Brain Tumors and Salivary Gland Cancers Among Cellular Telephone Users

Anssi Auvinen,[1] *Maila Hietanen*,[2] *Ritva Luukkonen*,[3] *and Riitta-Sisko Koskela*[3]

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.
(EPIDEMIOLOGY 2002;13:356–359)

Key words: brain neoplasms, salivary gland neoplasms, cellular telephones, radiofrequency fields.

The current number of mobile phone users worldwide is approximately 500 million.[1] Possible health hazards of radiofrequency (RF) electromagnetic fields emitted by cellular phones have been a subject of public debate. Possible carcinogenic effect of RF electromagnetic fields has been a special concern, but few epidemiologic studies on the subject have been published.[2–6] We conducted a population-based, case-control study on mobile phone use and brain tumors and salivary gland cancers with exposure assessment based on cellular network company records.

Methods

The ethical committee of the Finnish Institute of Occupational Health approved the study protocol, and the National Research and Development Centre for Welfare and Health granted permission for use of cancer register data.

From the [1]Finnish Cancer Registry and STUK-Radiation and Nuclear Safety Authority, and [2]Finnish Institute of Occupational Health, Department of Physics, and [3]Department of Epidemiology and Biostatistics, Helsinki, Finland.

Address correspondence to: Maila Hietanen, Finnish Institute of Occupational Health, Topeliuksenkatu 41 a A, FIN-00250 Helsinki, Finland; maila.hietanen@occuphealth.fi

This study was supported by the Finnish National Technology Agency (TEKES) research program, "Electromagnetic Fields from Mobile Phones as a Possible Health Risk." Finnish mobile phone manufacturers and network providers contributed to the funding for the TEKES research program.

Submitted 28 June 2001; final version accepted 10 January 2002.

Copyright © 2002 by Lippincott Williams & Wilkins, Inc.

Study Subjects

We identified all 398 brain tumors (198 gliomas, 129 meningiomas, and 72 other or unspecified types, excluding lymphomas) and 34 salivary gland cancers diagnosed in patients between 20 and 69 years of age in Finland in 1996 from the population-based Finnish Cancer Registry. The glioma group comprised astrocytomas, glioblastomas, oligodendrogliomas, oligoastrocytomas, and ependymomas. Eighty-eight percent of brain tumors (all of the gliomas and meningiomas, and 45% of other tumors) and 97% of salivary gland cancers were microscopically confirmed.

We selected five age- and sex-matched controls for each tumor case from the Population Registry Centre of Finland. Four controls were excluded because of a previous diagnosis of brain tumor. The mean age of both brain tumor cases and controls was 50.5 years; 56% were women. For salivary gland cancer cases and controls, the mean age was 52.6 years and 38% were women.

We also compared the location and histologic subtype of gliomas among cases with and without cellular phone subscription. We reviewed cancer register notifications for all 32 cases with a cellular phone subscription before 1996 (22 with analog, six with digital, and four with both), and compared these with 32 age- and sex-matched cases without cellular phone subscription.

Exposure Assessment

We identified all private subscribers (>500,000 subjects) to the cellular phone networks in Finland. Information on cellular phone subscriptions for the cases and controls was obtained from the two cellular network

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 1. Numbers and Percentages of Cases and Controls by Occupation, Place of Residence, and Socioeconomic Status

	Brain Tumors				Salivary Gland Cancers			
	Cases		Controls		Cases		Controls	
	No.	%	No.	%	No.	%	No.	%
Occupation								
Electrical/electronic work	4	1	33	2	1	2	3	2
Locomotive drivers	13	3	44	2	2	5	1	1
Motor vehicle drivers	9	2	44	2	2	5	5	3
Agricultural occupations	50	12	239	12	1	3	21	12
Place of residence								
Metropolitan	158	40	803	40	18	53	61	36
Urban/suburban	45	11	234	12	2	6	19	11
Rural	195	49	949	48	14	41	90	53
Socioeconomic status								
Employers and self-employed	21	5	91	5	5	15	5	3
Higher administrative	34	9	217	11	4	12	26	15
Lower administrative	102	26	398	20	5	15	35	21
Manual workers	211	53	1094	55	19	56	90	53
Farmers	21	5	125	6	—†		8	5
Others*	9	2	60	3	1	3	6	4

* Including students, retired, and unemployed persons and those with unknown occupation.
† Of 34 cases, none was a farmer.

providers operating in Finland in 1996. We used a computerized record linkage, based on the personal identification number, to identify cases and controls with cellular network subscriptions. We obtained information on the type of subscription (analog [transmitting constant RF signal] or digital [transmitting pulsed RF signal] 900 MHz system), and the start and end date of subscription. Use of 450 MHz analog phones was excluded, because these usually had a separate transmission unit ("bag phone") with little or no RF field exposure to the users. Subjects with multiple accounts were identified. For persons who had switched from analog phones to digital phones (N = 18), duration of use for each type of phone was considered in the analyses.

Potential Confounding Factors

Potential confounders were urban residence, socioeconomic status, and occupation either in farming or with exposure to electromagnetic fields. We obtained information on place of residence from the Population Registry Centre, and information on occupation and socioeconomic status from Statistics Finland based on the 1990, 1993, and 1995 censuses. No information on occupation was available for 20% of cases and 18% of controls. Occupations, socioeconomic status, and places of residence were similar for controls and subjects with brain tumors (Table 1). A smaller proportion of salivary gland cancer patients than controls were farmers. Prior radiotherapy to the head and neck was reported at the cancer register for only three brain tumor cases (two hemangiomas and one meningioma) and four controls.

Statistical Analysis

Adjusted odds ratios (ORs) were calculated using conditional logistic regression. The 95% confidence intervals (CIs) presented are likelihood based.

The statistical power of the study was sufficient to detect an odds ratio of 1.4 or higher for brain tumors and 2.8 or higher for salivary gland cancers (with $\alpha = 0.05$, two-sided and $1\text{-}\beta = 0.8$).

Results

Thirteen percent of brain tumor cases, 12% of salivary gland cancer cases, and 11% of the controls had ever had a personal subscription to a cellular phone network (Table 2). Average duration of subscription was 2–3 years for the analog system, but less than 1 year for the digital phones.

Odds ratios of 1.3 (95% CI = 0.9–1.8) for brain tumors and 1.3 (95% CI = 0.4–4.7) for salivary gland cancers were observed for ever having a cellular phone subscription (Table 3). Gliomas had a weak association with cellular phone use (OR = 1.5; 95% CI = 1.0–2.4), whereas meningiomas (OR = 1.1; 95% CI = 0.5–2.4) and other histologic types (OR = 0.9; 95% CI = 0.4–2.0) were not associated with cellular phone use. In analyses by phone type, gliomas were associated with use of analog phones (OR = 2.1; 95% CI = 1.3–3.4), but not digital phones (OR = 1.0; 95% CI = 0.5–2.0). We found a weak, increasing trend in ORs by duration of analog phone subscription for gliomas, when duration was used as a continuous variable (OR = 1.2 per year; 95% CI = 1.1–1.5), but not among ever users of mobile phones, when duration was classified into three groups (Table 3). No such trend was found for digital phones. No association with duration of analog phone subscription was found for meningiomas (OR = 1.0; 95% CI = 0.6–1.5), or salivary gland cancers (OR = 1.3; 95% CI = 0.7–2.5). The results concerning brain tumors remained similar after adjustment for place of residence, occupation, and socioeconomic status.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 2. Numbers and Percentages of Cases and Controls by Cellular Phone Type (Analog/Digital) and Duration of Cellular Phone Subscriptions

Type of Phone/ Duration (Yrs)	All Brain Tumors*				Gliomas				Meningiomas				Salivary Gland Cancers			
	Cases		Controls		Cases		Controls		Cases		Controls		Cases		Controls	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Analog																
0	358	90	1852	93	172	88	921	94	121	94	615	95	31	91	155	91
<1	8	2	27	1	4	2	13	1	3	2	7	1	—		3	2
1–2	15	4	51	3	11	5	24	2	3	2	10	2	2	6	11	6
>2	17	4	56	3	11	5	31	3	2	2	11	2	1	3	1	1
Digital																
0	382	96	1897	96	188	95	938	95	126	97	623	97	33	97	167	98
<1	4	1	35	2	3	2	20	2	1	1	9	1	—		2	1
1–2	11	3	46	2	7	3	25	2	2	2	10	2	1	3	1	1
>2	1	0	8	0	—		6	1	—		1	0	—		—	

* Including 198 gliomas, 129 meningiomas, and 72 other or unspecified tumors.

In a detailed analysis of histologic type and tumor location (lobe and laterality), no differences were observed between exposed and unexposed glioma cases (Table 4).

Discussion

Few epidemiologic studies have been published on the effects of cellular phone use on cancer risk. Two previous cohort studies and three case-control studies have not found an association between brain tumors and use of cellular phones.[2–6]

We designed a case-control study based on the entire Finnish population 20–69 years of age in 1996. To maximize the duration of exposure and latency, the latest year available at the cancer register was selected. We restricted the age range to 20–69 years because use of mobile phones is most common in this age group.

A register-based approach avoids recall bias, as well as selection bias related to nonresponse. However, we were not able to verify that the actual user of the cellular phone was the subscriber or someone else (such as a family member). In a study conducted in the United States, the cellular phone subscriber was the primary phone user in 69% of subscriptions and was the sole user in 48%.[7] We also had no information on the frequency or duration of calls, or on cellular phones provided by companies to their employees. Before 1996, there were more corporate than private subscriptions in Finland, and therefore more than half of all cellular phone users could have been classified as nonusers in this study. Low sensitivity and specificity of exposure tend to attenuate

TABLE 3. Odds Ratios with 95% Confidence Intervals of Brain Tumors and Salivary Gland Cancers by Histologic Type, Cellular Phone Type (Analog/Digital), and Duration of Subscription*

Cancer Type	Mobile Phone Subscription								Increase in OR Per Year	
	Ever		<1 Year		1–2 Years		>2 Years			
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
All brain tumors										
Analog	1.6	1.1–2.3	1.6	0.7–3.6	1.5	0.9–2.8	1.6	0.9–2.8	1.2	1.0–1.3
Digital	0.9	0.5–1.5	0.6	0.2–1.6	1.2	0.6–2.3	0.6	0.1–4.5	1.0	0.7–1.5
Total	1.3	0.9–1.8	1.0	0.6–2.1	1.2	0.7–2.0	1.5	0.9–2.5	1.1	1.0–1.3
Glioma										
Analog	2.1	1.3–3.4	1.6	0.5–5.1	2.4	1.2–5.1	2.0	1.0–4.1	1.2	1.1–1.5
Digital	1.0	0.5–2.0	0.8	0.2–2.6	1.4	0.6–3.4	0.0		1.0	0.6–1.7
Total	1.5	1.0–2.4	1.2	0.5–3.0	1.6	0.8–2.9	1.7	0.9–3.5	1.2	1.0–1.4
Meningioma										
Analog	1.5	0.6–3.5	2.3	0.6–9.2	1.6	0.4–6.1	1.0	0.2–4.4	1.0	0.6–1.5
Digital	0.7	0.2–2.6	0.6	0.1–4.4	1.0	0.2–4.6	0.0		1.0	0.4–2.5
Total	1.1	0.5–2.4	1.5	0.5–4.6	1.2	0.4–3.6	0.8	0.2–3.5	0.9	0.6–1.4
Other brain tumors										
Analog	0.9	0.4–2.2	0.7	0.1–6.4	0.6	0.1–2.6	1.4	0.4–4.3	1.1	0.8–1.4
Digital	0.8	0.2–2.7	0.0		0.9	0.2–4.0	4.9	0.3–79.0	1.0	0.4–2.3
Total	0.9	0.4–2.0	0.4	0.1–3.6	0.8	0.3–2.3	1.5	0.5–4.2	1.1	0.8–1.4
Salivary gland cancers										
Analog	1.0	0.3–4.0	0.0		0.9	0.2–4.9	4.4	0.3–71.6	1.3	0.7–2.5
Digital	1.7	0.2–16.0	0.0		5.0	0.3–80.0	. .†		1.5	0.2–11.9
Total	1.3	0.4–4.7	0.0		1.7	0.4–7.5	2.3	0.2–25.3	1.3	0.7–2.6

* ORs for never users = 1.0.
† No cases or controls had used a phone for longer than 2 years, so no OR can be calculated.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 4. Histologic Subtype, Lobe, and Laterality of Glioma by Use of Cellular Phone Before 1996; All 32 Cases with Cellular Phone Subscription (Users) and a Similar Number of Randomly Selected Age- and Sex-Matched Cases Without Subscription (Nonusers)

	Users	Nonusers
Histological subtype		
Astrocytoma gr I–III	13	13
Glioblastoma	10	14
Oligodendroglioma	4	2
Oligoastrocytoma	2	2
Unspecified glioma	3	1
Lobe		
Frontal	8	7
Temporal	5	8
Parietal	2	5
Occipital	1	1
Other cortex	5	3
Not cortical	6	5
Unknown	5	3
Laterality		
Left	9	14
Right	11	12
Bilateral/central	3	2
Unknown	9	4

exposure effect. However, 50% sensitivity in exposure assessment would have attenuated the effect by only about 10%, assuming a reference exposure prevalence of 20% and a true OR of 1.1–2.0.

In conclusion, information obtained directly from subjects on mobile phone use seems preferable to a register-based approach, which has insufficient level of information. An ongoing international collaborative study with exposure assessment based on personal interview rather than registries may provide more accurate results within a few years.[8] Future studies of these cancers with larger numbers of study subjects, more detailed exposure assessment, and longer periods of exposure and follow-up are needed for valid risk assessment.

Acknowledgments

We thank the Finnish Cancer Registry for the cancer data, Statistics Finland for the data on occupation and socioeconomic status, the Population Registry Centre for identifying the controls and providing data on vital status, and Sonera and Radiolinja for the provision of information on cellular phone subscriptions. We also thank the former Research Director, Sven Hernberg, and Professor Jorma Rantanen, Finnish Institute of Occupational Health, for their comments on the manuscript, and we gratefully acknowledge the assistance of Anna-Maija Hämäläinen throughout the study.

References

1. Independent Expert Group on Mobile Phones. *Mobile Phones and Health*. Chilton: National Radiological Protection Board, 2000.
2. Hardell L, Näsman A, Pahlson A, Hallquist A, Hansson Mild K. Use of cellular telephones and the risk of brain tumors: a case-control study. *Int J Oncol* 1999;15:113–116.
3. Dreyer NA, Loughlin JE, Rothman KJ. Cause-specific mortality in cellular phone users. *JAMA* 1999;282:1814–1816.
4. Muscat JE, Malkin MG, Thompson S, *et al*. Handheld cellular telephone use and risk of brain cancer. *JAMA* 2000;284:3001–3007.
5. Inskip PD, Tarone RE, Hatch EE, *et al*. Cellular telephone use and brain tumors. *N Engl J Med* 2001;344:79–86.
6. Johansen C, Boice JD Jr, McLaughlin JK, Olsen JH. Cellular telephones and cancer—a nationwide cohort study in Denmark. *J Natl Cancer Inst* 2001;93:203–207.
7. Funch DP, Rothman KJ, Loughlin JE, Dreyer NA. Utility of telephone company records for epidemiologic studies of cellular telephones. *Epidemiology* 1996;7:299–302.
8. Cardis E, Kilkenny M. International case-control study of adult brain, head and neck tumours: results of the feasibility study. *Radiat Prot Dosim* 1999;83:179–183.

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.