Electromagnetic Radiation Safety

Scientific & policy developments regarding the biological & health effects of electromagnetic radiation
cell phones, cell towers, Wi-Fi, Smart Meters, electric vehicles & other wireless technology, including 5
Website curated by Joel Moskowitz, Ph.D., School of Public Health, University of California, Berkeley.

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Key Cell Phone Radiation Research Studies

Note: This is not a comprehensive list. I have focused on papers published since 2009 and tried to be parsimonious. This list was last updated on November 20, 2025.

The links below were checked and updated on June 7, 2019.

National Toxicology Program cell phone radiation studies

- **2016 NTP Report of Partial Findings (Rats)**
- **TR-595: NTP Studies of Cell Phone Radiofrequency Radiation (Rats)** (Nov. 2018)
- **TR-596: NTP Studies of Cell Phone Radiofrequency Radiation (Mice)** (Nov. 2018)

Also see:

- **NTP Cell Phone Radiation Study: Final Reports**, **National Toxicology Program: Peer & public review**, **National Toxicology Program Finds Cell Phone Radiation Causes Cancer**, and **Ramazzini Institute Cell Phone Radiation Study Replicates NTP Study**

Tumor risk review papers

Myung et al (2009) Mobile phone use and risk of tumors: a meta-analysis. *J Clinical Oncology*. http://bit.ly/2F0ldUS
Khurana et al (2009) Cell phones and brain tumors: a review including long-term epidemiologic data. *Surgical Neurology*. http://bit.ly/2WTQwfk
Levis et al (2011) Mobile phones and head tumours: the discrepancies in cause-effect relationships in the epi studies-how do they arise. *Environ Health*. http://bit.ly/2IsQy4r
Levis et al (2012) Mobile phones and head tumours: a critical analysis of case-control epi studies. *Open Environ Sciences*. http://bit.ly/2EXT5ml
WHO (2013) IARC monographs on the evaluation of carcinogenic risks to humans. Volume 102: Non-ionizing radiation, Part 2: Radiofrequency electromagnetic fields. http://bit.ly/10olE3o
Morgan et al (2015) Mobile phone radiation causes brain tumors and should be classified as a probable human carcinogen (2A) (Review). *Int J Oncology*. http://bit.ly/2XwgVNa
Wang & Guo (2016) Meta-analysis of association between mobile phone use and glioma risk. *J Cancer Research Therapy* http://bit.ly/2o1dVcn
Bortkiewicz et al (2017) Mobile phone use and risk of intracranial tumors and salivary gland tumors - A meta-analysis. *Int J Occ Med Envir Health*. http://bit.ly/2nVJC5d
Prasad et al (2017) Mobile phone use and risk of brain tumours: a systematic review of association between study quality, source of funding, and research outcomes. *Neurol Sci*. http://bit.ly/2Xxp83P
Yang et al (2017). Mobile phone use and glioma risk: A systematic review and meta-analysis. *PLOS One*. https://doi.org/10.1371/journal.pone.0175136
Carlberg, Hardell (2017) 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*. http://bit.ly/2WwBX1K
Miller et al (2018). Cancer epidemiology update, following the 2011 IARC evaluation of radiofrequency electromagnetic fields (Monograph 102). *Environ Res*. http://bit.ly/2rJD7Fu
Choi, Moskowitz, et al (2020). Cellular phone use and risk of tumors: Systematic review and meta-analysis. *Int J Envir Res Public Health*. https://doi.org/10.3390/ijerph17218079.
Moon et al (2024). Relationship between radiofrequency-electromagnetic radiation from cellular phones and brain tumor: meta-analyses using various proxies for RF-EMR exposure-outcome assessment. *Environ Health*. https://doi.org/10.1186/s12940-024-01117-8.
Mevissen et al (2025). Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review. *Environ Intl* https://doi.org/10.1016/j.envint.2025.109482
Kundi, Hutter (2026). Interpretation of Epidemiological Studies on the Relationship Between Mobile Phone Use and Cancer. *Epidemiologia*. https://doi.org/10.3390/epidemiologia7030086

Also see **Long-Term Cell Phone Use Increases Brain Tumor Risk**

Tumor risk studies

Interphone Study Group (2010) Brain tumour risk in relation to mobile phone use: results of the Interphone international case-control study. *Int J Epidemiol*. http://bit.ly/2MzsceR
Interphone Study Group (2011) Acoustic neuroma risk in relation to mobile telephone use: results of the INTERPHONE international case-control study. *Cancer Epidemiol*. http://bit.ly/2Ix7BlQ
Aydin et al (2011) Mobile phone use & brain tumors in children & adolescents: a multi-center case-control study. (CEFALO Study). *JNCI*. http://bit.ly/31j0JBa
Hardell et al (2013) Case-control study of the association between malignant brain tumours diagnosed between 2007 and 2009 and mobile and cordless phone use. *Int J Oncology*. http://bit.ly/2ZaVJg5
Hardell et al (2013) Pooled analysis of case-control studies on acoustic neuroma diagnosed 1997-2003 and 2007-2009 and use of mobile and cordless phones. *Int J Oncology*. http://bit.ly/31gbDaO
Coureau et al (2014) Mobile phone use and brain tumours in the CERENAT case-control study. *Occup Envi Med*. http://bit.ly/1DWgzRi
Grell et al (2016) The intracranial distribution of gliomas in relation to exposure from mobile phones: Analyses from the INTERPHONE Study. *Am J Epidemiol*. http://bit.ly/2ZcawHu



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Key Posts

- Welcome to EMR Safety
- Overview of Contents
- Latest News
- Featured News Stories
- Thirty Years of EMF Effects Research (Henry Lai c
- Tips to Reduce Your Wireless Radiation Exposure

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Also see: Acoustic neuroma risk and cell phone use studies and Should Cellphones Have Warning Labels?

Breast cancer

West et al (2013) Multifocal breast cancer in young women with prolonged contact between their breasts and their cellular phones. *Case Rep Med*. http://bit.ly/2WW8n52
Shih et al (2020) The association between smartphone use and breast cancer risk among Taiwanese women: A case-control study. *Cancer Manag Res*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7605549/
Tahmasebi et al (2025) Radiofrequency radiation from mobile phones and the risk of breast cancer: A multicenter case–control study with an additional suspected comparison group. *J Res Medical Sciences*. https://bit.ly/4pwyn15

Brain tumor incidence trends

Inskip et al (2010) Brain cancer incidence trends in relation to cellular telephone use in the United States. *Neuro Oncology*. http://bit.ly/2K6rEuz
Zada et al (2012) Incidence trends in the anatomic location of primary malignant brain tumors in the United States: 1992-2006. World Neurosurg. http://bit.ly/2Wq1Dbm
Hardell & Carlberg (2015) Increasing rates of brain tumours in the Swedish National Inpatient Register & the Causes of Death Register. *Int J Envir Res Public Health*. http://bit.ly/1aDHJm
Devocht (2016) Inferring the 1985–2014 impact of mobile phone use on selected brain cancer subtypes using Bayesian structural time series and synthetic controls. *Environ Int*. http://bit.ly/2jJlbZu corrigendum (2017): http://bit.ly/2Cuq2nU
Hardell & Carlberg (2017) 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*. http://bit.ly/H-C2017
Philips et al (2018) Brain tumours: Rise in Glioblastoma Multiforme incidence in England 1995-2015 suggests an adverse environmental or lifestyle factor. *J Environ Public Health*. http://bit.ly/2KIY4aI

Also see: Brain Tumor Rates Are Rising in the US: The Role of Cell Phone & Cordless Phone Use

Mechanisms

Ruediger (2009) Genotoxic effects of radiofrequency electromagnetic fields. *Pathophysiology*. http://bit.ly/2EXGaRb
Behari (2010) Biological responses of mobile phone frequency exposure. *Indian J Exp Biology*. http://bit.ly/2Xx0Gzr
Giuliani and Soffritti (2010). Nonthermal effects and mechanisms of interaction between electromagnetic fields and living matter. ICEMS Monograph. Ramazzini Institute. 403 pp. http://bit.ly/2HUnO7R
Juutilainen et al (2011) Review of possible modulation-dependent biological effects of radiofrequency fields. *Bioelectromagnetics*. http://bit.ly/2MAQ7KJ
Volkow et al (2011) Effects of cell phone radiofrequency signal exposure on brain glucose metabolism. *JAMA*. http://bit.ly/2KyjIBT
Pall (2013) EMFs act via activation of voltage-gated calcium channels to produce beneficial or adverse effects. *J Cell Mol Med*. http://bit.ly/2K5yO2e
Calderon et al (2014) Assessment of extremely low frequency magnetic field exposure from GSM mobile phones. *Bioelectromagnetics*. http://bit.ly/2EA1N7e
Dasdag & Akdag (2015) The link between radiofrequencies emitted from wireless technologies & oxidative stress. *J Chem Neuroanat*. http://bit.ly/2EXN88W
Yakymenko et al (2016) Oxidative mechanisms of biological activity of low-intensity radiofrequency radiation. *Electromagnet Biol Med*. http://bit.ly/2qCGM4F
Barnes & Greenenbaum (2016) Some effects of weak magnetic fields on biological systems: RF fields can change radical concentrations and cancer cell growth rates. *IEEE Power Electronics J*. http://bit.ly/1WvQGiY
Tamrin et al (2016) Electromagnetic fields and stem cell fate: When physics meets biology. *Rev Physiol Biochem Pharmacol*. http://bit.ly/2b6Ht3y
Terzi et al (2016) The role of electromagnetic fields in neurological disorders. *J Chem Neuroanat*. https://bit.ly/3j9if6b
Havas (2017) When theory and observation collide: Can non-ionizing radiation cause cancer? *Environ Pollution*. http://bit.ly/2DssMS2
Barnes & Kandala (2018) Effects of time delays on biological feedback systems and electromagnetic field exposures. *Bioelectromagnetics*. http://bit.ly/2EZkZPS
Belpomme et al (2018) Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environ Pollution*. http://bit.ly/IntlEMFreview
Hinrikus et al (2018) Understanding physical mechanism of low-level microwave radiation effect. *Int J Radiation Biol*. http://bit.ly/2EwNyoU
Mortazavi et al (2019) Evaluation of the validity of a nonlinear J-shaped dose-response relationship in cancers induced by exposure to radiofrequency electromagnetic fields. *J Biomed Phys Eng*. http://bit.ly/37FlDxP
Nielsen et al (2019) Towards predicting intracellular radiofrequency radiation effects. *PLOS One*. http://bit.ly/2uaeFxY
Panagopoulos (2019) Comparing DNA damage induced by mobile telephony and other types of man-made electromagnetic fields. *Mutation Res*. http://bit.ly/2HACI1O
Halgamuge et al (2020) A meta-analysis of in vitro exposures to weak radiofrequency radiation exposure from mobile phones (1990–2015). *Envir Res*. https://doi.org/10.1016/j.envres.2020.109227.
Bertagna et al (2021) Effects of electromagnetic fields on neuronal ion channels: a systematic review. *Annals of the New York Academy of Sciences*. https://bit.ly/2R3TigS
Panagopoulos et al (2021) Human-made electromagnetic fields: Ion forced-oscillation and voltage-gated ion channel dysfunction, oxidative stress and DNA damage (Review). *Int J Oncol*. https://www.spandidos-publications.com/ijo/59/5/92
Lai H, Levitt B. (2023) Cellular and molecular effects of non-ionizing electromagnetic fields. *Reviews on Environmental Health*. https://doi.org/10.1515/reveh-2023-0023.
Héroux P (2025) The Collision between Wireless and Biology. *Heliyon*. https://doi.org/10.1016/j.heliyon.2025.e42267.
Panagopoulos et al (2025). A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields. *Front Public Health*. https://doi.org/10.3389/fpubh.2025.1585441.
Leković Ž. Electromagnetic fields and oxidative stress: The link to the development of cancer, neurological diseases, and behavioral disorders. *Electromagn Biol Med*. 2025 Oct 21:1-25. https://doi.org/10.1080/15368378.2025.2567872
Panagopoulos et al (2026). Recording the extremely low frequency pulsations of wireless communication electromagnetic fields. *Electromagn Biol Med*. 2026 Apr 19:1-10. https://www.tandfonline.com/doi/full/10.1080/15368378.2026.2654072

Reproductive Health Effects

LaVignera et al (2011) Effects of the exposure to mobile phones on male reproduction: a review of the literature. *J Andrology*. http://bit.ly/2wL7zRO

Aldad et al (2012) Fetal radiofrequency radiation exposure from 800-1900 Mhz-rated cellular telephones affects neurodevelopment and behavior in mice. *Science Reports*. http://bit.ly/2Z6H45l

Divan et al (2012) Cell phone use and behavioural problems in young children. *J Epidemiol Commun Health*. http://bit.ly/2EV1bw8

Adams et al (2014) Effect of mobile telephones on sperm quality: A systematic review and meta-analysis. *Reproduction*. http://bit.ly/1pUnmDq

Houston et al (2016) The effects of radiofrequency electromagnetic radiation on sperm function. *Reproduction*. http://bit.ly/2cJJ2pE

Kim et al (2021) Effects of mobile phone usage on sperm quality – No time-dependent relationship on usage: A systematic review and updated meta-analysis. *Environ Research*. https://bit.ly/3squsu2

Kaur et al (2023) Genotoxic risks to male reproductive health from radiofrequency radiation. *Cells*. https://bit.ly/3PbbIaU

Also see: Effect of Mobile Phones on Sperm Quality and Pregnancy & Wireless Radiation Risks

Electromagnetic Hypersensitivity

See: Electromagnetic Hypersensitivity

Exposure & Exposure Limits

Kelsh et al (2010) Measured radiofrequency exposure during various mobile-phone use scenarios. *J Exposure Sci Environ Epidemiol*. http://bit.ly/2IuYH8s

Gandhi et al (2012) Exposure limits: the underestimation of absorbed cell phone radiation, especially in children. *Electromagnetic Biol Med*. http://bit.ly/2EZilbN

International EMF Scientist Appeal (2015). https://emfscientist.org/

International Appeal: Scientists call for protection from non-ionizing electromagnetic field exposure. *European J Oncology*. 20(3/4). 2015. http://bit.ly/EMFAppealEurOncol

Schmid & Kuster (2015) The discrepancy between maximum in vitro exposure levels and realistic conservative exposure levels of mobile phones operating at 900/1800 MHz. *Bioelectromagnetics*. http://bit.ly/31j46be

Sagar et al (2018) Comparison of radiofrequency electromagnetic field exposure levels in different everyday microenvironments in an international context. *Environ Intl*. http://bit.ly/2E5QR10

Gandhi OP (2019) Microwave emissions from cell phones exceed safety limits in Europe and the US when touching the body. *IEEE Access*. http://bit.ly/2QUTI4N

Wall et al (2019) Real-world cell phone radiofrequency electromagnetic field exposures. *Environ Research*. https://bit.ly/CDPHphone

Calderón et al (2022) Estimation of RF and ELF dose by anatomical location in the brain from wireless phones in the MOBI-Kids study. *Environ Intl*. https://bit.ly/3Or2x3F

Barnes F, Freeman JER (2022) Some thoughts on the possible health effects of electric and magnetic fields and exposure guidelines. *Front Public Health*. https://bit.ly/4f5cS3A

Lai H, Levitt BB (2022) The roles of intensity, exposure duration, and modulation on the biological effects of radiofrequency radiation and exposure guidelines. *Electromagnetic Biol Med*. https://bit.ly/RFLaiLevitt2022

ICBE-EMF (2022) Scientific evidence invalidates health assumptions underlying the FCC and ICNIRP exposure limit determinations for radiofrequency radiation: implications for 5G. *Environ Health*. https://bit.ly/ICBE-EMFpaper1

Lin J (2023) Incongruities in recently revised radiofrequency exposure guidelines and standards. *Environ Research*. https://bit.ly/3IijiUP

Miclaus et al (2023) An Exposimetric Electromagnetic Comparison of Mobile Phone Emissions: 5G versus 4G Signals Analyses by Means of Statistics and Convolutional Neural Networks Classification. *Technologies*. https://bit.ly/3ParNO5

Melnick RL, Moskowitz JM, ICBE-EMF (2026). Exposure limits to radiofrequency EMF do not account for cancer risk or reproductive toxicity assessed from data in experimental animals. *Environ Health*. https://link.springer.com/article/10.1186/s12940-026-01288-6

Genetic Effects

Lai H (2021) Genetic effects of non-ionizing electromagnetic fields. *Electromagnetic Biol Med*. https://www.tandfonline.com/doi/abs/10.1080/15368378.2021.1881866

Weller et al (2025) A scoping review and evidence map of radiofrequency field exposure and genotoxicity: assessing in vivo, in vitro, and epidemiological data. *Front. Public Health*. https://www.frontiersin.org/journals/public-health/articles/10.3389/fpubh.2025.1613353/full

Lai & Levitt (2025). Radiofrequency radiation-induced gene expression. *Rev Environ Health*. https://www.degruyterbrill.com/document/doi/10.1515/reveh-2025-0104/html

Blood-Brain Barrier Studies

AirPods: Are Apple's New Wireless Earbuds Safe? (Blood-Brain Barrier Effects)

5G and Millimeter Wave Studies

5G Wireless Technology: Is 5G Harmful to Our Health?
5G Wireless Technology: Millimeter Wave Health Effects

Other

Huss et al (2007) Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. *Environ Health Perspec*. http://bit.ly/2wBEmYp

Fragopoulou et al (2010) Scientific panel on electromagnetic field health risks: consensus points, recommendations, and rationales. *Rev Environ Health*. http://bit.ly/2tWiXHP

Alster, N (2015) *Captured agency: How the FCC is dominated by the industries it presumably regulates*. Harvard University. http://bit.ly/FCCcaptured

Consumer Reports (2015) "Does cell-phone radiation cause cancer?" http://bit.ly/CRoncellphoneradiation

Kostoff R, Lau C (2017). Modified health effects of non-ionizing electromagnetic radiation combined with other agents reported in the biomedical literature. In C.D. Geddes (ed.), Microwave Effects on DNA and Proteins. http://b.gatech.edu/2uyMAz0

Bandara P, Carpenter DO (2018). Planetary electromagnetic pollution: it is time to assess its impact. *The Lancet Planetary Health*. http://bit.ly/2GqpJQF

Foerster et al (2018). A prospective cohort study of adolescents' memory performance and individual brain dose of microwave radiation from wireless communication. *Environ Health Perspect*. http://bit.ly/2wJs0Pm

Hertsgaard, M, Dowie, M (2018). "How Big Wireless Made Us Think That Cell Phones Are Safe: A Special Investigation." *The Nation*, March 29, 2018. https://bit.ly/BigWirelessNation

Miller et al (2019). Risks to health and well-being from radio-frequency radiation emitted by cell phones and other wireless devices. *Front Public Health*. http://bit.ly/2TsUNIN

Kostoff et al (2020). Adverse health effects of 5G mobile networking technology under real-life conditions. *Toxicology Letters*. https://pubmed.ncbi.nlm.nih.gov/31991167/

Hardell & Carlberg (2021). Lost opportunities for cancer prevention: historical evidence on early warnings with emphasis on radiofrequency radiation. *Rev Envir Res*. http://bit.ly/Hardell2021

Grigoriev YG (2022). *Frequencies used in Telecommunications – An Integrated Radiobiological Assessment* (ORSAA translation; free 198 page book). https://bit.ly/GrigorievBook

Ishai et al (2023). Problems in evaluating the health impacts of radio frequency radiation. *Envir Res*. https://bit.ly/Ishai2023

Nyberg et al (2023). The European Union assessments of radiofrequency radiation health risks – another hard nut to crack (Review). *Rev Environ Health*. https://doi.org/10.1515/reveh-2023-0046

Davis D. Wireless technologies, non-ionizing electromagnetic fields and children: Identifying and reducing health risks. *Curr Probl Pediatr Adolesc Health Care*. 2023. doi: 10.1016/j.cppeds.2023.101374.

Lin JC (2025) Health and safety practices and policies concerning human exposure to RF/microwave radiation. *Front Public Health*. https://doi.org/10.3389/fpubh.2025.1619781

Levitt et al (2025) Flora and fauna: how nonhuman species interact with natural and man-made EMF at ecosystem levels and public policy recommendations. *Front Public Health*, https://doi.org/10.3389/fpubh.2025.1693873

Scarato (2025). U.S. policy on wireless technologies and public health protection: regulatory gaps and proposed reforms. *Front. Public Health*. https://doi.org/10.3389/fpubh.2025.1677583.

Also see:

Effects of Exposure to Electromagnetic Fields (studies published from 1990 on)
Recent Research on Wireless Radiation and Electromagnetic Fields (2000+ abstracts from 2016 on)
PowerWatch: 1,670 Scientific Papers on EMF (1979 - 2018)
Effects of Cell Phone Use on Adolescents
Cell Tower Health Effects
Recent Research on WiFi Effects
Effects of Wireless Radiation on Birds and Other Wildlife
Electromagnetic fields threaten wildlife

Labels: cell phone, exposure, mechanisms, references, reproductive health effects, research studies, review, tumor risk, wireless

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