-EMFs can be associated with a wide spectrum of changes ranged from the modified bacterial growth to the alterations of the pattern of antibiotic resistance. Our laboratory at the nonionizing department of the Ionizing and Non-ionizing Radiation Protection Research Center has performed experiments on the health effects of exposure to animal models and humans to different sources of electromagnetic fields such as cellular phones, mobile base

stations, mobile phone jammers, laptop computers, radars, dentistry cavitrons, magnetic resonance imaging, and Helmholtz coils. On the other hand, we have previously studied different aspects of the challenging issue of the ionizing or nonionizing radiation-induced alterations in the susceptibility of microorganisms to antibiotics. In this study, we assessed if the exposure to 900 MHz GSM mobile phone radiation and 2.4 GHz radiofrequency radiation emitted from common Wi-Fi routers alters the susceptibility of microorganisms to different antibiotics. The pure cultures of *Listeria monocytogenes* and *Escherichia coli* were exposed to RF-EMFs generated either by a GSM 900 MHz mobile phone simulator and a common 2.4 GHz Wi-Fi router. It is also shown that exposure to RF-EMFs within a narrow level of irradiation (an exposure window) makes microorganisms resistant to antibiotics. This adaptive phenomenon and its potential threats to human health should be further investigated in future experiments. Altogether, the findings of this study showed that exposure to Wi-Fi and RF simulator radiation can significantly alter the inhibition zone diameters and growth rate for *L monocytogenes* and *E coli.* These findings may have implications for the management of serious infectious diseases.

**Tahvanainen K, Niño J, Halonen P, Kuusela T, Laitinen T, Länsimies E, Hartikainen J, Hietanen M, Lindholm H. Cellular phone use does not acutely affect blood pressure or heart rate of humans. Bioelectromagnetics 25:73-83, 2004.**

A recent study raised concern about increase of resting blood pressure after a 35 min exposure to the radiofrequency (RF) field emitted by a 900 MHz cellular phone. In this randomized, double blind, placebo controlled crossover trial, 32 healthy subjects were submitted to 900 MHz (2 W), 1800 MHz (1 W) cellular phone exposure, and to sham exposure in separate sessions. Arterial blood pressure (arm cuff method) and heart rate were measured during and after the 35 min RF and sham exposure sessions. We evaluated cardiovascular responses in terms of blood pressure and heart rate during controlled breathing, spontaneous breathing, head-up tilt table test, Valsalva manoeuvre and deep breathing test. Arterial blood pressure and heart rate did not change significantly during or after the 35 min RF exposures at 900 MHz or 1800 MHz, compared to sham exposure. The results of this study indicate that exposure to a cellular phone, using 900 MHz or 1800 MHz with maximal allowed antenna powers, does not acutely change arterial blood pressure and heart rate.

**Tahvanainen K, Nino J, Halonen P, Kuusela T, Alanko T, Laitinen T, Lansimies E, Hietanen M, Lindholm H. Effects of cellular phone use on ear canal temperature measured by NTC thermistors. Clin Physiol Funct Imaging. 27(3):162-172, 2007.**

The earlier studies using phantom models and human subjects concerning warming effects during cellular phone use have been controversial, partly because radiofrequency (RF) exposures have been variable. In this randomized, double-blind, placebo-controlled crossover trial, 30 healthy subjects were submitted to 900 MHz (2W) and 1800 MHz (1W) cellular phone RF exposure, and to sham exposure in separate study sessions. Temperature signals were recorded continuously in both ear canals before, during and after the 35-min RF exposure and the 35-min sham exposure sessions. Temperature was measured by using small-sized NTC thermistors placed in the ear canals through disposable ear plugs. The mean temperature changes were determined during a set cardiovascular autonomic

function studies: during a 5-min controlled breathing test, during a 5-min spontaneous breathing test, during 7-min head-up tilting, 1-min before, during and after two consecutive Valsalva manoeuvres and during a deep breathing test. Temperatures in the exposed ear were significantly higher during RF exposures compared with sham exposure in both 900 and 1800 MHz studies with maximum differences of 1.2 +/- 0.5 degrees C (900 MHz exposure) and 1.3 +/- 0.7 degrees C (1800 MHz exposure). Temperatures in the RF-exposed ear were also significantly higher during the postexposure period compared with post-sham exposure period with maximum differences of 0.6 +/- 0.3 degrees C for 900 MHz and 0.5 +/- 0.5 degrees C for 1800 MHz. The results of this study suggest that RF exposure to a cellular phone, either using 900 or 1800 MHz with their maximal allowed antenna powers, increases the temperature in the ear canal. The reason for the ear canal temperature rising is a consequence of mobile phone battery warming during maximal antenna power use. The earlier published articles do not indicate that temperature rising in the ear canal has any significant contribution from the RF fields emitted from mobile phones.

**Takahashi S, Inaguma S, Cho Y-M, Imaida K, Wang J, Fujiwara O, Shirai T,Lack of Mutation Induction with Exposure to 1.5 GHz Electromagnetic Near Fields Used for Cellular Phones in Brains of Big Blue Mice. Cancer Res 62:1956-1960, 2002.**

The possible mutagenic potential of exposure to 1.5 GHz electromagneticnear field (EMF) was investigated using brain tissues of BigBlue mice (BBM). Male BBM were locally exposed to EMF in thehead region at 2.0, 0.67, and 0 W/kg specific absorption ratefor 90 min/day, 5 days/week, for 4 weeks. No gliosis or degenerativelesions were histopathologically noted in brain tissues, andno obvious differences in Ki-67 labeling and apoptotic indicesof glial cells were evident among the groups. There was no significantvariation in the frequency of independent mutations of the lacItransgene in the brains. G:C to A:T transitions at CpG sitesconstituted the most prevalent mutations in all groups and atall time points. Deletion mutations were slightly increasedin both the high and low EMF exposure groups as compared withthe sham-exposed group, but the differences were not statisticallysignificant. These findings suggest that exposure to 1.5 GHzEMF is not mutagenic to mouse brain cells and does not createany increased hazard with regard to brain tumor development.

**Takahashi S, Imai N, Nabae K, Wake K, Kawai H, Wang J, Watanabe S, Kawabe M, Fujiwara O, Ogawa K, Tamano S, Shirai T. Lack of adverse effects of whole-body exposure to a mobile telecommunication electromagnetic field on the rat fetus.Radiat Res. 173(3):362-372, 2010.**

The recent steep increase in the number of users of cellular phones is resulting in marked increase of exposure of humans to radiofrequency electromagnetic fields (EMFs). Children are of particular concern. Our goal was to evaluate potential adverse effects of long-term whole-body exposure to EMFs simulating those from base stations for cellular phone communication. Pregnant rats were given low, high or no exposure. At the high level, the average specific absorption rate (SAR)for the dams was 0.066-0.093 W/kg. The SAR for the fetuses and the F(1) progeny was 0.068-0.146 W/kg. At the low level, the SARs were about 43% of these. The 2.14 GHz signals were applied for 20 h per day during the gestation and lactation periods. No abnormal findings were observed in either

the dams or the F(1) generation exposed to the EMF or in the F(2) offspring. Parameters evaluated included growth, gestational condition and organ weights for dams and survival rates, development, growth, physical and functional development, hormonal status, memory function and reproductive ability of the F(1) offspring (at 10 weeks of age) along with embryotoxicity and teratogenicity in the F(2) rats. Thus, under our experimental conditions, whole-body exposure to 2.14 GHz for 20 h per day during gestation and lactation did not cause any adverse effects on pregnancy or the development of rats.

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**Takashima Y, Hirose H, Koyama S, Suzuki Y, Taki M, Miyakoshi J. Effects of continuous and intermittent exposure to RF fields with a wide range of SARs on cell growth, survival, and cell cycle distribution. Bioelectromagnetics.27(5):392-400, 2006.**

To examine the biological effects of radio frequency (RF) electromagnetic fields in vitro, we have examined the fundamental cellular responses, such as cell growth, survival, and cell cycle distribution, following exposure to a wide range of specific absorption rates (SAR). Furthermore, we compared the effects of continuous and intermittent exposure at high SARs. An RF electromagnetic field exposure unit operating at a frequency of 2.45 GHz was used to expose cells to SARs from 0.05 to 1500 W/kg. When cells were exposed to a continuous RF field at SARs from 0.05 to 100 W/kg for 2 h, cellular growth rate, survival, and cell cycle distribution were not affected. At 200 W/kg, the cell growth rate was suppressed and cell survival decreased. When the cells were exposed to an intermittent RF field at 300 W/kg(pk), 900 W/kg(pk) and 1500 W/kg(pk) (100 W/kg(mean)), no significant differences were observed between these conditions and intermittent wave exposure at 100 W/kg. When cells were exposed to a SAR of 50 W/kg for 2 h, the temperature of the medium around cells rose to 39.1 degrees C, 100 W/kg exposure increased the temperature to 41.0 degrees C, and 200 W/kg exposure increased the temperature to 44.1 degrees C. Exposure to RF radiation results in heating of the medium, and the thermal effect depends on the mean SAR. Hence, these results suggest that the proliferation disorder is caused by the thermal effect.

**Takebayashi T, Akiba S, Kikuchi Y, Taki M, Wake K, Watanabe S, Yamaguchi N. Mobile phone use and acoustic neuroma risk in Japan. Occup Environ Med.63(5):802-807, 2006.**

OBJECTIVES: The rapid increase of mobile phone use has increased public concern about its possible health effects in Japan, where the mobile phone system is unique in terms of the characteristics of the signal transmission. To examine the relationship between mobile phone use and acoustic neuroma, a case-control study was initiated. METHODS: The study followed the common, core protocol of the international collaborative study, INTERPHONE study. A prospective case recruitment was done in Japan for 2000-2004. One hundred and one acoustic neuroma cases, who were 30-69 years of age and resided in the Tokyo area, and 339 age-, sex-, and residency-matched controls were interviewed using a common computer-assisted personal interview system. Education- and marital status-adjusted odds ratio was calculated with a conditional logistic regression analysis. RESULTS: Fifty-one cases (52.6%) and 192 controls (58.2%) were regular mobile phone users on the reference date, which was set as 1 year before

the diagnosis, and no significant increase of acoustic neuroma risk was observed, with the odds ratio (OR) being 0.73 (95% confidence interval : 0.43-1.23). No exposure-related increase in the risk of acoustic neuroma was observed when the cumulative length of use (<4 years, 4-8 years, >8years) or cumulative call time (<300 h, 300-900 h, >900h) was used as an exposure index. The OR was 1.09 (95%CI:0.58-2.06) when the reference date was set as 5 years before the diagnosis. Further, laterality of mobile phone use was not associated with tumors. CONCLUSIONS: These results suggest that there is no significant increase in the risk of acoustic neuroma in association with mobile phone use in Japan.

**Takebayashi T, Varsier N, Kikuchi Y, Wake K, Taki M, Watanabe S, Akiba S, Yamaguchi N. Mobile phone use, exposure to radiofrequency electromagnetic field, and brain tumour: a case-control study. Br J Cancer. 98(3):652-659, 2008.**

In a case-control study in Japan of brain tumours in relation to mobile phone use, we used a novel approach for estimating the specific absorption rate (SAR) inside the tumour, taking account of spatial relationships between tumour localisation and intracranial radiofrequency distribution. Personal interviews were carried out with 88 patients with glioma, 132 with meningioma, and 102 with pituitary adenoma (322 cases in total), and with 683 individually matched controls. All maximal SAR values were below 0.1 W kg(-1), far lower than the level at which thermal effects may occur, the adjusted odds ratios (ORs) for regular mobile phone users being 1.22 (95% confidence interval (CI): 0.63-2.37) for glioma and 0.70 (0.42-1.16) for meningioma. When the maximal SAR value inside the tumour tissue was accounted for in the exposure indices, the overall OR was again not increased and there was no significant trend towards an increasing OR in relation to SAR-derived exposure indices. A non-significant increase in OR among glioma patients in the heavily exposed group may reflect recall bias.

**Takeda H, Yasunaga K, Sakuma N, Hirose H, Nojima T, Miyakoshi J. 2-GHz Band CW and W-CDMA modulated radiofrequency fields have no significant effect on cell proliferation and gene expression profile in human cells. J Radiat Res (Tokyo). 51(3):277-284, 2010.**

We investigated the mechanisms by which radiofrequency (RF) fields exert their activity, and the changes in both cell proliferation and the gene expression profile in the human cell lines, A172 (glioblastoma), H4 (neuroglioma), and IMR-90 (fibroblasts from normal fetal lung) following exposure to 2.1425 GHz continuous wave (CW) and Wideband Code Division Multiple Access (W-CDMA) RF fields at three field levels. During the incubation phase, cells were exposed at the specific absorption rates (SARs) of 80, 250, or 800 mW/kg with both CW and W-CDMA RF fields for up to 96 h. Heat shock treatment was used as the positive control. No significant differences in cell growth or viability were observed between any test group exposed to W-CDMA or CW radiation and the sham-exposed negative controls. Using the Affymetrix Human Genome Array, only a very small (< 1%) number of available genes (ca. 16,000 to 19,000) exhibited altered expression in each experiment. The results confirm that low-level exposure to 2.1425 GHz CW and W-CDMA RF fields for up to 96 h did not act as an acute cytotoxicant in either cell proliferation or the gene expression profile. These results suggest that RF exposure up to the limit of whole-body average SAR

levels as specified in the ICNIRP guidelines is unlikely to elicit a general stress response in the tested cell lines under these conditions.

**Talebnejad MR, Sadeghi-Sarvestani A, Hossein Nowroozzadeh M, Mortazavi SMJ, Khalili MR. The effects of microwave radiation on rabbit's retina. Journal of Current Ophthalmology, Available online 9 October 2017.**

Purpose  Mobile cell phones are used extensively these days, and their microwave (MW) radiation has been shown to affect the eye. The purpose of the present study was to evaluate the effects of MW radiation on rabbit retina. Methods  This experimental study (concluded in 2015) was conducted on 40 adult white New Zealand rabbits. A Global System for Mobile Communications (GSM) cell phone simulator was used for MW irradiation. The rabbits were randomized into five groups (8 in each) and treated as follows: Group 1: no irradiation (sham); Group 2: irradiation at 10 cm for 1 day; Group 3: irradiation at 30 cm for 1 day; Group 4: irradiation at 10 cm for 3 days; and Group 5: irradiation at 30 cm for 3 days. Scotopic and photopic electroretinography (ERG) responses were obtained at baseline and 7 days after the last exposure. Then all the rabbits were euthanized, and their eyes were enucleated and sent for pathology examination. Kruskal–Wallis and Chi-Square tests were used to evaluate intergroup differences in ERG parameters and histological findings, respectively. Results  ERG responses obtained 7 days after irradiation did not show any statistically significant difference between the groups ($P > 0.1$, for all tested parameters). There were statistically non-significant trends toward greater changes in the MW irradiated eyes. In pathological examination, retina was normal with no sign of degeneration or infiltration. Ciliary body congestion was observed in greater fraction of those who received higher MW doses. ($P = 0.005$). Conclusions Histopathologically, cell phone simulated MW irradiation had no significant detrimental effect on the retina. However, ciliary body congestion was observed in greater fraction of those who received higher MW doses. Although there was no significant difference between post-treatment mean ERG values, there were statistically non-significant trends toward greater changes in the MW irradiated eyes.

**Talei D, Valdiani A, Maziah M, Mohsenkhah M. Germination response of MR 219 rice variety to different exposure times and periods of 2450 MHz microwave frequency. ScientificWorldJournal. 2013 Nov 6;2013:408026. doi: 10.1155/2013/408026. eCollection 2013.**

Germination is a key process in plants' phenological cycles. Accelerating this process could lead to improvment of the seedling growth as well as the cultivation efficiency. To achieve this, the effect of microwave frequency on the germination of rice seeds was examined. The physiological feedbacks of the MR 219 rice variety in terms of seed germination rate (GR), germination percentage (GP), and mean germination time (MGT) were analyzed by exposing its seeds to 2450 MHz of microwave frequency for one, four, seven, and ten hours. It was revealed that exposing the seeds to the microwave frequency for 10 hours resulted in the highest GP. This treatment led to 100% of germination after three days with a mean germination time of 2.1 days. Although the other exposure times of microwave frequency caused the moderate effects on germination with

a GP(a3) ranged from 93% to 98%, they failed to reduce the MGT(a3). The results showed that ten-hour exposure times of microwave frequency for six days significantly facilitated and improved the germination indices (primary shoot and root length). Therefore, the technique is expected to benefit the improvement of rice seed germination considering its simplicity and efficacy in increasing the germination percentage and rate as well as the primary shoot and root length without causing any environmental toxicity.

**Tamer A**, **Gündüz H**, **Ozyildirim S**. **The cardiac effects of a mobile phone positioned closest to the heart. Anadolu Kardiyol Derg. 9(5):380-384, 2009.**

OBJECTIVE: The aim of this study was to evaluate the effect of mobile phone (MP) on cardiac electrical activity by examining the heart rate variability (HRV), QT, P dispersions and blood pressure (BP) while the MP is located on the precordium. METHODS: A total of 24 healthy volunteers were included in this prospective study. In the first step; 12-lead electrocardiogram (ECG) and BP recordings of the subjects without MP, while the MP is off, on, and ringing were recorded. In the second step; rhythm and BP were recorded for 30 minutes with the Holter without MP, and when the MP was "on" at the precordial location. P-wave and QT interval dispersions were measured from 12-lead ECG, while Holter 24-hour recordings were used for HRV analysis. Statistical analysis was performed using paired t test for comparison of hemodynamic and HRV variables without MP and during MP on. ANOVA for repeated measures was used to compare hemodynamic and ECG variables through baseline and 3 experimental settings: MP on, off and ringing. RESULTS: There were no statistically significant differences between the groups in the BP, heart rate, P-wave dispersion, QT dispersion and QT corrected dispersion parameters ($p>0.05$) in the first step of the study. In the second step, there were no significant differences between two groups in the BP, heart rate and HRV parameters ($p>0.05$). CONCLUSION: We conclude that MP has no effect on hemodynamic (heart rate, blood pressure) and cardiac electrical activity (P-wave and QT dispersions) parameters when it is positioned on the chest in immediate proximity to the heart, and it does not cause cardiac autonomic dysfunction examined by HRV analysis in healthy adult subjects.

**Tang J, Zhang Y, Yang L, Chen Q, Tan L, Zuo S, Feng H, Chen Z, Zhu G. Exposure to 900 MHz electromagnetic fields activates the mkp-1/ERK pathway and causes blood-brain barrier damage and cognitive impairment in rats. Brain Res. 1601:92-101, 2015.**

With the rapid increase in the number of mobile phone users, the potential adverse effects of the electromagnetic field radiation emitted by a mobile phone has become a serious concern. This study demonstrated, for the first time, the blood-brain barrier and cognitive changes in rats exposed to 900 MHz electromagnetic field (EMF) and aims to elucidate the potential molecular pathway underlying these changes. A total of 108 male Sprague-Dawley rats were exposed to a 900 MHz, 1 mW/cm(2) EMF or sham (unexposed) for 14 or 28 days (3h per day). The specific energy absorption rate (SAR) varied between 0.016 (whole body) and 2 W/kg (locally in the head). In addition, the Morris water maze test was used to examine spatial memory performance determination. Morphological changes were investigated by examining ultrastructural changes in the

hippocampus and cortex, and the Evans Blue assay was used to assess blood brain barrier (BBB) damage. Immunostaining was performed to identify heme oxygenase-1 (HO-1)-positive neurons and albumin extravasation detection. Western blot was used to determine HO-1 expression, phosphorylated ERK expression and the upstream mediator, mkp-1 expression. We found that the frequency of crossing platforms and the percentage of time spent in the target quadrant were lower in rats exposed to EMF for 28 days than in rats exposed to EMF for 14 days and unexposed rats. Moreover, 28 days of EMF exposure induced cellular edema and neuronal cell organelle degeneration in the rat. In addition, damaged BBB permeability, which resulted in albumin and HO-1 extravasation were observed in the hippocampus and cortex. Thus, for the first time, we found that EMF exposure for 28 days induced the expression of mkp-1, resulting in ERK dephosphorylation. Taken together, these results demonstrated that exposure to 900 MHz EMF radiation for 28 days can significantly impair spatial memory and damage BBB permeability in rat by activating the mkp-1/ERK pathway.

**Tanvir S, Thuróczy G, Selmaoui B, Pires-Antonietti VS, SonnetP, Arnaud-Cormos D, Lévêque P, Pulvin S, de Seze R. Effects of 3G cell phone exposure on the structure and function of the human cytochrome P450 reductase. Bioelectrochemistry Available online 11 May 2016.**

Cell phones increase exposure to radiofrequency (RF) electromagnetic fields (EMFs). Whether EMFs exert specific effects on biological systems remains debatable. This study investigated the effect of cell phone exposure on the structure and function of human NADPH-cytochrome P450 reductase (CPR). CPR plays a key role in the electron transfer to cytochrome P450, which takes part in a wide range of oxidative metabolic reactions in various organisms from microbes to humans. Human CPR was exposed for 60 min to 1966-MHz RF inside a transverse electromagnetic cell (TEM-cell) placed in an incubator. The specific absorption rate (SAR) was 5 $W \cdot kg^{-1}$. Conformation changes have been detected through fluorescent spectroscopy of flavin and tryptophan residues, and investigated through circular dichroism, dynamic light scattering and microelectrophoresis. These showed that CPR was narrowed. By using cytochrome C reductase activity to assess the electron flux through the CPR, the Michaelis Menten constant (Km) and the maximum initial velocity (Vmax) decreased by 22% as compared with controls. This change was due to small changes in the tertiary and secondary structures of the protein at 37 °C. The relevance of these findings to an actual RF exposure scenario demands further biochemical and in-vivo confirmation.

**Tas M, Dasdag S, Akdag MZ, Cirit U, Yegin K, Seker U, Ozmen MF, Eren LB. Long-term effects of 900 MHz radiofrequency radiation emitted from mobile phone on testicular tissue and epididymal semen quality. Electromagn Biol Med. 2013 Jun 19. [Epub ahead of print]**

Abstract The purpose of this study is to bridge this gap by investigating effects of long term 900 MHz mobile phone exposure on reproductive organs of male rats. The study was carried out on 14 adult Wistar Albino rats by dividing them randomly into two groups (n: 7) as sham group and exposure group. Rats were exposed to 900 MHz

radiofrequency (RF) radiation emitted from a GSM signal generator. Point, 1 g and 10 g specific absorption rate (SAR) levels of testis and prostate were found as 0.0623 W/kg, 0.0445 W/kg and 0.0373 W/kg, respectively. The rats in the exposure group were subject to RF radiation 3 h per day (7 d a week) for one year. For the sham group, the same procedure was applied, except the generator was turned off. At the end of the study, epididymal sperm concentration, progressive sperm motility, abnormal sperm rate, all-genital organs weights and testis histopathology were evaluated. Any differences were not observed in sperm motility and concentration ($p > 0.05$). However, the morphologically normal spermatozoa rates were found higher in the exposure group ($p < 0.05$). Although histological examination showed similarity in the seminiferous tubules diameters in both groups, tunica albuginea thickness and the Johnsen testicular biopsy score were found lower in the exposure group ($p < 0.05$, $p < 0.0001$). In conclusion, we claim that long-term exposure of 900 MHz RF radiation alter some reproductive parameters. However, more supporting evidence and research is definitely needed on this topic.

**Tashiro M, Horikawa E, Mochizuki H, Sakurada Y, Kato M, Inokuchi T, Ridout F, Hindmarch I, Yanai K. Effects of fexofenadine and hydroxyzine on brake reaction time during car-driving with cellular phone use. Hum Psychopharmacol. 20(7):501-509, 2005.**

Antihistamines are a mainstay treatment for allergic rhinitis; however, many older agents cause adverse events, including sedation and central nervous system (CNS) impairment. Research has shown sedating effects of antihistamines on driving; currently, no known study has examined whether cellular phone usage while driving further compounds impairment in individuals administered antihistamines. The aim of this study was to examine this endpoint. In a randomized, double-blind, placebo-controlled, three-way crossover study, healthy volunteers received fexofenadine HCl 120 mg, hydroxyzine HCl 30 mg and placebo. Brake reaction time (BRT) was used to examine driving performance across four conditions: driving only; driving while completing simple calculations; complex calculations; and conversing on a cellular phone. Subjective sedation assessments were also conducted. Brake reaction time with and without cellular phone usage in fexofenadine-treated subjects did not differ significantly from placebo in any condition. In contrast, hydroxyzine-treated subjects were significantly more sedated and had slower BRTs, suggesting slower hazard recognition and brake application, compared with the fexofenadine and placebo groups in all conditions. Importantly, cellular phone operation was an additive factor, increasing BRTs in hydroxyzine-treated volunteers. Fexofenadine did not impair CNS function in subjects involved in a divided attention task of driving and cellular phone operation.

**Taskinen H, Kyyronen P, Hemminki K, Effects of ultrasound, shortwaves, and physical exertion on pregnancy outcome in physiotherapists. J Epidemiol Community Health 44(3):196-201, 1990.**

STUDY OBJECTIVE--The aim of the study was to investigate whether occupational exposure among physiotherapists is associated with spontaneous abortion or congenital malformation in the offspring. DESIGN--The study was a retrospective nested case-control study, where the pregnancy outcome data were based on the

medical registers. SETTING--All registered physiotherapists in Finland who had become pregnant during the study period were included in the study. SUBJECTS--Cases were defined as women who had been treated for spontaneous abortion during 1973-1983 or had delivered a malformed child during 1973-1982. One pregnancy per woman was randomly selected for the study. Three age matched (+/-18 months) controls were selected for each abortion case and five for each malformation case. The final study population was 204 cases and 483 controls in the spontaneous abortion study, and 46 cases and 187 controls in the congenital malformation study. MEASUREMENTS AND MAIN RESULTS--Exposure information was collected by mailed questionnaires from 1329 women. The response rate was 92% in the spontaneous abortion study, and 89% in the congenital malformation study. Heavy lifting (including patient transfers) was associated significantly with spontaneous abortion. Exposure to ultrasound and shortwaves showed about threefold odds ratios for spontaneous abortions occurring after the 10th week of gestation but in analysis where potential confounding variables were controlled, neither reached statistical significance. Deep heat therapies together, and shortwaves alone, were associated significantly with congenital malformations, but the increase was found in the lower exposure category only. From the potential confounding variables, previous abortion (spontaneous or induced) was associated significantly with spontaneous abortion, and febrile disease in early pregnancy was associated with congenital malformation. CONCLUSION--Physical exertion during early pregnancy seems to be a risk factor for spontaneous abortion. The findings raise suspicion of the potential harmful effect of shortwaves and ultrasound on the pregnancy, but no firm conclusion can be drawn on the bases of these results alone.

**Tat FH, Wah KC, Hung YH. A follow-up study of electromagnetic interference of cellular phones on electronic medical equipment in the emergency department. Emerg Med (Fremantle) 14(3):315-319, 2002.**

OBJECTIVE: Considering the growing use of cellular phones and the fast appearance of new phone models, the electromagnetic interference of currently popular cellular phones on electronic medical equipment was tested. METHODS: Three Personal Communication System cellular phones were put at different distances from multiple electronic medical devices, the interference effect was observed and the electromagnetic field strength measured with a spectrum analyser. RESULTS: Only two small pieces of equipment, the CO2 airway adapter and the haemoglucostix meter were affected and then only when the phone was in very close proximity. CONCLUSION: Compared to the results of our study in 1997 testing Global System for Mobile Communication phones, the Personal Communication System phones generated less electromagnetic interference. However a much larger scaled study and an accurate international electromagnetic interference standard are recommended before any change in the current restrictive hospital policy on mobile phone usage could be recommended.

**Tattersall JE, Scott IR, Wood SJ, Nettell JJ, Bevir MK, Wang Z, Somasiri NP, Chen X. Effects of low intensity radiofrequency electromagnetic fields on electrical activity in rat hippocampal slices. Brain Res 904(1):43-53, 2001.**

Slices of rat hippocampus were exposed to 700 MHz continuous wave radiofrequency

(RF) fields (25.2-71.0 V m(-1), 5-15 min exposure) in a stripline waveguide. At low field intensities, the predominant effect on the electrically evoked field potential in CA1 was a potentiation of the amplitude of the population spike by up to 20%, but higher intensity fields could produce either increases or decreases of up to 120 and 80%, respectively, in the amplitude of the population spike. To eliminate the possibility of RF-induced artefacts due to the metal stimulating electrode, the effect of RF exposure on spontaneous epileptiform activity induced in CA3 by 4-aminopyridine (50-100 &mgr;M) was investigated. Exposure to RF fields (50.0 V m(-1)) reduced or abolished epileptiform bursting in 36% of slices tested. The maximum field intensity used in these experiments, 71.0 V m(-1), was calculated to produce a specific absorption rate (SAR) of between 0.0016 and 0.0044 W kg(-1) in the slices. Measurements with a Luxtron fibreoptic probe confirmed that there was no detectable temperature change (+/-0.1 degrees C) during a 15 min exposure to this field intensity. Furthermore, imposed temperature changes of up to 1 degrees C failed to mimic the effects of RF exposure. These results suggest that low-intensity RF fields can modulate the excitability of hippocampal tissue in vitro in the absence of gross thermal effects. The changes in excitability may be consistent with reported behavioural effects of RF fields.

**Taylor DM, Bennett DM, Carter M, Garewal D. Mobile telephone use among Melbourne drivers: a preventable exposure to injury risk. Med J Aust. 179(3):140-142, 2003.**

OBJECTIVE: To determine the rate of handheld mobile telephone use among motor vehicle drivers. DESIGN AND SETTING: Observational study of motor vehicle drivers at three times (10: 00-11: 00; 14: 00-15: 00; 17: 00-18: 00) on three consecutive Fridays in October 2002 at 12 highway sites in metropolitan Melbourne. MAIN OUTCOME MEASURES: Rates of mobile phone use overall and by sex and age group, highway site (major metropolitan road, central business district, freeway exit ramp) and time of day (morning, afternoon, evening). RESULTS: 315 of 17 023 drivers were observed using mobile phones (18.5 users/1000 drivers; 95% CI, 16.5-20.6). Men had a slightly higher rate of use (19.0; 95% CI, 16.5-21.6) than women (17.5; 95% CI, 14.1-20.9), but the difference was not significant. Older drivers (50 years or more) had a significantly lower rate (4.8; 95% CI, 2.5-7.0) than middle-aged (21.9; 95% CI, 18.8-25.1) or young drivers (23.2; 95% CI, 18.9-27.5). Central business district drivers had a slightly, but not significantly, higher rate (20.5; 95% CI, 16.8-24.3) compared with those on major metropolitan roads (16.7; 95% CI, 13.3-20.2) or freeway exit ramps (18.2; 95% CI, 14.8-21.6). The rate of mobile phone use was significantly higher in the evening (23.5; 95% CI, 19.8-27.3) compared with the morning (16.0; 95% CI, 12.6-19.4) and afternoon (15.2; 95% CI, 11.9-18.4). CONCLUSION: Mobile phone use is common among Melbourne metropolitan drivers despite restrictive legislation. This issue needs to be further addressed by Victoria Police and public health and education agencies. Similar research is indicated to determine the extent of mobile phone use in other states.

**Teerapot Wessapan, Phadungsak Rattanadecho. Specific absorption rate and temperature increase in the human eye due to electromagnetic fields exposure at different frequencies. International Journal of Heat and Mass Transfer, 64:426-435, September 2013.**

This study presents a numerical analysis of the specific absorption rate (SAR) and the heat transfer in a heterogeneous human eye model exposed to electromagnetic (EM) fields of 900 and 1800 MHz. In this study, the effect of operating frequency on the SAR and temperature distributions in the eye was systematically investigated. The SAR value and the temperature distribution in various tissues in the eye during exposure to EM fields were obtained by numerical simulation of EM wave propagation and a heat transfer model was then developed based on the natural convection and porous media theories. The study highlights two transport phenomena: heat and mass transfer in the eye during exposure to EM fields at different frequencies. This study indicated that when the eye exposed to EM fields at the frequencies of 900 and 1800 MHz, the highest SAR values at two chosen frequencies was in the cornea, and the highest temperature at the frequency of 900 MHz was in the anterior chamber while the highest for the frequency of 1800 MHz was in the vitreous. The temperature distribution in the eye induced by EM fields was not directly related to the SAR distribution due to the effect of the interaction among the dielectric properties, thermal properties, blood perfusion, and penetration depth of the EM power. Moreover, this study also showed that the exposure time had an influence on the temperature increase in the eye.

**Teerapot Wessapan, Phadungsak Rattanadecho. Influence of ambient temperature on heat transfer in the human eye during exposure to electromagnetic fields at 900 MHz. International Journal of Heat and Mass Transfer 70: 378-388, 2014.**
The topic of temperature increase in human tissue when exposed to EM fields, particularly those radiated to the eye, has been of interest for many years. This study presents a numerical analysis of the specific absorption rate (SAR) and the heat transfer in a heterogeneous two-dimensional human eye model exposed to TM-mode of electromagnetic (EM) fields of 900 MHz at various power densities. In this study, the effects of ambient temperature and power density on the temperature distributions and fluid flow in the eye during exposure to electromagnetic fields were systematically investigated. The electric field, SAR, temperature distribution and fluid flow in various tissues in the eye during exposure to EM fields were obtained by numerical simulation of EM wave propagation and a heat transfer model. The heat transfer model was then developed based on the porous media theories. The study highlights heat transfer and fluid flow in the eye during exposure to EM fields at different ambient temperatures. This study indicated that when the eye exposed to EM fields at the frequency of 900 MHz, the highest electric field intensity and SAR values at the chosen frequency was in the cornea. At the highest power density of 100 $mW/cm^2$, the absorbed EM energy is converted to heat causes a further increase of 3 °C in corneal temperature in cases of hot, moderate and cold ambient temperatures. The result shows important information related to a complex interaction between ambient temperature, fluid flow and temperature distribution in the eye during exposure to electromagnetic fields. Moreover, this study also showed that the power density had a strong influence on the temperature increase and fluid flow in the eye.

**Tell RA, Sias GG, Vazquez A, Sahl J, Turman JP, Kavet RI, Mezei G. RADIOFREQUENCY FIELDS ASSOCIATED WITH THE ITRON SMART METER.Radiat Prot Dosimetry.151(1):17-29, 2012.**

This study examined radiofrequency (RF) emissions from smart electric power meters deployed in two service territories in California for the purpose of evaluating potential human exposure. These meters included transmitters operating in a local area mesh network (RF LAN, ~250 mW); a cell relay, which uses a wireless wide area network (WWAN, ~1 W); and a transmitter serving a home area network (HAN, ~70 mW). In all instances, RF fields were found to comply by a wide margin with the RF exposure limits established by the US Federal Communications Commission. The study included specialised measurement techniques and reported the spatial distribution of the fields near the meters and their duty cycles (typically <1 %) whose value is crucial to assessing time-averaged exposure levels. This study is the first to characterise smart meters as deployed. However, the results are restricted to a single manufacturer's emitters.

**Tell RA, Kavet R, Mezei G. Characterization of radiofrequency field emissions from smart meters. J Expo Sci Environ Epidemiol. 2012 Nov 7. doi: 10.1038/jes.2012.102. [Epub ahead of print]**

This study presents measurement data that describe radiofrequency emission levels and patterns from smart meters (rated nominally at 1 W) currently deployed in Pacific Gas and Electric Company's service territory in northern California. The smart meters in our investigation could not be set to operate continuously and required a Field Service Unit to induce short periods of emitted fields. To obtain peak field data under both laboratory and ambient conditions, a spectrum analyzer scanned across the 83 transmitting channels between 902 and 928 MHz used by the smart meter on a random frequency-hopping basis. To obtain data describing temporal emission patterns, the analyzer operated in scope mode. Duty cycle was estimated using transmit data acquired by the system operator from over 88,000 m. Instantaneous peak fields at 0.3 m in front of the meters were no more than 15% of the US Federal Communications Commission (FCC) exposure limit for the general public, and 99.9% of the meters operated with a duty cycle of 1.12% or less during the sampling period. In a sample of measurements in six single-detached residences equipped with individual smart meters, no interior measurement of peak field exceeded 1% of the FCC's general public exposure limit.

**Tell RA, Kavet R. A SURVEY OF THE URBAN RADIOFREQUENCY (RF) ENVIRONMENT. Radiat Prot Dosimetry. 2014 Feb 23. [Epub ahead of print]**

In 1980, Tell and Mantiply published a study of radiofrequency (RF) fields measured across 15 major metropolitan areas in the USA. They required a van fully equipped with instrumentation and computing capability for their measurements. This study aimed to assess whether and how hand-held instrumentation available today would facilitate and enhance the efficiency of large-scale surveys of ambient RF fields. In addition, the data would provide a suggestion as to how the profile of ambient RF fields has changed with respect to frequency content and magnitude. Not unexpectedly, the relative power densities were orders of magnitude lower than the Federal Communications Commission's (FCC) maximum permissible exposure (MPE) for the general public, with a maximum time-averaged value across the VHF-FM-UHF-cellular bands of 0.12 % of the MPE (AM's contribution was negligible). In

both the 1980 and the present study, the power density in the FM band was a major contributor to overall power density, but over time, power densities in the VHF and UHF band decreased and increased, respectively. From the perspective of absolute power density, the wideband values in the 1980 study, this study and any number of assessments conducted in European nations are not generally different from one another.

**Terao Y, Okano T, Furubayashi T, Ugawa Y. Effects of thirty-minute mobile phone use on visuo-motor reaction time. Clin Neurophysiol.117(11):2504-2511, 2006.**

OBJECTIVE: To investigate whether exposure to pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on the visuo-motor choice reaction time (RT) and movement time (MT). METHODS: A double blind, counterbalanced crossover design was employed. In 16 normal subjects, we studied the performance of a visuo-motor precued choice reaction time task (PCRT) before and after exposure to EMF emitted by a mobile phone for 30 minutes or sham exposure. RESULTS: The RTs and MTs under different conditions of precue information were not affected by exposure to pulsed EMF emitted by a mobile phone or by sham phone use. CONCLUSIONS: Thirty minutes of mobile phone use has no significant short-term effect on the cortical visuo-motor processing as studied by the present PCRT task. SIGNIFICANCE: This is the first study to investigate visuo-motor behavior in relation to mobile phone exposure. No significant effect of mobile phone use was demonstrated on the performance of the visuo-motor reaction time task.

**Terao Y, Okano T, Furubayashi T, Yugeta A, Inomata-Terada S, Ugawa Y Effects of thirty-minute mobile phone exposure on saccades. Clin Neurophysiol. 118(7):1545-1556, 2007.**

OBJECTIVE: To investigate whether exposure to pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone has short-term effects on saccade performances. METHODS: A double blind, counterbalanced crossover design was employed. In 10 normal subjects, we studied the performance of visually guided saccade (VGS), gap saccade (GAP), and memory guided saccade (MGS) tasks before and after exposure to EMF emitted by a mobile phone for thirty minutes or sham exposure. We also implemented a hand reaction time (RT) task in response to a visual signal. RESULTS: With the exception of VGS and MGS latencies, the parameters of VGS, GAP and MGS tasks were unchanged before and after real or sham EMF exposure. In addition, the latencies of VGS and MGS did not change differently after real and sham exposure. The hand RT shortened with the repetition of trials, but again this trend was of similar magnitude for real and sham exposures. CONCLUSIONS: Thirty minutes of mobile phone exposure has no significant short-term effect on saccade performances. SIGNIFICANCE: This is the first study to investigate saccade performance in relation to mobile phone exposure. No significant effect of mobile phone use was demonstrated on the performance of various saccade tasks, suggesting that the cortical processing for saccades and attention is not affected by exposure to EMF emitted by a mobile phone.

**Tereshin Siu, [The combined action of different forms of iodine and organic iodine compounds and of superhigh-frequency electromagnetic fields on the excitability and accommodative capacity of nervous and muscular tissues in frogs]. Vopr Kurortol Fizioter Lech Fiz Kult (5):31-33, 1999.** [Article in Russian]

Experiments on 130 male lake frogs were made to study a combined action of SHF electromagnetic fields (microwaves) and baths KI + I2, DMSO, KI + I2 + DMSO, iodinol, iodinol + DMSO, humic acids, humic acids + KI + I2, humic acids + DMSO, sapropel + DMSO on excitability and accommodation ability of nervous and muscular tissues. The most perspective combinations (by the number of statistically significant shifts of 6 electrophysiological parameters) were selected for screening on warm-blooded animals. These were SHF microwaves + KI + I2, SHF microwaves + iodinol.

**Terro F, Magnaudeix A, Crochetet M, Martin L, Bourthoumieu S, Wilson CM, Yardin C, Leveque P. GSM-900MHz at low dose temperature-dependently downregulates α-synuclein in cultured cerebral cells independently of chaperone-mediated-autophagy.Toxicology. 292(2-3):136-144, 2012.**

The expanding use of GSM devices has resulted in public concern. Chaperone-mediated autophagy (CMA) is a way for protein degradation in the lysosomes and increases under stress conditions as a cell defense response. α-synuclein, a CMA substrate, is a component of Parkinson disease. Since GSM might constitute a stress signal, we raised the possibility that GSM could alter the CMA process. Here, we analyzed the effects of chronic exposure to a low GSM-900MHz dose on apoptosis and CMA. Cultured cerebral cortical cells were sham-exposed or exposed to GSM-900MHz at specific absorption rate (SAR): 0.25W/kg for 24 h using a wire-patch cell. Apoptosis was analyzed by DAPI stain of the nuclei and western blot of cleaved caspase-3. The expression of proteins involved in CMA (HSC70, HSP40, HSP90 and LAMP-2A) and α-synuclein were analyzed by western blot. CMA was also quantified in situ by analyzing the cell localization of active lysosomes. 24 h exposure to GSM-900MHz resulted in ~0.5°C temperature rise. It did not induce apoptosis but increased HSC70 by 26% and slightly decreased HSP90 (<10%). It also decreased α-synuclein by 24% independently of CMA, since the localization of active lysosomes was not altered. Comparable effects were observed in cells incubated at 37.5°C, a condition that mimics the GSM-generated temperature rise. The GSM-induced changes in HSC70, HSP90 and α-synuclein are most likely linked to temperature rise. We did not observe any immediate effect on cell viability. However, the delayed and long term consequences (protective or deleterious) of these changes on cell fate should be examined.

**Testylier G, Tonduli L, Malabiau R, Debouzy JC. Effects of exposure to low level radiofrequency fields on acetylcholine release in hippocampus of freely moving rats. Bioelectromagnetics 23:249-255, 2002.**

Some central cholinergic effects have been reported in animals after acute exposure to radiofrequency electromagnetic field at low intensity. We studied acetylcholine (ACh) release in the brain of freely moving rats exposed for 1 h during the day to a 2.45 GHz continuous wave radiofrequency field (RF) (2 or 4 mW/cm$^2$) or exposed for 1 or 14 h during the night to a 800 MHz field modulated at 32 Hz (AM 200 mW/cm$^2$).

Measurements were performed by microdialysis using a membrane implanted through the upper CA1 region of the hippocampus. After irradiation with the 2.45 GHz RF, rats exposed at 2 mW/cm$^2$ did not show a significant modification of Ach release, whereas those exposed at 4 mW/cm$^2$ showed a significant 40% decrease in mean ACh release from hippocampus. This decrease was maximal at 5 h post exposure. Exposure to the 800 MHz RF for 1 h did not cause any significant effect, but exposure for 14 hrs induced a significant 43% decrease in ACh release during the period 11 p.m.-4 a.m. compared to control rats. In the control group we observed an increase of ACh release at the beginning of the night, which was linked to the waking period of rats. This normal increase was disturbed in rats exposed overnight to the 800 MHz RF. This work indicates that neurochemical modification of the hippocampal cholinergic system can be observed during and after an exposure to low intensity RF.

**Teven CM, Greives M, Natale RB, Su Y, Luo Q, He BC, Shenaq D, He TC, Reid RR. Differentiation of osteoprogenitor cells is induced by high-frequency pulsed electromagnetic fields. J Craniofac Surg. 23(2):586-593, 2012**.

Craniofacial defect repair is often limited by a finite supply of available autologous tissue (ie, bone) and less than ideal alternatives. Therefore, other methods to produce bony healing must be explored. Several studies have demonstrated that low-frequency pulsed electromagnetic field (PEMF) stimulation (ie, 5-30 Hz) of osteoblasts enhances bone formation. The current study was designed to investigate whether a Food and Drug Administration-approved, high-frequency PEMF-emitting device is capable of inducing osteogenic differentiation of osteoprogenitor cells. Osteoprogenitor cells (commercially available C3H10T1/2 and mouse calvarial) in complete Dulbecco modified Eagle medium were continuously exposed to PEMF stimulation delivered by the ActiPatch at a frequency of 27.1 MHz. Markers of cellular proliferation and early, intermediate, and terminal osteogenic differentiation were measured and compared with unstimulated controls. All experiments were performed in triplicate. High-frequency PEMF stimulation increases alkaline phosphatase activity in both cell lines. In addition, high-frequency PEMF stimulation augments osteopontin and osteocalcin expression as well as mineral nodule formation in C3H10T1/2 cells, indicating late and terminal osteogenic differentiation, respectively. Cellular proliferation, however, was unaffected by high-frequency PEMF stimulation. Mechanistically, high-frequency PEMF-stimulated osteogenic differentiation is associated with elevated mRNA expression levels of osteogenic bone morphogenetic proteins in C3H10T1/2 cells. Our findings suggest that high-frequency PEMF stimulation of osteoprogenitor cells may be explored as an effective tissue engineering strategy to treat critical-size osseous defects of the craniofacial and axial skeleton.

**Thielens A, Vermeeren G, Kurup D, Joseph W, Martens L. Compliance boundaries for multiple-frequency base station antennas in three directions. Bioelectromagnetics. 2013 Jan 29. doi: 10.1002/bem.21778. [Epub ahead of print]**

In this article, compliance boundaries and allowed output powers are determined for the front, back, and side of multiple-frequency base station antennas, based on the root-mean-squared electric field, the whole-body averaged specific absorption rate (SAR), and

the 10 g averaged SAR in both the limbs and the head and trunk. For this purpose, the basic restrictions and reference levels defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for both the general public and occupational exposure are used. The antennas are designed for Global System for Mobile Communications around 900 MHz (GSM900), GSM1800, High Speed Packet Access (HSPA), and Long Term Evolution (LTE), and are operated with output powers at the individual frequencies up to 300 W. The compliance boundaries are estimated using finite-difference time-domain simulations with the Virtual Family Male and have been determined for three directions with respect to the antennas for 800, 900, 1800, and 2600 MHz. The reference levels are not always conservative when the radiating part of the antenna is small compared to the length of the body. Combined compliance distances, which ensure compliance with all reference levels and basic restrictions, have also been determined for each frequency. A method to determine a conservative estimation of compliance boundaries for multiple-frequency (cumulative) exposure is introduced. Using the errors on the estimated allowed powers, an uncertainty analysis is carried out for the compliance distances. Uncertainties on the compliance distances are found to be smaller than 122%.

**Thielens A, Agneessens S, De Clercq H, Lecoutere J, Verloock L, Tanghe E, Aerts S, Puers R, Rogier H, Martens L, Joseph W. On-body calibration and measurements using a personal, distributed exposimeter for wireless fidelity. Health Phys. 2015 Apr;108(4):407-18. doi: 10.1097/HP.0000000000000238.**

This paper describes the design, calibration, and measurements with a personal, distributed exposimeter (PDE) for the on-body detection of radio frequency (RF) electromagnetic fields due to Wireless Fidelity (WiFi) networks. Numerical simulations show that using a combination of two RF nodes placed on the front and back of the body reduces the 50% prediction interval (PI50) on the incident free-space electric-field strength (Equation is included in full-text article.). Median reductions of 10 dB and 9.1 dB are obtained compared to the PI50 of a single antenna placed on the body using a weighted arithmetic and geometric average, respectively. Therefore, a simple PDE topology based on two nodes, which are deployed on opposite sides of the human torso, is applied for calibration and measurements. The PDE is constructed using flexible, dual-polarized textile antennas and wearable electronics, which communicate wirelessly with a Universal Serial Bus (USB) connected receiver and can be unobtrusively integrated into a garment. The calibration of the PDE in an anechoic chamber proves that the PI50 of the measured (Equation is included in full-text article.)is reduced to 3.2 dB. To demonstrate the real-life usability of the wireless device, a subject was equipped with the PDE during a walk in the city of Ghent, Belgium. Using a sample frequency of 2 Hz, an average incident power density of 59 nW m was registered in the WiFi frequency band during this walk.

**Thomas S, Kühnlein A, Heinrich S, Praml G, von Kries R, Radon K. Exposure to mobile telecommunication networks assessed using personal dosimetry and well-being in children and adolescents: the German MobilEe-study. Environ Health. 7(1):54, 2008.**

BACKGROUND: Despite the increase of mobile phone use in the last decade and the

growing concern whether mobile telecommunication networks adversely affect health and well-being, only few studies have been published that focussed on children and adolescents. Especially children and adolescents are important in the discussion of adverse health effects because of their possibly higher vulnerability to radio frequency electromagnetic fields. METHODS: We investigated a possible association between exposure to mobile telecommunication networks and well-being in children and adolescents using personal dosimetry. A population-based sample of 1.498 children and 1.524 adolescents was assembled for the study (response 52%). Participants were randomly selected from the population registries of four Bavarian (South of Germany) cities and towns with different population sizes. During a Computer Assisted Personal Interview data on participants' well-being, socio-demographic characteristics and potential confounder were collected. Acute symptoms were assessed three times during the study day (morning, noon, evening).Using a dosimeter (ESM-140 Maschek Electronics), we obtained an exposure profile over 24 hours for three mobile phone frequency ranges (measurement interval 1 second, limit of determination 0.05 V/m) for each of the participants. Exposure levels over waking hours were summed up and expressed as mean percentage of the ICNIRP (International Commission on Non-Ionizing Radiation Protection) reference level. RESULTS: In comparison to non-participants, parents and adolescents with a higher level of education who possessed a mobile phone and were interested in the topic of possible adverse health effects caused by mobile telecommunication network frequencies were more willing to participate in the study. The median exposure to radio frequency electromagnetic fields of children and adolescents was 0.18% and 0.19% of the ICNIRP reference level respectively. CONCLUSION: In comparison to previous studies this is one of the first to assess the individual level of exposure to mobile telecommunication networks using personal dosimetry, enabling objective assessment of exposure from all sources and longer measurement periods. In total, personal dosimetry was proofed to be a well accepted tool to study exposure to mobile phone frequencies in epidemiologic studies including health effects on children and adolescents.

**Thomas S, Heinrich S, von Kries R, Radon K. Exposure to radio-frequency electromagnetic fields and behavioural problems in Bavarian children and adolescents. Eur J Epidemiol. 25(2):135-141, 2010.**

Only few studies have so far investigated possible health effects of radio-frequency electromagnetic fields (RF EMF) in children and adolescents, although experts discuss a potential higher vulnerability to such fields. We aimed to investigate a possible association between measured exposure to RF EMF fields and behavioural problems in children and adolescents. 1,498 children and 1,524 adolescents were randomly selected from the population registries of four Bavarian (South of Germany) cities. During an Interview data on participants' mental health, socio-demographic characteristics and potential confounders were collected. Mental health behaviour was assessed using the German version of the Strengths and Difficulties Questionnaire (SDQ). Using a personal dosimeter, we obtained radio-frequency EMF exposure profiles over 24 h. Exposure levels over waking hours were expressed as mean percentage of the reference level. Overall, exposure to radiofrequency electromagnetic fields was far below the reference level. Seven percent of the

children and 5% of the adolescents showed an abnormal mental behaviour. In the multiple logistic regression analyses measured exposure to RF fields in the highest quartile was associated to overall behavioural problems for adolescents (OR 2.2; 95% CI 1.1-4.5) but not for children (1.3; 0.7-2.6). These results are mainly driven by one subscale, as the results showed an association between exposure and conduct problems for adolescents (3.7; 1.6-8.4) and children (2.9; 1.4-5.9). As this is one of the first studies that investigated an association between exposure to mobile telecommunication networks and mental health behaviour more studies using personal dosimetry are warranted to confirm these findings.

**Thomas S, Benke G, Dimitriadis C, Inyang I, Sim MR, Wolfe R, Croft RJ, Abramson MJ. Use of mobile phones and changes in cognitive function in adolescents. Occup Environ Med.67(12):861-866, 2010.**

Background Several studies have investigated the impact of mobile phone exposure on cognitive function in adults. However, children and adolescents are of special interest due to their developing nervous systems. Methods Data were derived from the Australian Mobile Radiofrequency Phone Exposed Users' Study (MoRPhEUS) which comprised a baseline examination of year 7 students during 2005/2006 and a 1-year follow-up. Sociodemographic and exposure data were collected with a questionnaire. Cognitive functions were assessed with a computerised test battery and the Stroop Color-Word test. Results 236 students participated in both examinations. The proportion of mobile phone owners and the number of voice calls and short message services (SMS) per week increased from baseline to follow-up. Participants with more voice calls and SMS at baseline showed less reductions in response times over the 1-year period in various computerised tasks. Furthermore, those with increased voice calls and SMS exposure over the 1-year period showed changes in response time in a simple reaction and a working memory task. No associations were seen between mobile phone exposure and the Stroop test. Conclusions We have observed that some changes in cognitive function, particularly in response time rather than accuracy, occurred with a latency period of 1 year and that some changes were associated with increased exposure. However, the increased exposure was mainly applied to those who had fewer voice calls and SMS at baseline, suggesting that these changes over time may relate to statistical regression to the mean, and not be the effect of mobile phone exposure.

**Thomée S, Härenstam A, Hagberg M. Mobile phone use and stress, sleep disturbances, and symptoms of depression among young adults--a prospective cohort study.BMC Public Health. 11:66, 2011.**

BACKGROUND: Because of the quick development and widespread use of mobile phones, and their vast effect on communication and interactions, it is important to study possible negative health effects of mobile phone exposure. The overall aim of this study was to investigate whether there are associations between psychosocial aspects of mobile phone use and mental health symptoms in a prospective cohort of young adults. METHODS: The study group consisted of young adults 20-24 years old (n = 4156), who responded to a questionnaire at baseline and 1-year follow-up. Mobile phone exposure variables included frequency of use, but also more qualitative variables: demands on

availability, perceived stressfulness of accessibility, being awakened at night by the mobile phone, and personal overuse of the mobile phone. Mental health outcomes included current stress, sleep disorders, and symptoms of depression. Prevalence ratios (PRs) were calculated for cross-sectional and prospective associations between exposure variables and mental health outcomes for men and women separately. RESULTS: There were cross-sectional associations between high compared to low mobile phone use and stress, sleep disturbances, and symptoms of depression for the men and women. When excluding respondents reporting mental health symptoms at baseline, high mobile phone use was associated with sleep disturbances and symptoms of depression for the men and symptoms of depression for the women at 1-year follow-up. All qualitative variables had cross-sectional associations with mental health outcomes. In prospective analysis, overuse was associated with stress and sleep disturbances for women, and high accessibility stress was associated with stress, sleep disturbances, and symptoms of depression for both men and women. CONCLUSIONS: High frequency of mobile phone use at baseline was a risk factor for mental health outcomes at 1-year follow-up among the young adults. The risk for reporting mental health symptoms at follow-up was greatest among those who had perceived accessibility via mobile phones to be stressful.Public health prevention strategies focusing on attitudes could include information and advice, helping young adults to set limits for their own and others' accessibility.

**Thompson CJ, Anderson V, Rowley JT. Assessment of guidelines for limiting exposures to emf using methods of probabilistic risk analysis. Health Phys 82(4):484-490, 2002.**

Allowable limits of human exposure to radiofrequency fields commonly include a "factor of safety," typically between 10 to 50, which is somewhat arbitrary. The broad objective in our work is to assess radiofrequency exposure limits, hazard thresholds, and safety factors using methods of probabilistic risk analysis. We focus our analysis on the variables affecting peak radiofrequency specific energy absorption rate (SAR) values in the brain from digital mobile telephones operating at approximately 900 MHz. As SAR is defined as a product of positive random variables, it is not unreasonable to assume that SAR has a lognormal distribution. Our analysis of component SAR variables such as conductivity and permittivity of grey brain matter and radiated field strengths using experimental and numerical modeling data strongly supports our hypothesis that SAR values are distributed lognormally. It then follows that the probability that the SAR exceeds a certain threshold can be derived directly and is shown to be very low for handset SARs relative to presently allowable standard limits.

**Thorlin, T., Rouquette, J.-M., Hamnerius, Y., Hansson, E., Persson, M., Bjorklund, U., Rosengren, L., Ronnback, L. and Persson, M. Exposure of Cultured Astroglial and Microglial Brain Cells to 900 MHz Microwave Radiation. Radiat. Res. 166, 409-421, 2006.**

The rapid rise in the use of mobile communications has raised concerns about health issues related to low-level microwave radiation. The head and brain are usually the most exposed targets in mobile phone users. In the brain, two types of glial cells, the astroglial and the microglial cells, are interesting in the context of biological effects

from microwave exposure. These cells are widely distributed in the brain and are directly involved in the response to brain damage as well as in the development of brain cancer. The aim of the present study was to investigate whether 900 MHz radiation could affect these two different glial cell types in culture by studying markers for damage-related processes in the cells. Primary cultures enriched in astroglial cells were exposed to 900 MHz microwave radiation in a temperature-controlled exposure system at specific absorption rates (SARs) of 3 W/kg GSM modulated wave (mw) for 4, 8 and 24 h or 27 W/kg continuous wave (cw) for 24 h, and the release into the extracellular medium of the two pro-inflammatory cytokines interleukin 6 (Il6) and tumor necrosis factor-alpha (Tnfa) was analyzed. In addition, levels of the astroglial cell-specific reactive marker glial fibrillary acidic protein (Gfap), whose expression dynamics is different from that of cytokines, were measured in astroglial cultures and in astroglial cell-conditioned cell culture medium at SARs of 27 and 54 W/kg (cw) for 4 or 24 h. No significant differences could be detected for any of the parameters studied at any time and for any of the radiation characteristics. Total protein levels remained constant during the experiments. Microglial cell cultures were exposed to 900 MHz radiation at an SAR of 3 W/kg (mw) for 8 h, and Il6, Tnfa, total protein and the microglial reactivity marker ED-1 (a macrophage activation antigen) were measured. No significant differences were found. The morphology of the cultured astroglial cells and microglia was studied and appeared to be unaffected by microwave irradiation. Thus this study does not provide evidence for any effect of the microwave radiation used on damage-related factors in glial cells in culture.

**Thors B, Thielens A, Fridén J, Colombi D, Törnevik C, Vermeeren G, Martens L, Joseph W. Radio frequency electromagnetic field compliance assessment of multi-band and MIMO equipped radio base stations. Bioelectromagnetics. 35(4):296-308. 2014.**

In this paper, different methods for practical numerical radio frequency exposure compliance assessments of radio base station products were investigated. Both multi-band base station antennas and antennas designed for multiple input multiple output (MIMO) transmission schemes were considered. For the multi-band case, various standardized assessment methods were evaluated in terms of resulting compliance distance with respect to the reference levels and basic restrictions of the International Commission on Non-Ionizing Radiation Protection. Both single frequency and multiple frequency (cumulative) compliance distances were determined using numerical simulations for a mobile communication base station antenna transmitting in four frequency bands between 800 and 2600 MHz. The assessments were conducted in terms of root-mean-squared electromagnetic fields, whole-body averaged specific absorption rate (SAR) and peak 10 g averaged SAR. In general, assessments based on peak field strengths were found to be less computationally intensive, but lead to larger compliance distances than spatial averaging of electromagnetic fields used in combination with localized SAR assessments. For adult exposure, the results indicated that even shorter compliance distances were obtained by using assessments based on localized and whole-body SAR. Numerical simulations, using base station products employing MIMO transmission schemes, were performed as well and were in agreement with reference measurements. The applicability of various field combination methods for

correlated exposure was investigated, and best estimate methods were proposed. Our results showed that field combining methods generally considered as conservative could be used to efficiently assess compliance boundary dimensions of single- and dual-polarized multicolumn base station antennas with only minor increases in compliance distances.

**Thuroczy G, Kubinyi G, Bodo M, Bakos J, Szabo LD, Simultaneous response of brain electrical activity (EEG) and cerebral circulation (REG) to microwave exposure in rats. Rev Environ Health 10(2):135-148, 1994.**

The correlations between physiological modalities in microwave field-activated systemic or localized regulatory mechanisms with changes in the central nervous system (CNS) seem not to be identical. These problems are important because of the increased number of radiating appliances, e.g. portable radios and mobile telephones. In two series of experiments on anaesthetized rats (N = 40) (i) before and after 10 min, whole body exposures to 2.45 GHz CW microwaves, and (ii) during 30 min exposures to 4 GHz amplitude modulated (AM, 16 Hz) microwaves, the effects on the CNS were observed simultaneously with those on the cardiovascular system by quantitative polygraphic measurement. In acute experiments on rats, electroencephalograms (EEG), rheoencephalograms (REG) as an index of cerebral blood flow (CBF), brain tissue DC impedance and temperature and ECG were recorded simultaneously. The total power of EEG spectra increased after whole body 30 mW/cm2 2.45 GHz CW exposure for 10 min. No changes occurred at 10 mW/cm2. The CBF increased after 10 mW/cm2 exposure. The power of EEG delta (0.5-4 Hz) waves was increased by thermal level of brain localized 4 GHz CW exposure at 42 mW/g specific absorption rate (SAR) simultaneously with the REG amplitude as an index of cerebral blood flow. Amplitude modulation at 16 Hz and 8.4 mW/g SAR was associated with increased power of EEG beta (14.5-30 Hz) waves but changes in the CBF were not observed. CW radiation at 8.4 mW/g increased the cerebral blood flow, but did not change EEG spectra.

**Tice RR, Hook GG, Donner M, McRee DI, Guy AW. Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. Bioelectromagnetics 23:113-126, 2002.**

As part of a comprehensive investigation of the potential genotoxicity of radiofrequency (RF) signals emitted by cellular telephones, in vitro studies evaluated the induction of DNA and chromosomal damage in human blood leukocytes and lymphocytes, respectively. The signals were voice modulated 837 MHz produced by an analog signal generator or by a time division multiple access (TDMA) cellular telephone, 837 MHz generated by a code division multiple access (CDMA) cellular telephone (not voice modulated), and voice modulated 1909.8 MHz generated by a global system of mobile communication (GSM)-type personal communication systems (PCS) cellular telephone. DNA damage (strand breaks/alkali labile sites) was assessed in leukocytes using the alkaline (pH>13) single cell gel electrophoresis (SCG) assay. Chromosomal damage was evaluated in lymphocytes mitogenically stimulated to divide postexposure using the cytochalasin B-binucleate cell micronucleus assay. Cells were exposed at 37±1°C, for 3 or 24 h at average specific absorption rates (SARs) of 1.0-10.0 W/kg. Exposure for either 3 or 24 h did not induce a significant increase in DNA damage in leukocytes, nor did

exposure for 3 h induce a significant increase in micronucleated cells among lymphocytes. However, exposure to each of the four RF signal technologies for 24 h at an average SAR of 5.0 or 10.0 W/kg resulted in a significant and reproducible increase in the frequency of micronucleated lymphocytes. The magnitude of the response (approximately four fold) was independent of the technology, the presence or absence of voice modulation, and the frequency (837 vs. 1909.8 MHz). This research demonstrates that, under extended exposure conditions, RF signals at an average SAR of at least 5.0 W/kg are capable of inducing chromosomal damage in human lymphocytes.

**Tillmann T, Ernst H, Ebert S, Kuster N, Behnke W, Rittinghausen S, Dasenbrock C. Carcinogenicity study of GSM and DCS wireless communication signals in B6C3F1 mice. Bioelectromagnetics.28(3):173-187, 2007.**

The purpose of this study using a total of 1170 B6C3F1 mice was to detect and evaluate possible carcinogenic effects in mice exposed to radio-frequency-radiation (RFR) from Global System for Mobile Communication (GSM) and Digital Personal Communications System (DCS) handsets as emitted by handsets operating in the center of the communication band, that is, at 902 MHz (GSM) and 1747 MHz (DCS). Restrained mice were exposed for 2 h per day, 5 days per week over a period of 2 years to three different whole-body averaged specific absorption rate (SAR) levels of 0.4, 1.3, 4.0 mW/g bw (SAR), or were sham exposed. Regarding the organ-related tumor incidence, pairwise Fisher's test did not show any significant increase in the incidence of any particular tumor type in the RF exposed groups as compared to the sham exposed group. Interestingly, while the incidences of hepatocellular carcinomas were similar in EMF and sham exposed groups, in both studies the incidences of liver adenomas in males decreased with increasing dose levels; the incidences in the high dose groups were statistically significantly different from those in the sham exposed groups. Comparison to published tumor rates in untreated mice revealed that the observed tumor rates were within the range of historical control data. In conclusion, the present study produced no evidence that the exposure of male and female B6C3F1 mice to wireless GSM and DCS radio frequency signals at a whole body absorption rate of up to 4.0 W/kg resulted in any adverse health effect or had any cumulative influence on the incidence or severity of neoplastic and non-neoplastic background lesions, and thus the study did not provide any evidence of RF possessing a carcinogenic potential.

**Tillmann T, Ernst H, Streckert J, Zhou Y, Taugner F, Hansen V, Dasenbrock C. Indication of cocarcinogenic potential of chronic UMTS-modulated radiofrequency exposure in an ethylnitrosourea mouse model. nt J Radiat Biol. 86(7):529-541, 2010.**

PURPOSE: To evaluate putative effects on tumour susceptibility in mice exposed to a UMTS (universal mobile telecommunications system) test signal for up to 24 months, commencing with embryo-fetal exposure.MATERIAL AND METHODS: Animals were exposed to UMTS fields with intensities of 0, 4.8, and 48 W/m(2), the low-dose group (4.8 W/m(2)) was subjected to additional prenatal ethylnitrosourea treatment (40 mg ENU/kg body weight).RESULTS: The high-level UMTS exposure (48 W/m(2)), the sham exposure, and the cage control groups showed comparable tumour incidences

in the protocol organs. In contrast, the ENU-treated group UMTS-exposed at 4.8 W/m(2) displayed an enhanced lung tumour rate and an increased incidence of lung carcinomas as compared to the controls treated with ENU only. Furthermore, tumour multiplicity of the lung carcinomas was increased and the number of metastasising lung tumours was doubled in the ENU/UMTS group as compared to the ENU control group.CONCLUSION: This pilot study indicates a cocarcinogenic effect of lifelong UMTS exposure (4.8 W/m(2)) in female B6C3F1 descendants subjected to pretreatment with ethylnitrosourea.

**Tiwari R, Lakshmi NK, Surender V, Rajesh AD, Bhargava SC, Ahuja YR.Combinative exposure effect of radio frequency signals from CDMA mobile phones and aphidicolin on DNA integrity. Electromagn Biol Med. 27(4):418-425, 2008.**

The aim of present study is to assess DNA integrity on the effect of exposure to a radio frequency (RF) signal from Code Division Multiple Access (CDMA) mobile phones. Whole blood samples from six healthy male individuals were exposed for RF signals from a CDMA mobile phone for 1 h. Alkaline comet assay was performed to assess the DNA damage. The combinative exposure effect of the RF signals and APC at two concentrations on DNA integrity was studied. DNA repair efficiency of the samples was also studied after 2 h of exposure. The RF signals and APC (0.2 microg/ml) alone or in synergism did not have any significant DNA damage as compared to sham exposed. However, univariate analysis showed that DNA damage was significantly different among combinative exposure of RF signals and APC at 0.2 microg/ml ($p < 0.05$) and at 2 microg/ml ($p < 0.02$). APC at 2 microg/ml concentration also showed significant damage levels ($p < 0.05$) when compared to sham exposed. DNA repair efficiency also varied in a significant way in combinative exposure sets ($p < 0.05$). From these results, it appears that the repair inhibitor APC enhances DNA breaks at 2 microg/ml concentration and that the damage is possibly repairable. Thus, it can be inferred that the in vitro exposure to RF signals induces reversible DNA damage in synergism with APC.

**Tkalec M, Malaric K, Pevalek-Kozlina B. Influence of 400, 900, and 1900 MHz electromagnetic fields on Lemna minor growth and peroxidase activity. Bioelectromagnetics. 26(3):185-193, 2005.**

Increased use of radio and microwave frequencies requires investigations of their effects on living organisms. Duckweed (Lemna minor L.) has been commonly used as a model plant for environmental monitoring. In the present study, duckweed growth and peroxidase activity was evaluated after exposure in a Gigahertz Transversal Electromagnetic (GTEM) cell to electric fields of frequencies 400, 900, and 1900 MHz. The growth of plants exposed for 2 h to the 23 V/m electric field of 900 MHz significantly decreased in comparison with the control, while an electric field of the same strength but at 400 MHz did not have such effect. A modulated field at 900 MHz strongly inhibited the growth, while at 400 MHz modulation did not influence the growth significantly. At both frequencies a longer exposure mostly decreased the growth and the highest electric field (390 V/m) strongly inhibited the growth. Exposure of plants to lower field strength (10 V/m) for 14 h caused significant decrease at 400 and 1900 MHz while 900 MHz did not

influence the growth. Peroxidase activity in exposed plants varied, depending on the exposure characteristics. Observed changes were mostly small, except in plants exposed for 2 h to 41 V/m at 900 MHz where a significant increase (41%) was found. Our results suggest that investigated electromagnetic fields (EMFs) might influence plant growth and, to some extent, peroxidase activity. However, the effects of EMFs strongly depended on the characteristics of the field exposure.

**Tkalec M, Malarić K, Pevalek-Kozlina B. Exposure to radiofrequency radiation induces oxidative stress in duckweed Lemna minor L. Sci Total Environ. 388(1-3):78-89, 2007.**

Widespread use of radiofrequency radiation emitting devices increased the exposure to electromagnetic fields (EMFs) from 300 MHz to 300 GHz. Various biological effects of exposure to these fields have been documented so far, but very little work has been carried out on plants. The aim of the present work was to investigate the physiological responses of the plant Lemna minor after exposure to radiofrequencyEMFs, and in particular, to clarify the possible role of oxidative stress in the observed effects. Duckweed was exposed for 2 h to EMFs of 400 and 900 MHz at field strengths of 10, 23, 41 and 120 V m(-1). The effect of a longer exposure time (4 h) and modulation was also investigated. After exposure, parameters of oxidative stress, such as lipid peroxidation, H(2)O(2) content, activities and isoenzyme pattern of antioxidative enzymes as well as HSP70 expression were evaluated. At 400 MHz, lipid peroxidation and H(2)O(2) content were significantly enhanced in duckweed exposed to EMFs of 23 and 120 V m(-1) while other exposure treatments did not have an effect. Compared to the controls, the activities of antioxidative enzymes showed different behaviour: catalase (CAT) activity increased after most exposure treatments while pyrogallol (PPX) and ascorbate peroxidase (APX) activities were not changed. Exceptions were reduced PPX and APX activity after longer exposure at 23 V m(-1) and increased PPX activity after exposures at 10 and 120 V m(-1). By contrast, at 900 MHz almost all exposure treatments significantly increased level of lipid peroxidation and H(2)O(2) content but mostly decreased PPX activity and did not affect CAT activity. Exceptions were exposures to a modulated field and to the field of 120 V m(-1) which increased PPX and CAT activity. At this frequency APX activity was significantly decreased after exposure at 10 V m(-1) and longer exposure at 23 V m(-1) but it increased after a shorter exposure at 23 V m(-1). At both frequencies no differences in isoenzyme patterns of antioxidative enzymes or HSP70 level were found between control and exposed plants. Our results showed that non-thermal exposure to investigated radiofrequency fields induced oxidative stress in duckweed as well as unspecific stress responses, especially of antioxidative enzymes. However, the observed effects markedly depended on the field frequencies applied as well as on other exposure parameters (strength, modulation and exposure time). Enhanced lipid peroxidation and H(2)O(2) content accompanied by diminished antioxidative enzymes activity caused by exposure to investigated EMFs, especially at 900 MHz, indicate that oxidative stress could partly be due to changed activities of antioxidative enzymes.

**Tkalec M, Malarić K, Pavlica M, Pevalek-Kozlina B, Vidaković-Cifrek Z. Effects of radiofrequency electromagnetic fields on seed germination and root meristematic cells of Allium cepa L. Mutat Res. 672(2):76-81, 2009.**

The effects of exposure to radiofrequency electromagnetic fields (RF-EMFs) on seed germination, primary root growth as well as mitotic activity and mitotic aberrations in root meristematic cells were examined in Allium cepa L. cv. Srebrnjak Majski. Seeds were exposed for 2h to EMFs of 400 and 900MHz at field strengths of 10, 23, 41 and 120Vm(-1). The effect of longer exposure time (4h) and field modulation was investigated at 23Vm(-1) as well. Germination rate and root length did not change significantly after exposure to radiofrequency fields under any of the treatment conditions. At 900MHz, exposures to EMFs of higher field strengths (41 and 120Vm(-1)) or to modulated fields showed a significant increase of the mitotic index compared with corresponding controls, while the percentage of mitotic abnormalities increased after all exposure treatments. On the other hand, at 400MHz the mitotic index increased only after exposure to modulated EMF. At this frequency, compared with the control higher numbers of mitotic abnormalities were found after exposure to modulated EMF as well as after exposure to EMFs of higher strengths (41 and 120Vm(-1)). The types of aberration induced by the EMFs of both frequencies were quite similar, mainly consisting of lagging chromosomes, vagrants, disturbed anaphases and chromosome stickiness. Our results show that non-thermal exposure to the radiofrequency fields investigated here can induce mitotic aberrations in root meristematic cells of A. cepa. The observed effects were markedly dependent on the field frequencies applied as well as on field strength and modulation. Our findings also indicate that mitotic effects of RF-EMF could be due to impairment of the mitotic spindle.

**Tkalec M, Stambuk A, Srut M, Malarić K, Klobučar GI. Oxidative and genotoxic effects of 900 MHz electromagnetic fields in the earthworm Eisenia fetida. Ecotoxicol Environ Saf. 90:7-12, 2013.**

Accumulating evidence suggests that exposure to radiofrequency electromagnetic field (RF-EMF) can have various biological effects. In this study the oxidative and genotoxic effects were investigated in earthworms Eisenia fetida exposed in vivo to RF-EMF at the mobile phone frequency (900 MHz). Earthworms were exposed to the homogeneous RF-EMF at field levels of 10, 23, 41 and 120 V m(-1) for a period of 2h using a Gigahertz Transversal Electromagnetic (GTEM) cell. At the field level of 23 V m(-1) the effect of longer exposure (4h) and field modulation (80% AM 1 kHz sinusoidal) was investigated as well. All exposure treatments induced significant genotoxic effect in earthworms coelomocytes detected by the Comet assay, demonstrating DNA damaging capacity of 900 MHz electromagnetic radiation. Field modulation additionally increased the genotoxic effect. Moreover, our results indicated the induction of antioxidant stress response in terms of enhanced catalase and glutathione reductase activity as a result of the RF-EMF exposure, and demonstrated the generation of lipid and protein oxidative damage. Antioxidant responses and the potential of RF-EMF to induce damage to lipids, proteins and DNA differed depending on the field level applied, modulation of the field and duration of E. fetida exposure to 900 MHz electromagnetic radiation. Nature of detected

DNA lesions and oxidative stress as the mechanism of action for the induction of DNA damage are discussed.

**Tök L, Nazıroğlu M, Doğan S, Kahya MC, Tök O. Effects of melatonin on Wi-Fi-induced oxidative stress in lens of rats. Indian J Ophthalmol. 62(1):12-15, 2014. doi: 10.4103/0301-4738.126166.**

Introduction: Melatonin has been considered a potent antioxidant that detoxifies a variety of reactive oxygen species in many pathophysiological states of eye. The present study was designed to determine the effects of Wi-Fi exposure on the lens oxidant, antioxidant redox systems, as well as the possible protective effects of melatonin on the lens injury induced by electromagnetic radiation (EMR). Materials and Methods: Thirty-two rats were used in the current study and they were randomly divided into four equal groups as follows: First and second groups were cage-control and sham-control rats. Rats in third group were exposed to Wi-Fi (2.45 GHz) for duration of 60 min/day for 30 days. As in the third group, the fourth group was treated with melatonin. The one-hour exposure to irradiation in second, third and fourth took place at noon each day. Results: Lipid peroxidation levels in the lens were slightly higher in third (Wi-Fi) group than in cage and sham control groups although their concentrations were significantly ($P < 0.05$) decreased by melatonin supplementation. Glutathione peroxidase (GSH-Px) activity was significantly ($P < 0.05$) lower in Wi-Fi group than in cage and sham control groups although GSH-Px ($P < 0.01$) and reduced glutathione ($P < 0.05$) values were significantly higher in Wi-Fi + melatonin group than in Wi-Fi group. Conclusions: There are poor oxidative toxic effects of one hour of Wi-Fi exposure on the lens in the animals. However, melatonin supplementation in the lens seems to have protective effects on the oxidant system by modulation of GSH-Px activity.

**Tokola K, Kurttio P, Salminen T, Auvinen A. Reducing overestimation in reported mobile phone use associated with epidemiological studies. Bioelectromagnetics. 29(7):559-563, 2008.**

Case-control studies of mobile phones are commonly based on retrospective, self-reported exposure information, which are often characterized as involving substantial uncertainty concerning data validity. We assessed the validity of self-reported mobile phone use and developed a statistical model to account for the over-reporting of exposure. We collected information on mobile phone use from 70 volunteers using two sources of data: self-report in an interview and network operator records. We used regression models to obtain bias-corrected estimates of exposure. A correlation coefficient of 0.71 was obtained between the self-reported and the network operators' data on average calling time (log-transformed minutes per month). A simple linear regression model, where the duration of calls acquired from network operators is explained with the self-reported duration fitted the data reasonably well (adjusted R(2) 0.51). The constant term was 2.71 and the regression coefficient 0.49 (logarithmic scale). No significant improvement in the model fit was achieved by including potential predictors of accuracy in self-reported exposure estimates, such as the pattern of mobile phone use, the modality of response to the questionnaire or demographic characteristics. Overestimation in self-reported intensity of mobile phone use can be accounted for by the

use of regression calibration. The estimates obtained in our study may not be applicable in other contexts, but similar methods could be used to reduce bias in other studies.

**Tombini M, Pellegrino G, Pasqualetti P, Assenza G, Benvenga A, Fabrizio E, Rossini PMMobile phone emissions modulate brain excitability in patients with focal epilepsy.Brain Stimul. 2012 Aug 9. [Epub ahead of print]**

BACKGROUND: Electromagnetic fields (EMFs) emitted by mobile phones had been shown to increase cortical excitability in healthy subjects following 45 min of continuous exposure on the ipsilateral hemisphere. OBJECTIVE: Using Transcranial Magnetic Stimulation (TMS), the current study assessed the effects of acute exposure to mobile phone EMFs on the cortical excitability in patients with focal epilepsy. METHODS: Ten patients with cryptogenic focal epilepsy originating outside the primary motor area (M1) were studied. Paired-pulse TMS were applied to the M1 of both the hemisphere ipsilateral (IH) and contralateral (CH) to the epileptic focus before and immediately after real/sham exposure to the GSM-EMFs (45 min). The TMS study was carried out in all subjects in three different experimental sessions (IH and CH exposure, sham), 1 week apart, according to a crossover, double-blind and counter-balanced paradigm. RESULTS: The present study clearly demonstrated that an acute and relatively prolonged exposure to GSM-EMFs modulates cortical excitability in patients affected by focal epilepsy; however, in contrast to healthy subjects, these effects were evident only after EMFs exposure over the hemisphere contralateral to the epileptic focus (CH). They were characterized by a significant cortical excitability increase in the exposed hemisphere paired with slight excitability decrease in the other one (IH). Both sham and real EMFs exposure of the IH did not affect brain excitability. CONCLUSION: Present results suggest a significant interaction between the brain excitability changes induced by EMFs and the epileptic focus, which eliminated the excitability enhancing effects of EMFs evident only in the CH.

**Tomitsch J**, **Dechant E**, **Frank W**. **Survey of electromagnetic field exposure in bedrooms of residences in lower Austria. Bioelectromagnetics.31(3):200-208, 2010.**

Previous investigations of exposure to electric, magnetic, or electromagnetic fields (EMF) in households were either about electricity supply EMFs or radio frequency EMFs (RF-EMFs). We report results from spot measurements at the bedside that comprise electrostatic fields, extremely low-frequency electric fields (ELF-EFs), extremely low-frequency magnetic fields (ELF-MFs), and RF-EMFs. Measurements were taken in 226 households throughout Lower Austria. In addition, effects of simple reduction measures (e.g., removal of clock radios or increasing their distance from the bed, turning off Digital Enhanced Cordless Telecommunication (DECT) telephone base stations) were assessed. All measurements were well below International Commission on Non-Ionizing Radiation Protection (ICNIRP) guideline levels. Average night-time ELF-MFs (long-term measurement from 10 pm to 6 am, geometric mean over households) above 100 nT were obtained in 2.3%, and RF-EMFs above 1000 microW/m(2) in 7.1% of households. Highest ELF-EFs were primarily due to lamps beside the bed (max = 166 V/m), and highest ELF-MFs because of transformers of devices (max = 1030 nT) or high current of power lines (max = 380 nT). The highest values of RF-EMFs were caused by DECT telephone base stations (max = 28979 microW/m(2)) and mobile phone base stations

(max = 4872 microW/m(2)). Simple reduction measures resulted in an average decrease of 23 nT for ELF-MFs, 23 V/m for ELF-EFs, and 246 microW/m(2) for RF-EMFs. A small but statistically significant correlation between ELF-MF exposure and overall RF-EMF levels of R = 0.16 (P = 0.008) was computed that was independent of type (flat, single family) and location (urban, rural) of houses.

**Tomitsch J, Dechant E. Trends in residential exposure to electromagnetic fields from 2006 to 2009.Radiat Prot Dosimetry. 149(4):384-391, 2012.**

After measuring extremely low frequency electric and magnetic fields (ELF-EFs, ELF-MFs) and radio frequency electromagnetic fields (RF-EMFs) in 2006, a follow-up investigation was done in 2009. Overall, 130 measurements in bedrooms at identical and 83 at changed locations within the same or a neighbouring building were performed. The median of ELF-EFs decreased from 25.15 to 17.35 V m(-1) from 2006 to 2009. The median of all-night ELF-MFs from power supply decreased from 16.86 to 12.76 nT, whereas the arithmetic mean was almost unchanged (+0.1%). No difference in the medians of all-night ELF-MFs of railway current was observed. RF-EMFs increased from 41.35 to 59.56 µW m(-2). Increases primarily occurred in the frequency ranges of Global System for Mobile 900 MHz, Universal Mobile Telecommunications System and Wireless Local Area Network. Television changeover from analogue to digital resulted in a reduction within the Ultra-high Frequency-band from 0.47 to 0.35 µW m(-2). The base stations of the recently established terrestrial trunked radio system caused a median of 0.05 µW m(-2).

**Tomitsch J, Dechant E. Exposure to electromagnetic fields in households-Trends from 2006 to 2012. Bioelectromagnetics. 2014 Nov 24. doi: 10.1002/bem.21887. [Epub ahead of print]**

This article is a follow-up study of extremely low-frequency electric and magnetic fields (ELF-EFs, ELF-MFs) and radiofrequency electromagnetic fields (RF-EMFs) using data collected in 2012 following earlier data sets from 2006 and 2009. Measurements were conducted in 219 bedrooms in Lower Austria. Out of these rooms 113 measurements were done in the same households in 2006, 2009 and 2012, and 106 were conducted in neighbouring buildings added in 2009 and newly recruited buildings in mainly urban areas in 2012. In revisited places the median of the ELF-EFs decreased from 23.20 V/m in 2006 to 13.90 V/m in 2012. The median of all-night measurements of ELF-MFs at 50 Hz decreased from 13.50 to 11.37 nT. The median of total RF-EMFs increased from 28.13 to 52.16 $\mu W/m^2$ . Highest increases were found for universal mobile telecommunication system (UMTS) and wireless local area networks (WLAN). The analysis of all households showed higher total RF-EMFs in urban (median = 117.73 $\mu W/m^2$ ) than in rural (median = 34.52 $\mu W/m^2$ ) areas. Long-term evolution (LTE) in the 2600 MHz frequency range was detected at 17 locations with a maximum of 38.20 $\mu W/m^2$ . Indoor RF-EMF sources resulted in decreased exposure in the frequency range of digital enhanced cordless telecommunications telephones (DECT) and increased exposure in the frequency range of WLAN.

**Tong J, Chen S, Liu XM, Hao DM. [Effect of electromagnetic radiation on discharge activity of neurons in the hippocampus CA1 in rats]. Zhongguo Ying Yong Sheng Li Xue Za Zhi. 29(5):423-427, 2013. [Article in Chinese]**

OBJECTIVE: In order to explore effect of electromagnetic radiation on learning and memory ability of hippocampus neuron in rats, the changes in discharge patterns and overall electrical activity of hippocampus neuron after electromagnetic radiation were observed. METHODS: Rat neurons discharge was recorded with glass electrode extracellular recording technology and a polygraph respectively. Radiation frequency of electromagnetic wave was 900 MHZ and the power was 10 W/m2. In glass electrode extracellular recording, the rats were separately irradiated for 10, 20, 30, 40, 50 and 60 min, every points repeated 10 times and updated interval of 1h, observing the changes in neuron discharge and spontaneous discharge patterns after electromagnetic radiation. In polygraph recording experiments, irradiation group rats for five days a week, 6 hours per day, repeatedly for 10 weeks, memory electrical changes in control group and irradiation group rats when they were feeding were repeatedly monitored by the implanted electrodes, observing the changes in peak electric digits and the largest amplitude in hippocampal CA1 area, and taking some electromagnetic radiation sampling sequence for correlation analysis. RESULTS: (1) Electromagnetic radiation had an inhibitory role on discharge frequency of the hippocampus CA1 region neurons. After electromagnetic radiation, discharge frequency of the hippocampus CA1 region neurons was reduced, but the changes in scale was not obvious. (2) Electromagnetic radiation might change the spontaneous discharge patterns of hippocampus CA1 region neurons, which made the explosive discharge pattern increased obviously. (3) Peak potential total number within 5 min in irradiation group was significantly reduced, the largest amplitude was less than that of control group. (4) Using mathematical method to make the correlation analysis of the electromagnetic radiation sampling sequence, that of irradiation group was less than that of control group, indicating that there was a tending to be inhibitory connection between neurons in irradiation group after electromagnetic radiation. CONCLUSION: Electromagnetic radiation may cause structure and function changes of transfer synaptic in global, make hippocampal CA1 area neurons change in the overall discharge characteristic and discharge patterns, thus lead to decrease in the ability of learning and memory.

**Topal Z, Hanci H, Mercantepe T, Erol HS, Keleş ON, Kaya H, Mungan S, Odaci E. The effects of prenatal long-duration exposure to** 900-MHz **electromagnetic field on the 21-day-old newborn male rat liver. Turk J Med Sci. 45(2):291-297, 2015.**

BACKGROUND/AIM: To determine what effect a **900**-**MHz** electromagnetic field (EMF) applied in the prenatal period would have on the liver in the postnatal period. MATERIALS AND METHODS: At the start of the study, adult pregnant rats were divided into two groups, control and experimental. The experimental group was exposed to a **900**-**MHz** EMF for 1 h daily during days 13-21 of pregnancy. After birth, no procedure was performed on either mothers or pups. Male rat pups (n = 6) from the control group mothers (CGMR) and male rat pups (n = 6) from the experimental group mothers (EGMR) were sacrificed on postnatal day 21. RESULTS: Biochemical analyses showed that malondialdehyde and superoxide dismutase values increased and glutathione levels

decreased in the EGMR pups. Marked hydropic degeneration in the parenchyma, particularly in pericentral regions, was observed in light microscopic examination of EGMR sections stained with hematoxylin and eosin. Examinations under transmission electron microscope revealed vacuolization in the mitochondria, expansion in the endoplasmic reticulum, and necrotic hepatocytes. CONCLUSION: The study results show that a **900**-**MHz** EMF applied in the prenatal period caused oxidative stress and pathological alterations in the liver in the postnatal period.

**Tornros JE, Bolling AK. Mobile phone use-Effects of handheld and handsfree phones on driving performance. Accid Anal Prev. 37(5):902-909, 2005.**

The study was concerned with effects of handsfree and handheld mobile phone dialling and conversation in simulated driving. In the main experiment dealing with conversation, 48 participants drove a distance of about 70km on a route which led through urban and rural environments. In the dialling experiment, the participants drove a distance of 15km on a rural two-lane road. The experimental design was mixed with phone mode as a between-subjects factor and phone use (yes/no) as a within-subjects factor. Performance on a peripheral detection task (PDT) while driving was impaired by dialling and conversation for both phone modes, interpreted as an increase in mental workload. Driving performance was impaired by dialling-lateral position deviation increased in a similar way for both phone modes. Conversation had, however, opposite effects-lateral position deviation decreased in a similar way for both phone modes. Driving speed decreased as an effect of dialling with the greatest effect for handsfree phone mode. Conversation also caused reduced speed, but only for handheld phone mode. The effects on speed can be interpreted as a compensatory effort for the increased mental workload. In spite of the compensatory behaviour, mental workload was still markedly increased by phone use. Subjective effects of dialling and conversation were also analysed. Most participants reported a speed decrease but no effect on lateral position deviation as an effect of dialling or conversation. In the conversation experiment, driving performance was rated better for handsfree than for handheld mode. In the dialling experiment, no difference between the two phone modes appeared.

**Tomruk A, Guler G, Dincel AS. The influence of 1800 MHz GSM-like signals on hepatic oxidative DNA and lipid damage in nonpregnant, pregnant, and newly born rabbits. Cell Biochem Biophys. 56(1):39-47, 2010.**

The aim of our study is to evaluate the possible biological effects of whole-body 1800 MHz GSM-like radiofrequency (RF) radiation exposure on liver oxidative DNA damage and lipid peroxidation levels in nonpregnant, pregnant New Zealand White rabbits, and in their newly borns. Eighteen nonpregnant and pregnant rabbits were used and randomly divided into four groups which were composed of nine rabbits: (i) Group I (nonpregnant control), (ii) Group II (nonpregnant-RF exposed), (iii) Group III (pregnant control), (iv) Group IV (pregnant-RF exposed). Newborns of the pregnant rabbits were also divided into two groups: (v) Group V (newborns of Group III) and (vi) Group VI (newborns of Group III). 1800 MHz GSM-like RF radiation whole-body exposure (15 min/day for a week) was applied to Group II and Group IV. No significant differences were found in liver 8 OHdG/10(6) dG levels of exposure groups

(Group II and Group IV) compared to controls (Group I and Group III). However, in Group II and Group IV malondialdehyde (MDA) and ferrous oxidation in xylenol orange (FOX) levels were increased compared to Group I ($P < 0.05$, Mann-Whitney). No significant differences were found in liver tissue of 8 OHdG/10(6) dG and MDA levels between Group VI and Group V ($P > 0.05$, Mann-Whitney) while liver FOX levels were found significantly increased in Group VI with respect to Group V ($P < 0.05$, Mann-Whitney). Consequently, the whole-body 1800 MHz GSM-like RF radiation exposure may lead to oxidative destruction as being indicators of subsequent reactions that occur to form oxygen toxicity in tissues.

**Tri JL, Hayes DL, Smith TT, Severson RP, Cellular phone interference with external cardiopulmonary monitoring devices. Mayo Clin Proc 76(1):11-15, 2001.**

OBJECTIVES: To determine the potential effect (electromagnetic interference) of cellular telephones on external cardiopulmonary monitoring devices. METHODS: For this study, we tested 17 different medical devices with 5 portable telephones (4 digital, 1 analog) to assess the potential for electromagnetic interference. The telephones were tested in a normal operating mode to simulate a typical hospital environment with patients or their families using their cellular phones. The medical devices were connected to the appropriate simulators for proper operation while the tests were under way. The screens and alarms of the medical devices were monitored while the telephones were maneuvered in the y and z planes near the devices. Clinically important interference was defined as interference that may hinder interpretation of the data or cause the equipment to malfunction. RESULTS: Any type of interference occurred in 7 (41%) of the 17 devices tested during 54.7% of the 526 tests. The incidence of clinically important interference was 7.4%. CONCLUSIONS: Cellular telephones may interfere with the operation of external cardiopulmonary monitoring devices. However, most of the test results showed that the interference would rarely be clinically important.

**Trigano AJ, Azoulay A, Rochdi M, Campillo, A Electromagnetic interference of external pacemakers by walkie-talkies and digital cellular phones: experimental study. Pacing Clin Electrophysiol 22(4 Pt 1):588-593, 1999.**

A number of experimental and clinical studies have documented the risk potential of interference with implanted pacemakers by various types of cellular phones. Radiofrequency susceptibility of external medical equipment has also been reported in experimental studies. The purpose of this experimental study was to evaluate electromagnetic interference of external pacemakers by walkie-talkies and digital cellular telephones. External bipolar pacing was monitored using a digital oscilloscope to record pacemaker pulses and electromagnetic interference separately. Tests with the walkie-talkie, Private Mobile Radio (PMR) (160 MHz, 2.5 W) were conducted during the calling phase. Tests with the cellular phones, global system for mobile communications (GSM) (900 MHz, 2 W) and Digital Cellular System (DCS) (1,800 MHz, 1 W) were conducted in the test mode. Nine widely used external pacemakers from four manufacturers were tested. Various disturbances including pacing inhibition and asynchronous pacing were observed in eight pacemakers by the PMR, in four by the GSM phone, and in two by the DCS phone. The maximum distance that

interference persisted ranged from 10-200 cm. This experimental study shows a potential risk of interference of external pacemakers by walkie-talkies and cellular digital phones. Appropriate warnings should be issued against the potentially serious risks of using communication devices in the vicinity of acutely ill patients treated with temporary transvenous cardiac pacemakers.

**Trigano A, Blandeau O, Dale C, Wong MF, Wiart J. Reliability of electromagnetic filters of cardiac pacemakers tested by cellular telephone ringing. Heart Rhythm. 2(8):837-841, 2005.**

BACKGROUND: State-of-the art cardiac pacemakers are protected against radiofrequency signals. Although there have been earlier clinical and in vitro reports of cellular phone interference with implantable devices, only a few studies have been performed in recent years. The ringing phase of digital GSM or PCS cellular phones includes a brief period of peak radiated power. OBJECTIVES: This study tested the protection offered by electromagnetic filters of cardiac pacemakers against cellular phone ringing. METHODS: We performed 330 consecutive tests in 158 patients at the time of routine examination in our pacemaker follow-up clinic. The programmed parameters remained unchanged before testing. During electrocardiographic monitoring, 2 single-band digital cellular phones consecutively placed over the pacemaker pocket each received a call. The phone systems tested were 1) GSM at a maximal power output of 2 W, operating on a 900 MHz carrier frequency, and 2) PCS at a maximal output of 1 W, operating on a 1800 MHz carrier frequency. RESULTS: Interference was noted in only 5 tests, due to interaction by the GSM system with 4 unprotected pacemaker models. The GSM test was negative in 12 other tests of identical pulse generator models. The overall incidence of interference was 1.5% of tests. CONCLUSIONS: Interference by cellular phone ringing occurred only with unprotected pacemaker models. Standard programming of these unprotected models was associated with a low incidence of interference.

**Trigano A, Blandeau O, Dale C, Wong MF, Wiart J.Risk of cellular phone interference with an implantable loop recorder. Int J Cardiol.116(1):126-130, 2007.**

This study examined the risk of cellular phone ringing interference with implantable loop recorders (ILR). The technical manual of ILR warns of potential interference by cellular phone in close proximity to the implanted device, corrupting the data stored in memory or causing inappropriate device operation. The ringing phase of a digital Global System for Mobile Communication (GSM) or Personal Communication Services (PCS) cellular phone includes a brief burst of peak emitted power. To obviate the risk of dysfunction in recipients of implanted ILRs, the testing was performed with externally applied devices. The ILR was positioned in the left parasternal region and the telemetry wand removed after regular programming. Digital cellular telephones were placed over the device at a 1-cm distance and calls were placed. The phone systems tested were single- or dual-band receivers. The GSM used a maximal power output of 2 W, operating on a 900 MHz carrier frequency, and the PCS a maximal output of 1 W, operating on a 1800 MHz carrier frequency. The device activator was used to store the episodes encompassing the tests. Sixty nine tests were performed in 45 patients. In 61 tests, high-frequency polymorphic artifacts were visible on manually activated recordings, beginning a few seconds before the first audible ringing tone and persisting throughout the ringing phase. Cellular phone

ringing in close proximity to an externally applied ILR caused bursts of high-frequency signals during electrocardiogram monitoring, without causing permanent device dysfunction or reprogramming. Cellular telephones are a potential source of electrocardiographic artifacts on ILR recordings.

**Trivino Pardo JC, Grimaldi S, Taranta M, Naldi I, Cinti C. Microwave electromagnetic field regulates gene expression in T-lymphoblastoid leukemia CCRF-CEM cell line exposed to 900 MHz. Electromagn Biol Med. 31(1):1-18, 2012.**

Electric, magnetic, and electromagnetic fields are ubiquitous in our society, and concerns have been expressed regarding possible adverse effects of these exposures. Research on Extremely Low-Frequency (ELF) magnetic fields has been performed for more than two decades, and the methodology and quality of studies have improved over time. Studies have consistently shown increased risk for childhood leukemia associated with ELFmagnetic fields. There are still inadequate data for other outcomes. More recently, focus has shifted toward Radio Frequencies (RF) exposures from mobile telephony. There are no persuasive data suggesting a health risk, but this research field is still immature with regard to the quantity and quality of available data. This technology is constantly changing and there is a need for continued research on this issue. To investigate whether exposure to high-frequency electromagnetic fields (EMF) could induce adverse health effects, we cultured acute T-lymphoblastoid leukemia cells (CCRF-CEM) in the presence of 900 MHz MW-EMF generated by a transverse electromagnetic (TEM) cell at short and long exposure times. We evaluated the effect of high-frequency EMF on gene expression and we identified functional pathways influenced by 900 MHz MW-EMF exposure.

**Trosic I, Matausicpisl M, Radalj Z, Prlic I, Animal study on electromagnetic field biological potency. Arh Hig Rada Toksikol 50(1):5-11, 1999.**

This recent basic research study used an animal model protocol to assess specific biomarkers of the effect of non-ionising, non-thermal radiation (2450 MHz microwave radiation at 5-15 mW/cm2) on bone marrow, peripheral blood, and bronchoalveolar free cell populations. Of 40 male Wistar rats taken in the study, 20 animals of the experimental group were irradiated for 2 hours a day, 5 days a week, and subsequently killed on days 1, 8, 16, and 30 of the experiment. The remaining 20 rats served as control. All animals were previously intratracheally instilled with biologically inert microspheres to see the influence of irradiation on lung retention kinetics. The cell response to chosen electromagnetic irradiation was followed quantitatively and qualitatively using the standard laboratory methods. The results of peripheral blood cell response suggested a decreasing tendency in total leukocyte count and in relative lymphocyte count in the treated group. A slight increase was also observed in granulocyte count and in the absolute count of peripheral blood erythrocytes over control animals.

**Trosic I. Multinucleated giant cell appearance after whole body microwave irradiation of rats. Int J Hyg Environ Health. 204(2-3):133-138, 2001.**

Multinucleated giant cells are common for some chronic inflammatory processes in the

lung. These cells are formed by fusion of macrophages, but how the process relates to the kinetics of alveolar macrophage generation is not clear. This study investigated the influence of 2450 MHz microwave irradiation on alveolar macrophage kinetics and formation of multinucleated giant cells after whole body irradiation of rats. The range of electromagnetic radiation was selected as 2450 MHz microwaves at a power density of 5-15 mW/cm2. A group of experimental animals was divided in four subgroups that received 2, 8, 13 and 22 irradiation treatments of two hours each. The animals were killed on experimental days 1, 8, 16, and 30. Free lung cell population was obtained by bronchoalveolar lavage. Cell response to the selected irradiation level was followed quantitatively, qualitatively and morphologically using standard laboratory methods. Total cell number retrieved by lavage slightly decreased in treated animals showing time- and dose-dependence. Cell viability did not significantly change in the irradiated animal group (G2) as compared with the control group (G1). Multinucleated cells significantly increased ($p < 0.01$) in treated animals. The elevation of the number of nuclei per cell was time- and dose-dependent. Macrophages with two nucleoli were more common in animals treated twice or eight times. Polynucleation, that is three and more nucleoli in a single cell, was frequently observed after 13 or 22 treatments. Binucleation and multinucleation of alveolar macrophages were sensitive time- and dose-dependent morphological indicators of pulmonary stress.

**Trosic I, Busljeta I, Kasuba V, Rozgaj R. Micronucleus induction after whole-body microwave irradiation of rats. Mutat Res 521(1-2):73-79, 2002.**

Adult male Wistar rats were exposed for 2h a day, 7 days a week for up to 30 days to continuous 2450MHz radiofrequency microwave (rf/MW) radiation at a power density of 5-10mW/cm(2). Sham-exposed rats were used as controls. After ether anesthesia, experimental animals were euthanized on the final irradiation day for each treated group. Peripheral blood smears were examined for the extent of genotoxicity, as indicated by the presence of micronuclei in polychromatic erythrocytes (PCEs). The results for the time-course of PCEs indicated significant differences ($P<0.05$) for the 2nd, the 8th and the 15th day between control and treated subgroups of animals. Increased influx of immature erythrocytes into the peripheral circulation at the beginning of the experiment revealed that the proliferation and maturation of nucleated erythropoietic cells were affected by exposure to the 2450MHz radiofrequency radiation. Such findings are indicators of radiation effects on bone-marrow erythropoiesis and their subsequent effects in circulating red cells. The incidence of micronuclei/1000 PCEs in peripheral blood was significantly increased ($P<0.05$) in the subgroup exposed to rf/MW radiation after eight irradiation treatments of 2h each in comparison with the sham-exposed control group. It is likely that an adaptive mechanism, both in erythrocytopoiesis and genotoxicity appeared in the rat experimental model during the subchronic irradiation treatment.

**Trosic I, Busljeta I, Pavicic I. Blood-forming system in rats after whole-body microwave exposure; reference to the lymphocytes. Toxicol Lett. 154(1-2):125-132, 2004.**

The influence of 2.45GHz microwave (RF/MW) irradiation on blood-forming cells after whole-body irradiation of rats was investigated. The exposures were conducted with a field power density of 5-10mW/cm(2), and whole-body average specific absorption rate

(SAR) of 1-2W/kg. Four experimental subgroups were created and irradiated 2, 8, 15 or 30 days, for 2h a day, 7 days a week. Concurrent sham-exposed rats were also included in the study. The cell response was assessed by number and type of the bone marrow nuclear cells and peripheral blood white cells using standard laboratory methods. Significant decrease in lymphoblast count was obtained at 15 and 30th experimental day ($P < 0.05$), whereas other examined parameters did not significantly differed in comparison to the sham-exposed controls. The findings point out at stress response in blood-forming system in rats after selected microwave exposure, which could be considered rather as sign of adaptation than malfunction.

**Trosic I, Busljeta I, Modlic B. Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: in vivo exposure. Mutagenesis. 19(5):361-364, 2004.**

An in vivo mammalian cytogenetic test (the erythrocyte micronucleus assay) was used to investigate the extent of genetic damage in bone marrow red cells of rats exposed to radiofrequency/microwave (RF/MW) radiation. Wistar rats (n = 40) were exposed to a 2.45 GHz continuous RF/MW field for 2 h daily, 7 days a week, at a power density of 5-10 mW/cm(2). The whole body average specific absorption rate (SARs) was calculated to be 1.25 +/- 0.36 (SE) W/kg. Four subgroups were irradiated for 4, 16, 30 and 60 h. Sham-exposed controls (n = 24) were included in the study. The animals of each treated subgroup were killed on the final day of irradiation. Bone marrow smears were examined to determine the extent of genotoxicity after particular treatment times. The results were statistically evaluated using non-parametric Mann-Whitney and Kruskal-Wallis tests. In comparison with the sham-exposed subgroups, the findings of polychromatic erythrocytes (PCE) revealed significant differences ($P < 0.05$) for experimental days 8 and 15. The frequency of micronucleated PCEs was also significantly increased on experimental day 15 ($P < 0.05$). Pair-wise comparison of data obtained after 2, 8 and 30 irradiation treatments did not reveal statistically significant differences between sham-exposed and treated subgroups. Under the applied experimental conditions the findings revealed a transient effect on proliferation and maturation of erythropoietc cells in the rat bone marrow and the sporadic appearance of micronucleated immature bone marrow red cells.

**Trosic I, Busljeta I. Frequency of micronucleated erythrocytes in rat bone marrow exposure to 2.45 GHz radiation. Physica Scripta T118: 168-170, 2005.**

Wistar rats were exposed to 2.45GHz continuous, radiofrequency microwave (RF/MW) field 2 hours daily, 7 days weekly, at power density 5–10mW/cm2. Four subgroups were created in order to be irradiated 4, 16, 30 and 60 hours. Sham exposed controls were included in the study. Animals were euthanized on the final irradiation day of each treated subgroup. Bone marrow smears were examined to determine the extent of genotoxicity after the particular treatment time. Mann- Whitney testwas used for statistical evaluation of data. In comparison to the sham exposed subgroups, the findings of polychromatic erythrocytes revealed significant differences for the 8th and 15th experimental day. Bone marrow erythrocyte maturation and/or proliferation initiated by subthermogenic RF/MW irradiation showed temporary disturbance. Thereafter, the frequency of micronucleated bone marrow red cells was significantly increased after 15 irradiation treatments. Comparison of micronucleus frequency data obtained after 2, 8 and 30 irradiation

treatments did not reveal statistically significant differences between sham and treated subgroups. Under the applied experimental conditions, RF/MWirradiation initiates transitory cytogenetic effect manifested with micronucleus formation in erythropoietic cells.

**Trosic I, Busljeta I. Erythropoietic dynamic equilibrium in rats maintained after microwave irradiation. Exp Toxicol Pathol. 57(3):247-251, 2006.**

The aim of study was to define influence of radiofrequency microwave (RF/MW) radiation on erythropoiesis in rats. The kinetics of polychromatic erythrocytes (PCEs) and micronucleated (MN) PCEs in the bone marrow (BM) and peripheral blood (PB) of rats during the intermittent subchronic experiment was followed. Rats were exposed 2h/day, 7 days/week to RF/MW of 2.45GHz and whole-body specific absorption rate (SAR) of 1.25+/-0.36W/kg. Control animals were included in the study. Each exposed and control group was killed on the final day of irradiation. Acridine-orange stained BM and blood smears were examined by fluorescence microscope. PCEs were obtained by inspection of 2000BM and 1000PB erythrocytes/slides. BMMNs and PBMNs frequency was obtained by observation of 1000PCEs/slides. BMPCEs were increased on day 8 and 15, and PBPCEs were elevated on days 2 and 8 ($p<0.05$). The BMMN frequency was increased on experimental day 15, and MNPCEs in the PB was increased on day 8 ($p<0.05$). Findings of BM and PBPCEs or MNPCEs declined nearly to the control values until the end of the experiment. Such findings are considered to be indicators of radiation effects on BM erythropoiesis consequently reflected in the PB. Rehabilitated dynamic haemopoietc equilibrium in rats by the end of experiment indicates possibility of activation adaptation process in rats to the selected experimental conditions of subchronic RF/MW exposure.

**Trosić I, Pavicić I. Disturbance of cell proliferation in response to mobile phone frequency radiation. Arh Hig Rada Toksikol. 60(1):109-115, 2009.**

The aim of study was to determine the influence of mobile phone frequency radiation on the proliferation, cytoskeleton structure, and mitotic index of V79 cells after 1 h, 2 h, and 3 h of exposure. V79 cells were cultured in standard laboratory conditions and exposed to continuous-wave (CW) RF/MW radiation of 935 MHz, electric field strength of (8.2+/-0.3) V m(-1), and specific absorption rate (SAR) of 0.12 W kg(-1). To identify proliferation kinetics, the cells were counted for each hour of exposure 24 h, 48 h, 72 h, and 96 h after respective exposures. Microtubule proteins were determined using specific immunocytochemical methods. Cell smears were analysed under a fluorescent microscope. The study included negative and positive controls. Mitotic index was determined by estimating the number of dividing cells 24 h after exposure and dividing it with the total number of cells. In comparison to the controls, cell proliferation declined in cells exposed for three hours 72 h after irradiation ($p < 0.05$). Microtubule structure was clearly altered immediately after three hours of irradiation ($p < 0.05$). The mitotic index in RF/MW-exposed cells did not differ from negative controls. However, even if exposure did not affect the number of dividing cells, it may have slowed down cell division kinetics as a consequence of microtubule impairment immediately after exposure.

**Trosić I, Pavicić I, Milković-Kraus S, Mladinić M, Zeljezić D. Effect of**

**electromagnetic radiofrequency radiation on the rats' brain, liver and kidney cells measured by comet assay. Coll Antropol. 35(4):1259-1264, 2011.**

The goal of study was to evaluate DNA damage in rat's renal, liver and brain cells after in vivo exposure to radiofrequency/microwave (Rf/Mw) radiation of cellular phone frequencies range. To determine DNA damage, a single cell gel electrophoresis/comet assay was used. Wistar rats (male, 12 week old, approximate body weight 350 g) (N = 9) were exposed to the carrier frequency of 915 MHz with Global System Mobile signal modulation (GSM), power density of 2.4 W/m2, whole body average specific absorption rate SAR of 0.6 W/kg. The animals were irradiated for one hour/day, seven days/week during two weeks period. The exposure set-up was Gigahertz Transversal Electromagnetic Mode Cell (GTEM--cell). Sham irradiated controls (N = 9) were apart of the study. The body temperature was measured before and after exposure. There were no differences in temperature in between control and treated animals. Comet assay parameters such as the tail length and tail intensity were evaluated. In comparison with tail length in controls (13.5 +/- 0.7 microm), the tail was slightly elongated in brain cells of irradiated animals (14.0 +/- 0.3 microm). The tail length obtained for liver (14.5 +/- 0.3 microm) and kidney (13.9 +/- 0.5 microm) homogenates notably differs in comparison with matched sham controls (13.6 +/- 0.3 microm) and (12.9 +/- 0.9 microm). Differences in tail intensity between control and exposed animals were not significant. The results of this study suggest that, under the experimental conditions applied, repeated 915 MHz irradiation could be a cause of DNA breaks in renal and liver cells, but not affect the cell genome at the higher extent compared to the basal damage.

**Trošić I, Mataušić-Pišl M, Pavičić I, Marjanović AM. Histological and Cytological Examination of Rat Reproductive Tissue After Short-Time Intermittent Radiofrequency Exposure / HISTOLOŠKA I CITOLOŠKA ISTRAŽIVANJA TKIVA REPRODUKTIVNOG SUSTAVA ŠTAKORA NAKON KRATKOTRAJNE ISPREKIDANE IZLOŽENOSTI RADIOFREKVENCIJSKOM ZRAČENJU. Arh Hig Rada Toksikol. 64(4):513-519, 2013. doi: 10.2478/10004-1254-64-2013-2394.**

The unfavourable outcomes of mobile phone use on male fertility have still not been fully elaborated. To establish the potentially adverse effects of everyday exposure to radiofrequency radiation (RF) on humans, we performed a controlled animal study that aimed to investigate the influence of RF radiation on rat testis histology as well as the amount, mobility, and structure of epididymal free sperm cell population. Eighteen adult male rats were divided into two groups of nine. One group comprised sham-exposed control animals, while the other group endured total body irradiation for an hour daily during two weeks. A 915 MHz RF field, power density of 2.4 W m-2 and strength of 30 V m-1 was generated in a Gigahertz Transversal Electromagnetic chamber. The specific absorption rate (SAR) was 0.6 W kg-1. Body mass and temperature were measured before and after each exposure treatment. Immediately after the last exposure, the animals were sacrificed and testes removed and prepared for histological analysis. The free sperm cells were collected from the cauda epididymis and their quantity, quality, and morphology were microscopically

determined using a haemocytometer. No statistically significant alteration in any of the endpoints was observed. This study found no evidence of an unfavourable effect of the applied RF radiation on testicular function or structure. Based on these results, we can conclude that short-time intermittent exposure to RF radiation does not represent a significant risk factor for rat reproductive functions.

**Troulis SE, Scanlon WG, Evans NE. Effect of a hands-free wire on specific absorption rate for a waist-mounted 1.8 GHz cellular telephone handset. Phys Med Biol. 48(12):1675-1684, 2003.**

A common feature of cellular telephony is the use of a 'hands-free' audio extension lead connected to a waist-worn handset. Interaction between the transmitting antenna, the wire and the user's body can occur, with detrimental effects including polar pattern degradation, reduced efficiency and localized increases in specific absorption rate (SAR). Using a realistic full-body model of an adult male, finite difference time domain analysis was employed to investigate the coupling between a hip-mounted 1.8 GHz handset fitted with a monopole antenna and a 1 m long wire representing a hands-free wire. Conduction current densities were computed for three identifiable coupling modes: magnetic-only, conductive-only and combined conductive-and-magnetic. Magnetic-only coupling was dominant. Without the lead, placing the handset at waist height led to a 42.8% increase in the total energy deposited in the body, compared to use at the head. Introducing the lead further increased the body loss, with a reduction in system radiation efficiency from 52% to 43.7%. Without the hands-free lead, the peak 1 g and 10 g SARs were 0.450 W kg(-1) and 0.265 W kg(-1), respectively, for 125 mW transmit power. With the hands-free lead connected, these values increased to 1.14 W kg(-1) and 0.430 W kg(-1), respectively.

**Trunk A, Stefanics G, Zentai N, Kovács-Bálint Z, Thuróczy G, Hernádi I. No effects of a single 3G UMTS mobile phone exposure on spontaneous EEG activity, ERP correlates, and automatic deviance detection.Bioelectromagnetics. 2012 Jun 4. doi: 10.1002/bem.21740. [Epub ahead of print]**

Potential effects of a 30 min exposure to third generation (3G) Universal Mobile Telecommunications System (UMTS) mobile phone-like electromagnetic fields (EMFs) were investigated on human brain electrical activity in two experiments. In the first experiment, spontaneous electroencephalography (sEEG) was analyzed (n = 17); in the second experiment, auditory event-related potentials (ERPs) and automatic deviance detection processes reflected by mismatch negativity (MMN) were investigated in a passive oddball paradigm (n = 26). Both sEEG and ERP experiments followed a double-blind protocol where subjects were exposed to either genuine or sham irradiation in two separate sessions. In both experiments, electroencephalograms (EEG) were recorded at midline electrode sites before and after exposure while subjects were watching a silent documentary. Spectral power of sEEG data was analyzed in the delta, theta, alpha, and beta frequency bands. In the ERP experiment, subjects were presented with a random series of standard (90%) and frequency-deviant (10%) tones in a passive binaural oddball

paradigm. The amplitude and latency of the P50, N100, P200, MMN, and P3a components were analyzed. We found no measurable effects of a 30 min 3G mobile phone irradiation on the EEG spectral power in any frequency band studied. Also, we found no significant effects of EMF irradiation on the amplitude and latency of any of the ERP components.In summary, the present results do not support the notion that a 30 min unilateral 3G EMF exposure interferes with human sEEG activity, auditory evoked potentials or automatic deviance detection indexed by MMN.

**Trunk A, Stefanics G, Zentai N, Bacskay I, Felinger A, Thuróczy G, Hernádi I. Lack of interaction between concurrent caffeine and mobile phone exposure on visual target detection: An ERP study. Pharmacol Biochem Behav. 2014 Jul 26. pii: S0091-3057(14)00215-9. doi: 10.1016/j.pbb.2014.07.011. [Epub ahead of print]**

BACKGROUND: Caffeine affects information processing by acting predominantly on cortical activation, arousal and attention. Millions consume caffeine and simultaneously use their mobile phone (MP) during everyday activities. However, it is not known whether and how MP-emitted electromagnetic fields (EMFs) can modulate known psychoactive effects of caffeine. Here we investigated behavioral and neural correlates of caffeine and simultaneous MP exposure in a third generation (3G) Universal Mobile Telecommunication System (UMTS) signal modulation scheme. METHODS: We recorded electroencephalography (EEG) and event related potentials (ERP) in an oddball paradigm to frequent standard (P=0.8) and rare target (P=0.2) stimuli in a placebo controlled, double blind, within-subject protocol in four experimental sessions: 1) no caffeine and no MP, 2) caffeine only, 3) MP only, 4) caffeine and MP. The subjects' task was to discriminate between standard and target stimuli and respond to the latter by pressing a button while reaction time (RT) and EEG were recorded. To provide a complete analysis of any possible caffeine and/or MP treatment effects that may have occurred, we analyzed the P300 ERP wave using four different ERP measures: 1) peak latency, 2) peak amplitude, 3) 50% fractional area latency (FAL) and 4) area under the curve (AUC). RESULTS: Caffeine significantly shortened RT and decreased AUC of the P300 component compared to the control or the UMTS MP alone conditions. However, no effects were observed on RT or P300 in the UMTS MP exposure sessions, neither alone nor in combination with caffeine. CONCLUSION: Overall, the present results did not demonstrate any interactive or synergistic effects of caffeine and UMTS MP like EMF exposure on basic neural or cognitive measures. However, we found that caffeine consistently enhanced behavioral and ERP measures of visual target detection, showing that present results were obtained using a pharmacologically validated, consistent and replicable methodology.

**Tseng MC, Lin YP, Hu FC, Cheng TJ. Risks Perception of Electromagnetic Fields in Taiwan: The Influence of Psychopathology and the Degree of Sensitivity to Electromagnetic Fields. Risk Anal. 2013 Mar 28. doi: 10.1111/risa.12041. [Epub ahead of print]**

Little is known about the perceived health risks of electromagnetic fields (EMFs) and factors associated with risk perception in non-Western countries. Psychological conditions

and risk perception have been postulated as factors that facilitate the attribution of health complaints to environmental factors. This study investigated people's perceived risks of EMFs and other environmental sources, as well as the relationships between risk perception, psychopathology, and the degree of self-reported sensitivity to EMFs. A total of 1,251 adults selected from a nationwide telephone interviewing system database responded to a telephone survey about the relationships between environmental sources and human health. The interview included questions assessing participants' psychiatric conditions and the presence and degree of sensitivity to EMFs. One hundred and seventy participants were self-identified as having sensitivity to EMFs, and 141 met the criteria for psychiatric conditions without EMF sensitivity. More than half of the survey respondents considered power lines and mobile phone base stations to affect people's health to a big extent. Higher sensitivity to EMFs, psychopathology, being female, being married, more years of education, and having a catastrophic illness had positive associations with perceived risks of EMF-related environmental sources as well as for all environmental sources combined. We observed no moderating effect of psychopathology on the association between degree of sensitivity to EMF and risk perception. Thus, psychopathology had influence on general people's risk perception without having influence on the relationship between people's degree of sensitivity to EMF and risk perception. The plausible explanations are discussed in the text.

**Tsurita G, Nagawa H, Ueno S, Watanabe S, Taki M, Biological and morphological effects on the brain after exposure of rats to a 1439 MHz TDMA field. Bioelectromagnetics 21(5):364-371, 2000.**

We investigated the effects of exposure to a 1439 MHz TDMA (Time Division Multiple Access) field, as used in cellular phones, on the permeability of the blood-brain barrier (BBB), on the morphological changes of the brain, and on body-mass fluctuations. Male Sprague-Dawley (SD) rats were divided into Three groups of eight rats each. The rats in the EM(+) group, which had their heads arrayed in a circle near the central antenna of an exposure system, were exposed to a 1439 MHz field for one hour a day. The rats in EM(-) group were also in the exposure system, however, without high-frequency electromagnetic wave (HF-EMW) exposure. The animals in the control group were neither placed in the system nor exposed to HF-EMWs. The exposure period was two or four weeks. The energy dose rate peaked at 2 W/kg in the brain; the average over the whole body was 0.25 W/kg. The changes in the permeability of BBB were investigated by Evans blue injection method and by immunostaining of serum albumin. HF-EMWs had no effect on the permeability of BBB. The morphological changes in the cerebellum were investigated by assessing the degeneration of Purkinje cells and the cell concentration in the granular layer. No significant changes were observed in the groups of rats exposed to HF-EMWs for two or four weeks. Averaged body masses were not affected by HF-EMWs exposure. In conclusion, a 1439 MHz TDMA field did not induce observable changes in the permeability of the BBB, morphological changes in the cerebellums, or body mass changes in rats, as evaluated by the conventional methods.

**Tsybulin O, Sidorik E, Kyrylenko S, Henshel D, Yakymenko I. GSM 900 MHz microwave radiation affects embryo development of Japanese quails. Electromagn Biol Med. 31(1):75-86, 2012.**

A wide range of non thermal biological effects of microwave radiation (MW) was revealed during the last decades. A number of reports showed evident hazardous effects of MW on embryo development in chicken. In this study, we aimed at elucidating the effects of MW emitted by a commercial model of GSM 900 MHz cell phone on embryo development in quails (Coturnix coturnix japonica) during both short and prolonged exposure. For that, fresh fertilized eggs were irradiated during the first 38 h or 14 days of incubation by a cell phone in "connecting" mode activated continuously through a computer system. Maximum intensity of incident radiation on the egg's surface was 0.2 μW/cm2.The irradiation led to a significant ($p<0.001$) increase in numbers of differentiated somites in 38-hour exposed embryos and to a significant ($p<0.05$) increase in total survival of embryos from exposed eggs after 14 days exposure. We hypothesized that observed facilitating effect was due to enhancement of metabolism in exposed embryos provoked via peroxidation mechanisms. Indeed, a level of thiobarbituric acid (TBA) reactive substances was significantly ($p<0.05$-$0.001$) higher in brains and livers of hatchlings from exposed embryos. Thus, observed effects of radiation from commercial GSM 900 MHz cell phone on developing quail embryos signify a possibility for non-thermal impact of MW on embryogenesis. We suggest that the facilitating effect of low doses of irradiation on embryo development can be explained by a hormesis effect induced by reactive oxygen species (ROS). Future studies need to be done to clarify this assumption.

**Tsybulin O, Sidorik E, Brieieva O , Buchynska L, Kyrylenko S, Henshel D, IYakymenko I. GSM 900 MHz cellular phone radiation can either stimulate or depress early embryogenesis in Japanese quails depending on the duration of exposure. Int J Rad Biol. Posted online on April 11, 2013. (doi:10.3109/09553002.2013.791408)**

*Purpose:* Our study was designed to assess the effects of low intensity radiation of a GSM (Global System for Mobile communication) 900 MHz cellular phone on early embryogenesis in dependence on the duration of exposure. *Materials and methods:* Embryos of Japanese Quails were exposed *in ovo* to GSM 900 MHz cellular phone radiation during initial 38 h of brooding or alternatively during 158 h (120 h before brooding plus initial 38 h of brooding) discontinuously with 48 sec ON (average power density 0.25 μW/cm$^2$, specific absorption rate 3 μW/kg) followed by 12 sec OFF intervals. A number of differentiated somites was assessed microscopically. Possible DNA damage evoked by irradiation was assessed by an alkaline comet assay. *Results:* Exposure to radiation from a GSM 900 MHz cellular phone led to a significantly altered number of differentiated somites. In embryos irradiated during 38 h the number of differentiated somites increased ($p<0.001$), while in embryos irradiated during 158 h this number decreased ($p<0.05$). The lower duration of exposure led to a significant ($p<0.001$) decrease in a level of DNA strand breaks in cells of 38-hour embryos, while the higher duration of exposure resulted in a significant ($p<0.001$) increase in DNA damage as compared to the control. *Conclusion:* Effects of GSM 900 MHz cellular phone radiation on early embryogenesis can be either stimulating or deleterious depending on the duration of exposure.

**Tumkaya L, Kalkan Y, Bas O, Yilmaz A. Mobile phone radiation during pubertal development has no effect on testicular histology in rats. Toxicol Ind Health. 2013 Oct 4. [Epub ahead of print]**

Mobile phones are extensively used throughout the world. There is a growing concern about the possible public health hazards posed by electromagnetic radiation emitted from mobile phones. Potential health risk applies particularly to the most intensive mobile phone users-typically, young people. The aim of this study was to investigate the effects of mobile phone exposure to the testes, by assessing the histopathological and biochemical changes in the testicular germ cells of rats during pubertal development. A total of 12 male Sprague Dawley rats were used. The study group (n = 6) was exposed to a mobile phone for 1 h a day for 45 days, while the control group (n = 6) remained unexposed. The testes were processed with routine paraffin histology and sectioned. They were stained with hematoxylin-eosin, caspase 3, and Ki-67 and then photographed. No changes were observed between the groups ($p > 0.05$). The interstitial connective tissue and cells of the exposed group were of normal morphology. No abnormalities in the histological appearance of the seminiferous tubules, including the spermatogenic cycle stage, were observed. Our study demonstrated that mobile phones with a low specific absorption rate have no harmful effects on pubertal rat testicles.

**Türedi S, Hancı H, Topal Z, Unal D, Mercantepe T, Bozkurt I, Kaya H, Odacı E. The effects of prenatal exposure to a 900-MHz electromagnetic field on the 21-day-old male rat heart. Electromagn Biol Med. 2014 Aug 28:1-8. [Epub ahead of print]**

Abstract The growing spread of mobile phone use is raising concerns about the effect on human health of the electromagnetic field (EMF) these devices emit. The purpose of this study was to investigate the effects on rat pup heart tissue of prenatal exposure to a 900 megahertz (MHz) EMF. For this purpose, pregnant rats were divided into experimental and control groups. Experimental group rats were exposed to a 900 MHz EMF (1 h/d) on days 13-21 of pregnancy. Measurements were performed with rats inside the exposure box in order to determine the distribution of EMF intensity. Our measurements showed that pregnant experimental group rats were exposed to a mean electrical field intensity of 13.77 V/m inside the box (0.50 $W/m^2$). This study continued with male rat pups obtained from both groups. Pups were sacrificed on postnatal day 21, and the heart tissues were extracted. Malondialdehyde, superoxide dismutase and catalase values were significantly higher in the experimental group rats, while glutathione values were lower. Light microscopy revealed irregularities in heart muscle fibers and apoptotic changes in the experimental group. Electron microscopy revealed crista loss and swelling in the mitochondria, degeneration in myofibrils and structural impairments in Z bands. Our study results suggest that exposure to EMF in the prenatal period causes oxidative stress and histopathological changes in male rat pup heart tissue.

**Türedi S, Hancı H, Çolakoğlu S, Kaya H, Odacı E. Disruption of the ovarian follicle reservoir of prepubertal rats following prenatal exposure to a continuous 900-MHz electromagnetic field. Int J Radiat Biol. 92(6):329-337, 2016.**

The effects on human health of electromagnetic field (EMF) have begun to be seriously questioned with the entry into daily life of devices establishing EMF, such as cell phones, wireless fidelity, and masts. Recent studies have reported that exposure to EMF, particularly during pregnancy, affects the developing embryo/fetus. The aim of this study was therefore to examine the effects of exposure to continuous 900-Megahertz (MHz) EMF applied in the prenatal period on ovarian follicle development and oocyte differentiation. Six pregnant Sprague Dawley rats were divided equally into a non-exposed control group (CNGr) and a group (EMFGr) exposed to continuous 900-MHz EMF for 1 h daily, at the same time every day, on days 13-21 of pregnancy. New groups were established from pups obtained from both groups after birth. One group consisting of female pups from CNGr rats was adopted as newborn CNGr (New-CNGr, n = 6), and another group consisting of female pups from EMFGr rats was adopted as newborn EMFGr (New-EMFGr, n = 6). No procedure was performed on New-CNGr or New-EMFGr rats. All rat pups were sacrificed on the postnatal 34th day, and their ovarian tissues were removed. Follicle count, histological injury scoring and morphological assessment with apoptotic index criteria were performed with sections obtained following routine histological tissue preparation. Follicle count results revealed a statistically significant decrease in primordial and tertiary follicle numbers in New-EMFGr compared to New-CNGr ($p < 0.05$), while atretic follicle numbers and apoptotic index levels increased significantly ($p < 0.05$). Histopathological examination revealed severe follicle degeneration, vasocongestion, a low level of increased stromal fibrotic tissue and cytoplasmic vacuolization in granulosa cell in New-EMFGr. Prenatal exposure to continuous 900-MHz EMF for 1 hour each day from days 13-21 led to a decrease in ovarian follicle reservoirs in female rat pups at the beginning of the prepubertal period.

**Türedi S, Kerimoğlu G, Mercantepe T, Odacı E. Biochemical and pathological changes in the male rat kidney and bladder following exposure to continuous** 900**-MHz electromagnetic field on postnatal days 22-59. Int J Radiat Biol. 93(9):990-999, 2017.**

PURPOSE: To investigate the effect on male rat kidney and bladder tissues of exposure to **900**-megahertz (MHz) electromagnetic field (EMF) applied on postnatal days 22-59, inclusive.MATERIALS AND METHODS: Twenty-four male Sprague Dawley rats, aged 21 days, were used. These were divided equally into one of three groups, control (CG), sham (SG) or EMF (EMFG). CG was not exposed to any procedure. SG rats were kept inside a cage, without being exposed to the effect of EMF, for 1 h a day on postnatal days 22-59, inclusive. EMFG rats were exposed to continuous **900**-MHz EMF for 1 h a day under the same conditions as those for the SG rats. Rats were sacrificed on postnatal day 60, and the kidney and bladder tissues were removed. Tissues were stained with hematoxylin and eosin (H&E) and Masson trichrome for histomorphological evaluation. The TUNEL method was used to assess apoptosis. Transmission electron microscopy (TEM) was also used for the kidney tissue. Oxidant/antioxidant parameters were studied in terms of biochemical values.RESULTS: The findings showed that tissue malondialdehyde increased in EMFG compared to CG and SG in both kidney ($p = 0.004$ and $p = 0.004$, respectively) and bladder tissue ($p = 0.004$, $p = 0.006$, respectively), while

catalase and glutathione levels decreased compared to CG (p = 0.004; p = 0.004, respectively) and SG (p = 0.004; p = 0.004, respectively). In the EMF group, pathologies such as dilatation and vacuolization in the distal and proximal tubules, degeneration in glomeruli and an increase in cells tending to apoptosis were observed in kidney tissue. In bladder tissue, degeneration in the transitional epithelium and stromal irregularity and an increase in cells tending to apoptosis were observed in EMFG. Additionally, EMFG samples exhibited glomerular capillary degeneration with capillary basement membranes under TEM.CONCLUSIONS: We conclude that continuous exposure to the effect of **900**-MHz EMF for 1 h a day on postnatal days 22-59, inclusive, causes an increase in oxidative stress and various pathological changes in male rat kidney and bladder tissues.

**Türker Y, Nazıroğlu M, Gümral N, Celik O, Saygın M, Cömlekçi S, Flores-Arce M. Selenium and L-carnitine reduce oxidative stress in the heart of rat induced by 2.45-GHz radiation from wireless devices. Biol Trace Elem Res. 143(3):1640-1650, 2011.**

The aim of this study was to investigate the possible protective role of selenium and L-carnitine on oxidative stress induced by 2.45-GHz radiation in heart of rat. For this purpose, 30 male Wistar Albino rats were equally divided into five groups namely controls, sham controls, radiation-exposed rats, radiation-exposed rats treated with intraperitoneal injections of sodium selenite at a dose of 1.5 mg/kg/day, and radiation-exposed rats treated with intraperitoneal injections of L-carnitine at a dose of 1.5 mg/kg/day. Except for the controls and sham controls, the animals were exposed to 2.45-GHz radiation during 60 min/day for 28 days. The lipid peroxidation (LP) levels were higher in the radiation-exposed groups than in the control and sham control groups. The lipid peroxidation level in the irradiated animals treated with selenium and L-carnitine was lower than in those that were only exposed to 2.45-GHz radiation. The concentrations of vitamins A, C, and E were lower in the irradiated-only group relative to control and sham control groups, but their concentrations were increased in the groups treated with selenium- and L-carnitine. The activity of glutathione peroxidase was higher in the selenium-treated group than in the animals that were irradiated but received no treatment. The erythrocyte-reduced glutathione and β-carotene concentrations did not change in any of the groups. In conclusion, 2.45-GHz electromagnetic radiation caused oxidative stress in the heart of rats. There is an apparent protective effect of selenium and L-carnitine by inhibition of free radical formation and support of the antioxidant redox system.

**Tuschl, H, Neubauer, G, Garn, H, Duftschmid, K, Winker, N, Brusl, H, Occupational exposure to high frequency electromagnetic fields and its effect on human immune parameters. Int J Occup Med Environ Health;12(3):239-251, 1999.**

The present study recorded a considerable excess of recommended exposure limitsin the vicinity of shortwave diathermy devices used for medical treatment of patients. Different kinds of field probes were used to measure electric and magnetic field strength and the whole body exposure of medical personnel operating shortwave, decimeter wave and microwave units was calculated. To investigate the

influence of chronic exposure on the immune system of operators, blood was sampled from physiotherapists working at the above mentioned devices. Eighteen exposed and thirteen control persons, matched by sex and age, were examined. Total leucocyte and lymphocyte counts were performed and leucocytic subpopulations determined by flow cytometry and monoclonal antibodies against surface antigens. In addition, to quantify subpopulations of immunocompetent cells, the activity of lymphocytes was measured. Lymphocytes were stimulated by mitogen phytohemagglutinin and their proliferation measured by a flow cytometric method. No statistically significant differences between the control and exposed persons were found. In both study groups all immune parameters were within normal ranges.

**Tuschl H, Novak W, Molla-Djafari H. In vitro effects of GSM modulated radiofrequency fields on human immune cells. Bioelectromagnetics.27(3):188-196, 2006.**

Despite the important role of the immune system in defending the body against infections and cancer, only few investigations on possible effects of radiofrequency (RF) radiation on function of human immune cells have been undertaken. Aim of the present investigation was therefore to assess whether GSM modulated RF fields have adverse effects on the functional competence of human immune cells. Within the frame of the multidisciplinary project "Biological effects of high frequency electromagnetic fields (EMF)" sponsored by the National Occupation Hazard Insurance Association (AUVA) in vitro investigations were carried out on human blood cells. Exposure was performed at GSM Basic 1950 MHz, an SAR of 1 mW/g in an intermittent mode (5 min "ON", 10 min "OFF") and a maximum Delta T of 0.06 degrees C for the duration of 8 h. The following immune parameters were evaluated: (1) the intracellular production of interleukin-2 (IL-2) and interferon (INF) gamma in lymphocytes, and IL-1 and tumor necrosis factor (TNF)-alpha in monocytes were evaluated with monoclonal antibodies. (2) The activity of immune-relevant genes (IL 1-alpha and beta, IL-2, IL-2-receptor, IL-4, macrophage colony stimulating factor (MCSF)-receptor, TNF-alpha, TNF-alpha-receptor) and housekeeping genes was analyzed with real time PCR. (3) The cytotoxicity of lymphokine activated killer cells (LAK cells) against a tumor cell line was determined in a flow cytometric test. For each parameter, blood samples of at least 15 donors were evaluated. No statistically significant effects of exposure were found and there is no indication that emissions from mobile phones are associated with adverse effects on the human immune system.

**Tynes T, Hannevik M, Andersen A, Vistnes AI, Haldorsen T, Incidence of breast cancer in Norwegian female radio and telegraph operators. Cancer Causes Control 7(2):197-204, 1996.**

Exposure to electromagnetic fields may cause breast cancer in women if it increases susceptibility to sex-hormone-related cancer by diminishing the pineal gland's production of melatonin. We have studied breast cancer incidence in female radio and telegraph operators with potential exposure to light at

night, radio frequency (405 kHz-25 MHz), and, to some extent, extremely low frequency fields (50 Hz). We linked the Norwegian Telecom cohort of female radio and telegraph operators working at sea to the Cancer Registry of Norway to study incident cases of breast cancer. The cohort consisted of 2,619 women who were certified to work as radio and telegraph operators between 1920 and 1980. Cancer incidence was analyzed on the basis of the standardized incidence ratio (SIR), with the Norwegian female population as the comparison group. The incidence of all cancers was close to unity (SIR = 1.2). An excess risk was seen for breast cancer (SIR = 1.5). Analysis of a nested case-control study within the cohort showed an association between breast cancer in women aged 50+ years and shift work. In a model with adjustment for age, calendar year, and year of first birth, the rate ratio for breast cancer associated with being a radio and telegraph operator--in comparison with all Norwegian women born 1935 or later--analyzed with Poisson regression, was 1.5 after adjustment for fertility factors. These results support a possible association between work as a radio and telegraph operator and breast cancer. Future epidemiologic studies on breast cancer in women aged 50 and over, should address possible disturbances of chronobiological parameters by environmental factors.

**Tzaphlidou M, Fotiou E. The effects of 910-MHz electromagnetic field on rat cranial arachnoid and dura mater collagen. The axial periodicity of collagen fibrils. ScientificWorldJournal. 4 Suppl 2:70-74, 2004.**

The axial periodicity of rat arachnoid and dura mater collagen fibrils exposed to 910 MHz for 2 h/day for 30 consecutive days was measured by means of image analysis of electron-optical data. Such measurements were compared with those from sham-exposed animals. These measurements reveal that on exposure, the intermolecular interactions during collagen fibril assembly are affected.

**Ulashchik VS, [Changes in drug pharmacokinetics and pharmacodynamics under the influence of microwaves of different ranges]. Vopr Kurortol Fizioter Lech Fiz Kult 4):1-6, 1993.** [Article in Russian]

Human and animal experiments were conducted to compare the effect of microwaves different by their range on drug pharmacodynamics and pharmacokinetics. The response to the microwaves depended on the dose and site of the exposure, on the frequency of the electromagnetic modes. The results suggest that it is possible to use microwaves for potentiating and prolongation of some drugs action.

**Uloziene I, Uloza V, Gradauskiene E, Saferis V. Assessment of potential effects of the electromagnetic fields of mobile phones on hearing. BMC Public Health. 5(1):39, 2005.**

BACKGROUND: Mobile phones have become indispensable as communication tools; however, to date there is only a limited knowledge about interaction between electromagnetic fields (EMF) emitted by mobile phones and auditory function. The aim of the study was to assess potential changes in hearing function as a consequence of exposure to low-intensity EMF's produced by mobile phones at frequencies of 900 and

1800 MHz. METHODS: The within-subject study was performed on thirty volunteers (age 18-30 years) with normal hearing to assess possible acute effect of EMF. Participants attended two sessions: genuine and sham exposure of EMF. Hearing threshold levels (HTL) on pure tone audiometry (PTA) and transient evoked otoacoustic emissions (TEOAE's) were recorded before and immediately after 10 min of genuine and/or sham exposure of mobile phone EMF. The administration of genuine or sham exposure was double blind and counterbalanced in order. RESULTS: Statistical analysis revealed no significant differences in the mean shift of PTA and TEOAE's values before and after genuine and/or sham mobile phone EMF 10 min exposure. The data collected showed that average TEOAE levels (averaged across a frequency range) changed less than 2 dB between pre- and post-, real and sham exposure. The greatest individual change was 10dB(A), with a decrease in level from pre- to post- real exposure. CONCLUSIONS: It could be concluded that a 10-min close exposure of EMFs emitted from a mobile phone had no immediate after-effect on measurements of HTL of PTA and TEOAEs in young adult human subjects and no measurable hearing deterioration was detected in our study.

**Ulubay M, Yahyazadeh A, Deniz OG, Kıvrak EG, Altunkaynak BZ, Erdem G, Kaplan S. Effects of prenatal 900 MHz electromagnetic field exposures on the histology of rat kidney. Int J Radiat Biol. 2014 Aug 1:1-25. [Epub ahead of print]**

Purpose: To research the harmful effects of prenatal exposure of 900 megahertz (MHz) electromagnetic field (EMF) on kidneys of four-week-old male rats and to determine protective effects of melatonin (MEL) and omega-3 (ω-3). Materials and methods: Twenty-one Wistar albino rats were randomly placed into seven groups as follows: control (Cont), Sham, MEL, ω-3, EMF, EMF+MEL and EMF+ω-3. After mating, three groups (EMF, EMF+MEL, EMF+ ω-3) were exposed to an EMF. In the fourth week subsequent to parturition, six rats were randomly chosen from each group. Mean volume of kidneys and renal cortices, the total number of glomeruli and basic histological structure of kidney were evaluated by stereological and light microscopical methods, respectively. Results: Stereological results determined the mean volume of the kidneys and cortices were significantly increased in EMF-exposed groups compared to the Cont group. However, EMF-unexposed groups were not significantly modified compared to the Cont group. Additionally, the total number of glomeruli was significantly higher in EMF-unexposed groups compared to the Cont group. Alternatively, the number of glomeruli in EMF-exposed groups was decreased compared to the Cont group. Conclusions: Prenatal exposure of rat kidneys to 900 MHz EMF resulted in increased total kidney volume and decreased the numbers of glomeruli. Moreover, MEL and ω-3 prevented adverse effects of EMF on the kidneys.

**Unterlechner M, Sauter C, Schmid G, Zeitlhofer J. No effect of an UMTS mobile phone-like electromagnetic field of 1.97 GHz on human attention and reaction time. Bioelectromagnetics.29(2):145-153, 2008.**

Several studies in the past reported influences of electromagnetic emissions of GSM phones on reaction time in humans. However, there are currently only a few studies available dealing with possible effects of the electromagnetic fields emitted by UMTS mobile phones. In our study, 40 healthy volunteers (20 female, 20 male), aged 26.0 years

(range 21-30 years) underwent four different computer tests measuring reaction time and attention under three different UMTS mobile phone-like exposure conditions (two exposure levels plus sham exposure). Exposure of the subjects was accomplished by small helical antennas operated close to the head and fed by a generic signal representing the emissions of a UMTS mobile phone under constant receiving conditions as well as under a condition of strongly varying transmit power. In the high exposure condition the resulting peak spatial average exposure of the test subjects in the cortex of the left temporal lobe of the brain was 0.63 W/kg (min. 0.25 W/kg, max. 1.49 W/kg) in terms of 1 g averaged SAR and 0.37 W/kg (min. 0.16 W/kg, max. 0.84 W/kg) in terms of 10 g averaged SAR, respectively. Low exposure condition was one-tenth of high exposure and sham was at least 50 dB below low exposure. Statistical analysis of the obtained test parameters showed that exposure to the generic UMTS signal had no statistically significant immediate effect on attention or reaction. Therefore, this study does not provide any evidence that exposure of UMTS mobiles interferes with attention under short-term exposure conditions.

**Urban, P, Lukas, E, Roth, Z, Does acute exposure to the electromagnetic field emitted by a mobile phone influence visual evoked potentials? A pilot study. Cent Eur J Public Health 6(4):288-290, 1998.**

To search for a potential negative influence on the central nervous system (CNS) of the electromagnetic field emitted by a mobile phone, the authors performed a pilot experimental study of the influence of a single short acute exposure to the GSM mobile phone Motorola 8700, using visual evoked potentials (VEP) examination as an electrophysiological marker of CNS dysfunction. The study group consisted of 20 healthy volunteers. The duration of exposure was 5 minutes. The output power of the device was 1.5 W when the antenna was pulled up. Five parameters of VEP were evaluated by means of multifactorial ANOVA. Confounding effects of age, sex, and of the call in itself were taken into consideration. No statistically significant influence of the above-described exposure to the electromagnetic field emitted by the mobile phone on latencies or amplitudes of VEP was observed.

**Urbinello D, Röösli M. Impact of one's own mobile phone in stand-by mode on personal radiofrequency electromagnetic field exposure.J Expo Sci Environ Epidemiol. 23:545-548, 2013.**

When moving around, mobile phones in stand-by mode periodically send data about their positions. The aim of this paper is to evaluate how personal radiofrequency electromagnetic field (RF-EMF) measurements are affected by such location updates. Exposure from a mobile phone handset (uplink) was measured during commuting by using a randomized cross-over study with three different scenarios: disabled mobile phone (reference), an activated dual-band phone and a quad-band phone. In the reference scenario, uplink exposure was highest during train rides (1.19 mW/m(2)) and lowest during car rides in rural areas (0.001 mW/m(2)). In public transports, the impact of one's own mobile phone on personal RF-EMF measurements was not observable because of high background uplink radiation from other people's mobile phone. In a car, uplink exposure with an activated phone was orders of magnitude higher compared with the reference scenario. This study demonstrates that personal RF-EMF exposure is

affected by one's own mobile phone in stand-by mode because of its regular location update. Further dosimetric studies should quantify the contribution of location updates to the total RF-EMF exposure in order to clarify whether the duration of mobile phone use, the most common exposure surrogate in the epidemiological RF-EMF research, is actually an adequate exposure proxy.

**Urbinello D, Huss A, Beekhuizen J, Vermeulen R, Röösli M. Use of portable exposure meters for comparing mobile phone base station radiation in different types of areas in the cities of Basel and Amsterdam. Sci Total Environ. 468-469:1028-1033, 2014.**

BACKGROUND: Radiofrequency electromagnetic fields (RF-EMF) are highly variable and differ considerably within as well as between areas. Exposure assessment studies characterizing spatial and temporal variation are limited so far. Our objective was to evaluate sources of data variability and the repeatability of daily measurements using portable exposure meters (PEMs). METHODS: Data were collected at 12 days between November 2010 and January 2011 with PEMs in four different types of urban areas in the cities of Basel (BSL) and Amsterdam (AMS). RESULTS: Exposure from mobile phone base stations ranged from 0.30 to 0.53 V/m in downtown and business areas and in residential areas from 0.09 to 0.41 V/m. Analysis of variance (ANOVA) demonstrated that measurements from various days were highly reproducible (measurement duration of approximately 30 min) with only 0.6% of the variance of all measurements from mobile phone base station radiation being explained by the measurement day and only 0.2% by the measurement time (morning, noon, afternoon), whereas type of area (30%) and city (50%) explained most of the data variability. CONCLUSIONS: We conclude that mobile monitoring of exposure from mobile phone base station radiation with PEMs is useful due to the high repeatability of mobile phone base station exposure levels, despite the high spatial variation.

**Urbinello D, Joseph W, Huss A, Verloock L, Beekhuizen J, Vermeulen R, Martens L, Röösli M. Radio-frequency electromagnetic field (RF-EMF) exposure levels in different European outdoor urban environments in comparison with regulatory limits. Environ Int. 2014 Apr 2;68C:49-54. doi: 10.1016/j.envint.2014.03.007. [Epub ahead of print].**

BACKGROUND: Concerns of the general public about potential adverse health effects caused by radio-frequency electromagnetic fields (RF-EMFs) led authorities to introduce precautionary exposure limits, which vary considerably between regions. It may be speculated that precautionary limits affect the base station network in a manner that mean population exposure unintentionally increases. AIMS: The objectives of this multicentre study were to compare mean exposure levels in outdoor areas across four different European cities and to compare with regulatory RF-EMF exposure levels in the corresponding areas. METHODS: We performed measurements in the cities of Amsterdam (the Netherlands, regulatory limits for mobile phone base station frequency bands: 41-61V/m), Basel (Switzerland, 4-6V/m), Ghent (Belgium, 3-4.5V/m) and Brussels (Belgium, 2.9-4.3V/m) using a portable measurement device. Measurements were

conducted in three different types of outdoor areas (central and non-central residential areas and downtown), between 2011 and 2012 at 12 different days. On each day, measurements were taken every 4s for approximately 15 to 30min per area. Measurements per urban environment were repeated 12 times during 1year. RESULTS: Arithmetic mean values for mobile phone base station exposure ranged between 0.22V/m (Basel) and 0.41V/m (Amsterdam) in all outdoor areas combined. The 95th percentile for total RF-EMF exposure varied between 0.46V/m (Basel) and 0.82V/m (Amsterdam) and the 99th percentile between 0.81V/m (Basel) and 1.20V/m (Brussels). CONCLUSIONS: All exposure levels were far below international reference levels proposed by ICNIRP (International Commission on Non-Ionizing Radiation Protection). Our study did not find indications that lowering the regulatory limit results in higher mobile phone base station exposure levels.

**Urbinello D, Joseph W, Verloock L, Martens L, Röösli M. Temporal trends of radio-frequency electromagnetic field (RF-EMF) exposure in everyday environments across European cities. Environ Res. 2014 Aug 12;134C:134-142. doi: 10.1016/j.envres.2014.07.003. [Epub ahead of print]**

BACKGROUND: The rapid development and increased use of wireless telecommunication technologies led to a substantial change of radio-frequency electromagnetic field (RF-EMF) exposure in the general population but little is known about temporal trends of RF-EMF in our everyday environment. OBJECTIVES: The objective of our study is to evaluate temporal trends of RF-EMF exposure levels in different microenvironments of three European cities using a common measurement protocol. METHODS: We performed measurements in the cities of Basel (Switzerland), Ghent and Brussels (Belgium) during one year, between April 2011 and March 2012. RF-EMF exposure in 11 different frequency bands ranging from FM (Frequency Modulation, 88MHz) to WLAN (Wireless Local Area Network, 2.5GHz) was quantified with portable measurement devices (exposimeters) in various microenvironments: outdoor areas (residential areas, downtown and suburb), public transports (train, bus and tram or metro rides) and indoor places (airport, railway station and shopping centers). Measurements were collected every 4s during 10-50min per environment and measurement day. Linear temporal trends were analyzed by mixed linear regression models. RESULTS: Highest total RF-EMF exposure levels occurred in public transports (all public transports combined) with arithmetic mean values of 0.84V/m in Brussels, 0.72V/m in Ghent, and 0.59V/m in Basel. In all outdoor areas combined, mean exposure levels were 0.41V/m in Brussels, 0.31V/m in Ghent and 0.26V/m in Basel. Within one year, total RF-EMF exposure levels in all outdoor areas in combination increased by 57.1% ($p<0.001$) in Basel by 20.1% in Ghent ($p=0.053$) and by 38.2% ($p=0.012$) in Brussels. Exposure increase was most consistently observed in outdoor areas due to emissions from mobile phone base stations. In public transports RF-EMF levels tended also to increase but mostly without statistical significance. DISCUSSION: An increase of RF-EMF exposure levels has been observed between April 2011 and March 2012 in various microenvironments of three European cities. Nevertheless, exposure levels were still far below regulatory limits of each country. A continuous monitoring is needed to identify high

exposure areas and to anticipate critical development of RF-EMF exposure at public places.

**Urech, M, Eicher, B, Siegenthaler, J, Effects of microwave and radio frequency electromagnetic fields on lichens. Bioelectromagnetics 17(4):327-334, 1996.**

The effects of electromagnetic fields on lichens were investigated. Field experiments of long duration (1-3 years) were combined with laboratory experiments and theoretical considerations. Samples of the lichen species Parmelia tiliacea and Hypogymnia physodes were exposed to microwaves (2.45 GHz; 0.2, 5, and 50 mW/cm2; and control). Both species showed a substantially reduced growth rate at 50 mW/cm2. A differentiation between thermal and nonthermal effects was not possible. Temperature measurements on lichens exposed to microwaves (2.45 GHz, 50 mW/cm2) showed a substantial increase in the surface temperature and an accelerated drying process. The thermal effect of microwave on lichens was verified. The exposure of lichens of both species was repeated near a short-wave broadcast transmitter (9.5 MHz, amplitude modulated; maximum field strength 235 V/m, 332 mA/m). No visible effects on the exposed lichens were detected. At this frequency, no thermal effects were expected, and the experimental results support this hypothesis. Theoretical estimates based on climatic data and literature showed that the growth reductions in the initial experiments could very likely have been caused by drying of the lichens from the heating with microwaves. The results of the other experiments support the hypothesis that the response of the lichens exposed to microwaves was mainly due to thermal effects and that there is a low probability of nonthermal effects.

**Ushiyama A, Ohtani S, Suzuki Y, Wada K, Kunugita N, Ohkubo C. Effects of 21-kHz intermediate frequency magnetic fields on blood properties and immune systems of juvenile rats. Int J Radiat Biol. 90(12):1211-1217, 2014.**

Purpose: Due to a lack of science-based evidence, we explored the effects of exposure to intermediate frequency magnetic fields (IF-MF) on experimental animals. We assessed several immunological parameters to determine the effect of exposure of the whole body to IF-MF. MATERIALS AND METHODS: Male Sprague-Dawley rats (4-5 weeks old) were divided into three groups: Cage-control, sham, and 3.8-mT (rms) exposure groups. The animals were exposed to IF-MF at 21 kHz under fixed conditions in an acrylic holder. Exposure was performed for 1 h/day for 14 consecutive days. On the 15th day following the exposure, biochemical and hematological parameters in blood were analyzed. The effects of the exposure on immunological functions such as the cytotoxic activity of lymphocytes, chemotactic and phagocytic activity of granulocytes, and T (cluster of differentiation 4 [CD4] and cluster of differentiation 8 [CD8])-cell frequency were also examined. RESULTS: Hematological parameters were not affected by IF-MF exposure. Other immune functions such as the cytotoxic activity and phagocytic activity were not affected. Populations of T cells after exposure also did not show any significant differences. In blood biochemistry, there was significant difference in inorganic phosphorus level between sham and exposure group. However, this will not induce any pathophysiological status, because they were still within physiological range. Overall,

no significant effect by exposure of IF-MF was observed under our experimental conditions. CONCLUSIONS: Our results suggest that exposure to 21-kHz sinusoidal IF-MF at 3.8 mT for 1 h/day for 14 days did not affect immune function in juvenile rats.

**Uskalova DV, Igolkina YV, Sarapultseva EI. Intravital Computer Morphometry on Protozoa: A Method for Monitoring of the Morphofunctional Disorders in Cells Exposed in the Cell Phone Communication Electromagnetic Field. Bull Exp Biol Med. 2016 Sep 3. [Epub ahead of print]**

Morphofunctional disorders in unicellular aquatic protozoa - Spirostomum ambiguum infusorians after 30-, 60-, and 360-min exposure in electromagnetic field at a radiation frequency of 1 GHz and energy flow density of 50 μW/cm$^2$ were analyzed by intravital computer morphometry. Significant disorders in morphometric values correlated with low mobility of the protozoa. The results suggested the use of intravital computer morphometry on the protozoa for early diagnosis of radiation-induced effects of the mobile communication electromagnetic field, for example, low mobility of spermatozoa.

**Utteridge TD, Gebski V, Finnie JW, Vernon-Roberts B, Kuchel TR. Long-Term Exposure of E μ-Pim1 Transgenic Mice to 898.4 MHz Microwaves does not Increase Lymphoma Incidence. Radiat Res 158(3):357-364, 2002.**

A total of 120 E μ-Pim1 heterozygous mice and 120 wild-type mice were exposed for 1 h/day 5 days/week at each of the four exposure levels in "Ferris-wheel" exposure systems for up to 104 weeks to GSM-modulated 898.4 MHz radiation at SARs of 0.25, 1.0, 2.0 and 4.0 W/kg. In addition, 120 heterozygous and 120 wild-type mice were sham-exposed; there was also an unrestrained negative control group. Four exposure levels were used to investigate whether a dose-response effect could be detected. Independent verification confirmed that the exposures in the current study were nonthermal. There was no significant difference in the incidence of lymphomas between exposed and sham-exposed groups at any of the exposure levels. A dose-response effect was not detected. The findings showed that long-term exposures of lymphoma-prone mice to 898.4 MHz GSM radiofrequency (RF) radiation at SARs of 0.25, 1.0, 2.0 and 4.0 W/kg had no significant effects when compared to sham-irradiated animals. A previous study (Repacholi et al., Radiat. Res. 147, 631-640, 1997) reported that long-term exposure of lymphoma-prone mice to one exposure level of 900 MHz RF radiation significantly increased the incidence of non-lymphoblastic lymphomas when compared to sham-irradiated animals.

**Vácha M, Puzová T, Kvícalová M. Radio frequency magnetic fields disrupt magnetoreception in American cockroach. J Exp Biol. 212(Pt 21):3473-3477, 2009.**

The sense that allows birds to orient themselves by the Earth's magnetic field can be disabled by an oscillating magnetic field whose intensity is just a fraction of the geomagnetic field intensity and whose oscillations fall into the medium or high frequency radio wave bands. This remarkable phenomenon points very clearly at one

of two existing alternative magnetoreception mechanisms in terrestrial animals, i.e. the mechanism based on the radical pair reactions of specific photosensitive molecules. As the first such study in invertebrates, our work offers evidence that geomagnetic field reception in American cockroach is sensitive to a weak radio frequency field. Furthermore, we show that the 'deafening' effect at Larmor frequency 1.2 MHz is stronger than at different frequencies. The parameter studied was the rise in locomotor activity of cockroaches induced by periodic changes in the geomagnetic North positions by 60 deg. The onset of the disruptive effect of a 1.2 MHz field was found between 12 nT and 18 nT whereas the threshold of a doubled frequency field 2.4 MHz fell between 18 nT and 44 nT. A 7 MHz field showed no impact even in maximal 44 nT magnetic flux density. The results indicate resonance effects rather than non-specific bias of procedure itself and suggest that insects may be equipped with the same magnetoreception system as the birds.

**Vagdatli E, Konstandinidou V, Adrianakis N, Tsikopoulos I, Tsikopoulos A, Mitsopoulou K. Effects of Electromagnetic Fields on Automated Blood Cell Measurements. J Lab Autom. 2014 Jan 24. [Epub ahead of print]**

The aim of this study is to investigate whether the electromagnetic fields associated with mobile phones and/or laptops interfere with blood cell counts of hematology analyzers. Random blood samples were analyzed on an Aperture Impedance hematology analyzer. The analysis was performed in four ways: (A) without the presence of any mobile phone or portable computer in use, (B) with mobile phones in use (B1: one mobile, B4: four mobiles), (C) with portable computers (laptops) in use (C1: one laptop, C3: three laptops), and (D) with four mobile phones and three laptops in use simultaneously. The results obtained demonstrated a statistically significant decrease in neutrophil, erythrocyte, and platelet count and an increase in lymphocyte count, mean corpuscular volume, and red blood cell distribution width, notably in the B4 group. Despite this statistical significance, in clinical practice, only the red blood cell reduction could be taken into account, as the mean difference between the A and B4 group was 60,000 cells/μL. In group D, the analyzer gave odd results after 11 measurements and finally stopped working. The combined and multiple use of mobile phones and computers affects the function of hematology analyzers, leading to false results. Consequently, the use of such electronic devices must be avoided.

**Valbonesi P, Franzellitti S, Piano A, Contin A, Biondi C, Fabbri E. Evaluation of HSP70 Expression and DNA Damage in Cells of a Human Trophoblast Cell Line Exposed to 1.8 GHz Amplitude-Modulated Radiofrequency Fields. Radiat Res. 169(3):270-279, 2008.**

The aim of this study was to determine whether high-frequency electromagnetic fields (EMFs) could induce cellular effects. The human trophoblast cell line HTR-8/SVneo was used as a model to evaluate the expression of proteins (HSP70 and HSC70) and genes (HSP70A, B, C and HSC70) of the HSP70 family and the primary DNA damage response after nonthermal exposure to pulse-modulated 1817 MHz sinusoidal waves (GSM-217 Hz; 1 h; SAR of 2 W/kg). HSP70 expression was

significantly enhanced by heat, which was applied as the prototypical stimulus. The HSP70A, B and C transcripts were differentially expressed under basal conditions, and they were all significantly induced above basal levels by thermal stress. Conversely, HSC70 protein and gene expression was not influenced by heat. Exposing HTR-8/SVneo cells to high-frequency EMFs did not change either HSP70 or HSC70 protein or gene expression. A significant increase in DNA strand breaks was caused by exposure to H(2)O(2), which was used as a positive stimulus; however, no effect was observed after exposure of cells to high-frequency EMFs. Overall, no evidence was found that a 1-h exposure to GSM-217 Hz induced a HSP70-mediated stress response or primary DNA damage in HTR-8/SVneo cells. Nevertheless, further investigations on trophoblast cell responses after exposure to GSM signals of different types and durations are needed.

**Valbonesi P, Franzellitti S, Bersani F, Contin A, Fabbri E. Effects of the exposure to intermittent 1.8 GHz radio frequency electromagnetic fields on HSP70 expression and MAPK signaling pathways in PC12 cells. Int J Radiat Biol. 90(5):382-391, 2014.**

Purpose: We previously reported effects on heat shock protein 70 (HSP70) mRNA expression, a cytoprotective protein induced under stressful condition, in human trophoblast cells exposed to amplitude-modulated Global System for Mobile Communication (GSM) signals. In the present work the same experimental conditions were applied to the rat PC12 cells, in order to assess the stress responses mediated by HSP70 and by the Mitogen Activated Protein Kinases (MAPK) in neuronal-like cells, an interesting model to study possible effects of mobile phone frequencies exposure. Materials and methods: HSP70 gene expression level was evaluated by reverse transcriptase polymerase chain reaction, HSP70 protein expression and MAPK phosphorylation were assessed by Western blotting. PC12 cells were exposed for 4, 16 or 24 h to 1.8 GHz continuous wave signal (CW, carrier frequency without modulation) or to two different GSM modulation schemes, GSM-217Hz and GSM-Talk (which generates temporal changes between two different GSM signals, active during talking or listening phases respectively, thus simulating a typical conversation). Specific adsorption rate (SAR) was 2 W/kg. Results: After PC12 cells exposure to the GSM-217Hz signal for 16 or 24 h, HSP70 transcription significantly increased, whereas no effect was observed in cells exposed to the CW or GSM-Talk signals. HSP70 protein expression and three different MAPK signaling pathways were not affected by the exposure to any of the three different 1.8 GHz signals. Conclusion: The positive effect on HSP70 mRNA expression, observed only in cells exposed to the GSM-217Hz signal, is a repeatable response previously reported in human trophoblast cells and now confirmed in PC12 cells. Further investigations towards a possible role of 1.8 GHz signal modulation are therefore advisable.

**Valbonesi P, Franzellitti S, Bersani F, Contin A, Fabbri E. Activity and expression of acetylcholinesterase in PC12 cells exposed to intermittent 1.8 GHz 217-GSM mobile phone signal. Int J Radiat Biol. 92(1):1-10.**

Purpose Due to its role in learning, memory and in many neurodegenerative diseases, acetylcholinesterase (AChE) represents an interesting endpoint to assess possible

targets of exposure to radiofrequency electromagnetic fields (RF-EMF) generated by mobile phones. We investigated possible alterations of enzymatic activity, gene and protein expression of AChE in neuronal-like cells exposed to a 1.8 GHz Global System for Mobile Communication (GSM) modulated signal (217-GSM). Materials and methods Rat PC12 cells were exposed for 24 h to 1.8 GHz 217-GSM signal. Specific adsorption rate (SAR) was 2 W/kg. AChE enzyme activity was assessed spectrophotometrically by Ellman's method, mRNA expression level was evaluated by real time polymerase chain reaction, and protein expression was assessed by Western blotting. Results AChE enzymatic activity increased of 1.4-fold in PC12 cells exposed to 217-GSM signal for 24 h, whilst AChE transcriptional or translational pathways were not affected. Conclusion Our results provide the first evidence of effects on AChE activity after in vitro exposure of mammalian cells to the RF-EMF generated by GSM mobile phones, at the SAR value 2 W/kg. The obtained evidence promotes further investigations on AChE as a possible target of RF-EMF and confirm the ability of 1.8 GHz 217-GSM signal to induce biological effects in different mammalian cells.

**Valentini E, Ferrara M, Presaghi F, De Gennaro L, Curcio G. Republished review: systematic review and meta-analysis of psychomotor effects of mobile phone electromagnetic fields.Postgrad Med J. 87(1031):643-651, 2011.**

OBJECTIVES Over the past 10 years there has been increasing concern about the possible behavioural effects of mobile phone use. This systematic review and meta-analysis focuses on studies published since 1999 on the human cognitive and performance effects of mobile phone-related electromagnetic fields (EMF). METHODS PubMed, Biomed, Medline, Biological Sciences, PsychInfo, PsycARTICLES, Environmental Sciences and Pollution Management, Neurosciences Abstracts and Web of Science professional databases were searched and 24 studies selected for meta-analysis. Each study had to have at least one psychomotor measurement result as a main outcome. Data were analysed using standardised mean difference (SMD) as the effect size measure. RESULTS Only three tasks (2-back, 3-back and simple reaction time (SRT)) displayed significant heterogeneity, but after studies with extreme SMD were excluded using sensitivity analysis, the statistical significance disappeared ($\chi(2)(7)=1.63$, $p=0.20$; $\chi(2)(6)=1.00$, $p=0.32$; $\chi(2)(10)=14.04$, $p=0.17$, respectively). Following sensitivity analysis, the effect of sponsorship and publication bias were assessed. Meta-regression indicated a significant effect (b1/40.12, $p<0.05$) only for the 2-back task with mixed funding (industry and public/charity). Funnel plot inspection revealed a significant publication bias only for two cognitive tasks: SRT (Begg's rank correlation r=0.443; Egger's test b=-0.652) and the subtraction task (Egger's test b=-0.687). CONCLUSIONS Mobile phone-like EMF do not seem to induce cognitive and psychomotor effects. Nonetheless, the existence of sponsorship and publication biases should encourage WHO intervention to develop official research standards and guidelines. In addition, future research should address critical and neglected issues such as investigation of repeated, intensive and chronic exposures, especially in highly sensitive populations such as children.

**Valič B, Kos B, Gajšek P. TYPICAL EXPOSURE OF CHILDREN TO EMF: EXPOSIMETRY AND DOSIMETRY. Radiat Prot Dosimetry. 2014 Apr 10. [Epub ahead of print]**

A survey study with portable exposimeters, worn by 21 children under the age of 17, and detailed measurements in an apartment above a transformer substation were carried out to determine the typical individual exposure of children to extremely low- and radio-frequency (RF) electromagnetic field. In total, portable exposimeters were worn for >2400 h. Based on the typical individual exposure the in situ electric field and specific absorption rate (SAR) values were calculated for an 11-y-old female human model. The average exposure was determined to be low compared with ICNIRP reference levels: 0.29 μT for an extremely low-frequency (ELF) magnetic field and 0.09 V $m^{-1}$ for GSM base stations, 0.11 V $m^{-1}$ for DECT and 0.10 V $m^{-1}$ for WiFi; other contributions could be neglected. However, some of the volunteers were more exposed: the highest realistic exposure, to which children could be exposed for a prolonged period of time, was 1.35 μT for ELF magnetic field and 0.38 V $m^{-1}$ for DECT, 0.13 V $m^{-1}$ for WiFi and 0.26 V $m^{-1}$ for GSM base stations. Numerical calculations of the in situ electric field and SAR values for the typical and the worst-case situation show that, compared with ICNIRP basic restrictions, the average exposure is low. In the typical exposure scenario, the extremely low frequency exposure is <0.03 % and the RF exposure <0.001 % of the corresponding basic restriction. In the worst-case situation, the extremely low frequency exposure is <0.11 % and the RF exposure <0.007 % of the corresponding basic restrictions. Analysis of the exposures and the individual's perception of being exposed/unexposed to an ELF magnetic field showed that it is impossible to estimate the individual exposure to an ELF magnetic field based only on the information provided by the individuals, as they do not have enough knowledge and information to properly identify the sources in their vicinity.

**Van de Kamer JB, Lagendijk, JJW, Computation of high-resolution SAR distributions in a head due to a radiating dipole antenna representing a hand-held mobile phone. Phys. Med. Biol. 47:1827-1835, 2002.**

SAR distributions in a healthy female adult head as a result of a radiating vertical dipole antenna (frequency 915 MHz) representing a hand-held mobile phone have been computed for three different resolutions: 2 mm, 1 mm and 0.4 mm. The extremely high resolution of 0.4 mm was obtained with our quasistatic zooming technique, which is briefly described in this paper.For an effectively transmitted power of 0.25 W, the maximum averaged SAR values in both cubic- and arbitrary-shaped volumes are, respectively, about 1.72 and 2.55 W kg-1 for 1 g and 0.98 and 1.73 W kg-1 for 10 g of tissue. These numbers do not vary much (<8%) for the different resolutions, indicating that SAR computations at a resolution of 2 mm are sufficiently accurate to describe the large-scale distribution. However, considering the detailed SAR pattern in the head, large differences may occur if high-resolution computations are performed rather than low-resolution ones. These deviations are caused by both increased modelling accuracy and improved anatomical description in higher resolution simulations. For example, the SAR profile across a boundary between tissues with high dielectric contrast is much more accurately described at higher resolutions. Furthermore, low-resolution dielectric geometries may

suffer from loss of anatomical detail, which greatly affects small-scale SAR distributions. Thus, for strongly inhomogeneous regions high-resolution SAR modelling is an absolute necessity.

**Van Den Bossche M, Verloock L, Aerts S, Joseph W, Martens L. IN SITU EXPOSURE ASSESSMENT OF INTERMEDIATE FREQUENCY FIELDS OF DIVERSE DEVICES. Radiat Prot Dosimetry. 2014 Aug 14. pii: ncu257. [Epub ahead of print]**

In this study, in situ exposure assessment of both electric and magnetic fields of different intermediate frequency (IF) sources is investigated. The authors investigated smart boards and touchscreens, energy-saving bulbs, fluorescent lamps, a portable hearing unit and an electrosurgical unit (ESU). For most of these sources, the electric field is the dominating quantity. International Commission on Non-Ionizing Radiation Protection reference levels are exceeded for touchscreens (44 kHz: up to 155.7 V $m^{-1}$ at 5 cm), energy-saving bulbs (38-52 kHz: up to 117.3 V $m^{-1}$), fluorescent lamps (52 kHz: up to 471 V $m^{-1}$ at 5 cm) and ESUs (up to 920 kHz: 792 V $m^{-1}$ at 0.5 cm). Magnetic field strengths up to 1.8 and 10.5 A $m^{-1}$ were measured close to the ESU and portable hearing unit (69 V $m^{-1}$), respectively. Large differences of measured field values exist among the various operating modes of the IF equipment. Compliance distances for general public range from 15.3 cm (touchscreen) to 25 cm (fluorescent lamps).

**van Kleef E, Fischer AR, Khan M, Frewer LJ. Risk and Benefit Perceptions of Mobile Phone and Base Station Technology in Bangladesh. Risk Anal.30(6):1002-1015, 2010.**

Research in developed countries showed that many citizens perceive that radio signals transmitted by mobile phones and base stations represent potential health risks. Less research has been conducted in developing countries focused on citizen perceptions of risks and benefits, despite the recent and rapid introduction of mobile communication technologies. This study aims to identify factors that are influential in determining the tradeoffs that Bangladeshi citizens make between risks and benefits in terms of mobile phone technology acceptance and health concerns associated with the technology. Bangladesh was selected as representative of many developing countries inasmuch as terrestrial telephone infrastructure is insubstantial, and mobile phone use has expanded rapidly over the last decade, even among the poor. Issues of importance were identified in a small-scale qualitative study among Bangladeshi citizens (n = 13), followed by a survey within a sample of Bangladeshi citizens (n = 500). The results demonstrate that, in general, the perceived benefits of mobile phone technology outweigh the risks. The perceived benefits are primarily related to the social and personal advantages of mobile phone use, including the ability to receive emergency news about floods, cyclones, and other natural disasters. Base stations were seen as a symbol of societal advance. The results furthermore suggest that overall risk perceptions are relatively low, in particular health risks, and are primarily driven by perceptions that related to crime and social inconvenience. Perceived health risks are relatively small. These findings show that risk communication and management may be particularly effective when contextual factors of the society where the system is implemented are taken into consideration.

**Vanderwaal RP, Cha B, Moros EG, Roti Roti JL. HSP27 phosphorylation increases after 45 degrees C or 41 degrees C heat shocks but not after non-thermal TDMA or GSM exposures. Int J Hyperthermia. 22(6):507-519, 2006.**

Purpose: Experiments with cultured HeLa, S3 and E.A. Hy296 cells were performed to determine if exposure to acute (30 min at 45 degrees C) or chronic (2 h at 41 degrees C) heat shocks or to non-thermal exposures of radiofrequency radiation (RF) induce changes in HSP27 phosphorylation.Materials and methods: The radiofrequency (RF) exposures used in this study were 847 MHz time division multiple access modulated (TDMA) at a specific absorption rate (SAR) of 5 W kg-1 for 1, 2 or 24 h or 900 MHz GSM modulated (GSM) at a SAR of 3.7 W kg-1 for 1, 2 or 5 h. HSP27 phosphorylation was evaluated by resolving the various phosphorylation forms using two-dimensional gel electrophoresis measuring the relative amount of each by densitometry. Alternatively, an antibody specific for phosphorylated HSP27 was used to detect changes in HSP27 phosphorylation levels. All heat shock and RF exposure conditions were analysed simultaneously along with a matched incubator control sample. Each experiment was repeated three times.Results: Following heat shock, the degree of phosphorylation of HSP27 varied with the heat dose, with acute hyperthermia (45 degrees C) having an increased proportion of higher phosphorylated forms. Exposure of HeLa S3 cells to 5 W kg-1 TDMA for 1, 2 or 24 h did not induce significant differences in the levels of HSP27 phosphorylation compared to incubator control or sham. Exposure of E.A. Hy926 cells to 3.7 W kg-1 900 MHz GSM for 1, 2 or 5 h did not induce significant differences in the levels of HSP27 phosphorylation compared to sham exposed.Conclusions: Acute and moderate hyperthermia significantly increase HSP27 phosphorylation, but there was no significant change in the levels of HSP27 following non-thermal exposure to TDMA and GSM modulated RF radiations.

**Van Leeuwen GM, Lagendijk JJ, Van Leersum BJ, Zwamborn AP, Hornsleth SN, Kotte AN, Calculation of change in brain temperatures due to exposure to a mobile phone. Phys Med Biol 44(10):2367-2379, 1999.**

In this study we evaluated for a realistic head model the 3D temperature rise induced by a mobile phone. This was done numerically with the consecutive use of an FDTD model to predict the absorbed electromagnetic power distribution, and a thermal model describing bioheat transfer both by conduction and by blood flow. We calculated a maximum rise in brain temperature of 0.11 degrees C for an antenna with an average emitted power of 0.25 W, the maximum value in common mobile phones, and indefinite exposure. Maximum temperature rise is at the skin. The power distributions were characterized by a maximum averaged SAR over an arbitrarily shaped 10 g volume of approximately 1.6 W kg(-1). Although these power distributions are not in compliance with all proposed safety standards, temperature rises are far too small to have lasting effects. We verified our simulations by measuring the skin temperature rise experimentally. Our simulation method can be instrumental in further development of safety standards.

**Vangelova K, Israel M, Mihaylov S. The effect of low level radiofrequency electromagnetic radiation on the excretion rates of stress hormones in operators during 24-hour shifts. Cent Eur J Public Health 10(1-2):24-28, 2002**.

The aim of the study was to investigate the effect of long term exposure to low level radiofrequency (RF) electromagnetic (EM) radiation on the excretion rates of stress hormones in satellite station operators during 24-hour shifts. Twelve male operators at a satellite station for TV communications and space research were studied during 24-hour shifts. Dosimetric evaluation of the exposure was carried out and showed low level exposure with specific absorption of 0.1127 J.kg-1. A control group of 12 unexposed male operators with similar job task and the same shift system were studied, too. The 11-oxycorticosteroids (11-OCS), adrenaline and noradrenaline were followed by spectrofluorimetric methods on 3-hour intervals during the 24-hour shifts. The data were analyzed by tests for interindividual analysis, Cosinor analysis and analysis of variance (ANOVA). Significant increase in the 24-hour excretion of 11-OCS and disorders in its circadian rhythm, manifested by increase in the mesor, decrease in the amplitude and shift in the acrophase were found in the exposed operators. The changes in the excretion rates of the catecholamines were significant and showed greater variability of both variables. The long term effect of the exposure to low-level RF EM radiation evoked pronounced stress reaction with changes in the circadian rhythm of 11-OCS and increased variability of catecholamines secretion. The possible health hazards associated with observed alteration in the stress system need to be clarified by identification of their significance and prognostic relevance.

**Vangelova KK, Israel MS. Variations of melatonin and stress hormones under extended shifts and radiofrequency electromagnetic radiation. Rev Environ Health. 20(2):151-161, 2005.**

We studied the time-of-day variations in urinary levels of 6-sulphatoxy-melatonin and three stress hormones in operators working fast-rotating extended shifts under radiofrequency electromagnetic radiation (EMR). The excretion rate of the hormones was monitored by radioimmunoassay and spectrofluorimetry at 4-hour intervals in a group of 36 male operators comprising 12 broadcasting station operators, 12 TV station operators, and a control group of 12 satellite station operators. Measuring the time-weighted average (TWA) of EMR exposure revealed a high-level of exposure in broadcasting station operators (TWAmean= 3.10 microW/ cm2, TWAmax = 137.00 microW/cm2), a low-level in TV station operators (TWAmean = 1.89 microW/cm2, TWAmax = 5.24 microW/cm2), and a very low level in satellite station operators. The differences among the groups remained the same after confounding factors were taken into account. Radiofrequency EMR had no effect on the typical diurnal pattern of 6-sulphatoxymelatonin. High-level radiofrequency EMR exposure significantly increased the excretion rates of cortisol ($p < 0.001$), adrenaline ($p = 0.028$), and noradrenaline ($p < 0.000$), whereas changes under low-level exposure did not reach significance. The 24-hour excretion of cortisol and noradrenaline correlated with TWAmean and TWAmax. In conclusion, the excretion of 6-sulphatoxymelatonin retained a typical diurnal pattern under fast-rotating extended shifts and radiofrequency EMR, but showed an exposure-effect relation with stress hormones.

**Vangelova K, Deyanov C, Israel M.Cardiovascular risk in operators under radiofrequency electromagnetic radiation.Int J Hyg Environ Health. 209(2):133-138, 2006.**

The aim of the study was to assess the long-term effects of radiofrequency electromagnetic radiation (EMR) on the cardiovascular system. Two groups of exposed operators (49 broadcasting (BC) station and 61 TV station operators) and a control group of 110 radiorelay station operators, matched by sex and age, with similar job characteristics except for the radiofrequency EMR were studied. The EMR exposure was assessed and the time-weighted average (TWA) was calculated. The cardiovascular risk factors arterial pressure, lipid profile, body mass index, waist/hip ratio, smoking, and family history of cardiovascular disease were followed. The systolic and diastolic blood pressure (SBP and DBP), total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) were significantly higher in the two exposed groups. It was found that the radiofrequency EMR exposure was associated with greater chance of becoming hypertensive and dyslipidemic. The stepwise multiple regression equations showed that the SBP and TWA predicted the high TC and high LDL-C, while the TC, age and abdominal obesity were predictors for high SBP and DBP. In conclusion, our data show that the radiofrequency EMR contributes to adverse effects on the cardiovascular system.

**van Wyk MJ, Bingle M, Meyer FJ. Antenna modeling considerations for accurate SAR calculations in human phantoms in close proximity to GSM cellular base station antennas. Bioelectromagnetics. 26(6):502-509, 2005.**

International bodies such as International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute for Electrical and Electronic Engineering (IEEE) make provision for human exposure assessment based on SAR calculations (or measurements) and basic restrictions. In the case of base station exposure this is mostly applicable to occupational exposure scenarios in the very near field of these antennas where the conservative reference level criteria could be unnecessarily restrictive. This study presents a variety of critical aspects that need to be considered when calculating SAR in a human body close to a mobile phone base station antenna. A hybrid FEM/MoM technique is proposed as a suitable numerical method to obtain accurate results. The verification of the FEM/MoM implementation has been presented in a previous publication; the focus of this study is an investigation into the detail that must be included in a numerical model of the antenna, to accurately represent the real-world scenario. This is accomplished by comparing numerical results to measurements for a generic GSM base station antenna and appropriate, representative canonical and human phantoms. The results show that it is critical to take the disturbance effect of the human phantom (a large conductive body) on the base station antenna into account when the antenna-phantom spacing is less than 300 mm. For these small spacings, the antenna structure must be modeled in detail. The conclusion is that it is feasible to calculate, using the proposed techniques and methodology, accurate occupational compliance zones around base station antennas based on a SAR profile and basic restriction guidelines.

**Varghese R, Majumdar A, Kumar G, Shukla A. Rats exposed to 2.45GHz of non-ionizing radiation exhibit behavioral changes with increased brain expression of**

**apoptotic caspase 3. Pathophysiology. 2017 Nov 14. pii: S0928-4680(17)30052-4. doi: 10.1016/j.pathophys.2017.11.001.**

In recent years there has been a tremendous increase in use of Wi-Fi devices along with mobile phones, globally. Wi-Fi devices make use of 2.4 GHz frequency. The present study evaluated the impact of 2.45 GHz radiation exposure for 4h/day for 45 days on behavioral and oxidative stress parameters in female Sprague Dawley rats. Behavioral tests of anxiety, learning and memory were started from day 38. Oxidative stress parameters were estimated in brain homogenates after sacrificing the rats on day 45. In morris water maze, elevated plus maze and light dark box test, the 2.45 GHz radiation exposed rats elicited memory decline and anxiety behavior. Exposure decreased activities of super oxide dismutase, catalase and reduced glutathione levels whereas increased levels of brain lipid peroxidation was encountered in the radiation exposed rats, showing compromised anti-oxidant defense. Expression of caspase 3 gene in brain samples were quantified which unraveled notable increase in the apoptotic marker caspase 3 in 2.45 GHz radiation exposed group as compared to sham exposed group. No significant changes were observed in histopathological examinations and brain levels of TNF-α. Analysis of dendritic arborization of neurons showcased reduction in number of dendritic branching and intersections which corresponds to alteration in dendritic structure of neurons, affecting neuronal signaling. The study clearly indicates that exposure of rats to microwave radiation of 2.45GHz leads to detrimental changes in brain leading to lowering of learning and memory and expression of anxiety behavior in rats along with fall in brain antioxidant enzyme systems.

**Varsier N, Dahdouh S, Serrurier A, De la Plata JP, Anquez J, Angelini ED, Bloch I, Wiart J. Influence of pregnancy stage and fetus position on the whole-body and local exposure of the fetus to RF-EMF. Phys Med Biol. 2014 Aug 7;59(17):4913-4926. [Epub ahead of print]**

This paper analyzes the influence of pregnancy stage and fetus position on the whole-body and brain exposure of the fetus to radiofrequency electromagnetic fields. Our analysis is performed using semi-homogeneous pregnant woman models between 8 and 32 weeks of amenorrhea. By analyzing the influence of the pregnancy stage on the environmental whole-body and local exposure of a fetus in vertical position, head down or head up, in the 2100 MHz frequency band, we concluded that both whole-body and average brain exposures of the fetus decrease during the first pregnancy trimester, while they advance during the pregnancy due to the rapid weight gain of the fetus in these first stages. From the beginning of the second trimester, the whole-body and the average brain exposures are quite stable because the weight gains are quasi proportional to the absorbed power increases.The behavior of the fetus whole-body and local exposures during pregnancy for a fetus in the vertical position with the head up were found to be of a similar level, when compared to the position with the head down they were slightly higher, especially in the brain.

**Vecchio F, Babiloni C, Ferreri F, Curcio G, Fini R, Del Percio C, Rossini PM. Mobile**

**phone emission modulates interhemispheric functional coupling of EEG alpha rhythms. Eur J Neurosci. 25(6):1908-1913, 2007.**

We tested the working hypothesis that electromagnetic fields from mobile phones (EMFs) affect interhemispheric synchronization of cerebral rhythms, an important physiological feature of information transfer into the brain. Ten subjects underwent two electroencephalographic (EEG) recordings, separated by 1 week, following a crossover double-blind paradigm in which they were exposed to a mobile phone signal (global system for mobile communications; GSM). The mobile phone was held on the left side of the subject head by a modified helmet, and orientated in the normal position for use over the ear. The microphone was orientated towards the corner of the mouth, and the antenna was near the head in the parietotemporal area. In addition, we positioned another similar phone (but without battery) on the right side of the helmet, to balance the weight and to prevent the subject localizing the side of GSM stimulation (and consequently lateralizing attention). In one session the exposure was real (GSM) while in the other it was Sham; both sessions lasted 45 min. Functional interhemispheric connectivity was modelled using the analysis of EEG spectral coherence between frontal, central and parietal electrode pairs. Individual EEG rhythms of interest were delta (about 2-4 Hz), theta (about 4-6 Hz), alpha 1 (about 6-8 Hz), alpha 2 (about 8-10 Hz) and alpha 3 (about 10-12 Hz). Results showed that, compared to Sham stimulation, GSM stimulation modulated the interhemispheric frontal and temporal coherence at alpha 2 and alpha 3 bands. The present results suggest that prolonged mobile phone emission affects not only the cortical activity but also the spread of neural synchronization conveyed by interhemispherical functional coupling of EEG rhythms.

**Vecchio F, Babiloni C, Ferreri F, Buffo P, Cibelli G, Curcio G, Dijkman SV, Melgari JM, Giambattistelli F, Rossini PM. Mobile phone emission modulates inter-hemispheric functional coupling of EEG alpha rhythms in elderly compared to young subjects. Clin Neurophysiol. 121(2):163-171, 2010.**

OBJECTIVE: It has been reported that GSM electromagnetic fields (GSM-EMFs) of mobile phones modulate - after a prolonged exposure - inter-hemispheric synchronization of temporal and frontal resting electroencephalographic (EEG) rhythms in normal young subjects [Vecchio et al., 2007]. Here we tested the hypothesis that this effect can vary on physiological aging as a sign of changes in the functional organization of cortical neural synchronization. METHODS: Eyes-closed resting EEG data were recorded in 16 healthy elderly subjects and 5 young subjects in the two conditions of the previous reference study. The GSM device was turned on (45min) in one condition and was turned off (45min) in the other condition. Spectral coherence evaluated the inter-hemispheric synchronization of EEG rhythms at the following bands: delta (about 2-4Hz), theta (about 4-6Hz), alpha 1 (about 6-8Hz), alpha 2 (about 8-10Hz), and alpha 3 (about 10-12Hz). The aging effects were investigated comparing the inter-hemispheric EEG coherence in the elderly subjects vs. a young group formed by 15 young subjects (10 young subjects of the reference study; Vecchio et al., 2007). RESULTS: Compared with the young subjects, the elderly subjects showed a statistically significant ($p<0.001$) increment of the inter-hemispheric coherence of frontal and temporal alpha rhythms (about 8-12Hz) during

the GSM condition. CONCLUSIONS: These results suggest that GSM-EMFs of a mobile phone affect inter-hemispheric synchronization of the dominant (alpha) EEG rhythms as a function of the physiological aging. SIGNIFICANCE: This study provides further evidence that physiological aging is related to changes in the functional organization of cortical neural synchronization.

**Vecchio F, Buffo P, Sergio S, Iacoviello D, Rossini PM, Babiloni C. Mobile phone emission modulates event-related desynchronization of α rhythms and cognitive-motor performance in healthy humans.Clin Neurophysiol. 123(1):121-128, 2012.**

**OBJECTIVES:** It has been shown that electromagnetic fields of Global System for Mobile Communications phone (GSM-EMFs) affect human brain rhythms (Vecchio et al., 2007, 2010), but it is not yet clear whether these effects are related to alterations of cognitive functions.**METHODS:** Eleven healthy adults underwent two electroencephalographic (EEG) sessions separated by 1 week, following a cross-over, placebo-controlled, double-blind paradigm. In both sessions, they performed a visual go/no-go task before real exposure to GSM-EMFs or after a sham condition with no EMF exposure. In the GSM real session, temporal cortex was continuously exposed to GSM-EMFs for 45 min. In the sham session, the subjects were not aware that the EMFs had been switched off for the duration of the experiment. In the go/no-go task, a central fixation stimulus was followed by a green (50% of probability) or red visual stimulus. Subjects had to press the mouse button after the green stimuli (go trials). With reference to a baseline period, power decrease of low- (about 8-10 Hz) and high-frequency (about 10-12 Hz) alpha rhythms indexed the cortical activity.**RESULTS:** It was found less power decrease of widely distributed high-frequency alpha rhythms and faster reaction time to go stimuli in the post- than pre-exposure period of the GSM session. No effect was found in the sham session.**CONCLUSIONS:** These results suggest that the peak amplitude of alpha ERD and the reaction time to the go stimuli are modulated by the effect of the GSM-EMFs on the cortical activity.**SIGNIFICANCE:** Exposure to GSM-EMFs for 45 min may enhance human cortical neural efficiency and simple cognitive-motor processes in healthy adults.

**Vecchio F, Tombini M, Buffo P, Assenza G, Pellegrino G, Benvenga A, Babiloni C, Rossini PM. Mobile phone emission increases inter-hemispheric functional coupling of electroencephalographic alpha rhythms in epileptic patients. Int J Psychophysiol.84(2):164-171, 2012.**

It has been reported that GSM electromagnetic fields (GSM-EMFs) of mobile phones modulate - after a prolonged exposure - inter-hemispheric synchronization of temporal and frontal resting electroencephalographic (EEG) rhythms in normal young and elderly subjects (Vecchio et al., 2007, 2010). Here we tested the hypothesis that this can be even more evident in epileptic patients, who typically suffer from abnormal mechanisms governing synchronization of rhythmic firing of cortical neurons. Eyes-closed resting EEG data were recorded in ten patients affected by focal epilepsy in real and sham exposure conditions. These data were compared with those obtained from 15 age-matched normal subjects of the previous reference studies. The GSM device was turned on (45min) in the "GSM" condition and was turned off (45min) in the other condition ("sham"). The mobile phone was always positioned on the left

side in both patients and control subjects. Spectral coherence evaluated the inter-hemispheric synchronization of EEG rhythms at the following frequency bands: delta (about 2-4Hz), theta (about 4-6Hz), alpha1 (about 6-8Hz), alpha2 (about 8-10Hz), and alpha3 (about 10-12Hz). The effects on the patients were investigated comparing the inter-hemispheric EEG coherence in the epileptic patients with the control group of subjects evaluated in the previous reference studies. Compared with the control subjects, epileptic patients showed a statistically significant higher inter-hemispheric coherence of temporal and frontal alpha rhythms (about 8-12Hz) in the GSM than "Sham" condition. These results suggest that GSM-EMFs of mobile phone may affect inter-hemispheric synchronization of the dominant (alpha) EEG rhythms in epileptic patients. If confirmed by future studies on a larger group of epilepsy patients, the modulation of the inter-hemispheric alpha coherence due to the GSM-EMFs could have clinical implications and be related to changes in cognitive-motor function.

**Vecsei Z, Csathó A, Thuróczy G, Hernádi I. Effect of a single 30 min UMTS mobile phone-like exposure on the thermal pain threshold of young healthy volunteers. Bioelectromagnetics. 2013 Jun 20. doi: 10.1002/bem.21801. [Epub ahead of print]**

One of the most frequently investigated effects of radiofrequency electromagnetic fields (RF EMFs) on the behavior of complex biological systems is pain sensitivity. Despite the growing body of evidence of EMF-induced changes in pain sensation, there is no currently accepted experimental protocol for such provocation studies for the healthy human population. In the present study, therefore, we tested the effects of third generation Universal Mobile Telecommunications System (UMTS) RF EMF exposure on the thermal pain threshold (TPT) measured on the surface of the fingers of 20 young adult volunteers. The protocol was initially validated with a topical capsaicin treatment. The exposure time was 30 min and the genuine (or sham) signal was applied to the head through a patch antenna, where RF EMF specific absorption rate (SAR) values were controlled and kept constant at a level of 1.75 W/kg. Data were obtained using randomized, placebo-controlled trials in a double-blind manner. Subjective pain ratings were tested blockwise on a visual analogue rating scale (VAS). Compared to the control and sham conditions, the results provide evidence for intact TPT but a reduced desensitization effect between repeated stimulations within the individual blocks of trials, observable only on the contralateral side for the genuine UMTS exposure. Subjective pain perception (VAS) data indicated marginally decreased overall pain ratings in the genuine exposure condition only. The present results provide pioneering information about human pain sensation in relation to RF EMF exposure and thus may contribute to cover the existing gap between safety research and applied biomedical science targeting the potential biological effects of environmental RF EMFs.

**Velayutham P, Govindasamy GK, Raman R, Prepageran N, Ng KH. High-frequency hearing loss among mobile phone users. Indian J Otolaryngol Head Neck Surg. 66(Suppl 1):169-172, 2014.**

The objective of this study is to assess high frequency hearing (above 8 kHz) loss among prolonged mobile phone users is a tertiary Referral Center. Prospective single blinded study. This is the first study that used high-frequency audiometry. The wide usage of mobile phone is so profound that we were unable to find enough non-users as a control group. Therefore we compared the non-dominant ear to the dominant ear using audiometric measurements. The study was a blinded study wherein the audiologist did not know which was the dominant ear. A total of 100 subjects were studied. Of the subjects studied 53% were males and 47% females. Mean age was 27. The left ear was dominant in 63%, 22% were dominant in the right ear and 15% did not have a preference. This study showed that there is significant loss in the dominant ear compared to the non-dominant ear ($P < 0.05$). Chronic usage mobile phone revealed high frequency hearing loss in the dominant ear (mobile phone used) compared to the non dominant ear.

**Velizarov, S, Raskmark, P, Kwee, S, The effects of radiofrequency fields on cell proliferation are non-thermal. Bioelectrochem Bioenerg 48(1):177-180, 1999.**

The number of reports on the effects induced by radiofrequency (RF) electromagnetic fields and microwave (MW) radiation in various cellular systems is still increasing. Until now no satisfactory mechanism has been proposed to explain the biological effects of these fields. One of the current theories is that heat generation by RF/MW is the cause, in spite of the fact that a great number of studies under isothermal conditions have reported significant cellular changes after exposure to RF/MW. Therefore, this study was undertaken to investigate which effect MW radiation from these fields in combination with a significant change of temperature could have on cell proliferation. The experiments were performed on the same cell line, and with the same exposure system as in a previous work [S. Kwee, P. Raskmark, Changes in cell proliferation due to environmental non-ionizing radiation: 2. Microwave radiation, Bioelectrochem. Bioenerg., 44 (1998), pp. 251-255]. The field was generated by signal simulation of the Global System for Mobile communications (GSM) of 960 MHz. Cell cultures, growing in microtiter plates, were exposed in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell. The Specific Absorption Rate (SAR) value for each cell well was calculated for this exposure system. However, in this study thecells were exposed to the field at a higher or lower temperature than the temperature in the field-free incubator i.e., the temperature in the TEM cell was either 39 or 35 +/- 0.1 degrees C. The corresponding sham experiments were performed under exactly the same experimental conditions. The results showed that there was a significant change in cell proliferation in the exposed cells in comparison to the non-exposed (control) cells at both temperatures. On the other hand, no significant change in proliferation rate was found in the sham-exposed cells at both temperatures. This shows that biological effects due to RF/MW cannot be attributed only to a change of temperature. Since the RF/MW induced changes were of the same order of magnitude at both temperatures and also comparable to our previous results under isothermal conditions at 37 degrees C, cellular stress caused by electromagnetic fields could initiate the changes in cell cycle reaction rates. It is widely accepted that certain classes of heat-shock proteins are involved in

these stress reactions.

**Vereshchako GG, Chueshova NV, Gorokh GA, Naumov AD. State of the reproductive system in male rats of 1st generation obtained from irradiated parents and exposed to electromagnetic radiation (897 MHz) during embryogenesis and postnatal development. Radiats Biol Radioecol. 54(2):186-192, 2014.**

The consequences of prolonged exposure to electromagnetic radiation from cellular phone (897 MHz, daily 8 h/day) in male rats of the 1st generation obtained from irradiated parents and subjected to prolonged exposure to electromagnetic radiation of the range of mobile communications during ontogeny and postnatal development were studied. It has been found that irradiation causes a decrease in the number of births of animals, changing the sex ratio towards the increase in the number of males. It had a significant impact on the reproductive system of males, accelerating their sexual development, revealed at the age of two months. Radiation from cell phones led to significant disproportions in the cell number at different stages of spermatogenesis. It increased the number of mature spermatozoa which decreased viability.

**Vergassola R, Borgioli A, Chiodi L, Rossi D, Fazi A, Lebrun E, Vaccari M, [Changes in pacemakers and the wearers of pacemakers as a result of the use of different electromagnetic energy sources]. Minerva Cardioangiol 42(1-2):27-32, 1994.**

[Over the past decade there have been considerable advances in cardiac electrostimulation technologies. However, there are still reports of electromagnetic interference with pacemakers and pacemaker patients. We have studied the effects of various electromagnetic sources (short-wave diathermy, electrosurgical knives, electrotherapy and radiofrequencies) on both humans and animals. The results of the studies were completely negative and, therefore, we are convinced that today's pacemakers are much more reliable and hence less subject to interference from external electromagnetic sources. We performed the following tests: (a) Short-wave diathermy: various electrode positions in pigs and 8 patients with pacemakers. (b) Electrosurgical knives: several tests on pigs with unipolar electrosurgical knife; 6 tests on humans during automatic defibrillator implantation using two-pole electrosurgical knives; 23 pacemaker patients underwent abdominal surgery (3 inguinal hernias, 12 gastric resections; 6 cholecystotomies, 2 aortic aneurysms-with two-pole electrosurgical knives). (c) Electrotherapy (TENS): on pigs. (d) Radiofrequency (RF) for transcatheter ablation-several tests on pigs.

**Verloock L, Joseph W, Vermeeren G, Martens L. Procedure for assessment of general public exposure from WLAN in offices and in wireless sensor network testbed.Health Phys. 98(4):628-638, 2010.**

A fast and accurate measurement procedure to determine experimentally wireless local area network (WLAN) radiofrequency (RF) exposure and to test compliance with international guidelines for the general public is proposed. This is the first paper where all optimal settings for the measurement equipment (sweep time, resolution bandwidth, etc.)

are investigated, selected, and validated. The exposure to WLAN access points is determined for 222 locations with 7 WLAN networks present in office environments. The WLAN exposure is also characterized for the first time in a wireless sensor lab environment (WiLab) at IBBT-Ghent University in Belgium. Average background exposure to WLAN (WiLab off) is 0.12 V m(-1), with a 95 percentile of 0.90 V m(-1). With the WiLab in operation, average exposure increases to 1.9 V m(-1), with a 95 percentile of 4.7 V m(-1). All values are well below the International Commission on Non Ionizing Radiation Protection guidelines of 61 V m(-1) in the 2.4 GHz band (at least 9.1 times for distances of more than 1 m from the access points) but a significant increase of exposure is possible in WiLabs due to high duty cycles. By applying the proposed measurement method a relevant reduction in measurement time is obtained.

**Verloock L, Joseph W, Goeminne F, Martens L, Verlaek M, Constandt K. Assessment of Radio Frequency Exposures in Schools, Homes, and Public Places in Belgium. Health Phys. 107(6):503-513, 2014.**

Characterization of exposure from emerging radio frequency (RF) technologies in areas where children are present is important. Exposure to RF electromagnetic fields (EMF) was assessed in three "sensitive" microenvironments; namely, schools, homes, and public places located in urban environments and compared to exposure in offices. In situ assessment was conducted by performing spatial broadband and accurate narrowband measurements, providing 6-min averaged electric-field strengths. A distinction between internal (transmitters that are located indoors) and external (outdoor sources from broadcasting and telecommunication) sources was made. Ninety-four percent of the broadband measurements were below 1 V m. The average and maximal total electric-field values in schools, homes, and public places were 0.2 and 3.2 V m (WiFi), 0.1 and 1.1 V m (telecommunication), and 0.6 and 2.4 V m (telecommunication), respectively, while for offices, average and maximal exposure were 0.9 and 3.3 V m (telecommunication), satisfying the ICNIRP reference levels. In the schools considered, the highest maximal and average field values were due to internal signals (WiFi). In the homes, public places, and offices considered, the highest maximal and average field values originated from telecommunication signals. Lowest exposures were obtained in homes. Internal sources contributed on average more indoors (31.2%) than outdoors (2.3%), while the average contributions of external sources (broadcast and telecommunication sources) were higher outdoors (97.7%) than at indoor positions (68.8%). FM, GSM, and UMTS dominate the total downlink exposure in the outdoor measurements. In indoor measurements, FM, GSM, and WiFi dominate the total exposure. The average contribution of the emerging technology LTE was only 0.6%.

**Verma M, Dutta SK. Microwave induced alteration in the neuron specific enolase gene expression. Cancer Biochem Biophys. 13(4):239-244, 1993.**

Exposure of pNGE7, a recombinant clone containing the coding and regulatory sequences for the expression of neuron specific enolase gene, cells to electromagnetic radiations (915 MHz, 16 Hz AM, SAR 0.05 mW/kg) resulted in the elevation of neuron specific enolase (NSE), a diagnostic marker for neuron and lung cancer. Using ion-exchange chromatography we separated the neuron specific enolase activity from the

non-neuronal enolase (NNE) activity and observed an alteration in the expression of neuron specific enolase and non-neuronal enolase. The clinical applications of the present studies have been discussed.

**Vermeeren G, Gosselin MC, Kühn S, Kellerman V, Hadjem A, Gati A, Joseph W, Wiart J, Meyer F, Kuster N, Martens L. The influence of the reflective environment on the absorption of a human male exposed to representative base station antennas from 300 MHz to 5 GHz. Phys Med Biol. 55(18):5541-5555, 2010.**

The environment is an important parameter when evaluating the exposure to radio-frequency electromagnetic fields. This study investigates numerically the variation on the whole-body and peak spatially averaged-specific absorption rate (SAR) in the heterogeneous virtual family male placed in front of a base station antenna in a reflective environment. The SAR values in a reflective environment are also compared to the values obtained when no environment is present (free space). The virtual family male has been placed at four distances (30 cm, 1 m, 3 m and 10 m) in front of six base station antennas (operating at 300 MHz, 450 MHz, 900 MHz, 2.1 GHz, 3.5 GHz and 5.0 GHz, respectively) and in three reflective environments (a perfectly conducting wall, a perfectly conducting ground and a perfectly conducting ground + wall). A total of 72 configurations are examined. The absorption in the heterogeneous body model is determined using the 3D electromagnetic (EM) finite-difference time-domain (FDTD) solver Semcad-X. For the larger simulations, requirements in terms of computer resources are reduced by using a generalized Huygens' box approach. It has been observed that the ratio of the SAR in the virtual family male in a reflective environment and the SAR in the virtual family male in the free-space environment ranged from -8.7 dB up to 8.0 dB. A worst-case reflective environment could not be determined. ICNIRP reference levels not always showed to be compliant with the basic restrictions.

**Verschaeve, L., Heikkinen, P., Verheyen, G., Van Gorp, U., Boonen, F., Vander Plaetse, F., Maes, A., Kumlin, T., Maki-Paakkanen, J., Puranen, L. and Juutilainen, J. Investigation of Co-genotoxic Effects of Radiofrequency Electromagnetic Fields In Vivo. Radiat. Res. 165, 598-607, 2006.**

We investigated the possible combined genotoxic effects of radiofrequency (RF) electromagnetic fields (900 MHz, amplitude modulated at 217 Hz, mobile phone signal) with the drinking water mutagen and carcinogen 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX). Female rats were exposed to RF fields for a period of 2 years for 2 h per day, 5 days per week at average whole-body specific absorption rates of 0.3 or 0.9 W/kg. MX was given in the drinking water at a concentration of 19 mug/ml. Blood samples were taken at 3, 6 and 24 months of exposure and brain and liver samples were taken at the end of the study (24 months). DNA damage was assessed in all samples using the alkaline comet assay, and micronuclei were determined in erythrocytes. We did not find significant genotoxic activity of MX in blood and liver cells. However, MX induced DNA damage in rat brain. Co-exposures to MX and RF radiation did not significantly increase the response of blood, liver and brain cells compared to MX exposure only. In conclusion, this 2-year animal study involving long-term exposures to RF radiation and MX did not

provide any evidence for enhanced genotoxicity in rats exposed to RF radiation.

**Veyret B, Bouthet C, Deschaux P, de Seze R, Geffard M, Joussot-Dubien J, le Diraison M, Moreau JM, Caristan A, Antibody responses of mice exposed to low-power microwaves under combined, pulse-and-amplitude modulation. Bioelectromagnetics 12(1):47-56, 1991.**

Irradiation by pulsed microwaves (9.4 GHz, 1 microsecond pulses at 1,000/s), both with and without concurrent amplitude modulation (AM) by a sinusoid at discrete frequencies between 14 and 41 MHz, was assessed for effects on the immune system of Balb/C mice. The mice were immunized either by sheep red blood cells (SRBC) or by glutaric-anhydride conjugated bovine serum albumin (GA-BSA), then exposed to the microwaves at a low rms power density (30 microW/cm2; whole-body-averaged SAR approximately 0.015 W/kg). Sham exposure or microwave irradiation took place during each of five contiguous days, 10 h/day. The antibody response was evaluated by the plaque-forming cell assay (SRBC experiment) or by the titration of IgM and IgG antibodies (GA-BSA experiment). In the absence of AM, the pulsed field did not greatly alter immune responsiveness. In contrast, exposure to the field under the combined-modulation condition resulted in significant, AM-frequency-dependent augmentation or weakening of immune responses.

**Vian A, Roux D, Girard S, Bonnet P, Paladian F, Davies E, Ledoigt G. Microwave irradiation affects gene expression in plants. *Plant Signal Behav.* 1(2):67-70, 2006.**

The physiological impact of nonionizing radiation has long been considered negligible. However, here we use a carefully calibrated stimulation system that mimics the characteristics (isotropy and homogeneity) of electromagnetic fields present in the environment to measure changes in a molecular marker (mRNA encoding the stress-related bZIP transcription factor), and show that low amplitude, short duration, 900 MHz EMF evokes the accumulation of this mRNA. Accumulation is rapid (peaking 5-15 min after stimulation) and strong (3.5-fold), and is similar to that evoked by mechanical stimulations.

**Vian A, Davies E, Gendraud M, Bonnet P. Plant Responses to High Frequency Electromagnetic Fields. Biomed Res Int. 2016;2016:1830262. doi: 10.1155/2016/1830262. Epub 2016 Feb 14.**

High frequency nonionizing electromagnetic fields (HF-EMF) that are increasingly present in the environment constitute a genuine environmental stimulus able to evoke specific responses in plants that share many similarities with those observed after a stressful treatment. Plants constitute an outstanding model to study such interactions since their architecture (high surface area to volume ratio) optimizes their interaction with the environment. In the present review, after identifying the main exposure devices (transverse and gigahertz electromagnetic cells, wave guide, and mode stirred reverberating chamber) and general physics laws that govern EMF interactions with plants, we illustrate some of the observed responses after exposure to HF-EMF at the

cellular, molecular, and whole plant scale. Indeed, numerous metabolic activities (reactive oxygen species metabolism, α- and β-amylase, Krebs cycle, pentose phosphate pathway, chlorophyll content, terpene emission, etc.) are modified, gene expression altered (calmodulin, calcium-dependent protein kinase, and proteinase inhibitor), and growth reduced (stem elongation and dry weight) after low power (i.e., nonthermal) HF-EMF exposure. These changes occur not only in the tissues directly exposed but also systemically in distant tissues. While the long-term impact of these metabolic changes remains largely unknown, we propose to consider nonionizing HF-EMF radiation as a noninjurious, genuine environmental factor that readily evokes changes in plant metabolism.

**Viel JF, Cardis E, Moissonnier M, de Seze R, Hours M. Radiofrequency exposure in the French general population: band, time, location and activity variability. Environ Int. 35(8):1150-1154, 2009.**

Information on the exposure of individual persons to radiofrequency (RF) fields is scarce, although such data are crucial in order to develop a suitable exposure assessment method, and frame the hypothesis and design of future epidemiological studies. The main goal of this survey is to assess individual RF exposure on a population basis, while clarifying the relative contribution of different sources to the total exposure. A total of 377 randomly selected people were analyzed. Each participant was supplied with a personal exposure meter for 24-hour measurements (weekday), and kept a time-location-activity diary. Electric field strengths were recorded in 12 different RF bands every 13s. Summary statistics were calculated with the robust regression on order statistics method. Most of the time, recorded field strengths were not detectable with the exposure meter. Total field, cordless phones, WiFi-microwave, and FM transmitters stood apart with a proportion above the detection threshold of 46.6%, 17.2%, 14.1%, and 11.0%, respectively. The total field mean value was 0.201V/m, higher in urban areas, during daytime, among adults, and when moving. When focusing on specific channels, the highest mean exposure resulted from FM sources (0.044V/m), followed by WiFi-microwaves (0.038V/m), cordless phones (0.037V/m), and mobile phones (UMTS: 0.036V/m, UMTS: 0.037V/m). Various factors, however, contributed to a high variability in RF exposure assessment. These population-based estimates should therefore be confirmed by further surveys to better characterize the exposure situation in different microenvironments.

**Viel JF, Clerc S, Barrera C, Rymzhanova R, Moissonnier M, Hours M, Cardis E. Residential exposure to radiofrequency fields from mobile phone base stations, and broadcast transmitters: a population-based survey with personal meter. Occup Environ Med. 66(8):550-556, 2009.**

OBJECTIVES: Both the public perceptions, and most published epidemiologic studies, rely on the assumption that the distance of a particular residence from a base station or a broadcast transmitter is an appropriate surrogate for exposure to radiofrequency fields, although complex propagation characteristics affect the beams from antennas. The main goal of this study was to characterise the distribution of residential exposure from antennas using personal exposure meters. METHODS: A

total of 200 randomly selected people were enrolled. Each participant was supplied with a personal exposure meter for 24 h measurements, and kept a time-location-activity diary. Two exposure metrics for each radiofrequency were then calculated: the proportion of measurements above the detection limit (0.05 V/m), and the maximum electric field strength. Residential address was geocoded, and distance from each antenna was calculated. RESULTS: Much of the time, the recorded field strength was below the detection level (0.05 V/m), the FM band standing apart with a proportion above the detection threshold of 12.3%. The maximum electric field strength was always lower than 1.5 V/m. Exposure to GSM and DCS waves peaked around 280 m and 1000 m from the antennas. A downward trend was found within a 10 km range for FM. Conversely, UMTS, TV 3, and TV 4&5 signals did not vary with distance. CONCLUSIONS: Despite numerous limiting factors entailing a high variability in radiofrequency exposure assessment, but owing to a sound statistical technique, we found that exposures from GSM and DCS base stations increase with distance in the near source zone, to a maximum where the main beam intersects the ground. We believe these results will contribute to the ongoing public debate over the location of base stations and their associated emissions.

**Vijayalaxmi, Mohan, N, Meltz, ML, Wittler, MA, Proliferation and cytogenetic studies in human blood lymphocytes exposed in vitro to 2450 MHz radiofrequency radiation. Int J Radiat Biol 72(6):751-757, 1997.**

Aliquots of human peripheral blood collected from two healthy human volunteers were exposed in vitro to continuous wave 2450 MHz radiofrequency radiation (RFR), either continuously for a period of 90 min or intermittently for a total exposure period of 90 min (30 min on and 30 min off, repeated three times). Blood aliquots which were sham-exposed or exposed in vitro to 150 cGy gamma radiation served as controls. The continuous wave 2450 MHz RFR was generated with a net forward power of 34.5 W and transmitted from a standard gain rectangular antenna horn in a vertically downward direction. The mean power density at the position of the cells was 5.0 mW/cm2. The mean specific absorption rate calculated by Finite Difference Time Domain analysis was 12.46 W/kg. Immediately after exposure, lymphocytes were cultured for 48 and 72 h to determine the incidence of chromosomal aberrations and micronuclei, respectively. Proliferation indices were also recorded. There were no significant differences between RFR-exposed and sham-exposed lymphocytes with respect to; (a) mitotic indices; (b) incidence of cells showing chromosome damage; (c) exchange aberrations; (d) acentric fragments; (e) binucleate lymphocytes, and (f) micronuclei, for either the continuous or intermittent RFR exposures. In contrast, the response of positive control cells exposed to 150 cGy gamma radiation was significantly different from RFR-exposed and sham-exposed lymphocytes. Thus, there is no evidence for an effect on mitogen-stimulated proliferation kinetics or for excess genotoxicity within 72 h in human blood lymphocytes exposed in vitro to 2450 MHz RFR.

**Vijayalaxmi, Frei, MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR, Frequency of micronuclei in the peripheral blood and bone marrow of cancer-prone mice chronically exposed to 2450 MHz radiofrequency radiation. Radiat Res 147(4):495-500, 1997.**

C3H/HeJ mice, which are prone to mammary tumors, were exposed for 20 h/day, 7 days/week, over 18 months to continuous-wave 2450 MHz radiofrequency (RF) radiation in circularly polarized wave guides at a whole-body average specific absorption rate of 1.0 W/kg. Sham-exposed mice were used as controls. The positive controls were the sentinel mice treated with mitomycin C during the last 24 h before necropsy. At the end of the 18 months, all mice were necropsied. Peripheral blood and bone marrow smears were examined for the extent of genotoxicity as indicated by the presence of micronuclei in polychromatic erythrocytes (PCEs). The results indicate that the incidence of micronuclei/1,000 PCEs was not significantly different between groups exposed to RF radiation (62 mice) and sham-exposed groups (58 mice), and the mean frequencies were 4.5 +/- 1.23 and 4.0 +/- 1.12 in peripheral blood and 6.1 +/- 1.78 and 5.7 +/- 1.60 in bone marrow, respectively. In contrast, the positive controls (7 mice) showed a significantly elevated incidence of micronuclei/1,000 PCEs in peripheral blood and bone marrow, and the mean frequencies were 50.9 +/- 6.18 and 55.2 +/- 4.65, respectively. When the animals with mammary tumors were considered separately, there were no significant differences in the incidence of micronuclei/1,000 PCEs between the group exposed to RF radiation (12 mice) and the sham-exposed group (8 mice), and the mean frequencies were 4.6 +/- 1.03 and 4.1 +/- 0.89 in peripheral blood and 6.1 +/- 1.76 and 5.5 +/- 1.51 in bone marrow, respectively. Thus there was no evidence for genotoxicity in mice prone to mammary tumors that were exposed chronically to 2450 MHz RF radiation compared with sham-exposed controls.

**A correction was published in a subsequent issue of the journal, stating that there was actually a significant increase in micronucleus formation in peripheral blood and bone marrow cells after chronic exposure to the radiofrequency radiation. “Vijayalaxmi, Frei ,MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR, Correction of an error in calculation in the article "Frequency of micronuclei in the peripheral blood and bone marrow of cancer-prone mice chronically exposed to 2450 MHz radiofrequency radiation" (Radiat. Res. 147, 495-500, 1997). Radiat Res 149(3):308, 1998 “**

**Vijayalaxmi, Leal BZ, Szilagyi M, Prihoda TJ, Meltz ML, Primary DNA Damage in Human Blood Lymphocytes Exposed In Vitro to 2450 MHz Radiofrequency Radiation. Radiat Res 153(4):479-486, 2000.**

Human peripheral blood samples collected from three healthy human volunteers were exposed in vitro to pulsed-wave 2450 MHz radiofrequency (RF) radiation for 2 h. The RF radiation was generated with a net forward power of 21 W and transmitted from a standard gain rectangular antenna horn in a vertically downward direction. The average power density at the position of the cells in the flask was 5 mW/cm(2). The mean specific absorption rate, calculated by finite difference time domain analysis, was 2.135 (+/-0.005 SE) W/kg. Aliquots of whole blood that were sham-exposed or exposed in vitro to 50 cGy of ionizing radiation from a (137)Cs gamma-ray source were used as controls. The lymphocytes were examined to determine the extent of primary DNA damage (single-strand breaks and alkali-labile lesions) using the alkaline comet assay with three different slide-processing schedules. The assay was performed on the cells immediately after the exposures and at 4 h after incubation of the exposed blood at 37 +/- 1 degrees C to allow time for rejoining of any strand breaks present immediately after exposure, i.e. to assess

the capacity of the lymphocytes to repair this type of DNA damage. At either time, the data indicated no significant differences between RF-radiation- and sham-exposed lymphocytes with respect to the comet tail length, fluorescence intensity of the migrated DNA in the tail, and tail moment. The conclusions were similar for each of the three different comet assay slide-processing schedules examined. In contrast, the response of lymphocytes exposed to ionizing radiation was significantly different from RF-radiation- and sham-exposed cells. Thus, under the experimental conditions tested, there is no evidence for induction of DNA single-strand breaks and alkali-labile lesions in human blood lymphocytes exposed in vitro to pulsed-wave 2450 MHz radiofrequency radiation, either immediately or at 4 h after exposure.

**Vijayalaxmi, Seaman RL, Belt ML, Doyle JM, Mathur SP, Prihoda TJ, Frequency of micronuclei in the blood and bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation. Int J Radiat Biol 75(1):115-120, 1999.**

PURPOSE: To investigate the extent of genetic damage in the peripheral bloodand bone marrow cells of mice exposed to ultra-wideband electromagnetic radiation (UWBR). MATERIALS AND METHODS: CF-1 male mice were exposed to UWBRfor 15 min at an estimated whole-body average specific absorption rate of 37 mWx kg(-1). Groups of untreated control and positive control mice injected with mitomycin C were also included in the study. After various treatments, half of the mice were killed at 18 h, and the other half at 24 h. Peripheral blood and bone marrow smears were examined to determine the extent of genotoxicity, as assessed by the presence of micronuclei (MN) in polychromatic erythrocytes (PCE). RESULTS: The percentages of PCE and the incidence of MN per 2000 PCE inboth tissues in mice killed at 18 h were similar to the frequencies observed in mice terminated at 24 h. There were no significant differences in the percentage of PCE between control and the mice with or without UWBR exposure; the group mean values (+/- standard deviation) were in the range of 3.1+/-0.14 to 3.2+/-0.23 in peripheral blood, and 49.0+/-3.56 to 52.3+/-4.02 in bone marrow. The mean incidence of MN per 2000 PCE in control and in mice with or without UWBR exposure ranged from 7.7+/-2.00 to 9.7+/-2.54 in peripheral blood and 7.4+/-2.32 to 10.0+/-3.27 in bone marrow. Pairwise comparison of the data did not reveal statistically significant differences between the control and mice with or without UWBR exposure groups (excluding positive controls). CONCLUSION: Under the experimental conditions tested, there was no evidence for excess genotoxicity in peripheral blood or bone marrow cells of mice exposed to UWBR.

**Vijayalaxmi , Leal BZ, Meltz ML, Pickard WF, Bisht KS, Roti Roti JL , Straube WL, Moros EG, Cytogenetic Studies in Human Blood Lymphocytes Exposed In Vitro to Radiofrequency Radiation at a Cellular Telephone Frequency (835.62 MHz, FDMA). Radiat Res 155(1):113-121, 2001.**

Vijayalaxmi, Pickard, W. F., Bisht, K. S., Leal, B. Z., Meltz, M. L., Roti Roti, J. L., Straube, W. L. and Moros, E. G. Cytogenetic Studies in Human Blood Lymphocytes Exposed In Vitro to Radiofrequency Radiation at a Cellular Telephone Frequency (835.62 MHz, FDMA). Freshly collected peripheral blood samples from four healthy human volunteers were diluted with RPMI 1640 tissue culture medium and exposed in sterile T-75 tissue culture flasks in vitro for 24 h to 835.62 MHz radiofrequency (RF) radiation, a frequency employed for customer-to-base station transmission of cellular telephone

communications. An analog signal was used, and the access technology was frequency division multiple access (FDMA, continuous wave). A nominal net forward power of 68 W was used, and the nominal power density at the center of the exposure flask was 860 W/m(2). The mean specific absorption rate in the exposure flask was 4.4 or 5.0 W/kg. Aliquots of diluted blood that were sham-exposed or exposed in vitro to an acute dose of 1.50 Gy of gamma radiation were used as negative or positive controls. Immediately after the exposures, the lymphocytes were stimulated with a mitogen, phytohemagglutinin, and cultured for 48 or 72 h to determine the extent of genetic damage, as assessed from the frequencies of chromosomal aberrations and micronuclei. The extent of alteration in the kinetics of cell proliferation was determined from the mitotic indices in 48-h cultures and from the incidence of binucleate cells in 72-h cultures. The data indicated no significant differences between RF-radiation- and sham-exposed lymphocytes with respect to mitotic indices, incidence of exchange aberrations, excess fragments, binucleate cells, and micronuclei. In contrast, the response of the lymphocytes exposed to gamma radiation was significantly different from both RF-radiation- and sham-exposed cells for all of these indices. Thus, under the experimental conditions tested, there is no evidence for the induction of chromosomal aberrations and micronuclei in human blood lymphocytes exposed in vitro for 24 h to 835.62 MHz RF radiation at SARs of 4.4 or 5.0 W/kg.

**Vijayalaxmi, Bisht KS, Pickard WF, Meltz ML, Roti Roti JL, Moros EG. Chromosome damage and micronucleus formation in human blood lymphocytes exposed in vitro to radiofrequency radiation at a cellular telephone frequency (847.74 MHz, CDMA). Radiat Res 156(4):430-432, 2001.**

Peripheral blood samples collected from four healthy nonsmoking human volunteers were diluted with tissue culture medium and exposed in vitro for 24 h to 847.74 MHz radiofrequency (RF) radiation (continuous wave), a frequency employed for cellular telephone communications. A code division multiple access (CDMA) technology was used with a nominal net forward power of 75 W and a nominal power density of 950 W/m(2) (95 mW/cm(2)). The mean specific absorption rate (SAR) was 4.9 or 5.5 W/kg. Blood aliquots that were sham-exposed or exposed in vitro to an acute dose of 1.5 Gy of gamma radiation were included in the study as controls. The temperatures of the medium during RF-radiation and sham exposures in the Radial Transmission Line facility were controlled at 37 +/- 0.3 degrees C. Immediately after the exposures, lymphocytes were cultured at 37 +/- 1 degrees C for 48 or 72 h. The extent of genetic damage was assessed from the incidence of chromosome aberrations and micronuclei. The kinetics of cell proliferation was determined from the mitotic indices in 48-h cultures and from the incidence of binucleate cells in 72-h cultures. The data indicated no significant differences between RF-radiation-exposed and sham-exposed lymphocytes with respect to mitotic indices, frequencies of exchange aberrations, excess fragments, binucleate cells, and micronuclei. The response of gamma-irradiated lymphocytes was significantly different from that of both RF-radiation-exposed and sham-exposed cells for all of these indices. Thus there was no evidence for induction of chromosome aberrations and micronuclei in human blood lymphocytes exposed in vitro for 24 h to 847.74 MHz RF radiation (CDMA) at SARs of 4.9 or 5.5 W/kg.

**Vijayalaxmi, Pickard WF, Bisht KS, Prihoda TJ, Meltz ML, LaRegina MC, Roti Roti JL, Straube WL, Moros EG. Micronuclei in the peripheral blood and bone marrow**

**cells of rats exposed to 2450 MHz radiofrequency radiation. Int J Radiat Biol 77(11):1109-1115, 2001.**

PURPOSE: To determine the incidence of micronuclei in peripheral blood and bone marrow cells of rats exposed continuously for 24h to 2450 MHz continuous wave radiofrequency radiation (RFR) at an average whole-body specific absorption rate (SAR) of 12W/kg. MATERIALS AND METHODS: Eight adult male Sprague-Dawley rats were exposed to 2450 MHz RFR in circularly polarized waveguides. Eight sham-exposed rats were kept in similar waveguides without the transmission of RFR. Four rats were treated with mitomycin-C (MMC) and used as positive controls. All rats were necropsied 24h after the end of RFR and sham exposures, and after the 24h treatment with MMC. Peripheral blood and bone marrow smears were examined to determine the frequency of micronuclei (MN) in polychromatic erythrocytes (PCE). RESULTS: The results indicated that the incidence of MN/2000 PCE were not significantly different between RFR- and sham-exposed rats. The group mean frequencies of MN in the peripheral blood were 2.3+/-0.7 in RFR-exposed rats and 2.1+/-0.6 in sham-exposed rats. In bone marrow cells, the average MN incidence was 3.8+/-1.0 in RFR-exposed rats and 3.4+/-0.7 in sham-exposed rats. The corresponding values in positive control rats treated with MMC were 23.5+/-4.7 in the peripheral blood and 33.8+/-7.4 in bone marrow cells. CONCLUSION: There was no evidence for the induction of MN in peripheral blood and bone marrow cells of rats exposed for 24h to 2450 MHz continuous wave RFR at a whole body average SAR of 12 W/kg.

**Vijayalaxmi, Sasser LB, Morris JE, Wilson BW, Anderson LE. Genotoxic Potential of 1.6 GHz Wireless Communication Signal: In Vivo Two-Year Bioassay. Radiat Res 159(4):558-564, 2003**.

Timed-pregnant Fischer 344 rats (from nineteenth day of gestation) and their nursing offspring (until weaning) were exposed to a far-field 1.6 GHz Iridium wireless communication signal for 2 h/day, 7 days/week. Far-field whole-body exposures were conducted with a field intensity of 0.43 mW/cm(2) and whole-body average specific absorption rate (SAR) of 0.036 to 0.077 W/kg (0.10 to 0.22 W/kg in the brain). This was followed by chronic, head-only exposures of male and female offspring to a near-field 1.6 GHz signal for 2 h/day, 5 days/week, over 2 years. Near-field exposures were conducted at an SAR of 0.16 or 1.6 W/kg in the brain. Concurrent sham-exposed and cage control rats were also included in the study. At the end of 2 years, all rats were necropsied. Bone marrow smears were examined for the extent of genotoxicity, assessed from the presence of micronuclei in polychromatic erythrocytes. The results indicated that the incidence of micronuclei/2000 polychromatic erythrocytes were not significantly different between 1.6 GHz-exposed, sham-exposed and cage control rats. The group mean frequencies were 5.6 +/- 1.8 (130 rats exposed to 1.6 GHz at 0.16 W/kg SAR), 5.4 +/- 1.5 (135 rats exposed to 1.6 GHz at 1.6 W/kg SAR), 5.6 +/- 1.7 (119 sham-exposed rats), and 5.8 +/- 1.8 (100 cage control rats). In contrast, positive control rats treated with mitomycin C exhibited significantly elevated incidence of micronuclei/2000 polychromatic erythrocytes in bone marrow cells; the mean frequency was 38.2 +/- 7.0 (five rats). Thus there was no evidence for excess genotoxicity in rats that were chronically exposed to 1.6 GHz compared to sham-exposed and cage controls.

**Vijayalaxmi, Cytogenetic Studies in Human Blood Lymphocytes Exposed In Vitro to 2.45 GHz or 8.2 GHz Radiofrequency Radiation. Radiat. Res. 166, 532–538, 2006.**

Peripheral blood samples collected from healthy human volunteers were exposed in vitro to 2.45 GHz or 8.2 GHz pulsed-wave radiofrequency (RF) radiation. The net forward power, average power density, mean specific absorption rate, and the temperature maintained during the 2-h exposure of the cells to 2.45 GHz or 8.2 GHz were, respectively, 21 W or 60 W, 5 mW/cm$^2$ or 10 mW/cm$^2$, 2.13 W/kg or 20.71 W/kg, and 36.9 ± 0.1°C or 37.5 ± 0.2°C. Aliquots of the same blood samples that were either sham-exposed or exposed in vitro to an acute dose of 1.5 Gy γ radiation were used as unexposed and positive controls, respectively. Cultured lymphocytes were examined to determine the extent of cytogenetic damage assessed from the incidence of chromosomal aberrations and micronuclei. Under the conditions used to perform the experiments, the levels of damage in RF-radiation-exposed and sham-exposed lymphocytes were not significantly different. Also, there were no significant differences in the response of unstimulated lymphocytes and lymphocytes stimulated with phytohemagglutinin when exposed to 8.2 GHz RF radiation. In contrast, the positive control cells that had been subjected to γ irradiation exhibited significantly more damage than RF-radiation- and sham-exposed lymphocytes.

**Vijayalaxmi, Prihoda TJ. Mobile phones, non-ionizing radiofrequency fieldsand brain cancer: is there an adaptive response? Dose Response. 2014 Apr 22;12(3):509-514, 2014.**

There is widespread concern among the general public regarding the ever increasing use of mobile phones. The concern is mainly because the antenna which transmits nonionizing radiofrequency fields is held close to the head during use and thus might cause brain cancer. By far, the largest epidemiological study was conducted by the INTER-PHONE study group and the results were published in 2011. The author's conclusions were (i) no increased risk of meningioma and glioma in mobile phone users and (ii) there were suggestions of an increased risk for glioma at the highest exposure levels but, bias and error prevented a causal interpretation. We have carefully examined all of the odd ratios presented in the INTERPHONE study publication: our results showed 24.3% decreased and 0.7% increased risk for meningioma and 22.1% decreased and 6.6% increased risk for glioma. Hence, we hypothesize that the overwhelming evidence for the decreased risk for both diseases may be due to the induction of 'adaptive response' which is well-documented in scientific literature.

**Vijver MG, Bolte JF, Evans TR, Tamis WL, Peijnenburg WJ, Musters CJ, de Snoo GR. Investigating short-term exposure to electromagnetic fields on reproductive capacity of invertebrates in the field situation. Electromagn Biol Med. 2013 Jun 19. [Epub ahead of print]**

Abstract Organisms are exposed to electromagnetic fields from the introduction of wireless networks that send information all over the world. In this study we examined the impact of exposure to the fields from mobile phone base stations (GSM 900 MHz)

on the reproductive capacity of small, virgin, invertebrates. A field experiment was performed exposing four different invertebrate species at different distances from a radiofrequency electromagnetic fields (RF EMF) transmitter for a 48-h period. The control groups were isolated from EMF exposure by use of Faraday cages. The response variables as measured in the laboratory were fecundity and number of offspring. Results showed that distance was not an adequate proxy to explain dose-response regressions. No significant impact of the exposure matrices, measures of central tendency and temporal variability of EMF, on reproductive endpoints was found. Finding no impact on reproductive capacity does not fully exclude the existence of EMF impact, since mechanistically models hypothesizing non-thermal-induced biological effects from RF exposure are still to be developed. The exposure to RF EMF is ubiquitous and is still increasing rapidly over large areas. We plea for more attention toward the possible impacts of EMF on biodiversity.

**Violanti JM, Cellular phones and traffic accidents. Public Health 111(6):423-428, 1997.**

Cellular phone use in motor vehicles is becoming an increasing world-wide phenomenon. Using data obtained from traffic accidents reported between 1992 and 1995 in the state of Oklahoma, USA, this study examined statistical rate-ratios of accident characteristics between drivers with or without cellular phones. Rates were calculated between cellular phone involvement and reported accident causes, types of collision, driver actions immediately prior to the accident, location of the accident, the extent of fatalities, and age and gender of drivers. Results indicated a significant increased rate among drivers with cellular phones for inattention, unsafe speed, driving on wrong side of road, striking a fixed object, overturning their vehicle, swerving prior to the accident, and running off the roadway. People with phones stood an increased risk of being killed in an accident over persons without phones. Males with phones had a significantly higher rate than females for many of accident characteristics mentioned above. Rate-ratios of some accident characteristics and fatalities increased as age increased, with the exception of drivers under age 20 yrs, who had the highest fatality rate. *Limitations* of the study and possible prevention alternatives are discussed.

**Violanti JM, Cellular phones and fatal traffic collisions. Accid Anal Prev 30(4):519-524, 1998.**

A case-control study was conducted to determine statistical associations between traffic fatalities and the use or presence of a cellular phone, given involvement in a collision. The hypothesis of this study does not imply that cellular phones directly affect fatalities, but that phones increase the risk of certain accident characteristics in fatal collisions more than those same characteristics in non-fatal collisions. Analysis employed data from 223,137 traffic accidents occurring between 1992 and 1995. Information on collision characteristics and cellular phone involvement for each fatality was compared with the same information for each non-fatality (controls). Statistically

adjusting for other collision variables (age, gender, alcohol use, speed, inattention and driving left of center), an approximate nine-fold increased risk was found for a fatality given the use of a cellular phone. An approximate two-fold increased risk for a fatality was found given the presence of a cellular phone in the vehicle. Combined effects of reported phone use, driving to the left of center and inattention increased the risk of a fatal collision more than phone use did by itself. This analysis implies a statistical, but not necessarily a causal, relationship. A multitude of factors are involved in any traffic collision, and the exact cause of an accident and its severity level is difficult to disentangle.

**Violanti JM, Marshall JR, Cellular phones and traffic accidents: an epidemiological approach. Accid Anal Prev 28(2):265-270, 1996.**

Using epidemiological case-control design and logistic regression techniques, this study examined the association of cellular phone use in motor vehicles and traffic accident risk. The amount of time per month spent talking on a cellular phone and 18 other driver inattention factors were examined. Data were obtained from: (1) a case group of 100 randomly selected drivers involved in accidents within the past 2 years, and (2) a control group of 100 randomly selected licensed drivers not involved in accidents within the past 10 years. Groups were matched on geographic residence. Approximately 13% (N = 7) of the accident and 9% (N = 7) of the non-accident group reported use of cellular phones while driving. Data was obtained from Department of Motor Vehicles accident reports and survey information from study subjects. We hypothesized that increased use of cellular phones while driving was associated with increased odds of a traffic accident. Results indicated that talking more than 50 minutes per month on cellular phones in a vehicle was associated with a 5.59-fold increased risk in a traffic accident. The combined use of cellular phones and motor and cognitive activities while driving were also associated with increased traffic accident risk. Readers should be cautioned that this study: (1) consists of a small sample, (2) reveals statistical associations and not causal relationships, and (3) does not conclude that talking on cellular phones while driving is inherently dangerous.

**Virtanen H, Keshvari J, Lappalainen R. The effect of authentic metallic implants on the SAR distribution of the head exposed to 900, 1800 and 2450 MHz dipole near field. Phys Med Biol. 52(5):1221-1236, 2007**

As the use of radiofrequency (RF) electromagnetic (EM) fields has increased along with increased use of wireless communication, the possible related health risks have also been widely discussed. One safety aspect is the interaction of medical implants and RF devices like mobile phones. In the literature, effects on active implants like pacemakers have been discussed but the studies of passive metallic (i.e. conductive) implants are rare. However, some studies have shown that the EM power absorption in tissues may be enhanced due to metallic implants. In this study, the effect of authentic passive metallic implants in the head region was examined. A half-wave

dipole antenna was used as an exposure source and the specific absorption rate (SAR, W kg(-1)) in the near field was studied numerically. The idea was to model the presumably worst cases of most common implants in an accurate MRI-based phantom. As exposure frequencies GSM (900 and 1800 MHz) and UMTS (2450 MHz) regions were considered. The implants studied were skull plates, fixtures, bone plates and ear rings. The results indicate that some of the implants, under very rare exposure conditions, may cause a notable enhancement in peak mass averaged SAR.

**Vitulli WF, Nemeth YM, Conte CT, Ibuprofen effects on behavioral thermoregulation with microwave radiation in albino rats. Percept Mot Skills 92(2):391-394, 2001.**

This study determined whether ibuprofen causes a disruptive behavior pattern similar to aspirin yet contrary to acetaminophen regarding thermoregulatory effects. 8 Sprague-Dawley rats (3 males and 5 females) were drawn from a population of rats which had been conditioned to press a lever for food reinforcement in an undergraduate course in operant conditioning. Animals were conditioned in a refrigerated Skinner Box on a fixed-interval 2-min. (FI-2 min.) schedule of microwave radiation (5 sec. of radiation per exposure occasion) in a repeated-measures reversal (within-subjects) design. The rats were injected intraperitoneally with doses of ibuprofen in amounts of 10-50 mg/kg or methyl-cellulose control vehicle of equal volume over 8-hr. daily sessions. A multivariate analysis of variance showed significant differences due to doses (mg/kg) of ibuprofen for number of microwave heat reinforcers per hour and rate of responding (ns) both measures of which were significantly higher during the first 2 hours of the session. Comparative differences in behavioral thermoregulation in humans reflect the likelihood of underlying biochemical mechanisms based on research by Murphy, Badia, Myers, Boecker, and Wright in 1994.

**Vlasova II, Mikhalchik EV, Gusev AA, Balabushevich NG, Gusev SA, Kazarinov KD. Extremely high-frequency electromagnetic radiation enhances neutrophil response to particulate agonists. Bioelectromagnetics. 2017 Nov 30. doi: 10.1002/bem.22103.**

The growing use of extremely high-frequency electromagnetic radiation (EHF EMR) in information and communication technology and in biomedical applications has raised concerns regarding the potential biological impact of millimeter waves (MMWs). Here, we elucidated the effects of MMW radiation on neutrophil activation induced by opsonized zymosan or E. coli in whole blood ex vivo. After agonist addition to blood, two samples were prepared. A control sample was incubated at ambient conditions without any treatment, and a test sample was exposed to EHF EMR (32.9-39.6 GHz, 100 W/m2 ). We used methods that allowed us to assess the functional status of neutrophils immediately after exposure: oxidant production levels were measured by luminol-dependent chemiluminescence, and morphofunctional changes to neutrophils were observed in blood smears. Results revealed that the response of neutrophils to both agonists was intensified if blood was exposed to MMW radiation for 15 min. Neutrophils were intact in both the control and irradiated samples if no agonist was added to blood before incubation. Similarly, exposing suspensions of isolated neutrophils in plasma to MMW radiation.

**Volkow ND, Tomasi D, Wang GJ, Vaska P, Fowler JS, Telang F, Alexoff D, Logan J, Wong C.Effects of cell phone radiofrequency signal exposure on brain glucose metabolism.JAMA. 305(8):808-813, 2011.**

**CONTEXT:** The dramatic increase in use of cellular telephones has generated concern about possible negative effects of radiofrequency signals delivered to the brain. However, whether acute cell phone exposure affects the human brain is unclear.**OBJECTIVE:** To evaluate if acute cell phone exposure affects brain glucose metabolism, a marker of brain activity.**DESIGN, SETTING, AND PARTICIPANTS:** Randomized crossover study conducted between January 1 and December 31, 2009, at a single US laboratory among 47 healthy participants recruited from the community. Cell phones were placed on the left and right ears and positron emission tomography with ((18)F)fluorodeoxyglucose injection was used to measure brain glucose metabolism twice, once with the right cell phone activated (sound muted) for 50 minutes ("on" condition) and once with both cell phones deactivated ("off" condition). Statistical parametric mapping was used to compare metabolism between on and off conditions using paired t tests, and Pearson linear correlations were used to verify the association of metabolism and estimated amplitude of radiofrequency-modulated electromagnetic waves emitted by the cell phone. Clusters with at least 1000 voxels (volume >8 cm(3)) and P < .05 (corrected for multiple comparisons) were considered significant.**MAIN OUTCOME MEASURE:** Brain glucose metabolism computed as absolute metabolism (μmol/100 g per minute) and as normalized metabolism (region/whole brain).**RESULTS:** Whole-brain metabolism did not differ between on and off conditions. In contrast, metabolism in the region closest to the antenna (orbitofrontal cortex and temporal pole) was significantly higher for on than off conditions (35.7 vs 33.3 μmol/100 g per minute; mean difference, 2.4 [95% confidence interval, 0.67-4.2]; P = .004). The increases were significantly correlated with the estimated electromagnetic field amplitudes both for absolute metabolism (R = 0.95, P < .001) and normalized metabolism (R = 0.89; P < .001).**CONCLUSIONS:** In healthy participants and compared with no exposure, 50-minute cell phone exposure was associated with increased brain glucose metabolism in the region closest to the antenna. This finding is of unknown clinical significance.

**Vollrath L, Spessert R, Kratzsch T, Keiner M, Hollmann H, No short-term effects of high-frequency electromagnetic fields on the mammalian pineal gland. Bioelectromagnetics 18(5):376-387, 1997.**

There is ample experimental evidence that changes of earth-strength static magnetic fields, pulsed magnetic fields, or alternating electric fields (60 Hz) depress the nocturnally enhanced melatonin synthesis of the pineal gland of certain mammals. No data on the effects of high-frequency electromagnetic fields on melatonin synthesis is available. In the present study, exposure to 900 MHz electromagnetic fields [0.1 to 0.6 mW/cm2, approximately 0.06 to 0.36 W/kg specific absorption rate (SAR) in rats and 0.04 W/kg in Djungarian hamsters; both continuous and/or pulsed at 217 Hz, for 15 min to 6 hr at day or night had no notable short-term effect on pineal melatonin synthesis in male and female Sprague-Dawley rats and Djungarian hamsters. Pineal synaptic ribbon

profile numbers (studied in rats only) were likewise not affected. The 900 MHz electromagnetic fields, unpulsed or pulsed at 217 Hz, as applied in the present study, have no short-term effect on the mammalian pineal gland.

**Von Klitzing, L, Low-frequency pulsed electromagnetic fields influence EEG of man. Phys. Medica 11:77-80, 1995.**

New techniques using low-frequency puled electromagnetic fields (e.g., digital telecommunication) have raised the question for interference with the biological system of man. EEG data of man sampled under the influence of these electromagnetic fields are altered extremely in the range of alpha-activity as well as during after exposure for some hours. The biological effect is induced by field intensities lower than the given international limiting values.

**Vorobyov VV, Galchenko AA, Kukushkin NI, Akoev IG, Effects of weak microwave fields amplitude modulated at ELF on EEG of symmetric brain areas in rats. Bioelectromagnetics 18(4):293-298, 1997.**

Averaged electroencephalogram (EEG) frequency spectra were studied in eight unanesthetized and unmyorelaxed adult male rats with chronically implanted carbon electrodes in symmetrical somesthetic areas when a weak (0.1-0.2 mW/cm2) microwave (MW, 945 MHz) field, amplitude-modulated at extremely low frequency (ELF) (4 Hz), was applied. Intermittent (1 min "On," 1 min "Off") field exposure (10-min duration) was used. Hemispheric asymmetry in frequency spectra (averaged data for 10 or 1 min) of an ongoing EEG was characterized by a power decrease in the 1.5-3 Hz range on the left hemisphere and by a power decrease in the 10-14 and 20-30 Hz ranges on the right hemisphere. No differences between control and exposure experiments were shown under these routines of data averaging. Significant elevations of EEG asymmetry in 10-14 Hz range were observed during the first 20 s after four from five onsets of the MW field, when averaged spectra were obtained for every 10 s. Under neither control nor pre- and postexposure conditions was this effect observed. These results are discussed with respect to interaction of MW fields with the EEG generators.

**Vorobyov V, Pesic V, Janac B, Prolic Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects baseline and scopolamine-modified electroencephalograms in freely moving rats. Int J Radiat Biol. 80(9):691-698, 2004.**

PURPOSE: To compare in the electroencephalogram of rats the effects of scopolamine (an acetylcholine receptor antagonist) alone and after repeated exposure to low-level microwaves modulated at extremely low frequency. MATERIALS AND METHODS: Averaged frequency spectra (0.5-30 Hz) of the electroencephalogram were studied in freely moving rats with carbon electrodes implanted into the somatosensory cortex. The rats were repeatedly (3 days, 30 min day(-1)) exposed to low-intensity (approximately = 0.3 mW cm(-2)) microwaves (915 MHz, 20-ms pulse duration), amplitude modulated (square-wave) at extremely low frequency (4 Hz). RESULTS: The exposure to extremely low frequency microwaves alone significantly enhanced the fast electroencephalographic rhythms (18-30 Hz). This effect was observed neither in subsequent sham-exposure

experiment nor in radiation-naive animals. In the microwave-exposed rats, scopolamine (0.1 mg kg(-1), subcutaneously) did not cause a slowing in the electroencephalogram that was shown in non-exposed rats. A similarity between the scopolamine-induced electroencephalogram effect in the microwave-exposed rats and that of physostigmine (enhancing the acetylcholine level in the brain) in radiation-naive animals was noted. This paradoxical phenomenon stimulates new experimentation for understanding its mechanism(s). CONCLUSIONS: The data obtained provide additional evidence that repeated low-level exposure to extremely low frequency microwaves can modify an activity of cholinergic system in the brain.

**Vorobyov V, Janać B, Pesić V, Prolić Z. Repeated exposure to low-level extremely low frequency-modulated microwaves affects cortex-hypothalamus interplay in freely moving rats: EEG study. Int J Radiat Biol. 86(5):376-383, 2010.**

PURPOSE: To compare the effects of repeated exposure to extremely low frequency-modulated microwaves (ELF-MW) on cortical and hypothalamic electroencephalograms (EEG). MATERIALS AND METHODS: In 10 freely moving rats with carbon electrodes implanted into the cortex and dorsomedial hypothalamus, averaged frequency spectra (0.5-30 Hz) of the EEG were studied for five consecutive days either under sham exposures (five rats) or under mixed sham/MW-exposures (five rats). The rats were exposed to ELF-MW (915 MHz, 20-ms pulse duration, approximately 0.3 mW/cm(2), 4 Hz) intermittently (1-min 'On', 1-min 'Off') for 10 min (specific absorption rate, SAR, approximately 0.7 mW/g on average) several times per day, with 10-min pre- and post-exposure periods. RESULTS: In baseline EEG, the activities of 3.2-6.0 Hz and 17.8-30.5 Hz dominated in the cortex and of 6.0-17.8 Hz in the hypothalamus. This cortical-hypothalamic imbalance was relatively stable at sham-exposures and insensitive to ELF-MW in all frequency ranges but one. ELF-MW increased the beta(2) (17.8-30.5 Hz) level in the hypothalamus to a greater extent than in the cortex, causing significant diminishing of the initial EEG bias between them. Moreover, a cumulative phenomenon under repeated exposures to ELF-MW was revealed. CONCLUSIONS: These results are in line with evidence that repeated low-level exposure to ELF-MW affects brain functioning and provide an additional approach when analysing underlying mechanisms.

**Vrijheid M, Cardis E, Armstrong BK, Auvinen A, Berg G, Blaasaas KG, Brown J, Carroll M, Chetrit A, Christensen HC, Deltour I, Feychting M, Giles GG, Hepworth SJ, Hours M, Iavarone I, Johansen C, Klaeboe L, Kurttio P, Lagorio S, Lonn S, McKinney PA, Montestrucq L, Parslow RC, Richardson L, Sadetzki S, Salminen T, Schuz J, Tynes T, Woodward A; Interphone Study Group. Validation of short term recall of mobile phone use for the Interphone study. Occup Environ Med. 63(4):237-243, 2006.**

AIM: To validate short term recall of mobile phone use within Interphone, an international collaborative case control study of tumours of the brain, acoustic nerve, and salivary glands related to mobile telephone use. METHODS: Mobile phone use of 672 volunteers in 11 countries was recorded by operators or through the use of software modified phones, and compared to use recalled six months later using the Interphone study

questionnaire. Agreement between recalled and actual phone use was analysed using both categorical and continuous measures of number and duration of phone calls. RESULTS: Correlations between recalled and actual phone use were moderate to high (ranging from 0.5 to 0.8 across countries) and of the same order for number and duration of calls. The kappa statistic demonstrated fair to moderate agreement for both number and duration of calls (weighted kappa ranging from 0.20 to 0.60 across countries). On average, subjects underestimated the number of calls per month (geometric mean ratio of recalled to actual = 0.92, 95% CI 0.85 to 0.99), whereas duration of calls was overestimated (geometric mean ratio = 1.42, 95% CI 1.29 to 1.56). The ratio of recalled to actual use increased with level of use, showing underestimation in light users and overestimation in heavy users. There was substantial heterogeneity in this ratio between countries. Inter-individual variation was also large, and increased with level of use. CONCLUSIONS: Volunteer subjects recalled their recent phone use with moderate systematic error and substantial random error. This large random error can be expected to reduce the power of the Interphone study to detect an increase in risk of brain, acoustic nerve, and parotid gland tumours with increasing mobile phone use, if one exists.

**Vrijheid M, Deltour I, Krewski D, Sanchez M, Cardis E. The effects of recall errors and of selection bias in epidemiologic studies of mobile phone use and cancer risk. J Expo Sci Environ Epidemiol.16(4):371-384, 2006.**

This paper examines the effects of systematic and random errors in recall and of selection bias in case-control studies of mobile phone use and cancer. These sensitivity analyses are based on Monte-Carlo computer simulations and were carried out within the INTERPHONE Study, an international collaborative case-control study in 13 countries. Recall error scenarios simulated plausible values of random and systematic, non-differential and differential recall errors in amount of mobile phone use reported by study subjects. Plausible values for the recall error were obtained from validation studies. Selection bias scenarios assumed varying selection probabilities for cases and controls, mobile phone users, and non-users. Where possible these selection probabilities were based on existing information from non-respondents in INTERPHONE. Simulations used exposure distributions based on existing INTERPHONE data and assumed varying levels of the true risk of brain cancer related to mobile phone use. Results suggest that random recall errors of plausible levels can lead to a large underestimation in the risk of brain cancer associated with mobile phone use. Random errors were found to have larger impact than plausible systematic errors. Differential errors in recall had very little additional impact in the presence of large random errors. Selection bias resulting from underselection of unexposed controls led to J-shaped exposure-response patterns, with risk apparently decreasing at low to moderate exposure levels. The present results, in conjunction with those of the validation studies conducted within the INTERPHONE study, will play an important role in the interpretation of existing and future case-control studies of mobile phone use and cancer risk, including the INTERPHONE study

**Vrijheid M, Richardson L, Armstrong BK, Auvinen A, Berg G, Carroll M, Chetrit A, Deltour I, Feychting M, Giles GG, Hours M, Iavarone I, Lagorio S, Lönn S, McBride M, Parent ME, Sadetzki S, Salminen T, Sanchez M, Schlehofer B, Schüz J, Siemiatycki J, Tynes T, Woodward A, Yamaguchi N, Cardis E. Quantifying the impact of selection bias caused by nonparticipation in a case-control study of**

**mobile phone use. Ann Epidemiol. 19(1):33-41, 2009.**

PURPOSE: To quantitatively assess the impact of selection bias caused by nonparticipation in a multinational case-control study of mobile phone use and brain tumor. METHODS: Non-response questionnaires (NRQ) were completed by a subset of nonparticipants. Selection bias factors were calculated based on the prevalence of mobile phone use reported by nonparticipants with NRQ data, and on scenarios of hypothetical exposure prevalence for other nonparticipants. RESULTS: Regular mobile phone use was reported less frequently by controls and cases who completed the NRQ (controls, 56%; cases, 50%) than by those who completed the full interview (controls, 69%; cases, 66%). This relationship was consistent across study centers, sex, and age groups. Lower education and more recent start of mobile phone use were associated with refusal to participate. Bias factors varied between 0.87 and 0.92 in the most plausible scenarios. CONCLUSIONS: Refusal to participate in brain tumor case-control studies seems to be related to less prevalent use of mobile phones, and this could result in a downward bias of around 10% in odds ratios for regular mobile phone use. The use of simple selection bias estimation methods in case-control studies can give important insights into the extent of any bias, even when nonparticipant information is incomplete.

**Vrijheid M, Mann S, Vecchia P, Wiart J, Taki M, Ardoino L, Armstrong BK, Auvinen A, Bédard D, Berg-Beckhoff G, Brown J, Chetrit A, Collatz-Christensen H, Combalot E, Cook A, Deltour I, Feychting M, Giles GG, Hepworth SJ, Hours M, Iavarone I, Johansen C, Krewski D, Kurttio P, Lagorio S, Lönn S, McBride M, Montestruq L, Parslow R, Sadietzki S, Schüz J, Tynes T, Woodward A, Cardis E. Determinants of mobile phone output power in a multinational study - implications for exposure assessment. Occup Environ Med.66(10):664-671, 2009.**

OBJECTIVES: The output power of a mobile phone is directly related to its radiofrequency (RF) electromagnetic field strength, and may theoretically vary substantially in different networks and phone use circumstances due to power control technologies. To improve indices of RF exposure for epidemiological studies, we assessed determinants of mobile phone output power in a multi-national study. METHODS: More than 500 volunteers in twelve countries used software-modified GSM phones (SMPs) for approximately one month each. The SMPs recorded date, time, and duration of each call, and the frequency band and output power at fixed sampling intervals throughout each call. Questionnaires provided information on the typical circumstances of an individual's phone use. Linear regression models were used to analyse the influence of possible explanatory variables on the average output power and the percentage call-time at maximum power for each call. RESULTS: Measurements of over 60,000 phone calls showed that the average output power was approximately 50% of the maximum, and that output power varied by a factor of up to 2 to 3 between study centres and network operators. Maximum power was used during a considerable proportion of call-time (39% on average). Output power decreased with increasing call duration, but showed little variation in relation to reported frequency of use whilst in a moving vehicle or inside buildings. Higher output powers for rural compared with urban use of the SMP were observed principally in Sweden where the study covered very sparsely populated areas. CONCLUSIONS: Average power levels are substantially

higher than the minimum levels theoretically achievable in GSM networks. Exposure indices could be improved by accounting for average power levels of different telecommunications systems. There appears to be little value in gathering information on circumstances of phone use other than use in very sparsely populated regions.

**Vrijheid M, Martinez D, Forns J, Guxens M, Julvez J, Ferrer M, Sunyer J. Prenatal Exposure to Cell Phone Use and Neurodevelopment at 14 Months. Epidemiology. 21: 259-262, 2010.**

BACKGROUND:: Recently, an association was reported between prenatal and postnatal exposure to cell phones and neurobehavioral problems in children at the age of 7 years. METHODS:: A birth cohort was established in Sabadell, Spain between 2004 and 2006. Mothers completed questions about cell phone use in week 32 of the pregnancy (n = 587). Neurodevelopment of their children was tested at age 14 months using the Bayley Scales of Infant Development (n = 530). RESULTS:: We observed only small differences in neurodevelopment scores between the offspring of cell phone users and nonusers. Those of users had higher mental development scores and lower psychomotor development scores, which may be due to unmeasured confounding. There was no trend with amount of cell phone use within users. CONCLUSION:: This study gives little evidence for an adverse effect of maternal cell phone use during pregnancy on the early neurodevelopment of offspring.

**Wagner, P, Roschke, J, Mann, K, Hiller, W, Frank, C, Human sleep under the influence of pulsed radiofrequency electromagnetic fields: a polysomnographic study using standardized conditions. Bioelectromagnetics 19(3):199-202, 1998.**

To investigate the influence of radiofrequency electromagnetic fields (EMFs) of cellular phone GSM signals on human sleep electroencephalographic (EEG) pattern, all-night polysomnographies of 24 healthy male subjects were recorded, both with and without exposure to a circular polarized EMF (900 MHz, pulsed with a frequency of 217 Hz, pulse width 577 micros, power flux density 0.2 W/m2. Suppression of rapid eye movement (REM) sleep as well as a sleep-inducing effect under field exposure did not reach statistical significance, so that previous results indicating alterations of these sleep parameters could not be replicated. Spectral power analysis also did not reveal any alterations of the EEG rhythms during EMF exposure. The failure to confirm our previous results might be due to dose-dependent effects of the EMF on the human sleep profile.

**Wagner P, Roschke J, Mann K, Fell J, Hiller W, Frank C, Grozinger M, Human sleep EEG under the influence of pulsed radio frequency electromagnetic fields. results from polysomnographies using submaximal high power flux densities. Neuropsychobiology 42(4):207-212, 2000.**

Former exploratory investigations of sleep alterations due to global system for mobile communications (GSM) signals have shown a hypnotic and REM-suppressive effect under field exposure. This effect was observed in a first study using a power flux density of 0.5 W/m(2), and the same trend occurred in a second study with a power flux density of 0.2 W/m(2). For the present study, we applied a submaximal power flux density of 50 W/m(2). To investigate putative effects of radio frequency electromagnetic fields (EMFs)

of cellular GSM phones on human sleep EEG pattern, all-night polysomnographies of 20 healthy male subjects both with and without exposure to a circularly polarized EMF (900 MHz, pulsed with a frequency of 217 Hz, pulse duration 577 &mgr;s) were recorded. The results showed no significant effect of the field application either on conventional sleep parameters or on sleep EEG power spectra.

**Wake K**, **Varsier N**, **Watanabe S**, **Taki M**, **Wiart J**, **Mann S**, **Deltour I**, **Cardis E**. **The estimation of 3D SAR distributions in the human head from mobile phone compliance testing data for epidemiological studies. Phys Med Biol. 54(19):5695-5706, 2009.**

A worldwide epidemiological study called 'INTERPHONE' has been conducted to estimate the hypothetical relationship between brain tumors and mobile phone use. In this study, we proposed a method to estimate 3D distribution of the specific absorption rate (SAR) in the human head due to mobile phone use to provide the exposure gradient for epidemiological studies. 3D SAR distributions due to exposure to an electromagnetic field from mobile phones are estimated from mobile phone compliance testing data for actual devices. The data for compliance testing are measured only on the surface in the region near the device and in a small 3D region around the maximum on the surface in a homogeneous phantom with a specific shape. The method includes an interpolation/extrapolation and a head shape conversion. With the interpolation/extrapolation, SAR distributions in the whole head are estimated from the limited measured data. 3D SAR distributions in the numerical head models, where the tumor location is identified in the epidemiological studies, are obtained from measured SAR data with the head shape conversion by projection. Validation of the proposed method was performed experimentally and numerically. It was confirmed that the proposed method provided good estimation of 3D SAR distribution in the head, especially in the brain, which is the tissue of major interest in epidemiological studies. We conclude that it is possible to estimate 3D SAR distributions in a realistic head model from the data obtained by compliance testing measurements to provide a measure for the exposure gradient in specific locations of the brain for the purpose of exposure assessment in epidemiological studies. The proposed method has been used in several studies in the INTERPHONE.

**Wainwright P, Thermal effects of radiation from cellular telephones. Phys Med Biol 45(8):2363-2372, 2000.**

A finite element thermal model of the head has been developed to calculate temperature rises generated in the brain by radiation from cellular telephones and similar electromagnetic devices. A 1 mm resolution MRI dataset was segmented semiautomatically, assigning each volume element to one of ten tissue types. A finite element mesh was then generated using a fully automatic tetrahedral mesh generator developed at NRPB. There are two sources of heat in the model: firstly the natural metabolic heat production; and secondly the power absorbed from the electromagnetic field. The SAR was derived from a finite difference time domain model of the head, coupled to a model 'mobile phone', namely a quarter-wavelength antenna mounted on a metal box. The steady-state temperature distribution was calculated using the standard Pennes 'bioheat equation'. In the normal cerebral cortex the high blood perfusion rate

serves to provide an efficient cooling mechanism. In the case of equipment generally available to the public, the maximum temperature rise found in the brain was about 0.1 degrees C. These results will help in the further development of criteria for exposure guidelines, and the technique developed may be used to assess temperature rises associated with SARs for different types of RF exposure.

**Waldmann P, Bohnenberger S, Greinert R, Hermann-Then B, Heselich A, Klug SJ, Koenig J, Kuhr K, Kuster N, Merker M, Murbach M, Pollet D, Schadenboeck W, Scheidemann-Wesp U, Schwab B, Volkmer B, Weyer V, Blettner M. Influence of GSM Signals on Human Peripheral Lymphocytes: Study of Genotoxicity. Radiat Res. 2013 Jan 14. [Epub ahead of print]**

Exposure to radiofrequency (RF) electromagnetic fields (EMF) is continuously increasing worldwide. Yet, conflicting results of a possible genotoxic effect of RF EMF continue to be discussed. In the present study, a possible genotoxic effect of RF EMF (GSM, 1,800 MHz) in human lymphocytes was investigated by a collaboration of six independent institutes (institutes a, b, c, d, e, h). Peripheral blood of 20 healthy, nonsmoking volunteers of two age groups (10 volunteers 16-20 years old and 10 volunteers 50-65 years old) was taken, stimulated and intermittently exposed to three specific absorption rates (SARs) of RF EMF (0.2 W/kg, 2 W/kg, 10 W/kg) and sham for 28 h (institute a). The exposures were performed in a setup with strictly controlled conditions of temperature and dose, and randomly and automatically determined waveguide SARs, which were designed and periodically maintained by ITIS (institute h). Four genotoxicity tests with different end points were conducted (institute a): chromosome aberration test (five types of structural aberrations), micronucleus test, sister chromatid exchange test and the alkaline comet assay (Olive tail moment and % DNA). To demonstrate the validity of the study, positive controls were implemented. The genotoxicity end points were evaluated independently by three laboratories blind to SAR information (institute c = laboratory 1; institute d = laboratory 2; institute e = laboratory 3). Statistical analysis was carried out by institute b. Methods of primary statistical analysis and rules to adjust for multiple testing were specified in a statistical analysis plan based on a data review before unblinding. A linear trend test based on a linear mixed model was used for outcomes of comet assay and exact permutation test for linear trend for all other outcomes. It was ascertained that only outcomes with a significant SAR trend found by at least two of three analyzing laboratories indicated a substantiated suspicion of an exposure effect. On the basis of these specifications, none of the nine end points tested for SAR trend showed a significant and reproducible exposure effect. Highly significant differences between sham exposures and positive controls were detected by each analyzing laboratory, thus validating the study. In conclusion, the results show no evidence of a genotoxic effect induced by RF EMF (GSM, 1,800 MHz).

**Waldmann-Selsam C, Balmori-de la Puente A, Breunig H, Balmori A. Radiofrequency radiation injures trees around mobile phone base stations. Sci Total Environ. 572:554-569, 2016.**

In the last two decades, the deployment of phone masts around the world has taken place and, for many years, there has been a discussion in the scientific community about the possible environmental impact from mobile phone base stations. Trees have several advantages over animals as experimental subjects and the aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure. To achieve this, a detailed long-term (2006-2015) field monitoring study was performed in the cities of Bamberg and Hallstadt (Germany). During monitoring, observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. In 2015 measurements of RF-EMF (Radiofrequency Electromagnetic Fields) were carried out. A polygon spanning both cities was chosen as the study site, where 144 measurements of the radiofrequency of electromagnetic fields were taken at a height of 1.5m in streets and parks at different locations. By interpolation of the 144 measurement points, we were able to compile an electromagnetic map of the power flux density in Bamberg and Hallstadt. We selected 60 damaged trees, in addition to 30 randomly selected trees and 30 trees in low radiation areas (n=120) in this polygon. The measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. Thus, we found that side differences in measured values of power flux density corresponded to side differences in damage. The 30 selected trees in low radiation areas (no visual contact to any phone mast and power flux density under 50μW/$m^2$) showed no damage. Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts is harmful for trees. These results are consistent with the fact that damage afflicted on trees by mobile phone towers usually start on one side, extending to the whole tree over time.

**Wallace D, Eltiti S, Ridgewell A, Garner K, Russo R, Sepulveda F, Walker S, Quinlan T, Dudley S, Maung S, Deeble R, Fox E. Cognitive and physiological responses in humans exposed to a TETRA base station signal in relation to perceived electromagnetic hypersensitivity.Bioelectromagnetics. 33(1):23-39, 2012.**

Terrestrial Trunked Radio (TETRA) technology ("Airwave") has led to public concern because of its potential interference with electrical activity in the brain. The present study is the first to examine whether acute exposure to a TETRA base station signal has an impact on cognitive functioning and physiological responses. Participants were exposed to a 420 MHz TETRA signal at a power flux density of 10 mW/m(2) as well as sham (no signal) under double-blind conditions. Fifty-one people who reported a perceived sensitivity to electromagnetic fields as well as 132 controls participated in a double-blind provocation study. Forty-eight sensitive and 132 control participants completed all three sessions. Measures of short-term memory, working memory, and attention were administered while physiological responses (blood volume pulse, heart rate, skin conductance) were monitored. After applying exclusion criteria based on task performance for each aforementioned cognitive measure, data were analyzed for 36, 43, and 48 sensitive participants for these respective tasks and, likewise, 107,125, and 129 controls. We observed no differences in cognitive performance between sham and TETRA exposure in either group; physiological response also did not differ between the

exposure conditions. These findings are similar to previous double-blind studies with other mobile phone signals (900-2100 MHz), which could not establish any clear evidence that mobile phone signals affect health or cognitive function.

**Wallace D, Eltiti S, Ridgewell A, Garner K, Russo R, Sepulveda F, Walker S, Quinlan T, Dudley S, Maung S, Deeble R, Fox E. Do TETRA (Airwave) base station signals have a short-term impact on health and well-being? A randomized double-blind provocation study.Environ Health Perspect. 118(6):735-741, 2012.**

BACKGROUND: "Airwave" is the new communication system currently being rolled out across the United Kingdom for the police and emergency services,based on the Terrestrial Trunked Radio Telecommunications System (TETRA). Some police officers have complained about skin rashes, nausea, headaches, and depression as a consequence of using their Airwave handsets. In addition, a small subgroup in the population self-report being sensitive to electromagnetic fields (EMFs) in general. OBJECTIVES: We conducted a randomized double-blind provocation study to establish whether short-term exposure to a TETRA base station signal has an impact on the health and well-being of individuals with self-reported "electrosensitivity" and of participants who served as controls. METHODS: Fifty-one individuals with self-reported electrosensitivity and 132 age- and sex-matched controls participated in an open provocation test; 48 sensitive and 132 control participants went on to complete double-blind tests in a fully screened semianechoic chamber. Heart rate, skin conductance, and blood pressure readings provided objective indices of short-term physiological response. Visual analog scales and symptom scales provided subjective indices of well-being. RESULTS: We found no differences on any measure between TETRA and sham (no signal) under double-blind conditions for either controls or electrosensitive participants, and neither group could detect the presence of a TETRA signal at rates greater than chance (50%). When conditions were not double blind, however, the self-reported electrosensitive individuals did report feeling worse and experienced more severe symptoms during TETRA compared with sham.CONCLUSIONS: Our findings suggest that the adverse symptoms experienced by electrosensitive individuals are due to the belief of harm from TETRA base stations rather than to the low-level EMF exposure itself.

**Wallin MK, Marve T, Hakansson PK. Modern wireless telecommunication technologies and their electromagnetic compatibility with life-supporting equipment. Anesth Analg. 101(5):1393-1400, 2005.**

Hospitals rely on pagers and ordinary telephones to reach staff members in emergency situations. New telecommunication technologies such as General Packet Radio Service (GPRS), the third generation mobile phone system Universal Mobile Telecommunications System (UMTS), and Wireless Local Area Network (WLAN) might be able to replace hospital pagers if they are electromagnetically compatible with medical devices. In this study, we sought to determine if GPRS, UMTS (Wideband Code Division Multiple Access-Frequency Division Duplex [WCDMA FDD]), and WLAN (IEEE 802.11b) transmitted signals interfere with life-supporting equipment in the intensive care and operating room environment. According to United States standard, ANSI C63.18-1997,

laboratory tests were performed on 76 medical devices. In addition, clinical tests during 11 operations and 100 h of intensive care were performed. UMTS and WLAN signals caused little interference. Devices using these technologies can be used safely in critical care areas and during operations, but direct contact between medical devices and wireless communication devices ought to be avoided. In the case of GPRS, at a distance of 50 cm, it caused an older infusion pump to alarm and stop infusing; the pump had to be reset. Also, 10 cases of interference with device displays occurred. GPRS can be used safely at a distance of 1 m. Terminals/cellular phones using these technologies should be allowed without restriction in public areas because the risk of interference is minimal.

**Walsh SP, White KM, Hyde MK, Watson B. Dialling and driving: factors influencing intentions to use a mobile phone while driving. Accid Anal Prev. 40(6):1893-1900, 2008.**

Despite being identified as an unsafe (and, in some jurisdictions, illegal) driving practice, the psychological factors underlying people's decision to use their mobile phone while driving have received little attention. The present study utilised the theory of planned behaviour (TPB) to examine the role of attitudes, norms, control factors, and risk perceptions, in predicting people's intentions to use their mobile phone while driving. We examined the predictors of intentions to use a mobile phone while driving in general, and for calling and text messaging in 4 scenarios differing in descriptions of vehicle speed and time pressure. There was some support for the TPB given that attitudes consistently predicted intentions to drive while using a mobile phone and that pressure from significant others (norms) determined some phone use while driving intentions, although less support was found for the role of perceptions of control. Risk was not generally predictive of safer driving intentions. These findings indicate that different factors influence each form of mobile phone use while driving and, hence, a multi-strategy approach is likely to be required to address the issue.

**Walters TJ, Blick DW, Johnson LR, Adair ER, Foster KR, Heating and pain sensation produced in human skin by millimeter waves: comparison to a simple thermal model. Health Phys 78(3):259-267, 2000.**

Cutaneous thresholds for thermal pain were measured in 10 human subjects during 3-s exposures at 94 GHz continuous wave microwave energy at intensities up to approximately 1.8 W cm(-2). During each exposure, the temperature increase at the skin's surface was measured by infrared thermography. The mean (+/- s.e.m.) baseline temperature of the skin was 34.0+/-0.2 degrees C. The threshold for pricking pain was 43.9+/-0.7 degrees C, which corresponded to an increase in surface temperature of approximately 9.9 degrees C (from 34.0 degrees C to 43.9 degrees C). The measured increases in surface temperature were in good agreement with a simple thermal model that accounted for heat conduction and for the penetration depth of the microwave energy into tissue. Taken together, these results support the use of the model for predicting thresholds of thermal pain at other millimeter wave (length) frequencies.

**Walters TJ, Ryan KL, Belcher JC, Doyle JM, Tehrany MR, Mason PA,**

**Regional brain heating during microwave exposure (2.06 GHz), warm-water immersion, environmental heating and exercise. Bioelectromagnetics 19(6):341-353,1998.**

Nonuniform heating may result from microwave (MW) irradiation of tissues and is therefore important to investigate in terms of health and safety issues. Hypothalamic (Thyp), cortical (Tctx), tympanic (Tty), and rectal (Tre) temperatures were measured in rats exposed in the far field, k-polarization (i.e., head pointed toward the transmitter horn and E-field in vertical direction) to two power densities of 2.06 GHz irradiation. The high-power density (HPM) was 1700 mW/cm2 [specific absorption rate (SAR): hypothalamus 1224 W/kg; cortex 493 W/kg]; the low-power density (LPM) was 170 mW/cm2 (SAR: hypothalamus 122.4 W/kg; cortex 49.3 W/kg). The increase (rate-of-rise, in degrees C/s) in Thyp was significantly greater than those in Tctx or Tre when rats were exposed to HPM. LPM produced more homogeneous heating. Quantitatively similar results were observed whether rats were implanted with probes in two brain sites or a single probe in one or the other of the two sites. The qualitative difference between regional brain heating was maintained during unrestrained exposure to HPM in the h-polarization (i.e., body parallel to magnetic field). To compare the temperature changes during MW irradiation with those produced by other modalities of heating, rats were immersed in warm water (44 degrees C, WWI); exposed to a warm ambient environment (50 degrees C, WSED); or exercised on a treadmill (17 m/min 8% grade) in a warm ambient environment (35 degrees C, WEX). WWI produced uniform heating in the regions measured. Similar rates-of-rise occurred among regions following WSED or WEX, thus maintaining the pre-existing gradient between Thyp and Tctx These data indicate that HPM produced a 2-2.5-fold difference in the rate-of-heating within brain regions that were separated by only a few millimeters. In contrast, more homogeneous heating was recorded during LPM or nonmicrowave modalities of heating.

**Wang, BM, Lai, H, Acute exposure to pulsed 2450-MHz microwaves affects water maze learning in the rat. Bioelectromagnetics 21:52-56, 2000.**

Rats were trained in six sessions to locate a submerged platform in a circular water maze. They were exposed to pulsed 2450-MHz microwaves (pulse width 2 μs, 500 pulses/s, power density 2 mW/cm2, average whole body specific absorption rate 1.2 W/kg) for 1 hr in a circular waveguide system immediately before each training session. One hour after the last training session, they were tested in a probe trial during which the platform was removed and the time spent in the quadrant of the maze in which the platform had been located during the 1-min trial was scored. Three groups of animals: microwave-exposed, sham-exposed, and cage control were studied. Data show that microwave-exposed rats were slower than sham-exposed and cage control rats in learning to locate the platform. However, there was no significant difference in swim speed among the three groups of animals, indicating that the difference in learning was not due to a change in motor functions or motivation. During the probe trial, microwave-exposed animals spent significantly less time in the quadrant that had contained the platform, and their swim

patterns were different from those of the sham-exposed and cage control animals. The latter observation indicates that microwave-exposed rats used a different strategy in learning the location of the platform. These results show that acute exposure to pulsed microwaves caused a deficit in spatial "reference" memory in the rat.

**Wang C, Wang X, Zhou H, Dong G, Guan X, Wang L, Xu X, Wang S, Chen P, Peng R, Hu X. Effects of Pulsed 2.856 GHz Microwave Exposure on BM-MSCs Isolated from C57BL/6 Mice. PLoS One. 2015 Feb 6;10(2):e0117550. doi: 10.1371/journal.pone.0117550. eCollection 2015.**

The increasing use of microwave devices over recent years has meant the bioeffects of microwave exposure have been widely investigated and reported. However the exact biological fate of bone marrow MSCs (BM-MSCs) after microwave radiation remains unknown. In this study, the potential cytotoxicity on MSC proliferation, apoptosis, cell cycle, and in vitro differentiation were assayed following 2.856 GHz microwave exposure at a specific absorption rate (SAR) of 4 W/kg. Importantly, our findings indicated no significant changes in cell viability, cell division and apoptosis after microwave treatment. Furthermore, we detected no significant effects on the differentiation ability of these cells in vitro, with the exception of reduction in mRNA expression levels of osteopontin (OPN) and osteocalcin (OCN). These findings suggest that microwave treatment at a SAR of 4 W/kg has undefined adverse effects on BM-MSCs. However, the reduced-expression of proteins related to osteogenic differentiation suggests that microwave can the influence at the mRNA expression genetic level.

**Wang D, Li B, Liu Y, Ma YF, Chen SQ, Sun HJ, Dong J, Ma XH, Zhou J, Wang XH. [Impact of** mobile phone **radiation on the quality and DNA methylation of human sperm in vitro]. Zhonghua Nan Ke Xue. 21(6):515-520, 2015. [Article in Chinese]**
OBJECTIVE: To investigate the influences of mobile phone radiation on the quality and DNA methylation of human sperm in vitro. METHODS: According to the fifth edition of the WHO Laboratory Manual for the Examination and Processing of Human Semen, we randomly selected 97 male volunteers with normal semen parameters and divided each semen sample from the subjects into two equal parts, one exposed to mobile phone radiation at 1950 M Hz, SAR3. 0 W/kg for 3 hours while the other left untreated as the control. We obtained routine semen parameters as well as the acrosomal reaction ability, apoptosis and DNA methylation of sperm, and compared them between the two groups. RESULTS: Compared with the control, the radiation group showed significantly decreased progressive sperm motility ([36.64 ± 16.93] vs [27.56 ± 16.92]%, P < 0.01) and sperm viability ([63.72 ± 16.35] vs [54.31 ± 17.35]%, P < 0.01) and increased sperm head defects ([69.92 ± 4.46] vs [71.17 ± 4.89]%, P < 0.05), but no significant differences in sperm acrosomal reaction ([66.20 ± 6.75] vs [64.50 ± 3.47]%, P > 0.05). The early apoptosis rate of sperm cells was remarkably higher in the radiation group ([6.89 ± 9.84]%) than in the control ([4.44 ± 5.89]%) (P < 0.05). However, no statistically significant differences were found between the control and radiation groups in the DNA methylation patterns of the paternal imprinting gene H19 ICR ([0.60 ± 0.02] vs [1.40 ± 0.03]%, P > 0.05) or the maternal imprinting gene KvDMR1 ([0.00 ± 0.00] vs [1.80 ± 0.031%, P > 0.05). CONCLUSION: Mobile phone radiation reduces the progressive motility and

viability of human sperm and increases sperm head defects and early apoptosis of sperm cells.

**Wang H, Peng R, Zhou H, Wang S, Gao Y, Wang L, Yong Z, Zuo H, Zhao L, Dong J, Xu X, Su Z. Impairment of long-term potentiation induction is essential for the disruption of spatial memory after microwave exposure. Int J Radiat Biol. 2013 Jul 24. [Epub ahead of print]**

Purpose: To assess the impact of microwave exposure on learning and memory and to explore the underlying mechanisms. Materials and methods: 100 Wistar rats were exposed to a 2.856 GHz pulsed microwave field at average power densities of 0 $mW/cm^2$, 5 $mW/cm^2$, 10 $mW/cm^2$ and 50 $mW/cm^2$ for 6 min. The spatial memory was assessed by the Morris Water Maze (MWM) task. An in vivo study was conducted soon after microwave exposure to evaluate the changes of population spike (PS) amplitudes of long-term potentiation (LTP) in the medial perforant path (MPP)-dentate gyrus (DG) pathway. The structure of the hippocampus was observed by the light microscopy and the transmission electron microscopy (TEM) at 7 d after microwave exposure. Results: Our results showed that the rats exposed in 10 $mW/cm^2$ and 50 $mW/cm^2$ microwave displayed significant deficits in spatial learning and memory at 6 h, 1 d and 3 d after exposure. Decreased PS amplitudes were also found after 10 $mW/cm^2$ and 50 $mW/cm^2$ microwave exposure. In addition, varying degrees of degeneration of hippocampal neurons, decreased synaptic vesicles and blurred synaptic clefts were observed in the rats exposed in 10 $mW/cm^2$ and 50 $mW/cm^2$ microwave. Compared with the sham group, the rats exposed in 5 $mW/cm^2$ microwave showed no difference in the above experiments. Conclusions: This study suggested that impairment of LTP induction and the damages of hippocampal structure, especially changes of synapses, might contribute to cognitive impairment after microwave exposure.

**Wang H, Peng R, Zhao L, Wang S, Gao Y, Wang L, Zuo H, Dong J, Xu X, Zhou H, Su Z. The relationship between NMDA receptors and microwave induced learning and memory impairment: a long term observation on Wistar rats. Int J Radiat Biol. 2014 Nov 26:1-25. [Epub ahead of print]**

Purpose: In the present study, we intended to investigate whether the high power microwave could cause the continuous disorders of learning and memory in Wistar rats and to explore the underlying mechanisms. Materials and methods: 80 Wistar rats were exposed to a 2.856 GHz pulsed microwave source at a power density of 0 $mW/cm^2$ and 50 $mW/cm^2$ microwave for 6 min. The spatial memory ability, the structure of the hippocampus, contents of amino acids neurotransmitters in hippocampus and the expression of N-methyl-D-aspartic acid receptors (NMDAR) subunit 1, 2A and 2B (NR1, NR2A and NR2B) were detected at 1 m, 3 m, 6 m, 9 m, 12 m and 18 m after microwave exposure. Results: Our results showed that the microwave exposed rats showed consistent deficiencies in spatial learning and memory. The level of amino acid neurotransmitters also decreased after microwave radiation. The ratio of glutamate (Glu) and gammaaminobutyric acid (GABA) significantly decreased at 6 m. Besides, the

hippocampus showed varying degrees of degeneration of neurons, increased postsynaptic density and blurred synaptic clefts in the exposure group. The NR1 and NR2B expression showed a significant decrease, especially the NR2B expression. Conclusions: This study indicated that the content of amino acids neurotransmitters, the expression of NMDAR subunits and the variation of hippocampal structure might contribute to the long term cognitive impairment after microwave exposure.

**Wang J, Koyama S, Komatsubara Y, Suzuki Y, Taki M, Miyakoshi J. Effects of a 2450 MHz high-frequency electromagnetic field with a wide range of SARs on the induction of heat-shock proteins in A172 cells. Bioelectromagnetics. 27(6):479-486, 2006.**

In this study, we investigated whether exposure to 2450 MHz high-frequency electromagnetic fields (HFEMFs) could act as an environmental insult to evoke a stress response in A172 cells, using HSP70 and HSP27 as stress markers. The cells were exposed to a 2450 MHz HFEMF with a wide range of specific absorption rates (SARs: 5-200 W/kg) or sham conditions. Because exposure to 2450 MHz HFEMF at 50-200 W/kg SAR causes temperature increases in culture medium, appropriate heat control groups (38-44 degrees C) were also included. The expression of HSP 70 and HSP 27, as well as the level of phosphorylated HSP 27 ((78)Ser) (p-HSP27), was determined by Western blotting. Our results showed that the expression of HSP 70 increased in a time and dose-dependent manner at >50 W/kg SAR for 1-3 h. A similar effect was also observed in corresponding heat controls. There was no significant change in HSP 27 expression caused by HFEMF at 5-200 W/kg or by comparable heating for 1-3 h. However, HSP 27 phosphorylation increased transiently at 100 and 200 W/kg to a greater extent than at 40-44 degrees C. Phosphorylation of HSP 27 reached a maximum after 1 h exposure at 100 W/kg HFEMF. Our results suggest that exposure to a 2450 MHz HFEMF has little or no apparent effect on HSP70 and HSP27 expression, but it may induce a transient increase in HSP27 Phosphorylation in A172 cells at very high SAR (>100 W/kg).

**Wang J, Su H, Xie W, Yu S. Mobile Phone Use and The Risk of Headache: A Systematic Review and Meta-analysis of Cross-sectional Studies. Sci Rep. 7(1):12595, 2017.**

Headache is increasingly being reported as a detrimental effect of mobile phone (MP) use. However, studies aimed to investigate the association between MP use and headache yielded conflicting results. To assess the consistency of the data on the topic, we performed a systematic review and meta-analysis of the available cross-sectional studies. Published literature from PubMed and other databases were retrieved and screened, and 7 cross-sectional studies were finally included in this meta-analysis. The pooled odds ratio (OR) and 95% confidence interval (CI) were calculated. We found that the risk of headache was increased by 38% in MP user compared with non-MP user (OR, 1.38; 95% CI, 1.18-1.61, $p < 0.001$). Among MP users, the risk of headache was also increased in those who had longer daily call duration (2-15 min vs. <2 min: OR, 1.62; 95% CI, 1.34-1.98, $p < 0.001$; >15 min vs. <2 min: OR, 2.50; 95% CI, 1.76-3.54, $p < 0.001$) and higher daily call frequency (2-4 calls vs. <2 calls: OR, 1.37; 95% CI, 1.07-1.76, $p < 0.001$;

>4 calls vs. <2 calls: OR, 2.52; 95% CI, 1.78-3.58, p < 0.001). Our data indicate that MP use is significantly associated with headache, further epidemiologic and experimental studies are required to affirm and understand this association.

**Wang K, Lu JM, Xing ZH, Zhao QR, Hu LQ, Xue L, Zhang J, Mei YA. Effect of 1.8 GHz radiofrequency electromagnetic radiation on novel object associative recognition memory in mice. Sci Rep. 2017 Mar 17;7:44521. doi: 10.1038/srep44521.**

Mounting evidence suggests that exposure to radiofrequency electromagnetic radiation (RF-EMR) can influence learning and memory in rodents. In this study, we examined the effects of single exposure to 1.8 GHz RF-EMR for 30 min on subsequent recognition memory in mice, using the novel object recognition task (NORT). RF-EMR exposure at an intensity of >2.2 W/kg specific absorption rate (SAR) power density induced a significant density-dependent increase in NORT index with no corresponding changes in spontaneous locomotor activity. RF-EMR exposure increased dendritic-spine density and length in hippocampal and prefrontal cortical neurons, as shown by Golgi staining. Whole-cell recordings in acute hippocampal and medial prefrontal cortical slices showed that RF-EMR exposure significantly altered the resting membrane potential and action potential frequency, and reduced the action potential half-width, threshold, and onset delay in pyramidal neurons. These results demonstrate that exposure to 1.8 GHz RF-EMR for 30 min can significantly increase recognition memory in mice, and can change dendritic-spine morphology and neuronal excitability in the hippocampus and prefrontal cortex. The SAR in this study (3.3 W/kg) was outside the range encountered in normal daily life, and its relevance as a potential therapeutic approach for disorders associated with recognition memory deficits remains to be clarified.

**Wang KJ, Yao K, Lu DQ. [Effects of different dose microwave radiation on protein components of cultured rabbit lens] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 25(4):208-210, 2007.**[Article in Chinese]

OBJECTIVE: To study the effects of different dose microwave radiation on protein components of cultured rabbit lens, and analyze the mechanisms of lens injury caused by microwave radiation. METHODS: Cultured rabbit lens were exposed to microwave radiation with frequency of 2450 MHz and power density of 0.25, 0.50, 1.00, 2.00, 5.00 mW/cm(2) for 8 hours in vitro. The transparency of lens was observed. Changes of protein concentration were detected after different lens protein components were extracted, including water-soluble protein (WSP), urea soluble protein (USP), alkali soluble protein (ASP) and sonicated protein (SP). The influence of microwave radiation on WSP was analyzed using SDS-PAGE electrophoresis and coomassie-blue staining. RESULTS: Transparency of lens decreased after radiation. There was obvious opacification of lens cortex after 5.00 mW/cm(2) microwave radiation for 8 hours. After 1.00, 2.00 and 5.00 mW/cm(2) radiation, the percentage of WSP decreased while USP increased obviously. There was no change of ASP. The percentage of SP decreased when the power of microwave was 5.00 mW/cm(2). The low molecular weight protein of WSP decreased while high molecular weight protein increased after microwave radiation. CONCLUSION: Microwave radiation higher than

1.00 mW/cm(2) can affect the proportion of WSP and USP in cultured rabbit lens, and cause changes of lens transparency and refractive power, which leads to lens opacity.

**Wang LF, Li X, Gao YB, Wang SM, Zhao L, Dong J, Yao BW, Xu XP, Chang GM, Zhou HM, Hu XJ, Peng RY. Activation of VEGF/Flk-1-ERK Pathway Induced Blood-Brain Barrier Injury After Microwave Exposure. Mol Neurobiol. 2014 Sep 9. [Epub ahead of print]**

Microwaves have been suggested to induce neuronal injury and increase permeability of the blood-brain barrier (BBB), but the mechanism remains unknown. The role of the vascular endothelial growth factor (VEGF)/Flk-1-Raf/MAPK kinase (MEK)/extracellular-regulated protein kinase (ERK) pathway in structural and functional injury of the blood-brain barrier (BBB) following microwave exposure was examined. An in vitro BBB model composed of the ECV304 cell line and primary rat cerebral astrocytes was exposed to microwave radiation (50 mW/cm2, 5 min). The structure was observed by scanning electron microscopy (SEM) and the permeability was assessed by measuring transendothelial electrical resistance (TEER) and horseradish peroxidase (HRP) transmission. Activity and expression of VEGF/Flk-1-ERK pathway components and occludin also were examined. Our results showed that microwave radiation caused intercellular tight junctions to broaden and fracture with decreased TEER values and increased HRP permeability. After microwave exposure, activation of the VEGF/Flk-1-ERK pathway and Tyr phosphorylation of occludin were observed, along with down-regulated expression and interaction of occludin with zonula occludens-1 (ZO-1). After Flk-1 (SU5416) and MEK1/2 (U0126) inhibitors were used, the structure and function of the BBB were recovered. The increase in expression of ERK signal transduction molecules was muted, while the expression and the activity of occludin were accelerated, as well as the interactions of occludin with p-ERK and ZO-1 following microwave radiation. Thus, microwave radiation may induce BBB damage by activating the VEGF/Flk-1-ERK pathway, enhancing Tyr phosphorylation of occludin, while partially inhibiting expression and interaction of occludin with ZO-1.

**Wang LL, Chen GD, Lu DQ, Chiang H, Xu ZP. [Global gene response to GSM 1800 MHz radiofrequency electromagnetic field in MCF-7 cells.] Zhonghua Yu Fang Yi Xue Za Zhi. 40(3):159-163, 2006.** [Article in Chinese]

OBJECTIVE: To investigate whether GSM 1800 MHz radiofrequency electromagnetic field (RF EMF) can change the gene expression profile in MCF-7 cells and to screen RF EMF responsive genes. METHODS: Subcultured MCF-7 cells were intermittently (5-minute fields on/10-minute fields off) exposed or sham-exposed to GSM 1800 MHz RF EMF, which was modulated by 217 Hz EMF, for 24 hours at an average specific absorption rate (SAR) of 2.0 W/kg or 3.5 W/kg. Immediately after RF EMF exposure or sham-exposure, total RNA was isolated from MCF-7 cells and then purified. Affymetrix Human Genome U133A Genechip was applied to examine the change of gene expression profile according to the manufacturer's instruction. Data was analyzed by Affymetrix Microarray Suite 5.0 (MAS 5.0) and Affymetrix Data Mining Tool 3.0 (DMT 3.0). Quantitative reverse transcription polymerase chain reaction (RT-PCR) was used to

validate the differentially expressed genes identified by Genechip analysis. RESULTS: A small number of differential expression genes were found in each comparison after RF EMF exposure. Through reproducible and consistent analysis, no gene or five up-regulated genes were screened out after exposure to RF EMF at SAR of 2.0 W/kg or 3.5 W/kg, respectively. However, these five genes could not be further confirmed by RT-PCR. CONCLUSION: The present study did not provide clear evidence that RF EMF exposure might distinctly change the gene expression profile in MCF-7 cells under current experimental conditions, implying that the exposure might not affect the MCF-7 cell physiology, or this cell line might be less sensitive to the RF EMF exposure.

**Wang Q, Cao ZJ, Bai XT. [Effect of 900 MHz electromagnetic fields on the expression of GABA receptor of cerebral cortical neurons in postnatal rats] Wei Sheng Yan Jiu. 34(5):546-548, 2005**.

OBJECTIVE: To investigate the effects of 900 MHz microwave electromagnetic fields (EMF) on the expression of neurotransmitter GABA receptor of cerebral cortical neurons in postnatal rats. METHODS: Neurons were exposed to 900 MHz continuous microwave EMF (SAR = 1.15 - 3.22mW/g) for 2 hours per day in 6 consecutive days and for 12 hours at one time. GABA receptor was chosen to be the biological end. RESULTS: Significant changes had been observed in exposed neurons in the expression of GABA receptor. ($P < 0.01$) . CONCLUSION: The expression of GABA receptor of neurons were significantly regulated by 900 MHz microwave, and a power "window" effect was observed in the exposed neurons.

**Wang J, Sakurai T, Koyama S, Komatubara Y, Suzuki Y, Taki M, Miyakoshi J. Effects of 2450 MHz electromagnetic fields with a wide range of SARs on methylcholanthrene-induced transformation in C3H10T1/2 cells. J Radiat Res (Tokyo). 46(3):351-361, 2005.**

This study examined whether 2450 MHz continuous wave high frequency electromagnetic fields (HFEMF) could induce cancer-like changes in mouse C3H10T1/2 cells, and whether HFEMF could initiate malignant or synergistic transformation. Transformed foci, Type II and Type III, were independently counted as the experiment endpoint. The cells were exposed to HFEMF alone at a wide range of specific absorption rates (SARs) of 5 to 200 W/kg for 2 h and/or were treated with a known initiating chemical, methylcholanthrene (MC) (2.5 microg/ml). No significant differences were observed in the malignant transformation (Type II + Type III) frequency between the controls and HFEMF with or without 12-O-tetradecanoylphorbol-13-acetate (TPA) (0.5 ng/ml), a tumor promoter that could enhance transformation frequency initiated by MC in multistage carcinogenesis. However, the transformation frequency for HFEMF at SAR of more than 100 W/kg with MC or MC plus TPA was increased compared with MC alone or MC plus TPA. On the other hand, the corresponding heat groups (heat alone, heat + MC, and heat + MC + TPA) did not increase transformation compared with each control level in C3H10T1/2 cells. This result suggests that 2450 MHz HFEMF could not contribute to the initiation stage of tumor formation, but it may contribute to the promotion stage at the extremely high SAR (100 W/kg).

**Wang PW, Liu TL, Ko CH, Lin HC, Huang MF, Yeh YC, Yen CF. Association between Problematic Cellular Phone Use and Suicide: The Moderating Effect of**

**Family Function and Depression. Compr Psychiatry. 2013 Oct 19. pii: S0010-440X(13)00282-4. doi: 10.1016/j.comppsych.2013.09.006. [Epub ahead of print]**

BACKGROUND: Suicidal ideation and attempt among adolescents are risk factors for eventual completed suicide. Cellular phone use (CPU) has markedly changed the everyday lives of adolescents. Issues about how cellular phone use relates to adolescent mental health, such as suicidal ideation and attempts, are important because of the high rate of cellular phone usage among children in that age group. This study explored the association between problematic CPU and suicidal ideation and attempts among adolescents and investigated how family function and depression influence the association between problematic CPU and suicidal ideation and attempts. METHODS: A total of 5051 (2872 girls and 2179 boys) adolescents who owned at least one cellular phone completed the research questionnaires. We collected data on participants' CPU and suicidal behavior (ideation and attempts) during the past month as well as information on family function and history of depression. RESULTS: Five hundred thirty-two adolescents (10.54%) had problematic CPU. The rates of suicidal ideation were 23.50% and 11.76% in adolescents with problematic CPU and without problematic CPU, respectively. The rates of suicidal attempts in both groups were 13.70% and 5.45%, respectively. Family function, but not depression, had a moderating effect on the association between problematic CPU and suicidal ideation and attempt. CONCLUSION: This study highlights the association between problematic CPU and suicidal ideation as well as attempts and indicates that good family function may have a more significant role on reducing the risks of suicidal ideation and attempts in adolescents with problematic CPU than in those without problematic CPU.

**Wang X, Liu C, Ma Q, Feng W, Yang L, Lu Y, Zhou Z, Yu Z, Li W, Zhang L. 8-oxoG DNA Glycosylase-1 Inhibition Sensitizes Neuro-2a Cells to Oxidative DNA Base Damage Induced by 900 MHz Radiofrequency Electromagnetic Radiation. Cell Physiol Biochem. 2015 Sep 25;37(3):1075-1088. [Epub ahead of print]**

BACKGROUND/AIMS: The purpose of this study was to explore the in vitro putative genotoxicity during exposure of Neuro-2a cells to radiofrequency electromagnetic fields (RF-EMFs) with or without silencing of 8-oxoG DNA glycosylase-1 (OGG1). METHODS: Neuro-2a cells treated with or without OGG1 siRNA were exposed to 900 MHz Global System for Mobile Communication (GSM) Talk signals continuously at a specific absorption rate (SAR) of 0, 0.5, 1 or 2 W/kg for 24 h. DNA strand breakage and DNA base damage were measured by the alkaline comet assay and a modified comet assay using formamidopyrimidine DNA glycosylase (FPG), respectively. Reactive oxygen species (ROS) levels and cell viability were monitored using the non-fluorescent probe 2, 7-dichlorofluorescein diacetate (DCFH-DA) and CCK-8 assay. RESULTS: Exposure to 900 MHz RF-EMFs with insufficient energy could induce oxidative DNA base damage in Neuro-2a cells. These increases were concomitant with similar increases in the generation of reactive oxygen species (ROS). Without OGG1 siRNA, 2 W/kg RF-EMFs induced oxidative DNA base damage in Neuro-2a cells. Interestingly, with OGG1 siRNA, RF-EMFs could cause DNA base damage in Neuro-2a cells as low as 1 W/kg. However, neither DNA strand breakage nor altered cell viability was observed. CONCLUSION:

Even if further studies remain conducted we support the hypothesis that OGG1 is involved in the process of DNA base repair and may play a pivotal role in protecting DNA bases from RF-EMF induced oxidative damage.

**Wang XW, Ding GR, Shi CH, Zeng LH, Liu JY, Li J, Zhao T, Chen YB, Guo GZ. Mechanisms involved in the blood-testis barrier increased permeability induced by EMP. Toxicology. 276(1):58-63, 2010.**

The blood-testis barrier (BTB) plays an important role in male reproductive system. Lots of environmental stimulations can increase the permeability of BTB and then result in antisperm antibody (AsAb) generation, which is a key step in male immune infertility. Here we reported the results of male mice exposed to electromagneticpulse (EMP) by measuring the expression of tight-junction-associated proteins (ZO-1 and Occludin), vimentin microfilaments, and transforming growth factor-beta (TGF-beta3) as well as AsAb level in serum. Male BALB/c mice were sham exposed or exposed to EMP at two different intensities (200kV/m and 400kV/m) for 200 pulses. The testes were collected at different time points after EMP exposure. Immunofluorescence histocytochemistry, western blotting, laser confocal microscopy and RT-PCR were used in this study. Compared with sham group, the expression of ZO-1 and TGF-beta3 significantly decreased accompanied with unevenly stained vimentin microfilaments and increased serum AsAb levels in EMP-exposed mice. These results suggest a potential BTB injury and immune infertility in male mice exposed to a certain intensity of EMP.

**Warren HG, Prevatt AA, Daly KA, Antonelli PJ. Cellular telephone use and risk of intratemporal facial nerve tumor. Laryngoscope 113(4):663-667, 2003.**

OBJECTIVES/HYPOTHESISMicrowave radiation exposure from cellular telephone use has been implicated in the development of intracranial tumors. The intratemporal facial nerve (IFN) is exposed to higher levels of cellular telephone radiation than intracranial tissues. The purpose of the study was to determine whether cellular telephone use is associated with an increased risk of IFN tumors. STUDY DESIGNCase-control using a structured telephone survey at an academic, tertiary-care referral center. METHODS Patients with IFN tumors (n = 18) were case-matched with patients treated for acoustic neuroma (n = 51), rhinosinusitis (n = 72), and dysphonia or gastroesophageal reflux disease (n = 69). Risk of facial nerve tumorigenesis was compared by extent of cellular telephone use and other risk factors.RESULTSThe odds ratio of developing an IFN tumor was 0.6 (95% CI, 0.2-1.9) with any handheld cellular telephone use and 0.4 (95% CI, 0.1-2.1) with regular cellular telephone use. No factors were associated with an increased risk for IFN tumor development. CONCLUSIONS Regular cellular telephone use does not appear to be associated with a higher risk of IFN tumor development. The short duration of widespread cellular telephone use precludes definite exclusion as a risk for IFN tumor development.

**Watilliaux A, Edeline JM, Lévêque P, Jay TM, Mallat M. Effect of exposure to 1,800 MHz electromagnetic fields on heat shock proteins and glial cells in the brain of developing rats. Neurotox Res. 20(2):109-119, 2011.**

The increasing use of mobile phones by children raise issues about the effects of electromagnetic fields (EMF) on the immature Central Nervous System (CNS). In the present study, we quantified cell stress and glial responses in the brain of developing rats one day after a single exposure of 2 h to a GSM 1,800 MHz signal at a brain average Specific Absorption Rate (SAR) in the range of 1.7 to 2.5 W/kg. Young rats, exposed to EMF on postnatal days (P) 5 (n = 6), 15 (n = 5) or 35 (n = 6), were compared to pseudo-exposed littermate rats (n = 6 at all ages). We used western blotting to detect heat shock proteins (HSPs) and cytoskeleton- or neurotransmission-related proteins in the developing astroglia. The GSM signal had no significant effect on the abundance of HSP60, HSC70 or HSP90, of serine racemase, glutamate transporters including GLT1 and GLAST, or of glial fibrillary acid protein (GFAP) in either total or soluble tissue extracts. Imunohistochemical detection of CD68 antigen in brain sections from pseudo-exposed and exposed animals did not reveal any differences in the morphology or distribution of microglial cells. These results provide no evidence for acute cell stress or glial reactions indicative of early neural cell damage, in developing brains exposed to 1,800 MHz signals in the range of SAR used in our study.

**Wdowiak A, Wdowiak L, Wiktor H. Evaluation of the effect of using mobile phones on male fertility. Ann Agric Environ Med. 14(1):169-172, 2007.**

The problem of the lack of offspring is a phenomenon concerning approximately 15% of married couples in Poland. Infertility is defined as inability to conceive after a year of sexual intercourses without the use of contraceptives. In half of the cases the causative factor is the male. Males are exposed to the effect of various environmental factors, which may decrease their reproductive capabilities. A decrease in male fertility is a phenomenon which occurs within years, which may suggest that one of the reasons for the decrease in semen parameters is the effect of the development of techniques in the surrounding environment. A hazardous effect on male fertility may be manifested by a decrease in the amount of sperm cells, disorders in their mobility, as well as structure. The causative agents may be chemical substances, ionizing radiation, stress, as well as electromagnetic waves. The objective of the study was the determination of the effect of the usage of cellular phones on the fertility of males subjected to marital infertility therapy. The following groups were selected from among 304 males covered by the study: Group A: 99 patients who did not use mobile phones, Group B: 157 males who have used GSM equipment sporadically for the period of 1-2 years, and Group C: 48 people who have been regularly using mobile phone for more than 2 years. In the analysis of the effect of GSM equipment on the semen it was noted that an increase in the percentage of sperm cells of abnormal morphology is associated with the duration of exposure to the waves emitted by the GSM phone. It was also confirmed that a decrease in the percentage of sperm cells in vital progressing motility in the semen is correlated with the frequency of using mobile phones.

**Weisbrot D, Lin H, Ye L, Blank M, Goodman R. Effects of mobile phone radiation on reproduction and development in Drosophila melanogaster. J Cell Biochem 89(1):48-55, 2003.**

In this report we examined the effects of a discontinuous radio frequency (RF) signal produced by a GSM multiband mobile phone (900/1,900 MHz; SAR approximately 1.4 W/kg) on Drosophila melanogaster, during the 10-day developmental period from egg laying through pupation. As found earlier with low frequency exposures, the non-thermal radiation from the GSM mobile phone increased numbers of offspring, elevated hsp70 levels, increased serum response element (SRE) DNA-binding and induced the phosphorylation of the nuclear transcription factor, ELK-1. The rapid induction of hsp70 within minutes, by a non-thermal stress, together with identified components of signal transduction pathways, provide sensitive and reliable biomarkers that could serve as the basis for realistic mobile phone safety guidelines.

**Westermark A, Wisten A. Miniplate osteosynthesis and cellular phone create disturbance of infraorbital nerve. J Craniofac Surg 12(5):475-478, 2001.**

A 37-year-old man with a zygomatic fracture underwent surgical treatment with reduction of the fracture and osteosynthesis with a miniplate on the infraorbital rim. Postoperatively, he had numbness in the distribution area of the infraorbital nerve, but he also suffered from dysesthesia in the same area during periods when he was using his hand-held mobile phone. After surgical removal of the osteosynthesis plate, the dysesthesia associated with his mobile phone was no longer present. The plate was examined in a setup where we measured the electric current that developed on the surface of the plate under the influence of the magnetic field between the phone antenna and the metal plate. The highest currents measured on the actual plate were 141 mV in air, and 21 mV in saline. These findings indicate that there might have been a correlation between the presence of the miniplate close to the infraorbital nerve, and the dysesthesia experienced by the patient, under the influence of the energy emitted from the cellular phone.

**Whitehead TD, Brownstein BH, Parry JJ, Thompson D, Cha BA, Moros EG, Rogers BE, Roti Roti JL. Expression of the Proto-oncogene Fos after Exposure to Radiofrequency Radiation Relevant to Wireless Communications. Radiat Res. 164(4):420-430, 2005.**

In this study the expression levels of the proto-oncogene Fos were measured after exposure to radiofrequency (RF) radiation at two relatively high specific absorption rates (SARs) of 5 and 10 W/kg for three types of modulated signals: 847.74 MHz code division multiple access (CDMA), 835.62 MHz frequency division multiple access (FDMA), and 836.55 MHz time division multiple access (TDMA). This work was undertaken to confirm a previous report by Goswami et al. (Radiat. Res. 151, 300-309, 1999) that CDMA and FDMA radiation caused small but statistically significant increases in Fos levels as cells entered plateau phase during exposure. No effects on Myc or Jun levels were observed in that study. Therefore, in the present study, analyses were restricted to Fos expression during the transition from exponential growth to plateau phase. Fos expression was measured using the real-time polymerase chain reaction (RT-PCR) technique. Serum-stimulated C3H 10T(1/2) cells were used as a positive control for Fos expression. Possible influences of final cell number or pH variability on Fos expression were

evaluated. Expression of Fos mRNA in C3H 10T(1/2) cells was not significantly different from that found after sham exposure at either SAR level for any signal modulation. Therefore, the results of Goswami et al. could not be confirmed.

**Whitehead TD, Moros EG, Brownstein BH, Roti Roti JLGene expression does not change significantly in C3H 10T(1/2) cells after exposure to 847.74 CDMA or 835.62 FDMA radiofrequency radiation. Radiat Res. 165(6):626-635, 2006.**

.In vitro experiments with C3H 10T(1/2) mouse cells were performed to determine whether Frequency Division Multiple Access (FDMA) or Code Division Multiple Access (CDMA) modulated radiofrequency (RF) radiations induce changes in gene expression. After the cells were exposed to either modulation for 24 h at a specific absorption rate (SAR) of 5 W/ kg, RNA was extracted from both exposed and sham-exposed cells for gene expression analysis. As a positive control, cells were exposed to 0.68 Gy of X rays and gene expression was evaluated 4 h after exposure. Gene expression was evaluated using the Affymetrix U74Av2 GeneChip to detect changes in mRNA levels. Each exposure condition was repeated three times. The GeneChip data were analyzed using a two-tailed t test, and the expected number of false positives was estimated from t tests on 20 permutations of the six sham RF-field-exposed samples. For the X-ray-treated samples, there were more than 90 probe sets with expression changes greater than 1.3-fold beyond the number of expected false positives. Approximately one-third of these genes had previously been reported in the literature as being responsive to radiation. In contrast, for both CDMA and FDMA radiation, the number of probe sets with an expression change greater than 1.3-fold was less than or equal to the expected number of false positives. Thus the 24-h exposures to FDMA or CDMA RF radiation at 5 W/kg had no statistically significant effect on gene expression.

**Whitehead TD, Moros EG, Brownstein BH, Roti Roti JL. The number of genes changing expression after chronic exposure to Code Division Multiple Access or Frequency DMA radiofrequency radiation does not exceed the false-positive rate. Proteomics. 6(17):4739-4744, 2006.**

Experiments with cultured C3H 10T 1/2 cells were performed to determine if exposure to cell phone radiofrequency (RF) radiations induce changes in gene expression. Following a 24 h exposure of 5 W/kg specific adsorption rate, RNA was extracted from the exposed and sham control cells for microarray analysis on Affymetrix U74Av2 Genechips. Cells exposed to 0.68 Gy of X-rays with a 4-h recovery were used as positive controls. The number of gene expression changes induced by RF radiation was not greater than the number of false positives expected based on a sham versus sham comparison. In contrast, the X-irradiated samples showed higher numbers of probe sets changing expression level than in the sham versus sham comparison.

**Weyandt, TB, Schrader, SM, Turner, TW, Simon, SD, Semen analysis of military personnel associated with military duty assignments. Reprod Toxicol 10(6):521-528, 1996.**

A collaborative study between the U.S. Army Biomedical Research and DevelopmentLaboratory (USABRDL) and the National Institute for Occupational Safety

and Health (NIOSH) was designed to assess fecundity of male artillery soldiers with potential exposures to airborne lead aerosols. Potential exposure assessment was based upon information provided in an interactive questionnaire. It became apparent from extensive questionnaire data that many soldiers in the initial control population had potentially experienced microwave exposure as radar equipment operators. As a result, a third group of soldiers without potential for lead or microwave exposures, but with similar environmental conditions, was selected as a comparison population. Blood hormone levels and semen analyses were conducted on artillerymen (n = 30), radar equipment operators (n = 20), and the comparison group (n = 31). Analysis of the questionnaire information revealed that concern about fertility problems motivated participation of some soldiers with potential artillery or microwave exposures. Although small study population size and the confounding variable of perceived infertility limit the reliability of the study, several statistically significant findings wereidentified. Artillerymen who perceived a possible fertility concern demonstrated lower sperm counts/ejaculate (P = 0.067) and lower sperm/mL (P = 0.014) than the comparison group. The group of men with potential microwave exposures demonstrated lower sperm counts/mL (P = 0.009) and sperm/ejaculate (P = 0.027) than the comparison group. Variables used to assess endocrine, accessory sex gland, and sperm cell function were not different than the comparison group. Additional studies, incorporating larger numbers of individuals, should be performed in order to more optimally characterize potential lead and microwave exposure effects on male fecundity.

**Wiholm C, Lowden A, Kuster N, Hillert L, Arnetz BB, Akerstedt T, Moffat SD Mobile phone exposure and spatial memory. Bioelectromagnetics.30(1):59-65, 2009.**

Radiofrequency (RF) emission during mobile phone use has been suggested to impair cognitive functions, that is, working memory. This study investigated the effects of a 2 1/2 h RF exposure (884 MHz) on spatial memory and learning, using a double-blind repeated measures design. The exposure was designed to mimic that experienced during a real-life mobile phone conversation. The design maximized the exposure to the left hemisphere. The average exposure was peak spatial specific absorption rate (psSAR10g) of 1.4 W/kg. The primary outcome measure was a "virtual" spatial navigation task modeled after the commonly used and validated Morris Water Maze. The distance traveled on each trial and the amount of improvement across trials (i.e., learning) were used as dependent variables. The participants were daily mobile phone users, with and without symptoms attributed to regular mobile phone use. Results revealed a main effect of RF exposure and a significant RF exposure by group effect on distance traveled during the trials. The symptomatic group improved their performance during RF exposure while there was no such effect in the non-symptomatic group. Until this new finding is further investigated, we can only speculate about the cause.

**Wilen J, Sandstrom M, Hansson Mild K. Subjective symptoms among mobile phone users-A consequence of absorption of radiofrequency fields? Bioelectromagnetics 24(3):152-159, 2003.**

In a previous epidemiological study, where we studied the prevalence of subjective symptoms among mobile phone (MP) users, we found as an interesting side finding that the prevalence of many of the subjective symptoms increased with increasing calling time

and number of calls per day. In this extrapolative study, we have selected 2402 people from the epidemiological study who used any of the four most common GSM MP. We used the information about the prevalence of symptoms, calling time per day, and number of calls per day and combined it with measurements of the Specific Absorption Rate (SAR). We defined three volumes in the head and measured the maximum SAR averaged over a cube of 1 g tissue (SAR(1g)) in each volume. Two new exposure parameters Specific Absorption per Day (SAD) and Specific Absorption per Call (SAC) have been devised and are obtained as combinations of SAR, calling time per day, and number of calls per day, respectively. The results indicates that SAR values >0.5 W/kg may be an important factor for the prevalence of some of the symptoms, especially in combination with long calling times per day.

**Wilen J, Hornsten R, Sandstrom M, Bjerle P, Wiklund U, Stensson O, Lyskov E, Mild KH. Electromagnetic field exposure and health among RF plastic sealer operators. Bioelectromagnetics. 25(1): 5-15, 2004.**

Operators of RF plastic sealers (RF operators) are an occupational category highly exposed to radiofrequency electromagnetic fields. The aim of the present study was to make an appropriate exposure assessment of RF welding and examine the health status of the operators. In total, 35 RF operators and 37 controls were included. The leakage fields (electric and magnetic field strength) were measured, as well as induced and contact current. Information about welding time and productivity was used to calculate time integrated exposure. A neurophysiological examination and 24 h ECG were also carried out. The participants also had to answer a questionnaire about subjective symptoms. The measurements showed that RF operators were exposed to rather intense electric and magnetic fields. The mean values of the calculated 6 min, spatially averaged E and H field strengths, in line with ICNIRP reference levels, are 107 V/m and 0.24 A/m, respectively. The maximum measured field strengths were 2 kV/m and 1.5 A/m, respectively. The induced current in ankles and wrists varied, depending on the work situation, with a mean value of 101 mA and a maximum measured value of 1 A. In total, 11 out of 46 measured RF plastic sealers exceeded the ICNIRP reference levels. RF operators, especially the ready made clothing workers had a slightly disturbed two-point discrimination ability compared to a control group. A nonsignificant difference between RF operators and controls was found in the prevalence of subjective symptoms, but the time integrated exposure parameters seem to be of importance to the prevalence of some subjective symptoms: fatigue, headaches, and warmth sensations in the hands. Further, RF operators had a significantly lower heart rate (24 h registration) and more episodes of bradycardia compared to controls.

**Wilen J, Johansson A, Kalezic N, Lyskov E, Sandstrom M. Psychophysiological tests and provocation of subjects with mobile phone related symptoms. Bioelectromagnetics.27(3):204-214, 2006.**

The aim of the present study was to investigate the effect of exposure to a mobile phone-like radiofrequency (RF) electromagnetic field on persons experiencing subjective symptoms when using mobile phones (MP). Twenty subjects with MP-related symptoms were recruited and matched with 20 controls without MP-related symptoms. Each subject participated in two experimental sessions, one with true exposure and one with sham

exposure, in random order. In the true exposure condition, the test subjects were exposed for 30 min to an RF field generating a maximum SAR(1g) in the head of 1 W/kg through an indoor base station antenna attached to a 900 MHz GSM MP. The following physiological and cognitive parameters were measured during the experiment: heart rate and heart rate variability (HRV), respiration, local blood flow, electrodermal activity, critical flicker fusion threshold (CFFT), short-term memory, and reaction time. No significant differences related to RF exposure conditions were detected. Also no differences in baseline data were found between subject groups, except for the reaction time, which was significantly longer among the cases than among the controls the first time the test was performed. This difference disappeared when the test was repeated. However, the cases differed significantly from the controls with respect to HRV as measured in the frequency domain. The cases displayed a shift in low/high frequency ratio towards a sympathetic dominance in the autonomous nervous system during the CFFT and memory tests, regardless of exposure condition. This might be interpreted as a sign of differences in the autonomous nervous system regulation between persons with MP related subjective symptoms and persons with no such symptoms.

**Wilén J, Wiklund U, Hörnsten R, Sandström M. Changes in heart rate variability among RF plastic sealer operators. Bioelectromagnetics. 28(1):76-79, 2007.**

In a previous study, we showed that operators of radiofrequency (RF) plastic sealers, RF operators (n = 35) had a lower heart rate during nighttime compared to a control group (n = 37). We have analyzed the heart rate variability (HRV) on the same group of people to better understand the possible underlying rhythm disturbances. We found a significantly increased total HRV and very low frequency (VLF) power during nighttime among the RF operators compared to a control group. Together with our previous finding of a significantly lower heart rate during nighttime among the RF operators compared to the controls, this finding indicates a relative increase in parasympathetic cardiac modulation in RF operators. This could in turn be due to an adaptation of the thermoregulatory system and the cardiac autonomic modulation to a long-term low-level thermal exposure in the RF operators.

**Wilke A, Grimm W, Funck R, Maisch B, Influence of D-net (European GSM -Standard) cellular phones on pacemaker function in 50 patients with permanent pacemakers. Pacing Clin Electrophysiol 19(10):1456-1458, 1996.**

The widespread use of cellular phones in the last years has prompted some recent studies to suggest an interference of pacemaker function by cellular phone usage. To determine the risk of pacemaker patients using D-net cellular phones, we tested 50 patients with permanent pacemakers after routine pacemaker check by short phone calls using a cellular phone (Ericsson, D-net, frequency 890-915 MHz, digital information coding, equivalent to the European Groupe Systemes Mobiles standard). A six-channel surface ECG was continuously recorded from each patient to detect any interactions between pacemakers and cellular phones. Phone calls were repeated during the following pacemaker settings: (1) preexisting setting; (2) minimum ventricular rate of 90 beats/min and preexisting sensitivity; and (3) minimum ventricular rate of 90 beats/min and

maximum sensitivity without T wave oversensing. Only 2 (4%) of 50 patients repeatedly showed intermittent pacemaker inhibition during calls with the cellular phone. Both pacemakers had unipolar sensing. Therefore, although interactions between cellular phone use and pacemaker function appear to be rare in our study, pacemaker dependent patients in particular should avoid the use of cellular phones.

**Wolf R, Wolf D. Increased incidence of cancer near a cell-phone transmitter station. Inter J Cancer Prev 1(2):123-128, 2004.**

Significant concern has been raised about possible health effects from exposure to radiofrequency (RF) electromagnetic fields, especially after the rapid introduction of mobile telecommunication systems. Parents are especially concerned with the possibility that children might develop cancer after exposure to the RF emissions from mobile telephone base stations erected in or near schools. The few epidemiologic studies that did report on cancer incidence in relation to RF radiation have generally presented negative or inconsistent results, and thus emphasized the need for more studies that should investigate cohorts with high RF exposure for changes in cancer incidence. The aim of this study is to investigate whether there is an increased cancer incidence in populations, living in a small area, and exposed to RF radiation from a cell-phone transmitter station.

This is an epidemiologic assessment, to determine whether the incidence of cancer cases among individuals exposed to a cell-phone transmitter station is different from that expected in Israel, in Netanya, or as compared to people who lived in a nearby area. Participants are people (n=622) living in the area near a cell-phone transmitter station for 3-7 years who were patients of one health clinic (of DW). The exposure began 1 year before the start of the study when the station first came into service. A second cohort of individuals (n=1222) who get their medical services in a clinic located nearby with very closely matched, environment, workplace and occupational characteristics was used for comparison.

In the area of exposure (area) eight cases of different kinds of cancer were diagnosed in a period of only one year. This rate of cancers was compared both with the rate of 31 cases per 10,000 per year in the general population and the 2/1222 rate recorded in the nearby clinic (area B). Relative cancer rates for female were 10.5 for area A. 0.6 for area B and 1 for the whole town of Netanya. Cancer incidence of women in area A was thus significantly higher ($p<0.0001$) compared with that of area B and the whole city. A comparison of the relative risk revealed that there were 4.15 times more cases in area than in the entire population. The study indicates an association between increased incidence of cancer and living in proximity to a cell-phone transmitter station.

**Wolke S, Neibig U, Elsner R, Gollnick F, Meyer R, Calcium homeostasis of isolated heart muscle cells exposed to pulsed high-frequency electromagnetic fields. Bioelectromagnetics 17(2):144-153, 1996.**

The intracellular calcium concentration ([Ca(2+)]i) of isolated ventricular cardiac myocytes of the guinea pig was measured during the application of pulsed high-frequency electromagnetic fields. The high-frequency fields were applied in a transverse

electromagnetic cell designed to allow microscopic observation of the myocytes during the presence of the high-frequency fields. The [Ca(2+)]i was measured as fura-2 fluorescence by means of digital image analysis. Both the carrier frequency and the square-wave pulse-modulation pattern were varied during the experiments (carrier frequencies: 900, 1,300, and 1,800 MHz pulse modulated at 217Hz with 14 percent duty cycle; pulsation attern at 900 MHz: continuous wave, 16 Hz, and 50 Hz modulation with 50 percent duty cycle and 30 kHz modulation with 80 percent duty cycle). The mean specific absorption rate (SAR) values in the solution were within one order of magnitude of **1 mW/kg**. They varied depending on the applied carrier frequency and pulse pattern. The experiments were designed in three phases: 500 s of sham exposure, followed by 500 s of field exposure, then chemical stimulation without field. The chemical stimulation (K+ -depolarization) indicated the viability of the cells. The K+ depolarization yielded a significant increase in [Ca(2+)]i. Significant differences between sham exposure and high-frequency field exposure were not found except when a very small but statistically significant difference was detected in the case of 900 MHz/50 Hz. However, this small difference was not regarded as a relevant effect of the exposure.

**Wood A, Loughran S, Stough C, Does evening exposure to mobile phone radiation affect subsequent melatonin production? Int. J. Rad. Biol 82:69-76, 2006.**

Purpose: To test whether exposure to the emissions from a digital mobile phone handset prior to sleep alters the secretion of melatonin. Materials and methods: In a double-blind cross-over design, 55 adult volunteers were both actively exposed or sham-exposed (in random order on successive Sunday nights) to mobile phone emissions for 30 min (0.25 W average power). Urine collection occurred immediately prior to retiring to bed and on rising the next morning. Melatonin output was estimated from principal metabolite concentrations (6-sulphatoxymelatonin (aMT6s) via radioimmunoassay), urine volumes and creatinine concentrations. Results: Total melatonin metabolite output (concentration×urine volume) was unchanged between the two exposure conditions (active 14.1±1.1 µg; sham 14.6±1.3 µg). The pre- and post-bedtime outputs considered separately were also not significantly different, although the pre-bedtime value was less for active versus sham exposure. When melatonin metabolite output was estimated from the ratio of aMT6s to creatinine concentrations, the pre-bedtime value was significantly less ( p = 0.037) for active compared to sham. Examination of individual responses is suggestive of a small group of `responders'. Conclusions: Total nighttime melatonin output is unchanged by mobile phone handset emissions, but there could be an effect on melatonin onset time.

**Wu RY, Chiang H, Shao BJ, Li NG, Fu YD, Effects of 2.45-GHz microwave radiation and phorbol ester 12-O-tetradecanoylphorbol-13-acetate on dimethylhydrazine-induced colon cancer in mice. Bioelectromagnetics 15(6):531-538, 1994.**

The purpose of this study was to investigate the effects of 2.45 GHz microwave (MW) radiation on dimethylhydrazine (DMH)-induced colon cancer in mice. The subjects were 115 Balb/c mice 4 weeks of age. The animals were divided into group A (control), group B (DMH), group C (DMH+MW), and group D [DMH + 12-O-tetradecanoylphorbol-13-acetate (TPA)]. Radiation (10 mW/cm2) was delivered dorsally with the E field parallel to the mouse's long body axis in an anechoic chamber. Radiations were administered 3 hr

daily, 6 days per week, over a period of 5 months. The average SAR was estimated to be 10-12 W/kg. During the course of radiation treatments, DMH was injected once per week. The tumor promoter TPA was administered once per week for 10 weeks, from the third week on, after the initial treatment. The incidence of tumors did not significantly differ between the three test groups (groups B, C, and D; P > 0.25). However, the number of tumors, the size of the tumors, and the incidence of protuberant and infiltrative types in tumor-bearing animals were higher in group D compared to groups B and C (P < 0.05). No difference was found between groups B and C (P > 0.25). The study indicates that 2.45 GHz microwave radiation at 10 mW/cm2 power density did not promote DMH-induced colon cancers in young mice. The study also showed that TPA could accelerate colon tumor production if a tumor was initiated.

**Wu T, Shao Q, Yang L, Qi D, Lin J, Lin X, Yu Z. A large-scale measurement of electromagnetic fields near GSM base stations in Guangxi, China for risk communication. Radiat Prot Dosimetry. 155(1):25-31, 2013.**

Radiofrequency (RF) electromagnetic field (EMF) exposure from wireless telecommunication base station antennae can lead to debates, conflicts or litigations among the adjacent residents if inappropriately managed. This paper presents a measurement campaign for the GSM band EMF exposure in the vicinity of 827 base station sites (totally 6207 measurement points) in Guangxi, China. Measurement specifications are designed for risk communication with the residents who previously complained of over-exposure. The EMF power densities with the global positioning system coordinate at each measured point were recorded. Compliance with the International Commission on Non-Ionizing Radiation Protection guidelines and Chinese environmental EMF safety standards was studied. The results show that the GSM band EMF level near the base stations is very low. The measurement results and the EMF risk communication procedures positively influence public perception of the RF EMF exposure from the base stations and promote the exchange of EMF exposure-related knowledge.

**Wu W, Yao K, Wang KJ, Lu DQ, He JL, Xu LH, Sun WJ. [Blocking 1800 MHz mobile phone radiation-induced reactive oxygen species production and DNA damage in lens epithelial cells by noise magnetic fields.] Zhejiang Da Xue Xue Bao Yi Xue Ban. 37(1):34-38, 2008.** [Article in Chinese]

OBJECTIVE: To investigate whether the exposure to the electromagnetic noise can block reactive oxygen species (ROS) production and DNA damage of lens epithelial cells induced by 1800 MHz mobile phone radiation. METHODS: The DCFH-DA method and comet assay were used respectively to detect the intracellular ROS and DNA damage of cultured human lens epithelial cells induced by 4 W/kg 1800 MHz mobile phone radiation or/and 2microT electromagnetic noise for 24 h intermittently. RESULT: 1800 MHz mobile phone radiation at 4 W/kg for 24 h increased intracellular ROS and DNA damage significantly (P<0.05). However, the ROS level and DNA damage of mobile phone radiation plus noise group were not significant enhanced (P>0.05) as compared to sham exposure group. Conclusion: Electromagnetic noise can block intracellular ROS production and DNA damage of human lens epithelial

cells induced by 1800 MHz mobile phone radiation.

**Wu Y, Jia Y, Guo Y, Zheng Z, Influence of EMP on the nervous system of rats. ACTA Biophysica Sinica 15:152-157, 1999.**

To explore the effects of electromagnetic pulse (EMP) exposure on the nervous system of rats, Wistar rats were divided into four groups: three exposure groups and one normal control group. The measurement of ability of learning of rats was carried out with a y-maze, followed by the detection of the content of neurotransmitters in different areas of cerebrum. Compared with control group, in the following three days of EMP exposure, the ability of learning of exposed groups was decreased (P< 0.05). For one day group, in hippocampus, the content of 5-HT and DOPAC increased (P< 0.05), and in hypothalamus, the content of dopamine increased (P< 0.05), while the content of Adr decreased (p< 0.05). the content of Adr and 5-HT in hippocampus of the second day group was reduced (P< 0.05). the content of Adr in hippocampus of the third day group was still lower than that of control group (P< 0.05). According to the results above, we can conclude that EMP exposure results in changes of the content of neurotransmitters in different cerebral areas of rats, lowering their ability of learning.

**Xiong L, Sun CF, Zhang J, Gao YB, Wang LF, Zuo HY, Wang SM, Zhou HM, Xu XP, Dong J, Yao BW, Zhao L, Peng RY. Microwave Exposure Impairs Synaptic Plasticity in the Rat Hippocampus and PC12 Cells through Over-activation of the NMDA Receptor Signaling Pathway. Biomed Environ Sci. 28(1):13-24, 2015.**

OBJECTIVE: The aim of this study is to investigate whether microwave exposure would affect the N-methyl-D-aspartate receptor (NMDAR) signaling pathway to establish whether this plays a role in synaptic plasticity impairment. METHODS: 48 male Wistar rats were exposed to 30 mW/cm2 microwave for 10 min every other day for three times. Hippocampal structure was observed through H&E staining and transmission electron microscope. PC12 cells were exposed to 30 mW/cm2 microwave for 5 min and the synapse morphology was visualized with scanning electron microscope and atomic force microscope. The release of amino acid neurotransmitters and calcium influx were detected. The expressions of several key NMDAR signaling molecules were evaluated. RESULTS: Microwave exposure caused injury in rat hippocampal structure and PC12 cells, especially the structure and quantity of synapses. The ratio of glutamic acid and gamma-aminobutyric acid neurotransmitters was increased and the intracellular calcium level was elevated in PC12 cells. A significant change in NMDAR subunits (NR1, NR2A, and NR2B) and related signaling molecules (Ca2+/calmodulin-dependent kinase II gamma and phosphorylated cAMP-response element binding protein) were examined. CONCLUSION: 30 mW/cm2 microwave exposure resulted in alterations of synaptic structure, amino acid neurotransmitter release and calcium influx. NMDAR signaling molecules were closely associated with impaired synaptic plasticity.

**Xu Q, Tong J, Jin ZD, Lu MX, DU HB, Cao Y. [Radiation protection and possible mechanisms for low intensity microwave.] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 27(9):520-524, 2009.** [Article in Chinese]

OBJECTIVE: To investigate radiation protection and possible mechanisms of low

intensity microwave on gamma-ray exposed mice. METHODS: 96 healthy Kunming mice were randomly divided into the following four groups: normal control, microwave (120 microW/cm(2), 900 MHz), gamma-ray irradiation (5 Gy), combined exposure of microwave and gamma-ray (120 microW/cm(2) + 5 Gy). The microwave group and combined group were exposed to 120 microW/cm(2) microwave firstly, 1 h/d, for 14 days. Then the ionization and combined group were exposed to 5 Gy (60)Co gamma-ray irradiation on the 15th day. Animals were sacrificed on the third, 6th, 9th and 12th day after irradiation. The sternum and spleen paraffin section were produced, and the histological changes were observed. Apoptosis rate of mice splenic cells in each group was examined by flow cytometry, and serum concentration of antioxidase and lipid peroxide was detected at the same time. RESULTS: Bone marrow was obviously injured either by radiation or microwave exposure, characterized by undergoing four-phase lesions, namely apoptosis-necrosis, void, regeneration and recovery phase. Compared with the gamma-ray group, the pathological changes in combined group were slighter and the recovery was quicker. The pathological injuries of spleen were similar to that of bone marrow. Injuries in the combined group were slighter than gamma-ray group. It showed that apoptosis rate of splenic cells in combined group was significantly lower on the 6th and 9th day after gamma-ray radiation (23.02% +/- 15.18%, 25.37% +/- 11.62% respectively) from FCM results. Assays of oxidative damages suggested that serum superoxide dismutase (SOD) level in combined group increased while lipid peroxide level decreased significantly ($P < 0.05$). CONCLUSION: Low intensity microwave may exert protection effects on injuries induced by ionizing radiation. The underlying mechanisms might be related with suppression on the hematopoietic cells apoptosis induced by gamma-ray radiation, inhibition of oxidative damages, and thus enhanced reconstruction of the hematopoietic system.

**Xu S, Ning W, Xu Z, Zhou S, Chiang H, Luo J. Chronic exposure to GSM 1800-MHz microwaves reduces excitatory synaptic activity in cultured hippocampal neurons. Neurosci Lett.398(3):253-257,2006.**

The world wide proliferation of mobile phones raises the concern about the health effects of 1800-MHz microwaves on the brain. The present study assesses the effects of microwave exposure on the function of cultured hippocampal neurons of rats using whole cell patch-clamp analysis combined with immunocytochemistry. We showed that chronic exposure (15min per day for 8 days) to Global System for Mobile Communication (GSM) 1800-MHz microwaves at specific absorption rate (SAR) of 2.4W/kg induced a selective decrease in the amplitude of alpha-amino-3-hydroxy-5-methyl-4-soxazole propionic acid (AMPA) miniature excitatory postsynaptic currents (mEPSCs), whereas the frequency of AMPA mEPSCs and the amplitude of N-methyl-d-aspartate (NMDA) mEPSCs did not change. Furthermore, the GSM microwave treatment decreased the expression of postsynaptic density 95 (PSD95) in cultured neurons. Our results indicated that 2.4W/kg GSM 1800-MHz microwaves may reduce excitatory synaptic activity and the number of excitatory synapses in cultured rat hippocampal neurons.

**Xu S, Zhou Z, Zhang L, Yu Z, Zhang W, Wang Y, Wang X, Li M, Chen Y, Chen C, He M, Zhang G, Zhong M. Exposure to 1800 MHz radiofrequency radiation**

**induces oxidative damage to mitochondrial DNA in primary cultured neurons. Brain Res. 1311:189-196. 2010.**

Increasing evidence indicates that oxidative stress may be involved in the adverse effects of radiofrequency (RF) radiation on the brain. Because mitochondrial DNA (mtDNA) defects are closely associated with various nervous system diseases and mtDNA is highly susceptible to oxidative stress, the purpose of this study was to determine whether radiofrequency radiation can cause oxidative damage to mtDNA. In this study, we exposed primary cultured cortical neurons to pulsed RF electromagnetic fields at a frequency of 1800 MHz modulated by 217 Hz at an average special absorption rate (SAR) of 2 W/kg. At 24h after exposure, we found that RF radiation induced a significant increase in the levels of 8-hydroxyguanine (8-OHdG), a common biomarker of DNA oxidative damage, in the mitochondria of neurons. Consistent with this finding, the copy number of mtDNA and the levels of mitochondrial RNA (mtRNA) transcripts showed an obvious reduction after RF exposure. Each of these mtDNA disturbances could be reversed by pretreatment with melatonin, which is known to be an efficient in the brain. Together, these results suggested that 1800 MHz RF radiation could cause oxidative damage to mtDNA in primary cultured neurons. Oxidative damage to mtDNA may account for the neurotoxicity of RF radiation in the brain.

**Xu S, Chen G, Chen C, Sun C, Zhang D, Murbach M, Kuster N, Zeng Q, Xu Z. Cell Type-Dependent Induction of DNA Damage by 1800 MHz Radiofrequency Electromagnetic Fields Does Not Result in Significant Cellular Dysfunctions. PLoS One. 2013;8(1):e54906.**

**BACKGROUND:** Although IARC clarifies radiofrequency electromagnetic fields (RF-EMF) as possible human carcinogen, the debate on its health impact continues due to the inconsistent results. Genotoxic effect has been considered as a golden standard to determine if an environmental factor is a carcinogen, but the currently available data for RF-EMF remain controversial. As an environmental stimulus, the effect of RF-EMF on cellular DNA may be subtle. Therefore, more sensitive method and systematic research strategy are warranted to evaluate its genotoxicity. **OBJECTIVES:** To determine whether RF-EMF does induce DNA damage and if the effect is cell-type dependent by adopting a more sensitive method γH2AX foci formation; and to investigate the biological consequences if RF-EMF does increase γH2AX foci formation. **METHODS:** Six different types of cells were intermittently exposed to GSM 1800 MHz RF-EMF at a specific absorption rate of 3.0 W/kg for 1 h or 24 h, then subjected to immunostaining with anti-γH2AX antibody. The biological consequences in γH2AX-elevated cell type were further explored with comet and TUNEL assays, flow cytometry, and cell growth assay. **RESULTS:** Exposure to RF-EMF for 24 h significantly induced γH2AX foci formation in Chinese hamster lung cells and Human skin fibroblasts (HSFs), but not the other cells. However, RF-EMF-elevated γH2AX foci formation in HSF cells did not result in detectable DNA fragmentation, sustainable cell cycle arrest, cell proliferation or viability change. RF-EMF exposure slightly but not significantly increased the cellular ROS level. **CONCLUSIONS:** RF-EMF induces DNA damage in a cell type-dependent manner, but

the elevated γH2AX foci formation in HSF cells does not result in significant cellular dysfunctions.

**Yadav AS, Sharma MK. Increased frequency of micronucleated exfoliated cells among humans exposed in vivo to mobile telephone radiations. Mutat Res. 650(2):175-180, 2008.**

The health concerns have been raised following the enormous increase in the use of wireless mobile telephones throughout the world. This investigation had been taken, with the motive to find out whether mobile phone radiations cause any in vivo effects on the frequency of micronucleated exfoliated cells in the exposed subjects. A total of 109 subjects including 85 regular mobile phone users (exposed) and 24 non-users (controls) had participated in this study. Exfoliated cells were obtained by swabbing the buccal-mucosa from exposed as well as sex-age-matched controls. One thousand exfoliated cells were screened from each individual for nuclear anomalies including micronuclei (MN), karyolysis (KL), karyorrhexis (KH), broken egg (BE) and binucleated (BN) cells. The average daily duration of exposure to mobile phone radiations is 61.26min with an overall average duration of exposure in term of years is 2.35 years in exposed subjects along with the 9.84+/-0.745 micronucleated cells (MNCs) and 10.72+/-0.889 total micronuclei (TMN) as compared to zero duration of exposure along with average 3.75+/-0.774 MNC and 4.00+/-0.808 TMN in controls. The means are significantly different in case of MNC and TMN at 0.01% level of significance. The mean of KL in controls is 13.17+/-2.750 and in exposed subjects is 13.06+/-1.793. The value of means of KH in exposed subjects (1.84+/-0.432) is slightly higher than in controls (1.42+/-0.737). Mean frequency of broken egg is found to be more in exposed subjects (0.65+/-0.276) as compared to controls (0.50+/-0.217). Frequency of presence of more than one nucleus in a cell (binucleated) is also higher in exposed (2.72+/-0.374) in comparison to controls (0.67+/-0.231). Although there is a slight increase in mean frequency of KH, BE and BN in exposed subjects but the difference is not found statistically significant. Correlation between 0-1, 1-2, 2-3 and 3-4 years of exposure and the frequency of MNC and TMN has been calculated and found to be positively correlated.

**Yakymenko I, Sidorik E, Kyrylenko S, Chekhun V. Long-term exposure to microwave radiation provokes cancer growth: evidences from radars and mobile communication systems.Exp Oncol. 33(2):62-70, 2011.**

In this review we discuss alarming epidemiological and experimental data on possible carcinogenic effects of long term exposure to low intensity microwave (MW) radiation. Recently, a number of reports revealed that under certain conditions the irradiation by low intensity MW can substantially induce cancer progression in humans and in animal models. The carcinogenic effect of MW irradiation is typically manifested after long term (up to 10 years and more) exposure. Nevertheless, even a year of operation of a powerful base transmitting station for mobile communication reportedly resulted in a dramatic increase of cancer incidence among population living nearby. In addition, model studies in rodents unveiled a significant increase in carcinogenesis after 17-24 months of MW exposure both in tumor-prone and intact animals. To that, such metabolic changes, as

overproduction of reactive oxygen species, 8-hydroxi-2-deoxyguanosine formation, or ornithine decarboxylase activation under exposure to low intensity MW confirm a stress impact of this factor on living cells. We also address the issue of standards for assessment of biological effects of irradiation. It is now becoming increasingly evident that assessment of biological effects of non-ionizing radiation based on physical (thermal) approach used in recommendations of current regulatory bodies, including the International Commission on Non-Ionizing Radiation Protection (ICNIRP) Guidelines, requires urgent reevaluation. We conclude that recent data strongly point to the need for re-elaboration of the current safety limits for non-ionizing radiation using recently obtained knowledge. We also emphasize that the everyday exposure of both occupational and general public to MW radiation should be regulated based on a precautionary principles which imply maximum restriction of excessive exposure.

**Yamaguchi H, Tsurita G, Ueno S, Watanabe S, Wake K, Taki M, Nagawa H. 1439 MHz pulsed TDMA fields affect performance of rats in a T-maze task only when body temperature is elevated. Bioelectromagnetics 24(4):223-230, 2003.**

This study sought to clarify the effects of exposure to electromagnetic waves (EMW) used in cellular phones on learning and memory processes. Sprague-Dawley rats were exposed for either 1 h daily for 4 days or for 4 weeks to a pulsed 1439 MHz time division multiple access (TDMA) field in a carousel type exposure system. At the brain, average specific absorption rate (SAR) was 7.5 W/kg, and the whole body average SAR was 1.7 W/kg. Other subjects were exposed at the brain average SAR of 25 W/kg and the whole body average SAR of 5.7 W/kg for 45 min daily for 4 days. Learning and memory were evaluated by reversal learning in a food rewarded T-maze, in which rats learned the location of food (right or left) by using environmental cues. The animals exposed to EMW with the brain average SAR of 25 W/kg for 4 days showed statistically significant decreases in the transition in number of correct choices in the reversal task, compared to sham exposed or cage control animals. However, rats exposed to the brain average SAR of 7.5 W/kg for either 4 days or for 4 weeks showed no T-maze performance impairments. Intraperitoneal temperatures, as measured by a fiber optic thermometer, increased in the rats exposed to the brain average SAR of 25 W/kg but remained the same for the brain average SAR of 7.5 W/kg. The SAR of a standard cellular phone is restricted to a maximum of 2 W/kg averaged over 10 g tissue. These results suggest that the exposure to a TDMA field at levels about four times stronger than emitted by cellular phones does not affect the learning and memory processes when there are no thermal effects.

**Yan JG, Agresti M, Bruce T, Yan YH, Granlund A, Matloub HS. Effects of cellular phone emissions on sperm motility in rats. Fertil Steril.88(4):957-64, 2007.**

OBJECTIVE: To evaluate the effects of cellular phone emissions on rat sperm cells. DESIGN: Classic experimental. SETTING: Animal research laboratory. SUBJECTS: Sixteen 3-month-old male Sprague-Dawley rats, weighing 250-300 g. INTERVENTION(S): Rats in the experimental group were exposed to two 3-hour periods of daily cellular phone emissions for 18 weeks; sperm samples were then collected for evaluation. MAIN OUTCOME MEASURE(S): Evaluation of sperm motility, sperm cell morphology, total sperm cell number, and mRNA levels for two

cell surface adhesion proteins. RESULT(S): Rats exposed to 6 hours of daily cellular phone emissions for 18 weeks exhibited a significantly higher incidence of sperm cell death than control group rats through chi-squared analysis. In addition, abnormal clumping of sperm cells was present in rats exposed to cellular phone emissions and was not present in control group rats. CONCLUSION(S): These results suggest that carrying cell phones near reproductive organs could negatively affect male fertility.

**Yan JG, Agresti M, Zhang LL, Yan Y, Matloub HS. Upregulation of specific mRNA levels in rat brain after cell phone exposure. Electromagn Biol Med. 27(2):147-154, 2008.**

Adult Sprague-Dawley rats were exposed to regular cell phones for 6 h per day for 126 days (18 weeks). RT-PCR was used to investigate the changes in levels of mRNA synthesis of several injury-associated proteins. Calcium ATPase, Neural Cell Adhesion Molecule, Neural Growth Factor, and Vascular Endothelial Growth Factor were evaluated. The results showed statistically significant mRNA up-regulation of these proteins in the brains of rats exposed to cell phone radiation. These results indicate that relative chronic exposure to cell phone microwave radiation may result in cumulative injuries that could eventually lead to clinically significant neurological damage.

**Yang L, Hao D, Wang M, Zeng Y, Wu S, Zeng Y. Cellular Neoplastic Transformation Induced by 916 MHz Microwave Radiation. Cell Mol Neurobiol.32(6):1039-1046, 2012.**

There has been growing concern about the possibility of adverse health effects resulting from exposure to microwave radiations, such as those emitted by mobile phones. The purpose of this study was to investigate the cellular neoplastic transformation effects of electromagnetic fields. 916 MHz continuous microwave was employed in our study to simulate the electromagnetic radiation of mobile phone. NIH/3T3cells were adopted in our experiment due to their sensitivity to carcinogen or cancer promoter in environment. They were divided randomly into one control group and three microwave groups. The three microwave groups were exposed to 916 MHz EMF for 2 h per day with power density of 10, 50, and 90 w/m(2), respectively, in which 10 w/m(2) was close to intensity near the antenna of mobile phone. The morphology and proliferation of NIH/3T3cells were examined and furthermore soft agar culture and animal carcinogenesis assay were carried out to determine the neoplastic promotion. Our experiments showed NIH/3T3cells changed in morphology and proliferation after 5-8 weeks exposure and formed clone in soft agar culture after another 3-4 weeks depending on the exposure intensity. In the animal carcinogenesis study, lumps developed on the back of SCID mice after being inoculated into exposed NIH/3T3cells for more than 4 weeks. The results indicate that microwave radiation can promote neoplastic transformation of NIH/3T3cells.

**Yang L, Hao D, Wu S, Zhong R, Zeng Y. SAR and temperature distribution in the rat head model exposed to electromagnetic field radiation by 900 MHz dipole antenna. Australas Phys Eng Sci Med. 2013 Jun 6. [Epub ahead of print]**

Rats are often used in the electromagnetic field (EMF) exposure experiments. In the study for the effect of 900 MHz EMF exposure on learning and memory in SD rats, the specific absorption rate (SAR) and the temperature rise in the rat head are numerically evaluated. The digital anatomical model of a SD rat is reconstructed with the MRI images. Numerical method as finite difference time domain has been applied to assess the SAR and the temperature rise during the exposure. Measurements and simulations are conducted to characterize the net radiated power of the dipole to provide a precise dosimetric result. The whole-body average SAR and the localized SAR averaging over 1, 0.5 and 0.05 g mass for different organs/tissues are given. It reveals that during the given exposure experiment setup, no significant temperature rise occurs. The reconstructed anatomical rat model could be used in the EMF simulation and the dosimetric result provides useful information for the biological effect studies.

**Yang L, Chen Q, Lv B, Wu T. Long-Term Evolution Electromagnetic Fields Exposure Modulates the Resting State EEG on Alpha and Beta Bands. Clin EEG Neurosci. 2016 Apr 25. pii: 1550059416644887. [Epub ahead of print]**

Long-term evolution (LTE) wireless telecommunication systems are widely used globally, which has raised a concern that exposure to electromagnetic fields (EMF) emitted from LTE devices can change human neural function. To date, few studies have been conducted on the effect of exposure to LTE EMF. Here, we evaluated the changes in electroencephalogram (EEG) due to LTE EMF exposure. An LTE EMF exposure system with a stable power emission, which was equivalent to the maximum emission from an LTE mobile phone, was used to radiate the subjects. Numerical simulations were conducted to ensure that the specific absorption rate in the subject's head was below the safety limits. Exposure to LTE EMF reduced the spectral power and the interhemispheric coherence in the alpha and beta bands of the frontal and temporal brain regions. No significant change was observed in the spectral power and the inter-hemispheric coherence in different timeslots during and after the exposure. These findings also corroborated those of our previous study using functional magnetic resonant imaging.

**Yang M, Guo W, Yang C, Tang J, Huang Q, Feng S, Jiang A, Xu X, Jiang G.** Mobile phone **use and glioma risk: A systematic review and meta-analysis. PLoS One. 12(5):e0175136, 2017.**

OBJECTIVE: Many studies have previously investigated the potential association between **mobile phone** use and the risk of glioma. However, results from these individual studies are inconclusive and controversial. The objective of our study was to investigate the potential association between **mobile phone** use and subsequent glioma risk using meta-analysis.METHODS: We performed a systematic search of the Science Citation Index Embase and PubMed databases for studies reporting relevant data on **mobile phone** use and glioma in 1980-2016. The data were extracted and measured in terms of the odds ratio (OR) and 95% confidence interval (CI) using the random effects model. Subgroup analyses were also carried out. This meta-analysis eventually included 11 studies comprising a total 6028 cases and 11488 controls.RESULTS: There was a

significant positive association between long-term **mobile phone** use (minimum, 10 years) and glioma (OR = 1.44, 95% CI = 1.08-1.91). And there was a significant positive association between long-term ipsilateral **mobile phone** use and the risk of glioma (OR = 1.46, 95% CI = 1.12-1.92). Long-term **mobile phone** use was associated with 2.22 times greater odds of low-grade glioma occurrence (OR = 2.22, 95% CI = 1.69-2.92). **Mobile phone** use of any duration was not associated with the odds of high-grade glioma (OR = 0.81, 95% CI = 0.72-0.92). Contralateral **mobile phone** use was not associated with glioma regardless of the duration of use. Similarly, this association was not observed when the analysis was limited to high-grade glioma.CONCLUSIONS: Our results suggest that long-term **mobile phone** use may be associated with an increased risk of glioma. There was also an association between **mobile phone** use and low-grade glioma in the regular use or long-term use subgroups. However, current evidence is of poor quality and limited quantity. It is therefore necessary to conduct large sample, high quality research or better characterization of any potential association between long-term ipsilateral **mobile phone** use and glioma risk.

**Yang R, Chen J, Deng Z, Liu X, [Effect of vitamin E on morphological variation of retinal ganglion cells after microwave radiation]. Wei Sheng Yan Jiu 30(1):31-33, 2001.** [Article in Chinese]

To determine the morphological variation in the primary cultured pig retinal ganglion cells induced by microwave and the protection of VE can supply some experiment foundation for study of effect of microwave and its protection. Retinal ganglion cells of pig were cultured in vitro and added VE of different concentration, Each group was taken after 30 mW/cm2 microwave intensity radiated for 1 h in shielded room by 2450 MHz continuous wave physiotherapy machine. Immediately after radiation, the morphological variation of cells was observed by optics microscope and transmission electronic microscope. The result showed that a portion of cells congregated, with their axon disappeared after radiation. Mitochondria and endoplasmic reticulum are detected swelling by transmission electronic microscope. The results showed that A poptosis cells can be observed. Cells of VE added groups had not obvious changes with optics microscope, but could be found that mitochondria swelling lightly and integrate mitochondria cristae by transmission electronic microscope. The results showed that microwave induced the morphological damage in primary cultured retinal ganglion cells, VE could reduced the damage of retina ganglion cells by microwave in some extent.

**Yang X, He G, Hao Y, Chen C, Li M, Wang Y, Zhang G, Yu Z. The role of the JAK2-STAT3 pathway in pro-inflammatory responses of EMF-stimulated N9 microglial cells. J Neuroinflammation. 7:54, 2010.**

**BACKGROUND:** In several neuropathological conditions, microglia can become overactivated and cause neurotoxicity by initiating neuronal damage in response to pro-inflammatory stimuli. Our previous studies have shown that exposure to electromagnetic fields (EMF) activates cultured microglia to produce tumor necrosis factor (TNF)-α and nitric oxide (NO) through signal transduction involving the activator of transcription

STAT3. Here, we investigated the role of STAT3 signaling in EMF-induced microglial activation and pro-inflammatory responses in more detail than the previous study. **METHODS:** N9 microglial cells were treated with EMF exposure or a sham treatment, with or without pretreatment with an inhibitor (Pyridone 6, P6) of the Janus family of tyrosine kinases (JAK). The activation state of microglia was assessed via immunoreaction using the microglial marker CD11b. Levels of inducible nitric oxide synthase (iNOS), TNF-α and NO were measured using real-time reverse transcription-polymerase chain reaction (RT-PCR), enzyme-linked immunosorbent assay (ELISA) and the nitrate reductase method. Activation of JAKs and STAT3 proteins was evaluated by western blotting for specific tyrosine phosphorylation. The ability of STAT3 to bind to DNA was detected with an electrophoresis mobility shift assay (EMSA). **RESULTS:** EMF was found to significantly induce phosphorylation of JAK2 and STAT3, and DNA-binding ability of STAT3 in N9 microglia. In addition, EMF dramatically increased the expression of CD11b, TNF-α and iNOS, and the production of NO. P6 strongly suppressed the phosphorylation of JAK2 and STAT3 and diminished STAT3 activity in EMF-stimulated microglia. Interestingly, expression of CD11b as well as gene expression and production of TNF-α and iNOS were suppressed by P6 at 12 h, but not at 3 h, after EMF exposure. **CONCLUSIONS:** EMF exposure directly triggers initial activation of microglia and produces a significant pro-inflammatory response. Our findings confirm that the JAK2-STAT3 pathway may not mediate this initial microglial activation but does promote pro-inflammatory responses in EMF-stimulated microglial cells. Thus, the JAK2-STAT3 pathway might be a therapeutic target for reducing pro-inflammatory responses in EMF-activated microglia.

**Yang XS, He GL, Hao YT, Xiao Y, Chen CH, Zhang GB, Yu ZP. Exposure to 2.45 GHz electromagnetic fields elicits an HSP-related stress response in rat hippocampus. Brain Res Bull. 88(4):371-378, 2012.**

The issue of possible neurobiological effects of the electromagnetic field (EMF) exposure is highly controversial. To determine whether electromagnetic field exposure could act as an environmental stimulus capable of producing stress responses, we employed the hippocampus, a sensitive target of electromagnetic radiation, to assess the changes in its stress-related gene and protein expression after EMF exposure. Adult male Sprague-Dawley rats with body restrained were exposed to a 2.45 GHz EMF at a specific absorption rate (SAR) of 6 W/kg or sham conditions. cDNA microarray was performed to examine the changes of gene expression involved in the biological effects of electromagnetic radiation. Of 2048 candidate genes, 23 upregulated and 18 downregulated genes were identified. Of these differential expression genes, two heat shock proteins (HSP), HSP27 and HSP70, are notable because expression levels of both proteins are increased in the rat hippocampus. Result from immunocytochemistry revealed that EMF caused intensive staining for HSP27 and HSP70 in the hippocampus, especially in the pyramidal neurons of cornu ammonis 3 (CA3) and granular cells of dentate gyrus (DG). The gene and protein expression profiles of HSP27 and HSP70 were further confirmed by reverse transcription polymerase chain reaction (RT-PCR) and Western blot. Our data provide direct evidence that exposure to electromagnetic fields elicits a stress response in the rat hippocampus.

**Yao K, Wang KJ, Sun ZH, Tan J, Xu W, Zhu LJ, Lu de Q. Low power microwave radiation inhibits the proliferation of rabbit lens epithelial cells by upregulating P27Kip1 expression. Mol Vis. 10:138-143, 2004.**

PURPOSE: The goal of this study was to examine the effects of low power microwave radiation (<10 mW/cm2) on the proliferation of cultured rabbit lens epithelial cells (RLEC). METHODS: Cultured RLEC were exposed to continuous microwave radiation at a frequency of 2,450 MHz and power densities of 0.10, 0.25, 0.50, 1.00, and 2.00 mW/cm2 for 8 h. Cell morphologic changes were observed under a phase-contrast microscope. Cell viability was measured using the MTT assay and cell cycle analysis was measured using flow cytometry. After exposure to 2.00 mW/cm2 microwave radiation for 4, 6, and 8 h, the expression of cell cycle-regulatory proteins, P21WAF1 and P27Kip1, was examined using western blot analysis. Finally, the levels of P21WAF1 and P27Kip1 mRNA were analyzed by reverse transcription-polymerase chain reaction (RT-PCR). RESULTS: After 8 h of radiation treatment, cells treated with 0.50, 1.00, and 2.00 mW/cm2 microwave radiation exhibited decreased cell viability, increased cell condensation and an inhibition of DNA synthesis. RLEC showed significant G0/G1 arrest. No obvious changes could be detected in the 0.10 and 0.25 mW/cm2 microwave treatment groups. Protein expression of P27Kip1 was markedly increased after microwave radiation. However, the mRNA levels were unchanged. On the other hand, there were no detectable differences in P21WAF1 protein expression and mRNA levels between microwave treatment and control groups. CONCLUSIONS: This study suggests that low power microwave radiation higher than 0.50 mW/cm2 can inhibit lens epithelial cell proliferation, and increase the expression of P27Kip1. These effects may account for the decline of lens epithelial proliferation after exposure to microwave radiation.

**Yao K, Wu W, Wang K, Ni S, Ye P, Yu Y, Ye J, Sun L. Electromagnetic noise inhibits radiofrequency radiation-induced DNA damage and reactive oxygen species increase in human lens epithelial cells. Mol Vis. 14:964-969, 2008.**

PURPOSE: The goal of this study was to investigate whether superposing of electromagnetic noise could block or attenuate DNA damage and intracellular reactive oxygen species (ROS) increase of cultured human lens epithelial cells (HLECs) induced by acute exposure to 1.8 GHz radiofrequency field (RF) of the Global System for Mobile Communications (GSM). METHODS: An sXc-1800 RF exposure system was used to produce a GSM signal at 1.8 GHz (217 Hz amplitude-modulated) with the specific absorption rate (SAR) of 1, 2, 3, and 4 W/kg. After 2 h of intermittent exposure, the ROS level was assessed by the fluorescent probe, 2',7'-dichlorodihydrofluorescein diacetate (DCFH-DA). DNA damage to HLECs was examined by alkaline comet assay and the phosphorylated form of histone variant H2AX (gammaH2AX) foci formation assay. RESULTS: After exposure to 1.8 GHz RF for 2 h, HLECs exhibited significant intracellular ROS increase in the 2, 3, and 4 W/kg groups. RF radiation at the SAR of 3 W/kg and 4 W/kg could induce significant DNA damage, examined by alkaline comet assay, which was used to detect mainly single strand breaks (SSBs), while no statistical difference in double strand breaks (DSBs), evaluated by gammaH2AX foci, was found between RF exposure (SAR: 3 and 4 W/kg) and sham exposure groups. When RF was superposed with 2 muT electromagnetic noise could block RF-induced ROS increase and DNA

damage. CONCLUSIONS: DNA damage induced by 1.8 GHz radiofrequency field for 2 h, which was mainly SSBs, may be associated with the increased ROS production. Electromagnetic noise could block RF-induced ROS formation and DNA damage.

**Yariktas M, Doner F, Ozguner F, Gokalp O, Dogru H, Delibas N. Nitric oxide level in the nasal and sinus mucosa after exposure to electromagnetic field. Otolaryngol Head Neck Surg. 132(5):713-716, 2005.**

OBJECTIVE: The purpose of this study was to examine the changes in nitric oxide (NO) level in the nasal and paranasal sinus mucosa after exposure radiofrequency electromagnetic fields (EMF). STUDY DESIGN AND SETTING: Thirty male Sprague-Dawley rats were randomly grouped as follows: EMF group (group I; n, 10), EMF group in which melatonin received (group II; n, 10) and the control (sham operated) group (group III; n, 10). Groups I and II were exposed to a 900 MHz. Oral melatonin was given in group II. Control rats (group III) were also placed in the tube as the exposure groups, but without exposure to EMF. At the end of 2 weeks, the rats were sacrificed, and the nasal and paranasal sinus mucosa dissected. NO was measured in nasal and paranasal mucosa. RESULTS: The nasal and paranasal sinus mucosa NO levels of group I were significantly higher than those of the control group (group III) ( $P < 0.05$). However, there was no statistically significant difference between group II and the control group (group III) regarding NO output ( $P > 0.05$). CONCLUSION: Exposure to EMF released by mobile phones (900 MHz) increase NO levels in the sinus and nasal mucosa. SIGNIFICANCE: Increased NO levels may act as a defense mechanism and presumably related to tissue damage. In addition, melatonin may have beneficial effect to prevent these changes in the mucosa.

**Ye J, Yao K, Lu D, Wu R, Jiang H. Low power density microwave radiation induced early changes in rabbit lens epithelial cells. Chin Med J (Engl) 114(12):1290-1294, 2001.**

OBJECTIVE: To determine whether low power density microwave radiation can induce irreversible changes in rabbit lens epithelial cells (LECs) and the mechanisms of the changes. METHODS: One eye of each rabbit was exposed to 5 mW/cm2 or 10 mW/cm2 power density microwaves for 3 hours, while the contralateral eye served as a control. Annexin V-propidium iodide (PI) two-color flow cytometry (FCM) was used to detect the early changes in rabbit lens epithelial cells after radiation. RESULTS: Lots of rabbit LECs were in the initial phase of apoptosis in the 5 mW/cm2 microwave radiation group. A large number of cells became secondary necrotic cells, and severe damage could be found in the group exposed to 10 mW/cm2 microwave radiation. CONCLUSION: Low power densities of microwave radiation (5 mW/cm2 and 10 mW/cm2) can induce irreversible damage to rabbit LECs. This may be the non-thermal effect of microwave radiation.

**Ye J, Yao K, Zeng Q, Lu D. Changes in gap junctional intercellular communication in rabbits lens epithelial cells induced by low power density microwave radiation. Chin Med J (Engl) 115(12):1873-1876, 2002.**

OBJECTIVE: To demonstrate the changes in gap junctional intercellular communication (GJIC) mediated by low power density microwave radiation in rabbits lens epithelial cells (LECs) and its mechanisms. METHODS: Rabbits' eyes were exposed to 5 mW/cm(2)

and 10 mW/cm(2) power densities of microwave radiation for 3 hours. The fluorescence-recovery-after-photobleaching (FRAP) method was used to determine the GJIC. The localization and function of connexin 43 in LECs was detected by laser scanning confocal microscopy. RESULTS: The GJIC of rabbits LECs was inhibited by microwave radiation especially in the 10 mW/cm(2) irradiated samples. A decrease in connexin 43-positive staining was seen in 5 mW/cm(2) x 3 h treated LECs. Intracellular space accumulation and cytoplasmic internalization were clearly demonstrated in 10 mW/cm(2) group. CONCLUSIONS: Low power densities microwave radiation (5 mW/cm(2) and 10 mW/cm(2)) induces damage to connexin 43 and inhibits the GJIC of rabbits LECs. These changes result in an osmotic imbalance within the lens and induce early cataract. 5 mW/cm(2) or 10 mW/cm(2) microwave radiation is cataractogenic.

**Ye W, Wang F, Zhang W, Fang N, Zhao W, Wang J. Effect of Mobile Phone Radiation on Cardiovascular Development of Chick Embryo. Anat Histol Embryol. 2015 Jul 14. doi: 10.1111/ahe.12188. [Epub ahead of print]**

The biological effects on cardiovascular development of chicken embryos were examined after radiation exposure using mobile phone (900 MHz; specific absorption rate˜1.07 W/kg) intermittently 3 h per day during incubation. Samples were selected by morphological and histological methods. The results showed the rate of embryonic mortality and cardiac deformity increased significantly in exposed group ($P < 0.05$). No any histological pathological changes were observed on Day 5-7 (D5-D7) of incubation. A higher distribution of lipid droplets was unexpectedly present in myocardial tissue from the exposure groups on D10-D13. Soon afterwards, myofilament disruption, atrioventricular valve focal necrosis, mitochondria vacuolization and atrial natriuretic peptide (ANP) decrease appeared on D15-D21 of incubation. Comet assay data showed the haemocyte mean tail in the exposed group was significantly larger than that of the control ($P < 0.01$). The arterial vascular wall of exposed group was thicker ($P < 0.05$) than that of the control on D13, which was reversed to normal in later stages. Our findings suggest that long-term exposure of MPR may induce myocardium pathological changes, DNA damage and increased mortality; however, there was little effect on vascular development.

**Yee KC, Chou CK, Guy AW, Character of the effect of microwave on conduction velocity of frog ventricular muscle. Bioelectromagnetics 15(6):555-561, 1994.**

Thirty-two frog hearts were divided into four groups and placed individually in temperature-controlled waveguides filled with Ringer's solution. The pacemaker was removed, and stimulation was provided at 0.3 Hz by three carbon-loaded Teflon electrodes located on the aorta and the ventricular muscle. Conduction velocity was measured from the difference between two action potentials. One group served as control; the three other groups were exposed for 2 h to pulsed 2,450 MHz microwave fields (10 microseconds, 0.001 duty cycle, 16 Hz modulation) at specific absorption rates (SARs) of 0.003, 2, and 6 W/kg, respectively. No significant difference in conduction velocity was found between the control and the exposed groups.

**Yeolekar ME, Sharma A. Use of mobile phones in ICU--why not ban? J Assoc Physicians India. 52:311-313, 2004.**

Due to the rapid growth of mobile telecommunications it is predicted that by 2005 there will be 1.6 billion mobile phone users worldwide. The usage of cellphones in Intensive Care Units carries with it a high incidence of interference with a number of medical devices like implantable defibrillators, cardioverters, pacemakers, monitors and other important devices like ventilators. It is in this context that this article will throw a light on complications of cellphones use in the Intensive Care Units and various strategies that can be taken to restrict their use in the Intensive Care Units.

**Yildirim MS, Yildirim A, Zamani AG, Okudan N. Effect of mobile phone station on micronucleus frequency and chromosomal aberrations in human blood cells. Genet Couns. 21(2):243-251, 2010.**

The use of mobile telephones has rapidly increased worldwide as well as the number of mobile phone base stations that lead to rise low level radiofrequency emissions which may in turn have possible harm for human health. The national radiation protection board has published the known effects of radio waves exposure on humans living close to mobile phone base stations. However, several studies have claimed that the base station has detrimental effects on different tissues. In this study, we aimed to evaluate the effects of mobile phone base stations on the micronucleus (MN) frequency and chromosomal aberrations on blood in people who were living around mobile phone base stations and healthy controls. Frequency of MN and chromosomal aberrations in study and control groups was 8.96 +/- 3.51 and 6.97 +/- 1.52 (p: 0.16); 0.36 +/- 0.31 and 0.75 +/- 0.61 (p: 0.07), respectively. Our results show that there was not a significant difference of MN frequency and chromosomal aberrations between the two study groups. The results claim that cellular phones and their base stations do not produce important carcinogenic changes.

**Yilmaz F, Dasdag S, Akdag MZ, Kilinc N. Whole-body exposure of radiation emitted from 900 MHz mobile phones does not seem to affect the levels of anti-apoptotic bcl-2 protein. Electromagn Biol Med. 27(1):65-72, 2008.**

The purpose of the present study was to investigate the anti-apoptotic bcl-2 protein in rat brain and testes after whole-body exposure to radiation emitted from 900 MHz cellular phones. Two groups (sham and experimental) of Sprague-Dawley rats of eight rats each were used in the study. Exposure began approximately 10 min after transferring into the exposure cages, a period of time when rats settled down to a prone position and selected a fixed location inside the cage spontaneously. For the experimental group, the phones were in the speech condition for 20 min per day for 1 month. The same procedure was applied to the sham group rats, but the phones were turned off. Immunohistochemical staining of bcl-2 was performed according to the standardized avidin-biotin complex method. The results of this study showed that 20 min of the radiation emitted from 900 MHz cellular phones did not alter anti-apoptotic bcl-2 protein in the brain and testes of rats. We speculate that bcl-2 may not be involved in the effects of radiation on the brain and testes of rats.

**Yilmaz A, Yilmaz N, Serarslan Y, Aras M, Altas M, Ozgür T, Sefil F. The effects of mobile phones on apoptosis in cerebral tissue: an experimental study on rats. Eur Rev Med Pharmacol Sci. 18(7):992-1000, 2014.**

**INTRODUCTION:** The concern about mobile phone effects is increasing as the number of users increasing too. Different studies have different results, so this topic is still open to discussion. Aim of this report was to investigate the effects of the mobile phones on the Bcl-2 gene and p53 proteins in rat brains. **MATERIALS AND METHODS:** In the study group of 10 rats; mobile phones that spread EMW at a frequency between 1900-2100 MHz and Specific Absorption Rate range between 0.005 W/kg and 0.288 W/kg (Dialing mode), 0.004 W/kg and 0.029 W/kg (Calling mode) were attached to rat ears for simulating usage in daily life for 7 times a day during 5 minutes (3 seconds dialing mode, 4 minutes and 47 seconds of calling mode) for a four week period. Sham group (n=10) rats were only immobilized without EMW exposure. Another group of rats (n=10) were counted as control without any application. immunohistopathological examination was performed for p53 and Bcl-2 expression. **RESULTS:** Immunohistopathological examinations revealed that the samples in the study group had more p53 and Bcl-2 positive stained cells and they were stained denser. In both evaluations, these differences between the study and control group were found statistically significant ($p < 0.003$); In Bcl-2 evaluation statistically significant difference was found between study and sham group to ($p < 0.005$); however, the p53 evaluation between the study and the sham group did not show any statistically significant difference ($p > 0.005$). **CONCLUSIONS:** Our results showed that the electro-magnetic waves emitted by the mobile phones may have effect on apoptosis. Besides, obtained data revealed that more realistic application of mobile phones during experiments is more important as expected.

**Yilmaz A, Tumkaya L, Akyildiz K, Kalkan Y, Bodur AF, Sargin F, Efe H, Uydu HA, Yazici ZA. Lasting hepatotoxic effects of prenatal mobile phone exposure. J Matern Fetal Neonatal Med. 30(11):1355-1359, 2017.**

OBJECTIVE: In this study, the livers of rats born to mothers exposed to electromagnetic field (EMF) were examined 60 days postpartum for biochemical and histopathological changes. METHODS: Pregnant rats were exposed to radiation (900 MHz EMF, 24 h/day for 20 days) using a digital signal generator by placing the device centrally under the cage, which formed the study (EMF) group, while untreated matching rats served as controls. Livers and blood were obtained from litters (seven males and seven females) of both groups 60 days after birth, which were used for biochemical and histopathological analyses. RESULTS: There was a significant increase in the levels of malondialdehyde (MDA) ($p < 0.05$) that was accompanied by a significant fall in glutathione (GSH) ($p < 0.01$) in the liver. The serum levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were significantly increased ($p < 0.05$). Histopathologically, the liver sections of the EMF group showed intense degeneration in hepatocytes with cytoplasmic eosinophilic structures, pyknotic nuclei and fibrosis. CONCLUSION: We demonstrate that the intrauterin harmful effects of EMF on the livers of rats persist into adulthood.

**Yogesh S, Abha S, Priyanka S. Mobile usage and sleep patterns among medical students. Indian J Physiol Pharmacol. 58(1):100-103, 2014.**

Exposure of humans to radio frequency electromagnetic field (EMF) both during receiving and transmitting the signals has amplified public and scientific debate about possible adverse effects on human health. The study was designed with the objective of assessing the extent of mobile phone use amongst medical students and finding correlation if any between the hours of usage of mobile to sleep pattern and quality. hundred medical students grouped as cases (n = 57) (> 2 hours/day of mobile usage) and control (n = 43) (≤ 2 hours/day of mobile usage) were examined for their sleep quality & pattern by Pittsburg sleep Quality Index (PSQI). Differences between groups were examined with the Mann Whitney "U" test for proportions (Quantitative values) and with Student't' test for continuous variables. The association of variables was analyzed by Spearman Rank's correlation. Probability was set at < 0.05 as significant. Sleep disturbance, latency and day dysfunction was more in cases especially females. A significant association of hours of usage and sleep indices were observed in both genders (males r = 0.25; p = 0.04, females r = 0.31; p = 0.009). Evening usage of mobile phone in cases showed a statistically significant negative association (-0.606; p = 0.042) with Sleep quality (higher PSQI means sleep deprivation). Students using mobile for > 2 hours/day may cause sleep deprivation and day sleepiness affecting cognitive and learning abilities of medical students.

**Yoon S, Choi JW, Lee E, Ahn H, Kim HS, Choi HD, Kim N. Mobile phone use and risk of glioma: a case-control study in Korea for 2002-2007. Environ Health Toxicol. 2015 Dec 21. doi: 10.5620/eht.e2015015. [Epub ahead of print]**

Objectives: There has been a growing concern about the possible carcinogenic effects of the electromagnetic radiofrequency fields emitted from mobile phones. The purpose of this study was to investigate the association between mobile phone use and the development of gliomas in Korea. Methods: Our study methods were based on the International Interphone study that aimed to evaluate possible adverse effects of mobile phone use. This study included 285 histologically-confirmed Korean patients 15-69 years of age, with gliomas diagnosed between 2002 and 2007 in 9 hospitals. The 285 individually-matched controls were healthy individuals examined at the same hospitals for medical check-ups. Unconditional logistic regression was used to calculate the adjusted odds ratios (OR) and 95% confidence intervals (CIs) for use of mobile phones. Results: For the entire group, there was no significant association between gliomas and regular use of mobile phones, type of mobile phone, lifetime years of use, monthly service fee, and the other exposure indices investigated. Analyses restricted to self-respondents showed similar results. However, in case that the body side for usual mobile phone use agreed with the location of a glioma (ipsilateral use) for all the respondents, the ORs (95% Cis) for the lifetime years of use and cumulative hours of use were 1.25 (0.55-2.88) and 1.77 (0.32-1.84), respectively. The contralateral users showed slightly lower risk than the ipsilateral users. Conclusion: Our results do not support the hypothesis that the use of mobile phones increases the risk of gliomas in Koreans; however, we found a non-significant increase in risks among ipsilateral users. These findings warrant further evaluation for glioma risks among long-term mobile phone users.

**Yoshida Y, Seto T, Ohsu W, Hayashi S, Okazawa T, Nagase H, Yoshida M, Nakamura H, [Endocrine mechanism of placental circulatory disturbances induced by microwave in pregnant rats]. Nippon Sanka Fujinka Gakkai Zasshi 47(2):101-108, 1995.** [Article in Japanese]

Effects of microwaves on fetus and female genital organs remain to be elucidated. To demonstrate the placental circulatory disturbances induced by microwaves and to clarify the endocrine pathogenesis, placental blood flow and five endocrine indicators, i.e., corticosterone (CS), estradiol (E2), progesterone (P), prostaglandin E2 (PGE2) and prostaglandin F2 alpha (PGF2 alpha) were measured in rats exposed to whole-body microwaves with an intensity of 10 mW/cm2 at a frequency of 2,450 MHz. The placental blood flow at 45-90 min after exposure was significantly decreased in the rats exposed to the microwaves. Placental blood flow at 15 and 30 min was increased by pretreatment with intraperitoneal administration of angiotensin II (AII). In contrast, no significant change in placental blood flow was recognized in the AII pretreated rats exposed to the microwaves. An increase in CS and a decrease in E2 were induced by the microwave exposure independent of pretreatment with AII. P was increased by microwave exposure in the rats without pretreatment with AII. PGE2 was not changed by the microwave exposure in the case of either nonpretreatment or pretreatment with AII. PGF2 alpha was increased by the microwave exposure in the rats without pretreatment with AII. The present results indicate that excessive exposure to whole-body microwave disorders pregnancy in terms of placental circulatory dysfunction. The data suggest the involvement of endocrine mechanisms in the decrease in placental blood flow which is induced via a

detrimental effect of microwaves on PGF2 alpha and on pituitary functions such as general emotional stress.

**Yu D, Shen Y, Kuster N, Fu Y, Chiang H. Effects of 900 MHz GSM Wireless Communication Signals on DMBA-Induced Mammary Tumors in Rats. Radiat Res. 165(2):174-180, 2006.**

The purpose of the study was to investigate whether exposure to 900 MHz GSM wireless communication signals enhances mammary tumor development and growth induced by low-dose DMBA. Five hundred female Sprague-Dawley rats were treated with a single dose of 35 mg/kg DMBA and then divided into five groups in a blinded fashion: one cage control group and four exposure groups, including three microwave exposure groups and one sham exposure with specific absorption rates (SARs) of 4.0, 1.33, 0.44 and 0 W/kg, respectively. Exposure started on the day after DMBA administration and lasted 4 h/day, 5 days/week for 26 weeks. Rats were weighed and palpated weekly for the presence of tumors and were killed humanely at the end of the 26-week exposure period. All mammary glands were examined histologically. There were no statistically significant differences in body weight between sham- and GSM microwave-exposed groups. No significant differences in overall mammary tumor incidence, latency to tumor onset, tumor multiplicity, or tumor size were observed between microwave- and sham-exposed groups. There was a tendency for reduction of mammary adenocarcinoma incidence in the lowest microwave exposure group (0.44 W/ kg) compared with the sham-exposed group (P = 0.058). Additionally, a higher incidence of adenocarcinoma was noticed in the 4.0 W/kg group from the 15th to 26th weeks, especially in the 19th week (P = 0.358 compared to sham). However, neither tendency was statistically significant; thus this study does not provide evidence that GSM microwave exposure promotes mammary tumor development in rats. In the present study there were significant differences between the cage controls and the experimental groups (sham and exposure). Body weight and mammary tumor (malignant plus benign) incidence in the cage control group were significantly higher than in the sham- and GSM microwave-exposed groups. The latency to the mammary tumor onset was significantly shorter in the cage control group than in the other groups.

**Yu D, Zhang R, Liu Q. Influence of dentures on SAR in the visible Chinese human head voxel phantom exposed to a mobile phone at 900 and 1800 MHz. Bioelectromagnetics. 33(6):508-517, 2012.**

To investigate the influence of dentures on electromagnetic energy absorption during the daily use of a mobile phone, a high-resolution head phantom based on the Visible Chinese Human dataset was reconstructed. Simulations on phantoms with various dentures were performed by using the finite-difference time-domain method with a 0.47 wavelength dipole antenna and a mobile phone model as radiation sources at 900 and 1800 MHz. The Specific energy Absorption Rate (SAR) values including 1 and 10 g average SAR values were assessed. When the metallic dental crowns with resonance lengths of approximately one-third to one-half wavelength in the tissue nearby are parallel to the radiation source, up to 121.6% relative enhancement for 1 g average SAR and 17.1% relative enhancement for 10 g average SAR are observed due to the resonance effect in energy absorption. When the radiation sources operate in the normal configuration, the 10 g average SAR values are still in compliance with the basic

restrictions established by the Institute of Electrical and Electronic Engineers (IEEE) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP), indicating that the safety limits will not be challenged by the usage of dentures.

**Yu Y, Yao K, Wu W, Wang K, Chen G, Lu D. Effects of exposure to 1.8 GHz radiofrequency field on the expression of Hsps and phosphorylation of MAPKs in human lens epithelial cells. Cell Res. 18(12):1233-1235, 2008.**

**(No abstract available)** Last sentence of discussion:

**"**Our results suggest that exposure to RF of wireless communications can induce expression of Hsp27 and Hsp70 and the activation of ERK1/2 and JNK1/2 in human LECs. The induction of Hsp27 and Hsp70, by a non-thermal stress, together with the activation of signal transduction pathways, provides reliable and sensitive biomarkers that could serve as the basis for improved mobile phone safety guidelines."

**Yu Y, Yao K. Non-thermal cellular effects of lowpower microwave radiation on the lens and lens epithelial cells. J Int Med Res. 38(3):729-736, 2010.**

Because of the increased use of modern radiofrequency devices, public concern about the possible health effects of exposure to microwave radiation has arisen in many countries. It is well established that high-power microwave radiation can induce cataracts via its thermal effects. It remains unclear whether low-power microwave radiation, especially at levels below the current exposure limits, is cataractogenic. This review summarizes studies on the biological effects of low-power microwave radiation on lens and lens epithelial cells (LECs). It has been reported that exposure affects lens transparency, alters cell proliferation and apoptosis, inhibits gap junctional intercellular communication, and induces genetic instability and stress responses in LECs. These results raise the question of whether the ambient microwave environment can induce non-thermal effects in the lens and whether such effects have potential health consequences. Further in vivo studies on the effects on the lens of exposure to low-power microwave radiation are needed.

**Yuan K, Qin W, Wang G, Zeng F, Zhao L, Yang X, Liu P, Liu J, Sun J, von Deneen KM, Gong Q, Liu Y, Tian J. Microstructure abnormalities in adolescents with internet addiction disorder. PLoS One.6(6):e20708, 2011.**

**BACKGROUND:** Recent studies suggest that internet addiction disorder (IAD) is associated with structural abnormalities in brain gray matter. However, few studies have investigated theeffects of internet addiction on the microstructural integrity of major neuronal fiber pathways, and almost no studies have assessed the microstructural changes with the duration of internet addiction. **METHODOLOGY/PRINCIPAL FINDINGS:** We investigated the morphology of the brain in adolescents with IAD (N = 18) using an optimized voxel-based morphometry (VBM) technique, and studied the white matter fractional anisotropy (FA) changes using the diffusion tensor imaging (DTI) method, linking these brain structural measures to the duration of IAD. We provided evidences demonstrating the multiple structural changes of the brain in IAD subjects. VBM results indicated the decreased gray matter volume in the bilateral dorsolateral

prefrontal cortex (DLPFC), the supplementary motor area (SMA), the orbitofrontal cortex (OFC), the cerebellum and the left rostral ACC (rACC). DTI analysis revealed the enhanced FA value of the left posterior limb of the internal capsule (PLIC) and reduced FA value in the white matter within the right parahippocampal gyrus (PHG). Gray matter volumes of the DLPFC, rACC, SMA, and white matter FA changes of the PLIC were significantly correlated with the duration of internet addiction in the adolescents with IAD.**CONCLUSIONS:** Our results suggested that long-term internet addiction would result in brain structural alterations, which probably contributed to chronic dysfunction in subjects with IAD. The current study may shed further light on the potential brain effects of IAD.

**Yuasa K, Arai N, Okabe S, Tarusawa Y, Nojima T, Hanajima R, Terao Y, Ugawa Y. Effects of thirty minutes mobile phone use on the human sensory cortex. Clin Neurophysiol.117(4):900-905, 2006.**

OBJECTIVE: To investigate whether the pulsed high-frequency electromagnetic field (pulsed EMF) emitted by a mobile phone for 30min has short-term effects on human somatosensory evoked potentials (SEPs). METHODS: We studied somatosensory evoked potentials (SEPs) in 12 normal volunteers before and after exposure to the electromagnetic field emitted by a mobile phone for 30min compared with sham exposure. In 7 out of the subjects we also measured the recovery function of the SEP. RESULTS: Neither SEPs nor their recovery function was affected by exposure to pulsed EMF emitted by a mobile phone or sham phone use. CONCLUSIONS: As far as the present methods are concerned, 30min mobile phone use has no short-term effects on the human sensory cortex. SIGNIFICANCE: This is the first study of SEPs after electromagnetic exposure by the mobile phone. Our results support the safety of the mobile phone.

**Yüksel M, Nazıroğlu M, Özkaya MO. Long-term exposure to electromagnetic radiation from mobile phones and Wi-Fi devices decreases plasma prolactin, progesterone, and estrogen levels but increases uterine oxidative stress in pregnant rats and their offspring. Endocrine. 2015 Nov 14. [Epub ahead of print]**

We investigated the effects of mobile phone (900 and 1800 MHz)- and Wi-Fi (2450 MHz)-induced electromagnetic radiation (EMR) exposure on uterine oxidative stress and plasma hormone levels in pregnant rats and their offspring. Thirty-two rats and their forty newborn offspring were divided into the following four groups according to the type of EMR exposure they were subjected to: the control, 900, 1800, and 2450 MHz groups. Each experimental group was exposed to EMR for 60 min/day during the pregnancy and growth periods. The pregnant rats were allowed to stand for four generations (total 52 weeks) before, plasma and uterine samples were obtained. During the 4th, 5th, and 6th weeks of the experiment, plasma and uterine samples were also obtained from the developing rats. Although uterine lipid peroxidation increased in the EMR groups, uterine glutathione peroxidase activity (4th and 5th weeks) and plasma prolactin levels (6th week) in developing rats decreased in these groups. In the maternal rats, the plasma prolactin, estrogen, and progesterone levels decreased in the EMR groups, while the plasma total oxidant status, and body temperatures increased. There were no changes in the levels of

reduced glutathione, total antioxidants, or vitamins A, C, and E in the uterine and plasma samples of maternal rats. In conclusion, although EMR exposure decreased the prolactin, estrogen, and progesterone levels in the plasma of maternal rats and their offspring, EMR-induced oxidative stress in the uteri of maternal rats increased during the development of offspring. Mobile phone- and Wi-Fi-induced EMR may be one cause of increased oxidative uterine injury in growing rats and decreased hormone levels in maternal rats. TRPV1 cation channels are the possible molecular pathways responsible for changes in the hormone, oxidative stress, and body temperature levels in the uterus of maternal rats following a year-long exposure to electromagnetic radiation exposure from mobile phones and Wi-Fi devices. It is likely that TRPV1-mediated $Ca^{2+}$ entry in the uterus of pregnant rats involves accumulation of oxidative stress and opening of mitochondrial membrane pores that consequently leads to mitochondrial dysfunction, substantial swelling of the mitochondria with rupture of the outer membrane and release of oxidants such as superoxide ($O_2^-$) and hydrogen peroxide ($H_2O_2$). The superoxide radical is converted to $H_2O_2$ by superoxide dismutase (SOD) enzyme. Glutathione peroxidase (GSH-Px) is an important antioxidant enzyme for removing lipid hydroperoxides and hydrogen peroxide and it catalyzes the reduction of $H_2O_2$ to water.

**Yurekli AI, Ozkan M, Kalkan T, Saybasili H, Tuncel H, Atukeren P, Gumustas K, Seker S. GSM Base Station Electromagnetic Radiation and Oxidative Stress in Rats. Electromagn Biol Med. 2006;25(3):177-188, 2006.**

The ever increasing use of cellular phones and the increasing number of associated base stations are becoming a widespread source of nonionizing electromagnetic radiation. Some biological effects are likely to occur even at low-level EM fields. In this study, a gigahertz transverse electromagnetic (GTEM) cell was used as an exposure environment for plane wave conditions of far-field free space EM field propagation at the GSM base transceiver station (BTS) frequency of 945 MHz, and effects on oxidative stress in rats were investigated. When EM fields at a power density of 3.67 W/m2 (specific absorption rate = 11.3 mW/kg), which is well below current exposure limits, were applied, MDA (malondialdehyde) level was found to increase and GSH (reduced glutathione) concentration was found to decrease significantly ($p < 0.0001$). Additionally, there was a less significant ($p = 0.0190$) increase in SOD (superoxide dismutase) activity under EM exposure.

**Zajdel R, Zajdel J, Zwolińska A, Smigielski J, Beling P, Cegliński T, Nowak D. The sound of a mobile phone ringing affects the complex reaction time of its owner.Arch Med Sci.8(5):892-898, 2012.**

INTRODUCTION: Mobile phone conversation decreases the ability to concentrate and impairs the attention necessary to perform complex activities, such as driving a car. Does the ringing sound of a mobile phone affect the driver's ability to perform complex sensory-motor activities? We compared a subject's reaction time while performing a test either with a mobile phone ringing or without.MATERIAL AND METHODS: The examination was performed on a PC-based reaction time self-constructed system Reactor. The study group consisted of 42 healthy students. The protocol included instruction, control without phone and a proper session with subject's mobile phone ringing. The terms of the study

were standardised.RESULTS: There were significant differences ($p < 0.001$) in reaction time in control (597 ms), mobile (633 ms) and instruction session (673 ms). The differences in female subpopulation were also significant ($p < 0.01$). Women revealed the longest reaction time in instruction session (707 ms), were significantly quicker in mobile (657 ms, $p < 0.01$) and in control session (612 ms, $p < 0.001$). In men, the significant difference was recorded only between instruction (622 ms) and control session (573 ms, $p < 0.01$). The other differences were not significant ($p > 0.08$). Men proofed to complete significantly quicker than women in instruction ($p < 0.01$) and in mobile session ($p < 0.05$). Differences amongst the genders in control session was not significant ($p > 0.05$).CONCLUSIONS: The results obtained proofed the ringing of a phone exerts a significant influence on complex reaction time and quality of performed task.

**Zalata A, El-Samanoudy AZ, Shaalan D, El-Baiomy Y, Mostafa T. In vitro effect of cell phone radiation on motility, DNA fragmentation and clusterin gene expression in human sperm. Int J Fertil Steril. 9(1):129-136, 2015.**

BACKGROUND: Use of cellular phones emitting radiofrequency electromagnetic field (RF-EMF) has been increased exponentially and become a part of everyday life. This study aimed to investigate the effects of in vitro RF-EMF exposure emitted from cellular phones on sperm motility index, sperm DNA fragmentation and seminal clusterin (CLU) gene expression. MATERIALS AND METHODS: In this prospective study, a total of 124 semen samples were grouped into the following main categories: i. normozoospermia (N, n=26), ii. asthenozoospermia (A, n=32), iii. asthenoteratozoospermia (AT, n=31) and iv. oligoasthenoteratozoospermia (OAT, n=35). The same semen samples were then divided into two portions non-exposed and exposed samples to cell phone radiation for 1 hour. Before and immediately after exposure, both aliquots were subjected to different assessments for sperm motility, acrosin activity, sperm DNA fragmentation and CLU gene expression. Statistical differences were analyzed using paired t student test for comparisons between two sub-groups where $p<0.05$ was set as significant. RESULTS: There was a significant decrease in sperm motility, sperm linear velocity, sperm linearity index, and sperm acrosin activity, whereas there was a significant increase in sperm DNA fragmentation percent, CLU gene expression and CLU protein levels in the exposed semen samples to RF-EMF compared with non-exposed samples in OAT>AT>A>N groups, respectively ($p<0.05$). CONCLUSION: Cell phone emissions have a negative impact on exposed sperm motility index, sperm acrosin activity, sperm DNA fragmentation and seminal CLU gene expression, especially in OAT cases.

**Zareen N, Khan MY, Minhas LA. Derangement of chick embryo retinal differentiation caused by radiofrequency electromagnetic fields. Congenit Anom (Kyoto). 49(1):15-19, 2009.**

The possible adverse effects of radiofrequency electromagnetic fields (EMF) emitted from mobile phones present a major public concern. Biological electrical activities of the human body are vulnerable to interference from oscillatory aspects of EMF, which affect fundamental cellular activities, in particular, the highly active development process of embryos. Some studies highlight the possible health hazards of EMF, while others contest the hypothesis of biological impact of EMF. The present study was designed to

observe the histomorphological effects of EMF emitted by a mobile phone on the retinae of developing chicken embryos. Fertilized chicken eggs were exposed to a ringing mobile set on silent tone placed in the incubator at different ages of development. After exposure for the scheduled duration the retinae of the embryos were dissected out and processed for histological examination. The control and experimental embryos were statistically compared for retinal thickness and epithelial pigmentation grades. Contrasting effects of EMF on the retinal histomorphology were noticed, depending on the duration of exposure. The embryos exposed for 10 post-incubation days exhibited decreased retinal growth and mild pigmentation of the epithelium. Growth retardation reallocated to growth enhancement on increasing EMF exposure for 15 post-incubation days, with a shift of pigmentation grade from mild to intense. We conclude that EMF emitted by a mobile phone cause derangement of chicken embryo retinal differentiation.

**Zareen N, Khan MY, Minhas LA. Dose related shifts in the developmental progress of chick embryos exposed to mobile phone induced electromagnetic fields. J Ayub Med Coll Abbottabad.21(1):130-134, 2009.**

BACKGROUND: The possible adverse effects of Electromagnetic Fields (EMFs) emitted from mobile phones present a major public concern today. Some studies indicate EMFs effects on genes, free radical production, immunological and carcinogenic effects. On the other hand there are studies which do not support the hypothesis of any biological impacts of EMFs. This study was designed to observe the effects of mobile phone induced EMFs on survival and general growth and development of chick embryo, investigating dose-response relationship if any. METHODS: This was an experimental study in which developing chick embryos were exposed to different doses of mobile phone induced EMFs. For this purpose a mobile phone was placed in the incubator in the centre of fertilised eggs in silent ringing mode and was 'rung' upon from any other line or cell phone. After incubation for 10 or 15 days the eggs were opened and the developmental mile-stones of the surviving embryos were compared with the non exposed subgroup. RESULTS: EMFs exposure significantly decreased the survivability of the chick embryos. The lower doses of EMFs caused growth retardation. However, this effect of growth retardation reallocated to partial growth enhancement on increasing the dose of EMFs and shifted over to definite growth enhancement on further raising the dose. CONCLUSION: There is an adverse effect of EMFs exposure on embryo survivability. Chick embryos developmental process is influenced by EMFs. However, these effects are variable depending upon the dose of EMFs exposure.

**Zeng QL, Weng Y, Chen GD, Lu DQ, Chiang H, Xu ZP [Effects of GSM 1800 MHz radiofrequency electromagnetic fields on protein expression profile of human breast cancer cell MCF-7.] Zhonghua Yu Fang Yi Xue Za Zhi. 40(3):153-158, 2006.** [Article in Chinese]

OBJECTIVE: To study the effects of GSM 1800 MHz radiofrequency electromagnetic fields (RF EMF) exposure on protein expression profile of human breast cancer cell line (MCF-7), as to exploring the possible effects on normal cell physiological function. METHODS: MCF-7 cells were continuously or intermittently (5 minutes field on followed by 10 minutes off) exposed to RF EMF for different duration (1 hour, 3 hours, 6 hours, 12 hours, or 24 hours) at an average specific absorption rate (SAR) of 3.5 W/kg. The

extracted proteins were separated by 2-dimensional electrophoresis and the protein-spot distribution of the sliver-stained gels was analyzed by using PDQuest software 7.1. Each experiment was repeated three times. RESULTS: On the average, around 1100 proteins were detected using pH 4 - 7 IPG strip. There were no differential proteins found under continuous exposure at SAR of 3.5 W/kg for 6 hours. Under other exposure conditions, we found various differentially expressed proteins in exposure groups as compared with the sham-exposed controls. Especially in 3 hours intermittent exposure and 12 hours continuous exposure, eighteen and seven differential proteins were detected, respectively. The categories and functions of these differentially expressed proteins were analyzed by searching of SWISS-PROT protein database, which suggested that these proteins should be related to the functions of biosynthesization, signal transduction, and DNA damage and repair. CONCLUSIONS: Data indicated that the protein expression changes induced by RF radiation might depend on exposure duration and mode. Many biological processes might be affected by RF exposure.

**Zeng Q, Chen G, Weng Y, Wang L, Chiang H, Lu D, Xu Z. Effects of Global System for Mobile Communications 1800 MHz radiofrequency electromagnetic fields on gene and protein expression in MCF-7 cells. Proteomics.6(17):4732-4738, 2006.**

Despite many studies over a decade, it still remains ambiguous as to the real biological effects induced by radiofrequency electromagnetic fields (RF EMF) utilized in mobile telephony. Here we investigated global gene and protein responses to RF EMF simulating the Global System for Mobile Communications (GSM) 1800 MHz signal in human breast cancer cell line MCF-7 using genomic and proteomic approaches. GeneChip analysis identified a handful of consistent changed genes after exposure to RF EMF at specific absorption rates (SAR) of up to 3.5 W/kg for 24 h. However, these differentially transcribed genes could not be further confirmed by real-time RT-PCR assay. Meanwhile, systematic proteome analysis of the MCF-7 cells revealed that a few but different proteins were differentially expressed under continuous or intermittent RF EMF exposure at SAR of 3.5 W/kg for 24 h or less, implying that the observed effects might have occurred by chance. Overall, the present study does not provide convincing evidence that RF EMF exposure under current experimental conditions can produce distinct effects on gene and protein expression in the MCF-7 cells.

**Zeni, O., Schiavoni, A. S., Sannino, A., Antolini, A., Forigo, D., Bersani, F. and Scarfi, M. R. Lack of Genotoxic Effects (Micronucleus Induction) in Human Lymphocytes Exposed In Vitro to 900 MHz Electromagnetic Fields. Radiat. Res. 160, 152-158, 2003.**

In the present study, we investigated the induction of genotoxic effects in human peripheral blood lymphocytes after exposure to electromagnetic fields used in mobile communication systems (frequency 900 MHz). For this purpose, the incidence of micronuclei was evaluated by applying the cytokinesis-block micronucleus assay. Cytotoxicity was also investigated using the cytokinesis-block proliferation index. The experiments were performed on peripheral blood from 20 healthy donors, and several conditions were tested by varying the duration of exposure, the specific absorption rate (SAR), and the signal [continuous-wave (CW) or GSM (Global System of Mobile

Communication) modulated signal]. The following exposures were carried out: (1) CW intermittent exposure (SAR = 1.6 W/kg) for 6 min followed by a 3-h pause (14 on/off cycles); (2) GSM signal, intermittent exposure as described in (1); (3) GSM signal, intermittent exposure as described in (1) 24 h before stimulation with phytohemagglutinin (8 on/off cycles); (4) GSM signal, intermittent exposure (SAR = 0.2 W/kg) 1 h per day for 3 days. The SARs were estimated numerically. No statistically significant differences were detected in any case in terms of either micronucleus frequency or cell cycle kinetics.

**Zeni O, Romano M, Perrotta A, Lioi MB, Barbieri R, d'Ambrosio G, Massa R, Scarfi MR. Evaluation of genotoxic effects in human peripheral blood leukocytes following an acute in vitro exposure to 900 MHz radiofrequency fields. Bioelectromagnetics. 26(4):258-265, 2005.**

Human peripheral blood leukocytes from healthy volunteers have been employed to investigate the induction of genotoxic effects following 2 h exposure to 900 MHz radiofrequency radiation. The GSM signal has been studied at specific absorption rates (SAR) of 0.3 and 1 W/kg. The exposures were carried out in a waveguide system under strictly controlled conditions of both dosimetry and temperature. The same temperature conditions (37.0 ± 0.1 degrees C) were realized in a second waveguide, employed to perform sham exposures. The induction of DNA damage was evaluated in leukocytes by applying the alkaline single cell gel electrophoresis (SCGE)/comet assay, while structural chromosome aberrations and sister chromatid exchanges were evaluated in lymphocytes stimulated with phytohemagglutinin. Alterations in kinetics of cell proliferation were determined by calculating the mitotic index. Positive controls were also provided by using methyl methanesulfonate (MMS) for comet assay and mitomycin-C (MMC), for chromosome aberration, or sister chromatid exchange tests. No statistically significant differences were detected in exposed samples in comparison with sham exposed ones for all the parameters investigated. On the contrary, the positive controls gave a statistically significant increase in DNA damage in all cases, as expected. Thus the results obtained in our experimental conditions do not support the hypothesis that 900 MHz radiofrequency field exposure induces DNA damage in human peripheral blood leukocytes in this range of SAR.

**Zeni O, Di Pietro R, d'Ambrosio G, Massa R, Capri M, Naarala J, Juutilainen, J, Scarfi M R. Formation of reactive oxygen species in L929 cells after exposure to 900 MHz RF radiation with and without Co-exposure to 3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone. Radiat. Res. 167, 306-311, 2007.**

The aim of this study was to investigate the induction of reactive oxygen species in murine L929 fibrosarcoma cells exposed to radiofrequency (RF) radiation at 900 MHz, with or without co-exposure to 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX), a potent environmental carcinogen produced during chlorination of drinking water. Both continuous-wave and GSM mobile phone signals were applied for 10 or 30 min at specific absorption rates of 0.3 and 1 W/kg. Simultaneous sham exposures were performed for each exposure condition. MX treatment was performed at a subtoxic level of 500 muM, and the RF-field exposure was carried out during the first 10 or 30 min of the chemical treatment. The formation of reactive oxygen species was followed soon after the exposure and at different harvesting

times until 1 h after RF-field treatment. The studied provided no indication that 900 MHz RF-field exposure, either alone or in combination with MX, induced formation of reactive oxygen species under any of the experimental conditions investigated. In contrast, exposure to MX resulted in a statistically significant increase in the formation of reactive oxygen species for all the treatment durations investigated, confirming that MX is an inductor of oxidative stress in L929 cells.

**Zeni O, Schiavoni A, Perrotta A, Forigo D, Deplano M, Scarfi MR. Evaluation of genotoxic effects in human leukocytes after in vitro exposure to 1950 MHz UMTS radiofrequency field.Bioelectromagnetics.29(3):177-184, 2008.**

In the present study the third generation wireless technology of the Universal Mobile Telecommunication System (UMTS) signal was investigated for the induction of genotoxic effects in human leukocytes. Peripheral blood from six healthy donors was used and, for each donor, intermittent exposures (6 min RF on, 2 h RF off) at the frequency of 1950 MHz were conducted at a specific absorption rate of 2.2 W/kg. The exposures were performed in a transverse electro magnetic (TEM) cell hosted in an incubator under strictly controlled conditions of temperature and dosimetry. Following long duration intermittent RF exposures (from 24 to 68 h) in different stages of the cell cycle, micronucleus formation was evaluated by applying the cytokinesis block micronucleus assay, which also provides information on cell division kinetics. Primary DNA damage (strand breaks/alkali labile sites) was also investigated following 24 h of intermittent RF exposures, by applying the alkaline single cell gel electrophoresis (SCG)/comet assay. Positive controls were included by treating cell cultures with Mitomycin-C and methylmethanesulfonate for micronucleus and comet assays, respectively. The results obtained indicate that intermittent exposures of human lymphocytes in different stages of cell cycle do not induce either an increase in micronucleated cells, or change in cell cycle kinetics; moreover, 24 h intermittent exposures also fail to affect DNA structure of human leukocytes soon after the exposures, likely indicating that repairable DNA damage was not induced.

**Zeni O, Sannino A, Romeo S, Massa R, Sarti M, Reddy AB, Prihoda TJ, Vijayalaxmi, Scarfì MR. Induction of an adaptive response in human blood lymphocytes exposed to radiofrequencyfields: influence of the universal mobile telecommunication system (UMTS) signal and the specific absorption rate. Mutat Res. 747(1):29-35, 2012.**

The induction of an adaptive response (AR) was examined in human peripheral blood lymphocytes exposed to non-ionizing radiofrequencyfields (RF). Cells from nine healthy human volunteers were stimulated for 24h with phytohaemagglutinin and then exposed for 20h to an adaptive dose (AD) of a 1950MHz RF UMTS (universal mobile telecommunication system) signal used for mobile communications, at different specific absorption rates (SAR) of 1.25, 0.6, 0.3, and 0.15W/kg. This was followed by treatment of the cells at 48h with a challenge dose (CD) of 100ng/ml mitomycin C (MMC). Lymphocytes were collected at the end of the 72h total culture period. The cytokinesis-block method was used to record the frequency of micronuclei (MN) as genotoxicity end-point. When lymphocytes from six donors were pre-exposed to RF at 0.3W/kg SAR and then treated with MMC, these cells showed a significant

reduction in the frequency of MN, compared with the cells treated with MMC alone; this result is indicative of induction of AR. The results from our earlier study indicated that lymphocytes that were stimulated for 24h, exposed for 20h to a 900MHz RF GSM (global system for mobile communication) signal at 1.25W/kg SAR and then treated with 100ng/ml MMC, also exhibited AR. These overall data suggest that the induction of AR depends on RF frequency, type of the signal and SAR. Further characterization of RF-induced AR is in progress.

**Zhang DY, Xu ZP, Chiang H, Lu DQ, Zeng QL. [Effects of GSM 1800 MHz radiofrequency electromagnetic fields on DNA damage in Chinese hamster lung cells.] Zhonghua Yu Fang Yi Xue Za Zhi. 40(3):149-152, 2006.** [Article in Chinese]

OBJECTIVE: To study the effects of GSM 1800 MHz radiofrequency electromagnetic fields (RF EMF) on DNA damage in Chinese hamster lung (CHL) cells. METHODS: The cells were intermittently exposed or sham-exposed to GSM 1800 MHz RF EMF (5 minutes on/10 minutes off) at a special absorption rate (SAR) of 3.0 W/kg for 1 hour or 24 hours. Meanwhile, cells exposed to 2-acetaminofluorene, a DNA damage agent, at a final concentration of 20 mg/L for 2 hours were used as positive control. After exposure, cells were fixed by using 4% paraformaldehyde and processed for phosphorylated form of H2AX (gammaH2AX) immunofluorescence measurement. The primary antibody used for immunofluorescence was mouse monoclonal antibody against gammaH2AX and the secondary antibody was fluorescein isothiocyanate (FITC)-conjugated goat anti-mouse IgG. Nuclei were counterstained with 4, 6-diamidino-2-phenylindole (DAPI). The gammaH2AX foci and nuclei were visualized with an Olympus AX70 fluorescent microscope. Image Pro-Plus software was used to count the gammaH2AX foci in each cell. For each exposure condition, at least 50 cells were selected to detect gammaH2AX foci. Cells were classified as positive when more than five foci were detected. The percentage of gammaH2AX foci positive cells was adopted as the index of DNA damage. RESULTS: The percentage of gammaH2AX foci positive cell of 1800 MHz RF EMF exposure for 24 hours (37.9 +/- 8.6)% or 2-acetylaminofluorene exposure (50.9 +/- 9.4)% was significantly higher compared with the sham-exposure (28.0 +/- 8.4)%. However, there was no significant difference between the sham-exposure and RF EMF exposure for 1 hour (31.8 +/- 8.7)%. CONCLUSION: 1800 MHz RF EMF (SAR, 3.0 W/kg) for 24 hours might induce DNA damage in CHL cells.

**Zhang G, Yan H, Chen Q, Liu K, Ling X, Sun L, Zhou N, Wang Z, Zou P, Wang X, Tan L, Cui Z, Zhou Z, Liu J, Ao L, Cao J. Effects of cell phone use on semen parameters: Results from the MARHCS cohort study in Chongqing, China. Environ Int. 2016 Mar 4;91:116-121. doi: 10.1016/j.envint.2016.02.028. [Epub ahead of print]**

Epidemiological and experimental evidence for detrimental effects of cell phone use on semen quality is still equivocal. And that recruiting participants from infertility clinic not from general population may raise the possibility of a selection bias. To investigate effects of cell phone use on semen parameters in a general population, we screened and

documented the cell phone use information of 794 young men from the Male Reproductive Health in Chongqing College students (MARHCS) cohort study in 2013, followed by 666 and 568 in 2014 and 2015, respectively. In the univariate regression analyses, we found that the daily duration of talking on the cell phone was significantly associated with decreased semen parameters, including sperm concentration [β coefficient=-6.32% per unit daily duration of talking on the cell phone (h); 95% confidence interval (CI), -11.94, -0.34] and total sperm count (-8.23; 95% CI, -14.38, -1.63) in 2013; semen volume (-8.37; 95% CI, -15.93, -0.13) and total sperm count (-16.59; 95% CI, -29.91, -0.73) in 2015]. Internet use via cellular networks was also associated with decreased sperm concentration and total sperm counts in 2013 and decreased semen volume in 2015. Multivariate analyses were used to adjust for the effects of potential confounders, and significant negative associations between internet use and semen parameters remained. Consistent but nonsignificant negative associations between talking on the cell phone and semen parameters persisted throughout the three study years, and the negative association was statistically significant in a mixed model that considered all three years of data on talking on the cell phone and semen quality. Our results showed that certain aspects of cell phone use may negatively affect sperm quality in men by decreasing the semen volume, sperm concentration, or sperm count, thus impairing male fertility.

**Zhang J, Sumich A, Wang GY. Acute effects of radiofrequency electromagnetic field emitted by mobile phone on brain function. Bioelectromagnetics. 38(5):329-338, 2017.**

Due to its attributes, characteristics, and technological resources, the mobile phone (MP) has become one of the most commonly used communication devices. Historically, ample evidence has ruled out the substantial short-term impact of radiofrequency electromagnetic field (RF-EMF) emitted by MP on human cognitive performance. However, more recent evidence suggests potential harmful effects associated with MP EMF exposure. The aim of this review is to readdress the question of whether the effect of MP EMF exposure on brain function should be reopened. We strengthen our argument focusing on recent neuroimaging and electroencephalography studies, in order to present a more specific analysis of effects of MP EMF exposure on neurocognitive function. Several studies indicate an increase in cortical excitability and/or efficiency with EMF exposure, which appears to be more prominent in fronto-temporal regions and has been associated with faster reaction time. Cortical excitability might also underpin disruption to sleep. However, several inconsistent findings exist, and conclusions regarding adverse effects of EMF exposure are currently limited. It also should be noted that the crucial scientific question of the effect of longer-term MP EMF exposure on brain function remains unanswered and essentially unaddressed.

**Zhang JP, Zhang KY, Guo L, Chen QL, Gao P, Wang T, Li J, Guo GZ, Ding GR. Effects of 1.8 GHz Radiofrequency Fields on the Emotional Behavior and Spatial Memory of Adolescent Mice. Int J Environ Res Public Health. 14(11), 2017. pii: E1344. doi: 10.3390/ijerph14111344.**

The increasing use of mobile phones by teenagers has raised concern about the cognitive effects of radiofrequency (RF) fields. In this study, we investigated the effects of 4-week exposure to a 1.8 GHz RF field on the emotional behavior and spatial memory of adolescent male mice. Anxiety-like behavior was evaluated by open field test (OFT) and elevated plus maze (EPM) test, while depression-like behavior was evaluated by sucrose preference test (SPT), tail suspension test (TST) and forced swim test (FST). The spatial learning and memory ability were evaluated by Morris water maze (MWM) experiments. The levels of amino acid neurotransmitters were determined by liquid chromatography-mass spectrometry (LC-MS). The histology of the brain was examined by hematoxylin-eosin (HE) staining. It was found that the depression-like behavior, spatial memory ability and histology of the brain did not change obviously after RF exposure. However, the anxiety-like behavior increased in mice, while, the levels of γ-aminobutyric acid (GABA) and aspartic acid (Asp) in cortex and hippocampus significantly decreased after RF exposure. These data suggested that RF exposure under these conditions do not affect the depression-like behavior, spatial memory and brain histology in adolescent male mice, but it may however increase the level of anxiety, and GABA and Asp were probably involved in this effect.

**Zhang KY, Xu H, Du L, Xing JL, Zhang B, Bai QS, Xu YQ, Zhou YC, Zhang JP, Zhou Y, Ding GR. Enhancement of X-ray Induced Apoptosis by Mobile Phone-Like Radio-Frequency Electromagnetic Fields in Mouse Spermatocyte-Derived Cells. Int J Environ Res Public Health. 2017 Jun 7;14(6). pii: E616. doi: 10.3390/ijerph14060616.**

To explore the combined effects of environmental radio-frequency (RF) field and X-ray, mouse spermatocyte-derived (GC-1) cells were exposed to 1950 MHz RF field at specific absorption rate (SAR) of 3 W/kg for 24 h combined with or without X-ray irradiation at 6 Gy. After treatment, the cell proliferation level was determined by 3-(4,5-dimethyl-2-thiazolyl)-2,5-diphenyl-2-H-tetrazolium bromide (MTT) Assay and 5-Bromo-2-deoxy Uridine (BrdU) enzyme linked immunosorbent (ELISA) Assay. The apoptosis level was detected by annexin V flow cytometry assay, transferase-mediated deoxyuridine triphosphate-biotin nick end labeling (TUNEL) Assay and Caspase-3 Activity Assay. It was found that the proliferation and apoptosis level did not change in GC-1 cells after RF exposure alone. However, compared with the X-ray group, the proliferation level significantly decreased and the apoptotic rate significantly increased in the RF+X-ray group. Moreover, a significant decrease in Bcl-2 protein expression and increase in Bax protein expression were observed. The findings suggested that RF exposure at SAR of 3 W/kg did not affect apoptosis and proliferation in GC-1 cells by itself, but that it did enhance the effects of X-ray induced proliferation inhibition and apoptosis, in which B-cell lymphoma-2 (Bcl-2) and Bcl-2 associated X protein (Bax) might be involved.

**Zhang MB, He JL, Jin LF, Lu DQ. Study of low-intensity 2450-MHz microwave exposure enhancing the genotoxic effects of mitomycin C using micronucleus test and comet assay in vitro. Biomed Environ Sci 15(4):283-290, 2002.**

OBJECTIVE: To determine the interaction between 2450-MHz microwaves (MW)

radiation and mitomycin C (MMC). METHODS: The synergistic genotoxic effects of low-intensity 2450-MHz microwave and MMC on human lymphocytes were studied using single cell gel electrophoresis (SCGE) assay (comet assay) and cytokinesis-blocked micronucleus (CBMN) test in vitro. The whole blood cells from a male donor and a female donor were either only exposed to 2450-MHz microwaves (5.0 mW/cm2) for 2 h or only exposed to MMC (0.0125 microgram/mL, 0.025 microgram/mL and 0.1 microgram/mL) for 24 h; and the samples were exposed to MMC for 24 h after exposure to MW for 2 h. RESULTS: In the comet assay, the comet lengths (29.1 microns and 25.9 microns) of MW were not significantly longer than those (26.3 microns and 24.1 microns) of controls ($P > 0.05$). The comet lengths (57.4 microns, 68.9 microns, 91.4 microns, 150.6 microns, 71.7 microns, 100.1 microns, 145.1 microns) of 4 MMC groups were significantly longer than those of controls ($P < 0.01$). The comet lengths (59.1 microns, 92.3 microns, 124.5 microns, 182.7 microns and 57.4 microns, 85.5 microns, 137.5 microns, 178.3 microns) of 4 MW plus MMC groups were significantly longer than those of controls too ($P < 0.01$). The comet lengths of MW plus MMC groups were significantly longer than those of the corresponding MMC doses ($P < 0.05$ or $P < 0.01$) when the doses of MMC were > or = 0.025 microgram/mL. In the CBMN, the micronucleated cell (MNC) rates of MW were 5@1000 and 6@1000, which showed no difference compared with those (4@1000 and 4@1000) of controls ($P > 0.05$). The MNC rates of 4 MMC groups were 8@1000, 9@1000, 14@1000, 23@1000 and 8@1000, 8@1000, 16@1000, 30@1000 respectively. When the doses of MMC were > or = 0.05 microgram/mL, MNC rates of MMC were higher than those of controls ($P < 0.05$). MNC rates of 4 MW plus MMC groups were 12@1000, 13@1000, 20@1000, 32@1000 and 8@1000, 9@1000, 23@1000, 40@1000. When the doses of MMC were > or = 0.05 microgram/mL, MNC rates of MW plus MMC groups were much higher than those of controls ($P < 0.01$). MNC rates of 4 MW plus MMC groups were not significantly higher than those of the corresponding MMC doses. CONCLUSION: The low-intensity 2450-MHz microwave radiation can not induce DNA and chromosome damage, but can increase DNA damage effect induced by MMC in comet assay.

**Zhang MB, Jin LF, He JL, Hu J, Zheng W. [Effects of 2,450 MHz microwave on DNA damage induced by three chemical mutagens in vitro] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 21(4):266-269, 2003.** [Article in Chinese]

OBJECTIVE: To study the combined damage-effects of low-intensity 2,450 MHz microwave (MW) with three chemical mutagens on human lymphocyte DNA. METHODS: DNA damage of lymphocytes exposed to microwave and(or) with chemical mutagens were observed at different incubation time (0 h or 21 h) with comet assay in vitro. Three combination-exposure ways of MW with chemicals were used: MW irradiation before chemical exposures, simultaneously exposed to MW and chemicals and MW irradiation after chemical exposures. The three chemical mutagens were mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiometric agent), methyl methanesulfonate (MMS, alkylating agent). The exposure time of MW and chemical mutagens were 2 h and 3 h respectively. RESULTS: The differences of comet tail length between MW group and control group were not significant when lymphocytes were incubated for 0 h or 21 h ($P >0.05$). However, when lymphocytes were incubated for 21 h with 30.00 micro mol/L of MMC, the comet tail lengths of MW + MMC group, MW-MMC group and MMC + MW

group were (18.00 +/- 5.96), (21.79 +/- 11.47) and (22.32 +/- 8.10) micro m respectively; while with 3.00 micro mol/L of MMC, the comet tail lengths were (8.99 +/- 3.75), (12.40 +/- 5.35) and (14.00 +/- 5.38) micro m respectively, which were significantly higher than those of corresponding MMC groups [(9.42 +/- 3.34) and (6.50 +/- 2.89) micro m, $P < 0.01$ or $P < 0.05$]. The DNA damage of MW plus BLM groups and MW plus MMS groups were not significantly different from the corresponding BLM and MMS groups ($P < 0.05$). CONCLUSION: 2 450 MHz MW (5 mW/cm(2)) did not induce DNA damage directly, but could enhance the DNA damage effects induced by MMC. The synergistic effects of 2 450 MHz MW with BLM and MMS were not obvious.

**Zhang SZ, Yao GD, Lu DQ, Chiang H, Xu ZP. [Effect of 1.8 GHz radiofrequencyelectromagnetic fields on gene expression of rat neurons]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 26(8):449-452, 2008.** [Article in Chinese]

OBJECTIVE: To investigate the changes of gene expression in rat neuron induced by 1.8 GHz radiofrequencyelectromagnetic fields (RF EMF) to screen for RF EMF-responsive genes and the effect of different exposure times and modes on the gene expression in neuron. METHODS: Total RNA was extracted immediately and purified from the primary culture of neurons after intermittent exposed or sham-exposed to a frequency of 1.8 GHz RF EMF for 24 hours at an average special absorption rate (SAR) of 2 W/kg. Affymetrix Rat Neurobiology U34 array was applied to investigate the changes of gene expression in rat neuron. Differentially expressed genes (Egr-1, Mbp and Plp) were further confirmed by semi-quantitative revere transcription polymerase chain reaction (RT PCR). The expression levels of Egr-1, Mbp and Plp were observed at different exposure times (6, 24 h) and modes (intermittent and continuous exposure). RESULTS: Among 1200 candidate genes, 24 up-regulated and 10 down-regulated genes were found by using Affymetrix microarray suite software 5.0 which are associated with multiple cellular functions (cytoskeleton, signal transduction pathway, metabolism, etc.) after functional classification. Under 24 h and 6 h intermittent exposure, Egr-1 and Plp in experiment groups showed statistic significance ($P < 0.05$) compared with the control groups, while expression of Mbp did not change significantly ($P > 0.05$). After 24 h continuous exposure, Egr-1 and Mbp in experiment groups showed statistic significance ($P < 0.05$) compared with the control group, while expression of Plp did not change significantly ($P > 0.05$). Under the same exposure mode 6 h, expression of all the 3 genes did not change significantly. Different times (6, 24 h) and modes (intermittent and continuous exposure) of exposure exerted remarkable different influences on the expression of Egr-1, Mbp, Plp genes ($P < 0.01$). CONCLUSION: The changes of many genes transcription were involved in the effect of 1.8 GHz RF EMF on rat neurons; Down-regulation of Egr-1 and up-regulation of Mbp, Plp indicated the negative effects of RF EMF on neurons; The effect of RF intermittent exposure on gene expression was more obvious than that of continuous exposure; The effect of 24 h RF exposure (both intermittent and continuous) on gene expression was more obvious than that of 6 h (both intermittent and continuous).

**Zhang X, Gao Y, Dong J, Wang S, Yao B, et al. (2014) The Compound Chinese Medicine “Kang Fu Ling” Protects against High Power Microwave-Induced Myocardial Injury. PLoS ONE 9(7): e101532. doi:10.1371/journal.pone.0101532.**

Background. The prevention and treatment of Microwave-caused cardiovascular injury remains elusive. This study investigated the cardiovascular protective effects of compound Chinese medicine “Kang Fu Ling” (KFL) against high power microwave (HPM)-induced myocardial injury and the role of the mitochondrial permeability transition pore (mPTP) opening in KFL protection. Methods. Male Wistar rats (100) were divided into 5 equal groups: no treatment, radiation only, or radiation followed by treatment with KFL at 0.75, 1.5, or 3 g/kg/day. Electrocardiography was used to Electrophysiological examination. Histological and ultrastructural changes in heart tissue and isolated mitochondria were observed by light microscope and electron microscopy. mPTP opening and mitochondrial membrane potential were detected by confocal laser scanning microscopy and fluorescence analysis. Connexin-43 (Cx-43) and endothelial nitric oxide synthase (eNOS) were detected by immunohistochemistry. The expression of voltage-dependent anion channel (VDAC) was detected by western blotting. Results. At 7 days after radiation, rats without KFL treatment showed a significantly lower heart rate ($P<0.01$) than untreated controls and a J point shift. Myocyte swelling and rearrangement were evident. Mitochondria exhibited rupture, and decreased fluorescence intensity, suggesting opening of mPTP and a consequent reduction in mitochondrial membrane potential. After treatment with 1.5 g/kg/day KFL for 7 d, the heart rate increased significantly ($P<0.01$), and the J point shift was reduced flavorfully ($P<0.05$) compared to untreated, irradiated rats; myocytes and mitochondria were of normal morphology. The fluorescence intensities of dye-treated mitochondria were also increased, suggesting inhibition of mPTP opening and preservation of the mitochondrial membrane potential. The microwave-induced decrease of Cx-43 and VDAC protein expression was significantly reversed. Conclusion. Microwave radiation can cause electrophysiological, histological and ultrastructural changes in the heart. KFL at 1.5 g/kg/day had the greatest protective effect on these cardiovascular events. mPTP plays an important role in the protective effects of KFL against microwave-radiation-induced myocardial injury.

**Zhang Y, She F, Li L, Chen C, Xu S, Luo X, Li M, He M, Yu Z. p25/CDK5 is partially involved in neuronal injury induced by radiofrequency electromagnetic field exposure. Int J Radiat Biol. 2013 Jul 29. [Epub ahead of print]**

Purpose: Several studies suggest that radiofrequency electromagnetic field (RF-EMF) exposure can induce neuronal injury. The aim of the present work was to investigate whether the cyclin-dependent kinase 5 (CDK5) pathway is involved in neuronal injury induced by RF-EMF exposure. Materials and methods: Newborn Sprague-Dawley rats' primary cultured cortical neurons were exposed to pulsed 2.45 GHz RF-EMF for 10 min. The cellular viability was assessed using the 3-(4,5-Dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay. The apoptosis was assessed by Hoechst 33342 and terminal deoxynucleotidyl transferase (TdT)-mediated dUTP nick-end labeling co-staining. The protein expressions of CDK5, p35, p25, and phosphorylated tau at $Ser^{404}$ were examined by Western blot analysis. The CDK5 activity was detected using a histone-H1 kinase assay. Results: The cellular viability of neurons was significantly decreased ($p < 0.01$, Partial Eta Squared [$\eta_p^2$]: 0.554), and the percentage of apoptotic nuclei ($p < 0.01$, $\eta_p^2 = 0.689$), activity of

CDK5 ($p < 0.05$, $\eta_p^2 = 0.589$), ratio of p25 and p35 ($p < 0.05$, $\eta_p^2 = 0.670$), levels of tau phosphorylation at $Ser^{404}$ ($p < 0.01$, $\eta_p^2 = 0.896$) were significantly increased after RF-EMF exposure. No significant change was detected in CDK5 expression after RF-EMF exposure. Pretreatment with Roscovitine (a CDK5 inhibitor) significantly blocked the RF-EMF-induced decrease of cellular viability ($p < 0.05$, $\eta_p^2 = 0.398$) and tau hyperphosphorylation at $Ser^{404}$ ($p < 0.01$, $\eta_p^2 = 0.917$), but did not significantly block the RF-EMF-induced apoptosis ($p > 0.05$, $\eta_p^2 = 0.130$). Conclusions: These results suggest that abnormal activity of p25/CDK5 is partially involved in primary cultured cortical neuron injury induced by RF-EMF exposure.

**Zhang Y, Li Z, Gao Y, Zhang C. Effects of fetal microwave radiation exposure on offspring behavior in mice. J Radiat Res. 2014 Oct 30. pii: rru097. [Epub ahead of print]**

The recent rapid development of electronic communication techniques is resulting in a marked increase in exposure of humans to electromagnetic fields (EMFs). This has raised public concerns about the health hazards of long-term environmental EMF exposure for fetuses and children. Some studies have suggested EMF exposure in children could induce nervous system disorders. However, gender-dependent effects of microwave radiation exposure on cognitive dysfunction have not previously been reported. Here we investigated whether in utero exposure to 9.417-GHz microwave throughout gestation (Days 3.5-18) affected behavior, using the open field test (OFT), elevated-plus maze (EPM), tail suspension test (TST), forced swimming test (FST) and Morris water maze (MWM). We found that mice showed less movement in the center of an open field (using the OFT) and in an open arm (using the EPM) after in utero exposure to 9.417-GHz radiation, which suggested that the mice had increased anxiety-related behavior. Mice demonstrated reduced immobility in TST and FST after in utero exposure to 9.417-GHz radiation, which suggested that the mice had decreased depression-related behavior. From the MWM test, we observed that male offspring demonstrated decreased learning and memory, while females were not affected in learning and memory, which suggested that microwaves had gender-dependent effects.

**Zhao R, Zhang SZ, Yao GD, Lu DQ, Jiang H, Xu ZP.[Effect of 1.8 GHz radiofrequency electromagnetic fields on the expression of microtubule associated protein 2 in rat neurons] Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 24(4):222-225, 2006.** [Article in Chinese]

OBJECTIVE: To investigate the changes of gene expression in rat neurons induced by 1.8 GHz radiofrequency electromagnetic fields (RF EMF) and to screen for the RF EMF-responsive genes. METHODS: Newly-born SD rats in 24 hours were sacrificed to obtain cortex and hippocampus neurons. The cells were divided randomly into two groups: the experiment group (the irradiation group) and the control group (the false irradiation group). In the irradiation group, after twelve days' culture, neurons were exposed to 1.8 GHz RF EMF modulated by 217 Hz at a specific absorption rate (SAR) of 2 W/kg for 24 hours (5 minutes on/10 minutes off) while in the false control group, the neurons were put in the same waveguide as in the irradiation group, but were not exposed to any

irradiation. The total RNA was isolated and purified immediately after exposure. The affymetrix rat neurobiology U34 assay was used for detecting the changes in gene expression profile according to the manufacturer's instruction. RF EMF-responsive candidate gene was confirmed by using ribonuclease protection assay (RPA). RESULTS: Among 1200 candidate genes, the expression levels of 34 genes were up or down regulated. Microtubule associated protein 2 (Map2) gene was selected as the candidate and subjected to further analysis. RPA data clearly revealed that Map2 was statistically significantly up-regulated after neurons were exposed to the RF EMF ($P < 0.05$). CONCLUSION: The modulation of gene expression and function of Map2 as a neuron specific cytoskeleton protein is crucial to maintain the normal framework and function of neurons. The finding that 1.8 GHz RF EMF exposure increases the expression of Map2 might indicate some unknown effects of RF EMF on neurons.

**Zhao R, Zhang S, Xu Z, Ju L, Lu D, Yao G. Studying gene expression profile of rat neuron exposed to 1800MHz radiofrequency electromagnetic fields with cDNA microassay. Toxicology. 235(3):167-175, 2007.**

A widespread use of mobile phone (MP) evokes a growing concern for their possible adverse effects on human, especially the brain. Gene expression is a unique way of characterizing how cells and organism adapt to changes in the external environment, so the aim of this investigation was to determine whether 1800 MHz radiofrequency electromagnetic fields (RF EMF) can influence the gene expression of neuron. Affymetrix Rat Neurobiology U34 array was applied to investigate the changes of gene expression in rat neuron after exposed to the pulsed RF EMF at a frequency of 1800 MHz modulated by 217 Hz which is commonly used in MP. Among 1200 candidate genes, 24 up-regulated genes and 10 down-regulated genes were identified after 24-h intermittent exposure at an average special absorption rate (SAR) of 2 W/kg, which are associated with multiple cellular functions (cytoskeleton, signal transduction pathway, metabolism, etc.) after functional classification. The results were further confirmed by quantitative real-time polymerase chain reaction (RT PCR). The present results indicated that the gene expression of rat neuron could be altered by exposure to RF EMF under our experimental conditions.

**Zhao Z, Zhang S, Zho H, Zhang S, Su J, Li L**, **The effects of radiofrequency (< 30 MHz) radiation in humans. Rev Environ Health 10(3-4):213-215, 1994.**

121 workers who were exposed to RFR (< 30 MHz) over one year were examined. They were divided into two groups: one group was exposed to high electric field intensity (> or = 100 V/m), another to low intensity (< 100 V/m) and both groups were compared to control subjects. No significant changes in the functioning of the autonomic nervous system and blood parameters (Hb, WBC and blood platelets) occurred in the exposed subjects of either group. Some changes in ECG (ST-T interval and abnormal heart rate) were observed in the group exposed to high intensity (> or = 100 V/m) radiation. 100 V/m is suggested as an exposure limit for RF (< 30 MHz) radiation.

**Zhao Z, Zhang S, Wang S, Yao Z, Zho H, Tao S, Tao L, Exposure limits for ultra-short wave radiation in work environments. Rev Environ Health 10(3-4):217-220, 1994.**

Exposure limit values for ultra-short wave radiation of humans were derived on the basis of epidemiological survey and experimental exposure of rabbits. Eighteen male rabbits were divided into 4 groups randomly. Three groups were irradiated with ultra-short waves (100 MHz) at 35, 1.5-3.5, and 0.07 mW/cm2 power density in an E-polarized TEM Cell at 24 +/- 4 degrees C ambient temperature. The last group in a sham chamber served as controls. Irradiation was performed 3 hours per day, 5 days per week for 24 weeks. Thermal effects occurred in the group irradiated at 35 mW/cm2. The thermal threshold limit value was set at 1.5 mW/cm2. An epidemiological survey was carried out on 136 factory workers and TV operators exposed over one year to ultra-short wave radiation at 0.2 mW/cm2. They were compared with 108 controls. The only complaint of the exposed group was neurosis. The exposure limit value (ELV) to short wave radiation was set at 0.2 mW/cm2 by using a 15- and 20-fold safety factor.

**Zhao TY, Zou SP, Knapp PE Exposure to cell phone radiation up-regulates apoptosis genes in primary cultures of neurons and astrocytes.Neurosci Lett. 412(1):34-38, 2007.**

The health effects of cell phone radiation exposure are a growing public concern. This study investigated whether expression of genes related to cell death pathways are dysregulated in primary cultured neurons and astrocytes by exposure to a working Global System for Mobile Communication (GSM) cell phone rated at a frequency of 1900MHz. Primary cultures were exposed to cell phone emissions for 2h. We used array analysis and real-time RT-PCR to show up-regulation of caspase-2, caspase-6 and Asc (apoptosis associated speck-like protein containing a card) gene expression in neurons and astrocytes. Up-regulation occurred in both "on" and "stand-by" modes in neurons, but only in "on" mode in astrocytes. Additionally, astrocytes showed up-regulation of the Bax gene. The effects are specific since up-regulation was not seen for other genes associated with apoptosis, such as caspase-9 in either neurons or astrocytes, or Bax in neurons. The results show that even relatively short-term exposure to cell phone radiofrequency emissions can up-regulate elements of apoptotic pathways in cells derived from the brain, and that neurons appear to be more sensitive to this effect than astrocytes.

**Zhao YL, Li YX, Ma HB, Li D, Li HL, Jiang R, Kan GH, Yang ZZ, Huang ZX. The Screening of Genes Sensitive to Long-Term, Low-Level Microwave Exposure and Bioinformatic Analysis of Potential Correlations to Learning and Memory. Biomed Environ Sci. 28(8):558-570, 2015.**

OBJECTIVE: To gain a better understanding of gene expression changes in the brain following microwave exposure in mice. This study hopes to reveal mechanisms contributing to microwave-induced learning and memory dysfunction. METHODS: Mice were exposed to whole body 2100 MHz microwaves with specific absorption rates (SARs) of 0.45 W/kg, 1.8 W/kg, and 3.6 W/kg for 1 hour daily for 8 weeks. Differentially expressing genes in the brains were screened using high-density oligonucleotide arrays, with genes showing more significant differences further confirmed by RT-PCR. RESULTS: The gene chip results demonstrated that 41 genes (0.45 W/kg group), 29 genes (1.8 W/kg group), and 219 genes (3.6 W/kg group) were differentially expressed.

GO analysis revealed that these differentially expressed genes were primarily involved in metabolic processes, cellular metabolic processes, regulation of biological processes, macromolecular metabolic processes, biosynthetic processes, cellular protein metabolic processes, transport, developmental processes, cellular component organization, etc. KEGG pathway analysis showed that these genes are mainly involved in pathways related to ribosome, **Alzheimer's disease, Parkinson's disease**, long-term potentiation, **Huntington's disease**, and Neurotrophin signaling. Construction of a protein interaction network identified several important regulatory genes including synbindin (sbdn), Crystallin (CryaB), PPP1CA, Ywhaq, Psap, Psmb1, Pcbp2, etc., which play important roles in the processes of learning and memory. CONCLUSION: Long-term, low-level microwave exposure may inhibit learning and memory by affecting protein and energy metabolic processes and signaling pathways relating to neurological functions or diseases.

**Zheng F, Gao P, He M, Li M, Wang C, Zeng Q, Zhou Z, Yu Z, Zhang L. Association between** mobile phone **use and inattention in 7102 Chinese adolescents: a population-based cross-sectional study. BMC Public Health. 2014 Oct 1;14(1):1022. [Epub ahead of print]**

BACKGROUND: The dramatic growth of **mobile phone** (MP) use among young people has increased interest in its possible health hazards in this age group. The aim of this cross-sectional study was to investigate the association between MP use and inattention in adolescents. METHODS: A total of 7720 middle school students were involved in this cross-sectional study. Inattention was assessed as defined for the Attention Deficit component of Attention deficit/Hyperactivity disorder (ADHD) by the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev. [DSM-IV-TR]). The demographic characteristics and information on MP use were included in the questionnaire. Chi-square tests and logistic regression models were used to analyze the data. RESULTS: In total, 7102 (91.99%) valid questionnaires were obtained. After adjusted for confounders, inattention in adolescents was significantly associated with MP ownership, the time spent on entertainment on MP per day, the position of the MP during the day and the mode of the MP at night. The strongest association between inattention and the time spent on the MP was among students who spent more than 60 minutes per day playing on their MP. CONCLUSIONS: Our study shows some associations between MP use and inattention in Chinese adolescents. Decreasing MP usage to less than 60 minutes per day may help adolescents to stay focused and centered.

**Zheng F, Gao P, He M, Li M, Tan J, Chen D, Zhou Z, Yu Z, Zhang L. Association between** mobile phone **use and self-reported well-being in children: a questionnaire-based cross-sectional study in Chongqing, China. BMJ Open. 2015 May 11;5(5):e007302. doi: 10.1136/bmjopen-2014-007302.**

OBJECTIVES: In the past decade, the **mobile phone** (MP) has become extremely popular among children and the average age at which children own their first MP has decreased. The potential health effects of children's exposure to MP have been the subject of widespread public concern. The aim of our study is to investigate the associations between MP use and well-being in children. DESIGN:  Cross-sectional

study. SETTING: The questionnaires were completed in class with items regarding demographics, MP usage, self-reported well-being (symptoms were taken from the questionnaire of the HBSC survey) and possible confounding factors between October 2011 and May 2012 in Chongqing, China. Data were analysed using $\chi(2)$ tests and logistic regression models. PARTICIPANTS: Among the 793 children invited to participate, 781 returned the questionnaires. RESULTS: In total, 746 (94.1%) valid questionnaires were received. Fatigue was significantly associated with the years of MP usage (OR 1.85; 95% CI 1.07 to 3.22) and the daily duration of MP calls (OR 2.98; 95% CI 1.46 to 6.12). Headache was significantly associated with the daily duration of MP calls (OR 2.85; 95% CI 1.23 to 6.57). However, after adjusting for confounders only, the association between fatigue and MP usage remained statistically significant. There was no significant association between MP use and other physical symptoms in children. CONCLUSIONS: The present study indicated that there was a consistent significant association between MP use and fatigue in children. Further in-depth research is needed to explore the potential health effects of MP use in children.

**Zheng T, Blair A, Zhang Y, Weisenburger DD, Zahm SH, Occupation and Risk of Non-Hodgkin's Lymphoma and Chronic Lymphocytic Leukemia. J Occup Envir Med 44:469-474, 2002.**

To investigate the association between occupation and the risk of non-Hodgkin's lymphoma (NHL) and chronic lymphocytic leukemia (CLL), and to test whether the associations may vary by histological type of NHL, we analyzed data from two population-based, case-control studies of NHL performed in Kansas and Nebraska. A total of 555 incident NHL cases, 56 CLL cases, and 2380 population-based controls were included in the analysis. Information on occupation and other confounding factors was collected through telephone interviews. Study pathologists reviewed slides of tumor tissues in all cases. In men, we found an increased risk of NHL and CLL for those working in agricultural, forestry, and logging industries (odds ratio [OR], 1.6; 95% confidence interval [CI], 1.2 to 2.1). The OR was 1.9 (95% CI, 1.4 to 2.6) for those producing crops. An increased risk was also observed for industries involving metalworking machinery and equipment (OR, 8.4; 95% CI, 1.4 to 50.6), motor vehicles and motor vehicle equipment (OR, 4.2; 95% CI, 1.3 to 13.9), and telephone communications (OR, 3.1; 95% CI, 1.2 to 8.0), and for teachers (OR, 2.5; 95% CI, 1.0 to 6.5), farmers (OR, 2.0; 95% CI, 1.5 to 2.8), and welders and solderers (OR, 2.9; 95% CI, 1.2 to 6.9). The risks for these associations increased by duration of employment and seem to vary by histological type. Work in the printing and publishing industry was also associated with an increased risk of NHL among women. These data suggest that the workers employed in these industries or occupations experienced an increased risk of NHL and CLL, and the risks associated with these industries or occupations may vary by histological type of NHL.

**Zhijian C, Xiaoxue L, Wei Z, Yezhen L, Jianlin L, Deqiang L, Shijie C, Lifen J, Jiliang H. Studying the protein expression in human B lymphoblastoid cells exposed to 1.8-GHz (GSM) radiofrequency radiation (RFR) with protein microarray. Biochem Biophys Res Commun. 433(1):36-39, 2013.**

In the present study, the protein microarray was used to investigate the protein expression in human B-cell lymphoblastoid cells intermittently exposed to 1.8-GHz GSM radiofrequency radiation (RFR) at the specific absorption rate (SAR) of 2.0W/kg for 24h. The differential expression of 27 proteins was found, which were related to DNA damage repair, apoptosis, oncogenesis, cell cycle and proliferation (ratio >1.5-fold, P<0.05). The results validated with Western blot assay indicated that the expression of RPA32 was significantly down-regulated (P<0.05) while the expression of p73 was significantly up-regulated in RFR exposure group (P<0.05). Because of the crucial roles of those proteins in DNA repair and cell apoptosis, the results of present investigation may explain the biological effects of RFR on DNA damage/repair and cell apoptosis.

**Zhijian C, Xiaoxue L, Yezhen L, Shijie C, Lifen J, Jianlin L, Deqiang L, Jiliang H. Impact of 1.8-GHz radiofrequency radiation (RFR) on DNA damage and repair induced by doxorubicin in human B-cell lymphoblastoid cells. Mutat Res. 695(1-2):16-21, 2010.**

In the present in vitro study, a comet assay was used to determine whether 1.8-GHz radiofrequency radiation (RFR, SAR of 2W/kg) can influence DNA repair in human B-cell lymphoblastoid cells exposed to doxorubicin (DOX) at the doses of 0microg/ml, 0.05microg/ml, 0.075microg/ml, 0.10microg/ml, 0.15microg/ml and 0.20microg/ml. The combinative exposures to RFR with DOX were divided into five categories. DNA damage was detected at 0h, 6h, 12h, 18h and 24h after exposure to DOX via the comet assay, and the percent of DNA in the tail (% tail DNA) served as the indicator of DNA damage. The results demonstrated that (1) RFR could not directly induce DNA damage of human B-cell lymphoblastoid cells; (2) DOX could significantly induce DNA damage of human B-cell lymphoblastoid cells with the dose-effect relationship, and there were special repair characteristics of DNA damage induced by DOX; (3) E-E-E type (exposure to RFR for 2h, then simultaneous exposure to RFR and DOX, and exposure to RFR for 6h, 12h, 18h and 24h after exposure to DOX) combinative exposure could obviously influence DNA repair at 6h and 12h after exposure to DOX for four DOX doses (0.075microg/ml, 0.10microg/ml, 0.15microg/ml and 0.20microg/ml) in human B-cell lymphoblastoid cells.

**Zhijian C, Xiaoxue L, Yezhen L, Deqiang L, Shijie C, Lifen J, Jianlin L, Jiliang H. Influence of 1.8-GHz (GSM) radiofrequency radiation (RFR) on DNA damage and repair induced by X-rays in human leukocytes in vitro. Mutat Res. 677(1-2):100-104, 2009.**

In the present study, the in vitro comet assay was used to determine whether 1.8-GHz radiofrequency radiation (RFR) can influence DNA repair in human leukocytes exposed to X-rays. The specific energy absorption rate (SAR) of 2 W/kg (the current European safety limit) was applied. The leukocytes from four young healthy donors were intermittently exposed to RFR for 24 h (fields on for 5 min, fields off for 10 min), and then irradiated with X-rays at doses of 0.25, 0.5, 1.0 and 2.0 Gy. DNA damage to human leukocytes was detected using the comet assay at 0, 15, 45, 90, 150 and 240

min after exposure to X-rays. Using the comet assay, the percent of DNA in the tail (% tail DNA) served as the indicator of DNA damage; the DNA repair percentage (DRP) served as the indicator of the DNA repair speed. The results demonstrated that (1) the DNA repair speeds of human leukocytes after X-ray exposure exhibited individual differences among the four donors; (2) the intermittent exposures of 1.8-GHz RFR at the SAR of 2 W/kg for 24 h did not directly induce DNA damage or exhibit synergistic effects with X-rays on human leukocytes.

**Zhou H, Su Z, Ning J, Wang C, Xie X, Qu D, Wu K, Zhang X, Pan J, Yang G. EFFECTS OF FREQUENCY, IRRADIATION GEOMETRY AND POLARISATION ON COMPUTATION OF SAR IN HUMAN BRAIN. Radiat Prot Dosimetry. 2014 Jan 6. [Epub ahead of print]**

The power absorbed by the human brain has possible implications in the study of the central nervous system-related biological effects of electromagnetic fields. In order to determine the specific absorption rate (SAR) of radio frequency (RF) waves in the human brain, and to investigate the effects of geometry and polarisation on SAR value, the finite-difference time-domain method was applied for the SAR computation. An anatomically realistic model scaled to a height of 1.70 m and a mass of 63 kg was selected, which included 14 million voxels segmented into 39 tissue types. The results suggested that high SAR values were found in the brain, i.e. ~250 MHz for vertical polarisation and 900-1200 MHz both for vertical and horizontal polarisation, which may be the result of head resonance at these frequencies.

**Zhou LY, Zhang HX, Lan YL, Li Y, Liang Y, Yu L, Ma YM, Jia CW, Wang SY. Epidemiological investigation of risk factors of the pregnant women with early spontaneous abortion in Beijing. Chinese Journal of Integrative Medicine. 2015 Apr 14. [Epub ahead of print]**

OBJECTIVE: To determine the risk factors of the pregnant women with early spontaneous abortion [i.e., miscarriages] in Beijing. METHODS: A total of 34,417 cases of pregnant women were participated in the survey from January 2000 to December 2013. A questionnaire was informed to each woman. The content of questionnaire includes four parts: general condition, obstetrical history, past history and family history, and living environment and habits. The mental condition was evaluated with Self-Rating Anxiety Scale (SAS) and Self-Rating Depression Scale (SDS). RESULTS: A total of 32,296 questionnaires were collected. The spontaneous abortion rate in the total sample was 3.0%. There was no significant difference between the normal pregnancy group and spontaneous abortion group in terms of general condition, obstetrical and past history ($P>0.05$). Significant differences between the two groups were found in terms of decoration during pregnancy, keeping pets, near mobile communication base station within 100 m around the residence, drinking during pregnancy, having a cold during pregnancy and SAS ($P<0.05$). Having a cold during pregnancy, decoration during pregnancy, near mobile communication base station within 100 m around the residence, keeping pets and high SAS were determined the independent risk factors of spontaneous abortion by Logistic regression analysis. CONCLUSIONS: Having a cold during

pregnancy, decoration, keeping pets, near mobile communication base station within 100 m around the residence and high SAS are the independent risk factors of spontaneous abortion in Beijing.

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**Zhou ZD, Zeng QL, Zheng Y, Zhang JB, Chen HY, Lu DQ, Shao CS, Xia DJ. [Surface markers and functions of human dendritic cells exposed to mobile phone 1800 MHz electromagnetic fields.] Zhejiang Da Xue Xue Bao Yi Xue Ban. 37(1):29-33, 2008.**[Article in Chinese]

OBJECTIVE: To investigate the effects of mobile phone 1800 MHz electromagnetic fields (EMF) on the surface markers and the functions of human dendritic cells (DC). METHODS: Human DCs were exposed to intermittent 5 min on/10 min off EMF with specific absorption rates (SAR) 4 W/kg for 0 h, 1 h, 12 h or 24 h, respectively. FACS analysis was used to detect the positive percentage of DC surface markers including HLA-DR and co-stimulatory molecules such as CD80, CD86, CD40 and CD11c. CCK-8 kit was adopted to examine the function of allo-mixed lymphocyte reaction (allo-MLR) of DC, and enzyme linked immunosorbent assay (ELISA) to identify the levels of IL-12p70 and TNF-alpha secreted by DC. RESULT: Compared with the sham radiation group, after exposure to the electromagnetic fields for 1 h, 12 h, or 24 h, HLA-DR, CD80,CD86 and CD40 were all declined except CD11c. The ability of DC allo-MLR in each exposure group was decreased significantly (P<0.05), especially in the 24 h exposure group. However, the secreted levels of IL-12p70 and TNF-alphaof DC in each exposure group remained no changed. Conclusion: The study showed that EMF exposure could down-regulate the surface molecules and stimulation ability of human DC.

**Zhijian C, Xiaoxue L, Wei Z, Yezhen L, Jianlin L, Deqiang L, Shijie C, Lifen J, Jiliang H. Studying the protein expression in human B lymphoblastoid cells exposed to 1.8-GHz (GSM) radiofrequency radiation (RFR) with protein microarray. Biochem Biophys Res Commun. 433(1):36-39, 2013.**

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In the present in vitro study, a comet assay was used to determine whether 1.8-GHz radiofrequency radiation (RFR, SAR of 2W/kg) can influence DNA repair in human B-cell lymphoblastoid cells exposed to doxorubicin (DOX) at the doses of 0microg/ml, 0.05microg/ml, 0.075microg/ml, 0.10microg/ml, 0.15microg/ml and 0.20microg/ml. The combinative exposures to RFR with DOX were divided into five categories. DNA damage was detected at 0h, 6h, 12h, 18h and 24h after exposure to DOX via the comet assay, and the percent of DNA in the tail (% tail DNA) served as the indicator of DNA damage. The results demonstrated that (1) RFR could not directly induce DNA damage of human B-cell lymphoblastoid cells; (2) DOX could significantly induce DNA damage of human B-cell lymphoblastoid cells with the dose-effect relationship, and there were special repair characteristics of DNA damage induced by DOX; (3) E-E-E type (exposure to RFR for 2h, then simultaneous exposure to RFR and DOX, and exposure to RFR for 6h, 12h, 18h and 24h after exposure to DOX) combinative exposure could obviously influence DNA repair at 6h and 12h after exposure to DOX for four DOX doses (0.075microg/ml, 0.10microg/ml, 0.15microg/ml and 0.20microg/ml) in human B-cell lymphoblastoid cells.

**Zhijian C, Xiaoxue L, Yezhen L, Deqiang L, Shijie C, Lifen J, Jianlin L, Jiliang H. Influence of 1.8-GHz (GSM) radiofrequency radiation (RFR) on DNA damage and repair induced by X-rays in human leukocytes in vitro. Mutat Res. 677(1-2):100-104, 2009.**

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The power absorbed by the human brain has possible implications in the study of the central nervous system-related biological effects of electromagnetic fields. In order to determine the specific absorption rate (SAR) of radio frequency (RF) waves in the human brain, and to investigate the effects of geometry and polarisation on SAR

value, the finite-difference time-domain method was applied for the SAR computation. An anatomically realistic model scaled to a height of 1.70 m and a mass of 63 kg was selected, which included 14 million voxels segmented into 39 tissue types. The results suggested that high SAR values were found in the brain, i.e. ~250 MHz for vertical polarisation and 900-1200 MHz both for vertical and horizontal polarisation, which may be the result of head resonance at these frequencies.

**Zhou Z, Shan J, Zu J, Chen Z, Ma W, Li L, Xu J. Social behavioral testing and brain magnetic resonance imaging in chicks exposed to mobile phone radiation during development. BMC Neurosci. 17(1):36, 2016.**

BACKGROUND: The potential adverse effect of mobile phone radiation is currently an area of great concern in the field of public health. In the present study, we aimed to investigate the effect of mobile phone radiation (900 MHz radiofrequency) during hatching on postnatal social behaviors in chicks, as well as the effect on brain size and structural maturity estimated using 3.0 T magnetic resonance imaging. At day 4 of incubation, 76 normally developing chick embryos were divided into the control group (n = 39) and the radiation group (n = 37). Eggs in the radiation group were exposed to mobile phone radiation for 10 h each day from day 4 to 19 of incubation. Behavioral tests were performed 4 days after hatching. T2-weighted MR imaging and diffusion tensor imaging (DTI) were subsequently performed. The size of different brain subdivisions (telencephalon, optic lobe, brain stem, and cerebellum) and corresponding DTI parameters were measured. The Chi-square test and the student's t test were used for statistical analysis. $P < 0.05$ was considered statistically significant. RESULTS: Compared with controls, chicks in the radiation group showed significantly slower aggregation responses (14.87 ± 10.06 vs. 7.48 ± 4.31 s, respectively; $P < 0.05$), lower belongingness (23.71 ± 8.72 vs. 11.45 ± 6.53 s, respectively; $P < 0.05$), and weaker vocalization (53.23 ± 8.60 vs. 60.01 ± 10.45 dB/30 s, respectively; $P < 0.05$). No significant differences were found between the radiation and control group for brain size and structural maturity, except for cerebellum size, which was significantly smaller in the radiation group (28.40 ± 1.95 vs. 29.95 ± 1.41 cm(2), $P < 0.05$). The hatching and heteroplasia rates were also calculated and no significant difference was found between the two groups. CONCLUSIONS: Mobile phone radiation exposure during chick embryogenesis impaired social behaviors after hatching and possibly induced cerebellar retardation. This indicates potential adverse effects of mobile phone radiation on brain development.

**Zhu W, Zhang W, Li Y, Xu J, Luo J, Jiang Y, Lu X, Lü S. [Inhibitory effect of microwave radiation on proliferation of human pancreatic cancer JF305 cells and its mechanism]. Wei Sheng Yan Jiu. 42(6):1008-1011, 2013.**
**[Article in Chinese]**

**OBJECTIVE:** To investigate on the proliferation effect of different intensities 2450 MHz microwave radiation on human pancreatic cancer JF305 cells and its possible mechanism. **METHODS:** JF305 cells were radiated by intensity of 2.5, 5.0, 10.0, 15.0 and 20.0 mW/cm2 microwave for 20 min. The proliferation capacity of JF305 was

measured by MTT assays, Annexin V-FITC and PI staining was used for detecting cell apoptosis. The activity of Caspase-3 was examined. The expressions of Caspase-3 and HSP 70 protein after the cell treatment with microwave were detected by Western blotting. **RESULTS:** After microwave radiation, the proliferation inhibition rates of JF305 cells were significantly higher compared with control group. Annexin V-FITC and PI staining result showed that microwave radiation could induce cell apoptosis. Caspase-3 increased after radiated by microwave, compared with control group ($P < 0.05$). Results of Western blotting showed that the expression of Caspase-3 and HSP 70 protein increased significantly in different dosage radiation group. **CONCLUSION:** Microwave radiation can inhibit the proliferation of JF305 cells, the possible mechanism may be related with inducing cell apoptosis by changing of stress level.

**Zhu W, Cui Y, Feng X, Li Y, Zhang W, Xu J, Wang H, Lv S. The apoptotic effect and the plausible mechanism of microwave radiation on rat myocardial cells. Can J Physiol Pharmacol. 94(8):849-857, 2016.**

.Microwaves may exert adverse biological effects on the cardiovascular system at the integrated system and cellular levels. However, the mechanism underlying such effects remains poorly understood. Here, we report a previously uncharacterized mechanism through which microwaves damage myocardial cells. Rats were treated with 2450 MHz microwave radiation at 50, 100, 150, or 200 mW/cm(2) for 6 min. Microwave treatment significantly enhanced the levels of various enzymes in serum. In addition, it increased the malondialdehyde content while decreasing the levels of antioxidative stress enzymes, activities of enzyme complexes I-IV, and ATP in myocardial tissues. Notably, irradiated myocardial cells exhibited structural damage and underwent apoptosis. Furthermore, Western blot analysis revealed significant changes in expression levels of proteins involved in oxidative stress regulation and apoptotic signaling pathways, indicating that microwave irradiation could induce myocardial cell apoptosis by interfering with oxidative stress and cardiac energy metabolism. Our findings provide useful insights into the mechanism of microwave-induced damage to the cardiovascular system.

**Ziemann C, Brockmeyer H, Reddy SB, Vijayalaxmi, Prihoda TJ, Kuster N, Tillmann T, Dasenbrock C. Absence of genotoxic potential of 902 MHz (GSM) and 1747 MHz (DCS) wireless communication signals: In vivo two-year bioassay in B6C3F1 mice. Int J Radiat Biol. 85(5):454-464, 2009.**

PURPOSE: The aim of the present investigation was to determine the incidence of micronuclei in peripheral blood erythrocytes of B6C3F1 mice that had been chronically exposed to radiofrequencies (RF) used for mobile communication. MATERIALS AND METHODS: 'Ferris wheels' were used to expose tube-restrained male and female mice to simulated environmental RF signals of the Global System for Mobile Communications (GSM, 902 MHz) or Digital Cellular System (DCS, 1747 MHz). RF signals were applied to the mice for 2 hours/day on 5 days/week for two years, at maximal whole-body-averaged specific absorption rates of 0.4, 1.3, and 4.0 W/kg body weight. Concurrent sham-exposed mice, cage controls, and positive controls injected with mitomycin C were included in this investigation. At necropsy, peripheral blood smears were prepared, and coded slides were stained using May-Grunwald-Giemsa or acridine orange. The

incidence of micronuclei was recorded for each mouse in 2000 polychromatic and 2000 normochromatic erythrocytes. RESULTS: There were no significant differences in the frequency of micronuclei between RF-exposed, sham-exposed, and cage control mice, irrespective of the staining/counting method used. Micronuclei were, however, significantly increased in polychromatic erythrocytes of the positive control mice. CONCLUSIONS: In conclusion, the data did not indicate RF-induced genotoxicity in mice after two years of exposure.

**Zimmerman JW, Pennison MJ, Brezovich I, Yi N, Yang CT, Ramaker R, Absher D, Myers RM, Kuster N, Costa FP, Barbault A, Pasche B. Cancer cell proliferation is inhibited by specific modulation frequencies.Br J Cancer. 106(2):307-313, 2012.**

**BACKGROUND:** There is clinical evidence that very low and safe levels of amplitude-modulated electromagnetic fields administered via an intrabuccal spoon-shaped probe may elicit therapeutic responses in patients with cancer. However, there is no known mechanism explaining the anti-proliferative effect of very low intensity electromagnetic fields.**METHODS:** To understand the mechanism of this novel approach, hepatocellular carcinoma (HCC) cells were exposed to 27.12 MHz radiofrequency electromagnetic fields using in vitro exposure systems designed to replicate in vivo conditions. Cancer cells were exposed to tumour-specific modulation frequencies, previously identified by biofeedback methods in patients with a diagnosis of cancer. Control modulation frequencies consisted of randomly chosen modulation frequencies within the same 100 Hz-21 kHz range as cancer-specific frequencies.**RESULTS:** The growth of HCC and breast cancer cells was significantly decreased by HCC-specific and breast cancer-specific modulation frequencies, respectively. However, the same frequencies did not affect proliferation of nonmalignant hepatocytes or breast epithelial cells. Inhibition of HCC cell proliferation was associated with downregulation of XCL2 and PLP2. Furthermore, HCC-specific modulation frequencies disrupted the mitotic spindle.**CONCLUSION:** These findings uncover a novel mechanism controlling the growth of cancer cells at specific modulation frequencies without affecting normal tissues, which may have broad implications in oncology.

**Zmyslony M, Politanski P, Rajkowska E, Szymczak W, Jajte J. Acute exposure to 930 MHz CW electromagnetic radiation in vitro affects reactive oxygen species level in rat lymphocytes treated by iron ions. Bioelectromagnetics. 25(5):324-328, 2004.**

The aim of this study was to test the hypothesis that the 930 MHz continuous wave (CW) electromagnetic field, which is the carrier of signals emitted by cellular phones, affects the reactive oxygen species (ROS) level in living cells. Rat lymphocytes were used in the experiments. A portion of the lymphocytes was treated with iron ions to induce oxidative processes. Exposures to electromagnetic radiation (power density 5 W/m2, theoretical calculated SAR = 1.5 W/kg) were performed within a GTEM cell. Intracellular ROS were measured by the fluorescent probe dichlorofluorescin diacetate (DCF-DA). The results show that acute (5 and 15 min) exposure does not affect the number of produced ROS. If, however, FeCl2 with final concentration 10 microg/ml was added to the lymphocyte

suspensions to stimulate ROS production, after both durations of exposure, the magnitude of fluorescence (ROS level during the experiment) was significantly greater in the exposed lymphocytes. The character of the changes in the number of free radicals observed in our experiments was qualitatively compatible with the theoretical prediction from the model of electromagnetic radiation effect on radical pairs.

**Zong C, Ji Y, He Q, Zhu S, Qin F, Tong J, Cao Y. Adaptive Response in Mice Exposed to 900 MHz Radiofrequency Fields: Bleomycin-induced DNA and Oxidative Damage/Repair. Int J Radiat Biol. 2014 Oct 27:1-21. [Epub ahead of print]**

Purpose: To determine whether mice exposed to radiofrequency fields (RF) and then injected with a radiomimetic drug, bleomycin (BLM), exhibit adaptive response and provide some mechanistic evidence for such response. Materials and methods: Adult mice were exposed to 900 MHz RF at 120 μW/cm$^2$ power density for 4 hours/day for 7 days. Immediately after the last exposure, some mice were sacrificed while the others were injected with BLM 4 hours later. In each animal: (i) the primary DNA damage and BLM-induced damage as well as its repair kinetics were determined in blood leukocytes; (ii) the oxidative damage was determined from malondialdehyde (MDA) levels and the antioxidant status was assessed from superoxide dismutase (SOD) levels in plasma, liver and lung tissues. Results: There were no indications for increased DNA and oxidative damages in mice exposed to RF alone in contrast to those treated with BLM alone. Mice exposed to RF+BLM showed significantly: (a) reduced BLM-induced DNA damage and that is remaining after each 30, 60, 90, 120 and 150 minutes repair time, (c) decreased levels of MDA in plasma and liver, and increased SOD level in the lung. Conclusions: The overall data suggested that RF exposure was capable of inducing adaptive response and mitigated BLM-induced DNA and oxidative damages by activating certain cellular processes.

**Zook BC, Simmens SJ, The Effects of 860 MHz Radiofrequency Radiation on the Induction or Promotion of Brain Tumors and Other Neoplasms in Rats. Radiat Res 155(4):572-583, 2001.**

The Effects of 860 MHz Radiofrequency Radiation on the Induction or Promotion of Brain Tumors and Other Neoplasms in Rats. Sprague-Dawley rats were irradiated with a continuous- wave (CW) or a pulsed-wave (P) radiofrequency (RF) for 6 h/day, 5 days/week from 2 up to 24 months of age. The RFs emanated from dipole antennas (1 W average output) 2.0 +/- 0.5 cm from the tip of each rat's nose. The RFs had an 860 MHz frequency, and the specific absorption rate was 1.0 W/ kg averaged over the brain. Fifteen groups of 60 rats (900 total) were formed from offspring of females injected i.v. with 0 (groups 1, 2, 9, 10, 13), 2.5 (groups 5, 6, 7, 8, 11, 12, 14) or 10 mg/kg (groups 3, 4, 15) ethylnitrosourea (ENU) to induce brain tumors. Groups 1, 3, 5 and 7 received the PRF, and groups 9 and 11 the CWRF; groups 2, 4, 6, 8, 10 and 12 were sham-irradiated, and groups 13-15 were cage controls. All rats but 2, totaling 898, were necropsied, and major tissues were studied histopathologically. There was no statistically significant evidence that the PRF or CWRF induced neoplasia in any tissues. Additionally, there was no significant evidence of promotion of cranial or spinal nerve or spinal cord tumors. The PRF or CWRF had no statistically significant effect on the number, volume, location,

multiplicity, histological type, malignancy or fatality of brain tumors. There was a trend for the group that received a high dose of ENU and was exposed to the PRF to develop fatal brain tumors at a higher rate than its sham group; however, the result was not significant using the log-rank test (P = 0.14, 2-tailed). No statistically significant differences were related to the PRF or CWRF compared to controls in the low- or zero-dose groups regarding tumors of any kind.

**Zook BC,Simmens SJ. The Effects of Pulsed 860 MHz Radiofrequency Radiation on the Promotion of Neurogenic Tumors in Rats. Radiat. Res. 165, 608-615, 2006.**

In a previous study, this laboratory reported a statistically nonsignificant trend for shortened latency of ethylnitrosourea (ENU)-induced brain tumors in Sprague-Dawley rats exposed to an 860 MHz pulsed radiofrequency (RF) signal. The present study was designed to investigate further any promoting effect of the pulsed RF signal on latency and other characteristics of neurogenic tumors in the progeny of pregnant rats treated with 6.25 or 10 mg/kg ENU. The resulting 1080 offspring were randomized equally by number, sex and ENU dose into pulsed RF, sham and cage control groups. The rats were exposed to the pulsed RF signal 6 h per day 5 days per week; the sham-exposed group was similarly confined for the same periods, and the cage controls were housed in standard cages. An essentially equal number of rats from each group were killed humanely every 30 days between the ages of 171 and 325 days; 32 rats died and 225 rats were killed when they were moribund. Postmortem examinations on the 1080 rats revealed 38 spinal cord tumors, 191 spinal nerve tumors, 232 cranial nerve tumors, and 823 brain tumors. A methodical study of the tumor characteristics disclosed no evidence that exposure to the pulsed RF signal affected the incidence, malignancy, volume, multiplicity, latency or fatality associated with any kind of neurogenic tumor.

**Zothansiama, Zosangzuali M, Lalramdinpuii M, Jagetia GC. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. Electromagn Biol Med. 36(3):295-305, 2017**

Radiofrequency radiations (RFRs) emitted by mobile phone base stations have raised concerns on its adverse impact on humans residing in the vicinity of mobile phone base stations. Therefore, the present study was envisaged to evaluate the effect of RFR on the DNA damage and antioxidant status in cultured human peripheral blood lymphocytes (HPBLs) of individuals residing in the vicinity of mobile phone base stations and comparing it with healthy controls. The study groups matched for various demographic data including age, gender, dietary pattern, smoking habit, alcohol consumption, duration of mobile phone use and average daily mobile phone use. The RF power density of the exposed individuals was significantly higher ($p < 0.0001$) when compared to the control group. The HPBLs were cultured and the DNA damage was assessed by cytokinesis blocked micronucleus (MN) assay in the binucleate lymphocytes. The analyses of data from the exposed group (n = 40), residing within a perimeter of 80 m of mobile base stations, showed significantly ($p < 0.0001$) higher frequency of micronuclei when compared to the control group, residing 300 m away from the mobile base station/s. The analysis of various antioxidants in the plasma of exposed individuals revealed a significant attrition in glutathione (GSH) concentration ($p < 0.01$), activities of catalase

(CAT) ($p < 0.001$) and superoxide dismutase (SOD) ($p < 0.001$) and rise in lipid peroxidation (LOO) when compared to controls. Multiple linear regression analyses revealed a significant association among reduced GSH concentration ($p < 0.05$), CAT ($p < 0.001$) and SOD ($p < 0.001$) activities and elevated MN frequency ($p < 0.001$) and LOO ($p < 0.001$) with increasing RF power density.

**Zotti-Martelli L, Peccatori M, Scarpato R, Migliore L, Induction of micronuclei in human lymphocytes exposed in vitro to microwave radiation. Mutat Res 472(1-2):51-58, 2000.**

Increasing applications of electromagnetic fields are of great concern with regard to public health. Several in vitro studies have been conducted to detect effects of microwave exposure on the genetic material leading to negative or questionable results. The micronucleus (MN) assay which is proved to be a useful tool for the detection of radiation exposure-induced cytogenetic damage was used in the present study to investigate the genotoxic effect of microwaves in human peripheral blood lymphocytes in vitro exposed in G(0) to electromagnetic fields with different frequencies (2.45 and 7.7GHz) and power density (10, 20 and 30mW/cm(2)) for three times (15, 30 and 60min). The results showed for both radiation frequencies an induction of micronuclei as compared to the control cultures at a power density of 30mW/cm(2) and after an exposure of 30 and 60min. Our study would indicate that microwaves are able to cause cytogenetic damage in human lymphocytes mainly for both high power density and long exposure time.

**Zotti-Martelli L, Peccatori M, Maggini V, Ballardin M, Barale R. Individual responsiveness to induction of micronuclei in human lymphocytes after exposure in vitro to 1800-MHz microwave radiation. Mutat Res. 582(1-2):42-52, 2005.**

The widespread application of microwaves is of great concern in view of possible consequences for human health. Many in vitro studies have been carried out to detect possible effects on DNA and chromatin structure following exposure to microwave radiation. The aim of this study is to assess the capability of microwaves, at different power densities and exposure times, to induce genotoxic effects as evaluated by the in vitro micronucleus (MN) assay on peripheral blood lymphocytes from nine different healthy donors, and to investigate also the possible inter-individual response variability. Whole blood samples were exposed for 60, 120 and 180min to continuous microwave radiation with a frequency of 1800MHz and power densities of 5, 10 and 20mW/cm(2). Reproducibility was tested by repeating the experiment 3 months later. Multivariate analysis showed that lymphocyte proliferation indices were significantly different among donors ($p<0.004$) and between experiments ($p<0.01$), whereas the applied power density and the exposure time did not have any effect on them. Both spontaneous and induced MN frequencies varied in a highly significant way among donors ($p<0.009$) and between experiments ($p<0.002$), and a statistically significant increase of MN, although rather low, was observed dependent on exposure time ($p=0.0004$) and applied power density ($p=0.0166$). A considerable decrease in spontaneous and induced MN frequencies was measured in the second experiment. The results show that microwaves are able to induce MN in short-time exposures to medium power density fields. Our data analysis highlights a wide inter-individual variability in the response, which was confirmed to be a

characteristic reproducible trait by means of the second experiment.

**Zuo H, Lin T, Wang D, Peng R, Wang S, Gao Y, Xu X, Zhao L, Wang S, Su Z. RKIP Regulates Neural Cell Apoptosis Induced by Exposure to Microwave Radiation Partly Through the MEK/ERK/CREB Pathway. Mol Neurobiol. 2014 Aug 10. [Epub ahead of print]**

In the present study, we investigated whether Raf-1 kinase inhibitory protein (RKIP) is important for neural cell apoptosis induced by microwave exposure and explored the role of MEK/ERK/CREB pathway regulated by RKIP in the apoptosis. Differentiated PC12 cells were exposed to continuous microwave radiation at 2.856 GHz for 5 min with average power density of 30 mW/cm2. RKIP sense and anti-sense recombinant plasmids were constructed and transfected into PC12 cells, respectively. Terminal deoxynucleotidyl transferase (TdT)-mediated dUTP nick end labeling (TUNEL) staining and caspase-3 activity assay were used to detect cell apoptosis. The results showed that RKIP was downregulated after microwave exposure while the MEK/ERK/CREB signaling pathway was activated excessively. Moreover, the ratio of Bcl-2/Bax decreased, activity of caspase-3 increased, and thus apoptotic DNA fragmentation increased. RKIP overexpression significantly inhibited the phosphorylation of MEK, ERK, and CREB, while RKIP downregulation had the reverse effect. Furthermore, U0126 was found to antagonize the changes caused by RKIP downregulation after exposure to radiation. In conclusion, RKIP plays an important role in the neural cell apoptosis induced by microwave radiation, and the regulation of cell apoptosis by RKIP is partly through the MEK/ERK/CREB pathway. This suggests that RKIP may act as a key regulator of neuronal damage caused by microwave radiation. Extremely Low-Frequency Electromagnetic Fields Cause G1 Phase Arrest through the Activation of the ATM-Chk2-p21 Pathway.

**Zuo WQ, Hu YJ, Yang Y, Zhao XY, Zhang YY, Kong W, Kong WJ. Sensitivity of spiral ganglion neurons to damage caused by** mobile phone **electromagnetic radiation will increase in lipopolysaccharide-induced inflammation in vitro model. J Neuroinflammation. 2015 May 29;12(1):105. [Epub ahead of print]**

BACKGROUND: With the increasing popularity of mobile phones, the potential hazards of radiofrequency electromagnetic radiation (RF-EMR) on the auditory system remain unclear. Apart from RF-EMR, humans are also exposed to various physical and chemical factors. We established a lipopolysaccharide (LPS)-induced inflammation in vitro model to investigate whether the possible sensitivity of spiral ganglion neurons to damage caused by mobile phone electromagnetic radiation (at specific absorption rates: 2, 4 W/kg) will increase. METHODS: Spiral ganglion neurons (SGN) were obtained from neonatal (1- to 3-day-old) Sprague Dawley® (SD) rats. After the SGN were treated with different concentrations (0, 20, 40, 50, 100, 200, and 400 μg/ml) of LPS, the Cell Counting Kit-8 (CCK-8) and alkaline comet assay were used to quantify cellular activity and DNA damage, respectively. The SGN were treated with the moderate LPS concentrations before RF-EMR exposure. After 24 h intermittent exposure at an absorption rate of 2 and 4 W/kg, DNA damage was examined by alkaline comet assay, ultrastructure changes were detected by transmission electron microscopy, and expression of the autophagy

markers LC3-II and Beclin1 were examined by immunofluorescence and confocal laser scanning microscopy. Reactive oxygen species (ROS) production was quantified by the dichlorofluorescin-diacetate assay. RESULTS: LPS (100 μg/ml) induced DNA damage and suppressed cellular activity ($P < 0.05$). LPS (40 μg/ml) did not exhibit cellular activity changes or DNA damage ($P > 0.05$); therefore, 40 μg/ml was used to pretreat the concentration before exposure to RF-EMR. RF-EMR could not directly induce DNA damage. However, the 4 W/kg combined with LPS (40 μg/ml) group showed mitochondria vacuoles, karyopyknosis, presence of lysosomes and autophagosome, and increasing expression of LC3-II and Beclin1. The ROS values significantly increased in the 4 W/kg exposure, 4 W/kg combined with LPS (40 μg/ml) exposure, and $H_2O_2$ groups ($P < 0.05, 0.01$). CONCLUSIONS: Short-term exposure to radiofrequency electromagnetic radiation could not directly induce DNA damage in normal spiral ganglion neurons, but it could cause the changes of cellular ultrastructure at special SAR 4.0 W/kg when cells are in fragile or micro-damaged condition. It seems that the sensitivity of SGN to damage caused by mobile phone electromagnetic radiation will increase in a lipopolysaccharide-induced inflammation in vitro model.