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Incidence of Cancer in the Vicinity of Korean AM Radio Transmitters

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ABSTRACT. 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 100–1,500-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 1,500 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.

<Key words: AM radio transmitter, brain cancer, leukemia>

IN SEVERAL STUDIES of the effects of electromagnetic fields (EMFs) on human health, researchers have investigated extremely low frequencies (ELFs) emitted by high-power transmission lines.¹ Some epidemiologists have reported a possible relationship between ex-

posure to EMFs and human cancer, but until recently researchers lacked sufficient evidence to establish a definite causal relationship and/or a plausible interpretation of the biological mechanisms involved.^{2,3}

Radio and television transmission towers generate ra-

diofrequency radiation (RFR) in the range of 0.5 to 3,000 MHz.⁴ Recently, as more handheld mobile telephones and Personal Communications Service (PCS) phones have come into use, the number of transmitters that support these devices has increased, along with public concerns about the health effects of RFR. In urban areas of the United States, most of the RFR in the environment is reported to be produced by local radio and TV stations, with smaller contributions from cellular telephone communications and emergency services mobile radios.⁴ Thus, it is likely that radio and TV transmission towers are a major source of RFR in most industrialized countries.

In the field of epidemiology, RFR and its short- and long-term effects on health can be studied in 2 ways. In *ecological studies*, incidences of various diseases are compared between individuals from exposed and unexposed areas,^{5,6} whereas in *comparative studies*, exposed groups (e.g., occupationally exposed groups or individuals who use mobile phones) are compared with respect to disease incidence or prevalence vs. nonexposed control groups.^{7,8}

Until very recently, conclusions regarding the possible association between cancer type/incidence and RFR have been inconsistent, and evidence has been limited.^{9,10} In the present study, we investigated the health effects of RFR from radio-broadcast transmitters on populations residing near the transmitters. We used a cross-sectional ecological study design to compare cancer occurrence between populations living in proximity to high-power transmitters vs. those living near low-power transmitters, or vs. those who lived in control areas.

Method

Data sources. Korean medical-insurance data, census data, and resident registration data were used in our study. Korean medical-insurance data are produced by medical institutes for the purpose of documenting all medical services provided, as requested by the Korean National Health Insurance Corporation. The insurance data we used contained information for the period November 1993 to October 1996; variables included age, sex, main diagnosis, subdiagnosis (*International Classification of Diseases*, 9th rev. [ICD-9]¹¹ or *International Statistical Classification of Diseases and Related Health Problems*, 10th rev. [ICD-10]¹²), and a 13-digit resident registration number. A count of men and women who lived in the exposed and control areas was obtained from the 1995 census data. The census data describe the national population, which is surveyed every 5 yr. Census data for 1995 included information on population counts for the smallest administrative unit studied—Yup (in a small city in Do province)—as well as Myun (in a medium-sized rural area in Do) and Dong (in a large city in Do, or in Kwangyuk city). Patients' addresses were

confirmed from resident registration data obtained from the Government Administration Office.

Exposure and control areas. AM radio broadcasting commenced in the Yup, Myun, and Dong areas in 1927, and the last tower was built in 1980. We defined our study sites as follows: (a) "high-power sites" were those located 2 km or less from any AM radio transmitter that produced 100 kW or more of power; (b) "low-power sites" were those located 2 km or less from any radio transmitter that produced 50-kW power. On the basis of our definitions, 11 high-power sites (containing at total of 12 towers) and 31 low-power sites were included in our study.

We selected 4 control areas for each of the 11 high-power sites previously defined. Each control area was located in the same, or nearest adjacent, county as the high-power site and had no towers closer than 2 km. The actual geographic areas in this study were slightly larger than the defined areas because we included the entire units of Yup, Myun, and Dong if any portion(s) was within 2 km of the towers.

In this study, we focused on the possible association between exposure to RFR produced by radio-broadcast towers and certain cancers. The target cancers for this study were (a) leukemia (ICD-9 [204–208], ICD-10 [C91–95]) and malignant lymphoma (ICD-9 [200–202], ICD-10 [C81–85]), which have been examined previously for association with EMFs^{13,14}; (b) brain cancer (ICD-9 [191–192], ICD-10 [C70–72]), which was suspected to be associated with mobile phone and/or occupational exposures¹⁵; and (c) breast cancer (ICD-9 [174], ICD-10 [C50]), a hormone-related cancer investigated in relation to EMFs in some previous studies.^{13,16}

A list was obtained from medical-insurance data of patients who lived in either the high- or low-power sites or control areas during the period November 15, 1993, through October 31, 1996, and who suffered from the aforementioned cancers. Patients who were less than 10 yr of age were excluded because their address information from administrative resident registration data was incomplete. In addition, because the medical insurance data we used were based on fee for service, rather than fee per capita, we excluded repeated listings for the same individual in order to obtain the actual numbers of patients who were treated for the target cancers.

Statistical analysis. We employed the direct standardization method used by the World Health Organization standard world population¹⁷ to calculate the age-adjusted (5-yr intervals) incidence rates for the studied cancers in 2 groups: (1) those who lived in the 11 high-power sites and (2) those residing in the 31 low-power sites. The direct standardized incidence rate ratio was used to compare cancer incidences among the 2 groups, and 95% confidence intervals (CIs) were calculated by the square-root method.¹⁸ We also calculated

standardized incidence ratios (SIRs) using indirect standardization for each high-power site, as well as for site groupings by transmitter power (i.e., 100 kW, 250 kW, 500 kW, and 1,500 kW). The significances of SIRs were evaluated by calculating 95% CIs with Byar's approximation or exact-limit method.¹⁴

Results

The populations of the defined sites ranged from 3,152 to 126,523 persons per area. In Table 1 are shown the crude incidence rates, adjusted rates with age, and incidence rate ratios for the 11 high-power sites and 31

Table 1.—Incidence Rates and Incidence Rate Ratios for Study Sites Exposed to High-Power (100–1,500-kW) and Low-Power (50-kW) AM Radio-Broadcast Transmissions

Cancer type	Gender	Low-power sites (transmitter power = 50 kW)		High-power sites (transmitter power ≥ 100 kW)		Rate ratio†	95% CI	
		Crude*	Adjusted‡	Crude*	Adjusted‡			
All	M/F	250.2	330.1	326.4	407.4	1.2	1.1, 1.4	
	M	217.4	315.9	308.5	404.0	1.3	1.2, 1.4	
	F	282.9	344.3	344.3	410.7	1.2	1.1, 1.3	
Leukemia	M/F	4.7	5.7	7.2	8.5	1.5	0.7, 6.6	
	M	5.8	6.8	7.4	8.3	1.2	0.5, 5.3	
	F	3.6	4.6	7.0	8.7	1.9	0.8, 8.7	
Malignant lymphoma	M/F	5.7	7.1	7.8	9.6	1.4	0.6, 7.0	
	M	5.8	7.1	8.2	10.5	1.5	0.7, 8.6	
	F	5.6	7.1	7.4	8.7	1.2	0.6, 5.6	
Brain cancer	M/F	4.6	6.2	9.3	11.0	1.8	0.9, 11.1	
	M	4.5	6.2	8.2	10.0	1.6	0.8, 8.8	
	F	4.6	6.1	10.3	12.0	2.0	1.0, 13.6	
Breast cancer	F	30.4	33.6	37.4	39.7	1.2	0.8, 1.7	

Notes: CI = confidence interval, M = male, and F = female.

*Crude incidence rate (per 100,000 persons × yr).

†Age-adjusted direct standardized (using world's population, 5-yr intervals) rate (per 100,000 persons × yr).

‡Direct standardized rate ratio for high-power vs. low-power sites.

Table 2.—Standardized Incidence Rate Ratios of Total Cancer for Study Sites Exposed to High-Power (100–1,500-kW) AM Radio-Broadcast Transmissions

Site	Group	Observed*	Expected†	Observed/Expected	95% CI
Gangrung	A	135	84.10	1.61	1.45, 1.79
Gimjae-H	A	31	38.50	0.81	0.67, 0.97
Gwangju	A	204	101.10	2.02	1.68, 2.42
Gyung-san	A	138	90.60	1.52	1.23, 1.88
Gimhae	B	258	123.20	2.10	1.75, 2.52
Jeju	B	205	84.60	2.42	1.69, 3.36
Pohang	B	39	22.10	1.76	1.55, 2.00
Gimjae-B	C	52	31.10	1.67	1.13, 2.39
Hwasung	C	129	53.70	2.40	1.78, 3.17
Sihung	C	352	470.20	0.75	0.65, 0.86
Dangjin	D	93	63.60	1.46	1.18, 1.81
Totals	A	508	314.30	1.62	1.48, 1.77
	B	502	229.90	2.18	2.00, 2.39
	C	533	555.00	0.96	0.88, 1.05
	D	93	63.60	1.46	1.18, 1.81

Notes: CI = confidence interval. Group A: sites of 100-kW transmitter power; Group B: sites of 250-kW transmitter power; Group C: sites of 500-kW transmitter power; Group D: site of 1,500-kW transmitter power.

*Observed number of cases in each high-power site.

†Expected number of cases in each high-power site, calculated using age-specific incidence rates (5-yr intervals) for selected control sites.

Table 3.—Standardized Incidence Rate Ratios of Leukemia for Study Sites Exposed to High-Power (100–1,500-kW) AM Radio-Broadcast Transmissions

Site	Group	Observed*	Expected†	Observed/Expected	95% CI
Gangrung	A	5	2.28	2.19	0.71, 5.11
Gimjae-H	A	0	0.96	—	—
Gwangju	A	3	2.56	1.17	0.24, 3.42
Gyung-san	A	1	1.71	0.58	0.01, 3.26
Gimhae	B	6	1.94	3.09	1.14, 6.74
Jeju	B	6	2.71	2.21	0.81, 4.83
Pohang	B	0	0.24	—	—
Gimjae-B	C	2	0.39	5.13	0.62, 18.51
Hwasung	C	2	1.86	1.08	0.13, 3.88
Sihung	C	6	13.23	0.45	0.17, 0.99
Dangjin	D	4	0.94	4.26	1.16, 10.89
Totals	A	9	7.51	1.20	0.55, 2.28
	B	12	4.89	2.45	1.27, 4.29
	C	10	15.48	0.65	0.31, 1.19
	D	4	0.94	4.26	1.16, 10.89

Notes: CI = confidence interval. Group A: sites of 100-kW transmitter power; Group B: sites of 250-kW transmitter power; Group C: sites of 500-kW transmitter power; Group D: site of 1,500-kW transmitter power.

*Observed number of cases in each high-power site.

†Expected number of cases in each high-power site, calculated using age-specific incidence rates (5-yr intervals) for selected control sites.

Table 4.—Standardized Incidence Rate Ratios of Malignant Lymphoma for Study Sites Exposed to High-Power (100–1,500-kW) AM Radio-Broadcast Transmissions

Site	Group	Observed*	Expected†	Observed/Expected	95% CI
Gangrung	A	3	1.57	1.91	0.69, 5.58
Gimjae-H	A	1	0.28	3.57	0.09, 19.89
Gwangju	A	3	4.20	0.71	0.15, 2.09
Gyung-san	A	2	2.11	0.95	0.11, 3.42
Gimhae	B	6	6.26	0.96	0.35, 2.09
Jeju	B	5	2.96	1.69	0.55, 3.94
Pohang	B	2	0.92	2.17	0.26, 7.85
Gimjae-B	C	1	0.72	1.39	0.04, 7.74
Hwasung	C	4	3.15	1.27	0.35, 3.25
Sihung	C	11	12.40	0.89	0.44, 1.59
Dangjin	D	1	2.25	0.44	0.01, 2.48
Totals	A	9	8.16	1.10	0.51, 2.10
	B	13	10.14	1.28	0.68, 2.19
	C	16	16.27	0.98	0.56, 1.59
	D	1	2.25	0.44	0.01, 2.48

Notes: CI = confidence interval. Group A: sites of 100-kW transmitter power; Group B: sites of 250-kW transmitter power; Group C: sites of 500-kW transmitter power; Group D: site of 1,500-kW transmitter power.

*Observed number of cases in each high-power site.

†Expected number of cases in each high-power site, calculated using age-specific incidence rates (5-yr intervals) for selected control sites.

low-power sites. The high-power sites showed higher incidence rates than the low-power sites, but incidence rate ratios were not statistically significant, except for ratios of total cancer and brain cancer in women. The indirect SIRs in each of the 11 high-power sites and in the sites grouped by power, vs. control areas, are given in

Tables 2–6. Except at sites that transmitted powers of 100 kW and 500 kW, all SIRs for total numbers of cancer were statistically significantly higher than expected (Table 2). The observed number of leukemia cases in 7 of the 11 high-power sites exceeded the expected. Among these 7 sites, results for 2 which were exposed to

Table 5.—Standardized Incidence Rate Ratios of Brain Cancer for Study Sites Exposed to High-Power (100–1,500-kW) AM Radio-Broadcast Transmissions

Site	Group	Observed*	Expected†	Observed/Expected	95% CI
Gangrung	A	2	1.23	1.63	0.20, 5.87
Gimjae-H	A	1	0.47	2.13	0.05, 11.85
Gwangju	A	8	2.11	3.79	1.63, 7.47
Gyungsan	A	5	3.25	1.54	0.50, 3.58
Gimhae	B	4	4.72	0.85	0.23, 2.17
Jeju	B	6	6.15	0.98	0.36, 2.13
Pohang	B	0	0.72	—	—
Gimjae-B	C	2	1.07	1.87	0.23, 6.75
Hwasung	C	4	2.10	1.90	0.52, 4.88
Sihung	C	10	7.74	1.29	0.62, 2.38
Dangjin	D	3	1.37	2.19	0.45, 6.39
Totals	A	16	7.06	2.27	1.30, 3.67
	B	10	11.59	0.86	0.41, 1.59
	C	16	10.91	1.47	0.84, 2.38
	D	3	1.37	2.19	0.45, 6.39

Notes: CI = confidence interval. Group A: sites of 100-kW transmitter power; Group B: sites of 250-kW transmitter power; Group C: sites of 500-kW transmitter power; Group D: site of 1,500-kW transmitter power.

*Observed number of cases in each high-power site.

†Expected number of cases in each high-power site, calculated using age-specific incidence rates (5-yr intervals) for selected control sites.

Table 6.—Standardized Incidence Rate Ratios of Female Breast Cancer for Study Sites Exposed to High-Power (100–1,500-kW) AM Radio-Broadcast Transmissions

Site	Group	Observed*	Expected†	Observed/Expected	95% CI
Gangrung	A	16	10.20	1.57	0.90, 2.54
Gimjae-H	A	1	2.36	0.42	0.01, 2.36
Gwangju	A	7	5.27	1.33	0.53, 2.74
Gyungsan	A	5	4.66	1.07	0.35, 2.50
Gimhae	B	12	13.04	0.92	0.48, 1.61
Jeju	B	6	8.41	0.71	0.26, 1.56
Pohang	B	2	1.26	1.59	0.19, 5.73
Gimjae-B	C	3	1.42	2.11	0.44, 6.17
Hwasung	C	7	6.61	1.06	0.42, 2.18
Sihung	C	31	37.36	0.83	0.56, 1.19
Dangjin	D	3	1.37	2.19	0.45, 6.39
Totals	A	29	22.49	1.29	0.86, 1.86
	B	20	22.71	0.88	0.54, 1.36
	C	41	45.39	0.90	0.64, 1.23
	D	3	1.37	2.19	0.45, 6.39

Notes: CI = confidence interval. Group A: sites of 100-kW transmitter power; Group B: sites of 250-kW transmitter power; Group C: sites of 500-kW transmitter power; Group D: site of 1,500-kW transmitter power.

*Observed number of cases in each high-power site.

†Expected number of cases in each high-power site, calculated using age-specific incidence rates (5-yr intervals) for selected control sites.

transmitter power levels of 250 kW and 1,500 kW, respectively, were statistically significant (Table 3). At 6 sites, the number of cases of malignant lymphoma was greater than expected, but was not statistically significant (Table 4). At 8 sites, the observed incidence of brain cancer was higher than expected; at 1 site it was signif-

icantly higher than expected (Table 5). At 7 sites, the observed number of breast cancer cases was greater than expected, but not significantly so (Table 6). The SIRs of cancer in the sites grouped by transmitter power level did not appear to have any bearing on the dose-response effect for any type of cancer.

Discussion

The incidence of cancer in high-power sites located around a 100-kW or greater transmitter power antenna outnumbered that in the low-power sites (without statistical significance). When the indirectly adjusted SIRs of cancer in high-power sites vs. control areas were calculated, the incidence of leukemia was significantly higher at 2 of the 11 high-power sites; the incidence of brain cancer was significantly higher at only 1 of the 11 sites.

In a previous study, Hocking et al.⁵ reported a significantly greater incidence of leukemia among individuals of all ages, and among children, who lived in the vicinity of an Australian local TV transmitter. McKenzie et al.⁶ investigated the same area 2 yr later, using more-detailed location information, and found only 1 area near the transmission tower which showed an increased incidence of childhood leukemia, although it was emphasized that the cases in this area had occurred prior to the time when transmission actually commenced. In a study of the Sutton Coldfield transmitter in the United Kingdom, Dolk et al.¹⁹ reported that, among individuals who lived within 2 km of frequency modulation (FM)/TV towers, there was an excess of individuals with adulthood leukemia and skin cancer. When the authors expanded their study to 20 additional sites with FM/TV transmitters, however, the incidences of skin melanoma, adulthood leukemia, bladder cancer, childhood leukemia, and brain cancer were neither increased nor decreased.¹⁶

Because of the cross-sectional ecological design of the current study, results could not be extended to prove an etiological association between radiation exposure from AM radio-broadcast towers and cancer, rather it was our intention to explore the need for further analytical study. Our study had some limitations that deserve elucidation. First, some discrepancies between registered addresses and actual addresses could have resulted in misclassification bias, possibly leading to inaccurate classification of the exposed and unexposed individuals. A second limitation might have been the quality of exposure assessment. We used "2 km from the towers" as the criterion of exposure to RFR. In a previous study in which actual measurement was made around some broadcasting towers, the distances from the towers at which magnetic field strength decreased to an almost undetectable level were 1 km (in Gwangju) and 2 km (in Gimhae and Dangjin).²¹ Although the 2-km distance could be considered a reasonable criterion of exposure, there was likely some misclassification of exposure. The fact that we used administrative borders, not actual distances, could also have contributed to the dilution of exposed areas with those unexposed to AM radio-broadcast towers. Third, the medical insurance data we used were not produced

for the purposes of clinical diagnosis and patient treatment, but for medical administration. The validity of disease diagnosis recorded in the insurance data was known to vary, depending on the type of cancer/disease and the level of a medical institution in regard to the medical referral system. Researchers in Korea found an agreement rate of 93–99% for cancer diagnoses between medical insurance data and medical chart records (unpublished report). If the validity of diagnoses varied among the study areas, our results might have been distorted. Finally, we did not consider any confounding factors that could have influenced either residents' health or RFR exposure from AM radio transmitters.

Our results suggest a need for further studies to investigate a possible association between RFR from AM radio-broadcast towers and leukemia and brain cancer in some geographical areas of Korea. Future studies would benefit from more accurate exposure assessment, adjustment for other strong confounding factors, and a strong analytical study design.

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