Cellular and Cordless Telephone Use and the Association with Brain Tumors in Different Age Groups

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ABSTRACT. The authors' case-control study on the possible association between brain tumors and mobile and cordless telephone use included 1,617 patients and 1,617 controls. A questionnaire was answered by 1,429 (88%) cases and 1,470 (91 %) controls. Use of analog cellular telephones yielded an odds ratio (OR) for brain tumors of 1.31, 95% confidence interval (CI) = 1.04-1.64, increasing for ipsilateral use to OR = 1.65, 95% CI = 1.19-2.30. The authors found the highest risk for the 20-29-yr age group, with OR = 5.91, 95% CI = 0.63-55 for ipsilateral use of analog phones. The highest risks were associated with >5-year latency period in the 20-29-yr age group for analog phones (OR = 8.17, 95% CI = 0.94-71), and cordless phones (OR = 4.30, 95% CI = 1.22-15). <Key words: age groups, cancer risk, digital telephones, mobile telephones>

OUR FIRST STUDY on the use of cellular and cordless telephones and the risk for brain tumors indicated an increased risk for tumors appearing on the same side (ipsilateral) as the use of a cellular phone.[1] The results were based on fairly low numbers *(90%* of participating cases *[n = 209]* and *91%* of participating controls *[n = 425]),* so we performed a larger casecontrol study on the same issue [1-6] Clearly, these results showed an association with analog cellular telephones, with the highest risk for ipsilateral use. There has been much debate in the media regarding whether young people might be more sensitive to microwave emissions from cellular phones than older people. As to carcinogenesis, this hypothesis is supported by reports on atomic bomb survivors indicating that the risk was highest in children and teenagers for leukemia [7,8] breast cancer,[9,10] and thyroid cancer." To elucidate this matter, we have made a further analysis of our recent study[3-6] for different age groups.

Materials and Method

Details of the study design were published elsewhere,[3-6] and only a brief summary is given here. The geographical study area was the middle part of Sweden and encompassed patients aged *20-80* yr diagnosed between January *1, 1997,* and June *30, 2000,* with about *4.6* million inhabitants as the study base population. One control to each case was drawn at random from the population register, matched for sex and age

(5-yr age groups) and living in the same area as the cases. The ethical committee in each medical region (i.e., Uppsala-Örebro, Stockholm, Linköping, and Göteborg) approved the investigation.

We obtained the histopathology and information on tumor localization from the cancer registry. To obtain correct diagnosis and tumor localization, we requested copies of reports of neuroradiology investigations from the radiology units at different hospitals. We coded anatomical areas for the tumors without knowledge of the subject's exposure to cellular or cordless telephones.

Assessment of exposure. Cellular phone calls use radio frequency (RF) signals in the range of 400 to 2000 MHz. In Sweden, the analog system (Nordic Mobile Telephone System; NMT) was introduced in 1981, operating at 450 MHz, often in a car with a fixed external antenna. After 1984 the first portable analog phones were available. The NMT 900-MHz system operated in Sweden between 1986 and 2000. The digital system (Global System for Mobile Communication; GSM) began operation in 1991 and has been the most commonly used phone system in Sweden since the late 1990s. Moreover, desktop cordless telephones have been used in Sweden since 1988. First the analog system in the 800-900-MHz RF range was used, but now digital cordless telephones that operate at 1900 MHz are available.

We assessed exposures to cellular and cordless phones using a self-administered questionnaire, which also included items regarding exposure to certain agents and lifetime work history. Two trained interviewers, following a written protocol, supplemented, by telephone, the answers received from cases and controls. We requested mean numbers of daily calls and minutes to calculate the cumulative use in hours for all years. We also collected data on mobile telephone use in a car with a fixed external antenna, or outside a car using a hands-free device with an earpiece-both were taken as no exposure to microwaves. Respondents were asked to identify the ear most frequently used during cellular phone calls and whether both sides were used equally. We coded all data without knowing the subject's identity.

We regarded as unexposed those subjects who had begun using a mobile or cordless phone within 1 yr prior to diagnosis. The matched control was assigned in the same year as the case. We calculated the cumulative exposure in hours from the first year of use until the year before diagnosis.

Statistical analysis. We used the unconditional logistic regression analysis program from SAS Institute (Cary, NC) to calculate odds ratios (ORs) and 95% confidence intervals (CIs), making it possible for incomplete pairs (i.e., 126 cases with no control and 167 controls with no case) to be included in the analysis. We divided the material into two groups: exposed and unexposed. We further divided the exposed cases and controls according to phone type: analog, digital, and cordless. Note that a person may have been using more than one type of telephone. The unexposed group consisted of cases and controls without exposure to cellular or cordless telephones. We made adjustments for sex, age, and socioeconomic index (SEI) code. In the calculations of laterality of exposure, we assigned the matched control the same anatomical localization as the respective case. We also analyzed latency or tumor induction period using two time periods: >5 yr and >10 yr since first use of a cellular or cordless telephone until tumor diagnosis.

Results

Regional cancer registries reported 2,561 total cases. Of these, 1,617 (63%) cases fulfilled our inclusion criteria, the major exclusion being "deceased" (n = 540). Of the 1,617 cases, 1,429 (88%) answered the questionnaire; of the 1,617 controls, 1,470 (91%) answered the questionnaire, in total 1,243 men and 1,656 women. The median age for either cases or controls was 54 yr.

Table 1 displays the overall results and results by age group. Analog cellular phones yielded significantly increased risk with OR = 1.31, 95% CI = 1.04-1.64, increasing further to OR = 1.65, 95% CI = 1.19-2.30 for ipsilateral (same side as tumor) use. The risk was highest (but not statistically significant) in the age group of 20-29 yr with OR = 1.68, 95% CI = 0.60-4.74 and for ipsilateral use OR = 5.91, 95% CI = 0.63-55 in that age group.

Also, digital cellular phones increased the risk for ipsilateral use with OR = 1.34, 95% CI = 1.02-1.75. The risk was somewhat higher in the age groups 20-29 yr and 70-80 yr. Cordless phones did not increase the risk overall. However, we found the highest risk (not statistically significant) for ipsilateral use in the age group 20-29 yr, OR = 2.84, 95% CI = 0.94-8.52.

We also analyzed cumulative exposure as presented elsewhere in more detail.[5] We used the median number of hours of use among the controls as the cutoff. We found the highest OR among analog telephone users with >10 year latency period and >85 hours cumulative use yielding OR = 1.89, 95% CI = 1.17-3.05. No subject had used a digital phone >10 years. We calculated the highest (but not statistically significant) OR for >5 year latency and >55 hours cumulative use, OR = 1.37, 95% CI = 0.88-2.14, for digital phones. Only 10 cases versus 5 controls had used a cordless telephone with latency period >10 years and cumulative use >183 hours, yielding OR = 2.14, 95% CI = 0.73-6.31 (but not statistically significant).

Table 2 displays the result for different latency periods. We found the highest risk for analog phones with >10-yr latency yielding OR = 1.63, 95% CI = 1.07-2.47. Regarding different age groups, we found a high (but not statistically significant) risk for the 20-29-yr age group with >5-yr latency with OR = 8.17, 95% CI = 0.94-71.

Table 1.-Odds Ratios (ORs) and 95% Confidence Intervals (Cis) for the Use of Analog, Digital, and Cordless Phones by Age Group at Diagnosis

Age group (yr)	All Ca/Co (n) OR (95% CU	Ipsilateral Ca/Co (n) OR (95% CI)	Contralateral Ca/Co (n) OR (95% CI)	I psi-/Contra latera l Ca/Co (n) OR (95% CI)
		Analog phone		
All ages, total	247/218	121/73	68/72	22/21
	1.31	1.65	0.97	1.08
	1.04-1.64	1.19-2.30	0.67-1.40	0.58-2.01
20-29	12/8	6/1	2/5	2/1
	1.68	5.91	0.29	1.60
	0.60-4.74	0.63-55	0.04-1.90	0.13-20
30-39	32/35	18/9	6/11	4/5
	0.97	1.56	0.44	0.48
	0.49-1.93	0.58-4.18	0.14-1.40	0.10-2.27
40-49	58/50	31/16	13/22	7/1
	1.20	1.87	0.52	8.91
	0.73-1.97	0.91-3.86	0.23-1.17	0.99-80
50-59	98/81	43/30	34/23	6/8
	1.43	1.54	1.67	0.86
	0.97-2.11	0.89-2.69	0.90-3.10	0.28-2.63
60-69	38/37	18/14	11/8	2/5
	1.29	1.42	1.56	0.43
	0.75-2.19	0.65-3.08	0.60-4.07	0.08-2.35
70-80	9/7	5/3	2/3	1/1
	1.56	1.66	0.66	1.18
	0.54-4.55	0.37-7.46	0.10-4.30	0.07-21
		Digital phone		
All ages, total	423/433	182/132	138/142	44/43
	1.04	1.34	0.93	1.01
	0.87-1.25	1.02-1.75	0.71-1.22	0.65-1.58
20-29	34/31	13/7	7/5	7/4
	1.53	1.98	1.32	2.10
	0.76-3.07	0.64-6.18	0.34-5.03	0.51-8.63
30-39	68/66	29/24	18/18	8/8
	1.10	1.19	0.82	0.72
	0.65-1.87	0.57-2.49	0.36-1.85	0.23-2.28
40-49	107/104	47/28	39/43	8/9
	1.06	1.54	0.88	0.83
	0.71-1.57	0.85-2.81	0.51-1.53	0.30-2.29
50-59	148/160	64/53	55/55	13/17
	0.95	1.20	0.91	0.82
	0.69-1.30	0.77-1.88	0.58-1.44	0.37-1.78
60-69	55/64	24/18	14/17	8/5
	1.01	1.38	0.88	1.86
	0.65-1.56	0.70-2.73	0.41-1.87	0.59-5.91
70-80	11/8	5/2	5/4	0/0
	1.56	2.45	1.19	
	0.60-4.10	0.44-13.5	0.30-4.65	
		Cordless phone		
All ages, total	402/396	173/135	127/136	39/34
	1.08	1.21	0.91	1.12
	0.90-1.30	0.93-1.58	0.69-1.21	0.69-1.81
20-29	34/30	17/7	8/10	2/3
	1.40	2.84	0.79	0.80
	0.71-2.76	0.94-8.52	0.26-2.42	0.11-5.85
30-39	65/53	31/15	15/20	8/5
	1.28	1.75	0.64	1.23
	0.75-2.20	0.80-3.79	0.28-1.45	0.35-4.31
40-49	103/105	42/36	36/39	8/10
	0.99	1.08	0.85	0.73
	0.67-1.48	0.61-1.92	0.48-1.51	0.27-1.95
50-59	122/135	48/49	42/49	18/9
	0.92	0.94	0.78	1.99
	0.67-1.27	0.59-1.51	0.48-1.26	0.85-4.67
60-69	55/57	27/24	19/13	3/4
	1.09	1.14	1.61	0.88
	0.70-1.68	0.62-2.09	0.76-3.42	0.19-4.03
70-80	23/16	8/4	7/5	0/3
	1.61	1.82	1.23	
	0.81-3.20	0.53-6.28	0.37-4.09	

Note: Ca = cases; Co = controls.

Table 2.-Odds Ratios (ORs) and 95% Confidence Intervals (Cis) for the Use of Analog, Digital, and Cordless Phones by Age Group at Diagnosis and by Latency Period

Age group (yr)	>1-yr Latency			>5-yr Latency			>10-yr Latency		
	Ca/Co	OR	CI	Ca/Co	OR	CI	Ca/Co	OR	CI
				Analog phone					
All ages, total	247/218	1.31	1.04-1.64	160/135	1.35				
20-29	12/8	1 68	0.60-4.74	7/1	8.17	1.03-1.78	61/44	1.63	1.07-2.47
30-39	32/35	0.97	0.49-1.93	20/21	0.99	0.94-71	2/0		
40-49	58/50	1.20	0.73-1.97	32/33	1.01	0.45-2.22	7/7	1.35	0.39-4.68
50-59	98/81	1.43	0.97-2.11	69/55	1.56	0.56-1.83	16/7	2.33	0.88-6.20
60-69	38/37	1.29	0.75-2.19	26/22	1.42	0.99-2.46	25/22	1.61	0.83-3.14
70-80	9/7	1.56	0.54-4.55	6/3	2 37	0.75-2.69	7/6	1.43	0.46-4.47
						0.55-10	4/2	2.40	0.41-14
				Digital phone					
All ages, total	423/433	1.04	0.87-1.25	66/66	1.11	0.77-1.61			
20-29	34/31	1.53	0.76-3.07	1/1	0.84	0.04-16			
30-39	68/66	1.10	0.65-1.87	9/9	0 99	0.33-3.00			
40-49	107/104	1.06	0.71-1.57	16/16	1 02	0.46-2.23			
50-59	148/160	0.95	0.69-1.30	29/24	1.43	0.78-2.64			
60-69	55/64	1.01	0.65-1.56	10/15	0.83	0.36-1.96			
70-80	11/8	1.56	0.60-4.10	1/1	1.12	0.07-18			
				Cordless phone					
All ages, total	402/396	1.08	0.90-1.30	164/129	1.40	1.07-1.82	10/10	1 08	0.44-2.62
20-29	34/30	1.40	0.71-2.76	13/5	4.30	1.22-15	1/1	1.29	0.07-22
30-39	65/53	1.28	0.75-2.20	26/18	1.59	0.76-3.33	1/1	1.74	0.09-32
40-49	103/105	0.99	0.67-1.48	48/46	1.04	0.62-1.73	4/2	2.38	0.41-14
50-59	122/135	0.92	0.67-1.27	53/44	1.26	0.78-2.01	2/4	0.55	0.10-3.12
60-69	55/57	1 09	0.70-1.68	16/13	1.50	0.69-3.26	0/2		
70-80	23/16	1 61	0.81-3.20	8/3	2.90	0.75-11	2/0		

Note: Ca = cases; Co = controls.

With >10-yr latency time, only 2 cases and no controls were exposed in that age group.

For digital phones, we found no significantly increased risks in these calculations, and there was no clear risk pattern according to age.

For cordless phones, we found a significantly increased risk across all age groups, with >5 year latency period yielding OR = 1.40,95% CI = 1.07-1.82. When we analyzed according to different age groups, we found the highest risk for the 20-29-yr-old age group with >5-yr latency period, OR = 4.30, 95% CI = 1.22-15. The results in the group with >10-yr latency period were based on low numbers and did not allow us to make any conclusions.

We also performed an analysis for tumors located in the temporal area (i.e., the part of the brain with the highest microwave exposure). In most age groups we calculated somewhat higher (but not statistically significant) OR than for all age groups combined, for the whole study (data not shown). Thus, in the 20-29-yr-old age group analog phones yielded OR = 3.56, 95% CI = 0.29-44, digital phones yielded OR = 1.85, 95% CI = 0.39-8.67, and cordless phones yielded OR = 1.70, 95% CI = 0.41-7.02.

We also analyzed malignant and benign tumors separately. In several of the calculations, we found the highest risk in the 20-29-yr-old age group, but the calculations were based on low numbers and must be interpreted with caution.

To further explore the risk related to age at the start of cellular or cordless telephone use, we calculated the risk for subjects aged <18 yr at the time of their first reported use. This yielded no statistically significant results for analog phones OR = 5.29, 95% CI = 0.61-46 (*n* = 5 cases, 1 control), for digital phones OR = 3.44, 95% CI = 0.35-34 (*n* = 3 cases, 1 control), and for cordless phones OR = 2.35, 95% CI = 0.79-7.02 (*n* = 11 cases, 5 controls). These results, when compared with the results in all age groups, yielded OR = 1.31, 1.04, and 1.08, respectively (see Table 1). We also calculated the risk for persons with first use of any cellular or cordless phone (taken together) in the <1 8-yr-old age group. This yielded OR = 2.48, 95% CI = 0.98-6.30 (*n* = 16 cases, 7 controls) (not statistically significant).

Discussion

The main results of this study indicated an increased risk for brain tumors associated with the use of analog cellular phones. However, several of the ORs were elevated but not statistically significant. We found a higher risk in the temporal area, as would be expected because this part of the brain is most exposed to microwaves during cellular and cordless telephone calls. The risk increased further with tumor induction period. For ipsilateral use of a phone, the risk was higher than overall for all studied phone types (Table 1), significantly so for analog and digital phones. This seems to be of biological relevance because contralateral (opposite side of tumor) use did not significantly increase the risk. Analysis according to age groups yielded fairly consistently high ORs in the 20-29-yr age group. The risk was highest in that age group with >5-yr latency period.

For digital phones, we found significantly increased risk only for ipsilateral exposure for all ages combined. Across all age groups, we found the highest risks in the 20-29-yr age group and the 70-80-yr age group with >1-yr latency period.

For cordless phones, we found a significantly increased risk if we allowed a tumor induction period of >5 yr. We found the highest OR for the 20-29-yr age group with that latency period.

However, several OR calculations in different age groups were based on low numbers. The conclusion that younger individuals are at greater risk is still tenuous and may be due to the small size of the groups, which leads to elevated, but not significant, ORs. Social class and urban or rural living might be confounding factors. However, adjustment was made in the analyses for SEI-code, which makes such confounding unlikely.

The results seem to indicate that the association between cellular and cordless phones was most pronounced in the 20-29-yr age group, although the 70-80-yr age group in some of the calculations yielded a higher risk than in other age groups. A clear relation of age with higher risk among young persons for malignant disease among A-bomb survivors has been shown.[11] For brain tumors after medical and dental X-rays to the head, the strongest effect seems to be before age 20.[12] Teenagers were not included in our study, but certainly with a reasonable latency period at least some of the cases had been exposed as teenagers. Thus, for analog phones, in the 20-29-yr age group at diagnosis, the range of first reported use was 8-25 yr, median 21 yr.

Digital cellular phones and cordless phones have not been in use for as long as analog phones in Sweden, and this might be of importance for carcinogenesis. In our study, the median time of use (tumor induction period) was 7 yr for analog, 3 yr for digital, and 5 yr for cordless phones. Thus, no subjects had used digital phones for more than 10 yr (Table 2). The results for cordless phones with a >10-yr latency period were based on low numbers, and thus are difficult to interpret.

Other studies have investigated the use of mobile phones and the risk for brain tumors. A Finnish[13] study found significantly increased risk for glioma among analog cellular phone users, OR = 2.1, 95% CI = 1.3-3.4. Brief observation times in most of the studies preclude conclusions regarding an association, as we have discussed in our recent publications.[3-6]

Our population-based case-control study included patients with a histopathology diagnosis of brain tumor. Of the initially reported cases from the cancer registries, only 61% fulfilled the inclusion criteria. The major exclusion was death of the patient. This might be a shortcoming if exposure is related to prognosis, and thus could obscure an even higher risk. Furthermore, survival is shortest for the most malignant tumor types (i.e., glioblastoma), and it would certainly be prudent to study risk factors for that patient group. In the analyses, we made adjustments for age, sex (matching variables), and SEI-code because social class has been indicated to be a determinant for brain tumors.[14] The unexposed group consisted of cases and controls who had not used cellular or cordless telephones.

In a case-control study, recall bias can always influence the results. Observational bias also can be introduced during the interviews. We elucidated recall and observational bias, and our conclusion is that such bias could not explain the results, as we have discussed in detail elsewhere.[3] The consistently highest risk in the anatomical area with highest exposure strengthens that conclusion.

In summary, our present study showed an increased risk for brain tumors among users of analog cellular telephones. For digital cellular phones, we found no significantly increased risk overall, but ipsilateral exposure increased the risk significantly. Cordless phones yielded significantly increased risk overall with a >5-yr latency period. The risk seemed to be highest in the 20-29-yr age group, indicating that young subjects should use caution regarding emissions from cellular and cordless phones (e.g., consider using an external antenna and limiting the time spent using such phones). Certainly, childhood exposure should be studied more thoroughly in the future.

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