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A BRIEF ORIGINAL CONTRIBUTION

Leukemia Risk and Occupational Electric Field Exposure in Los Angeles County, California

Leeka I. Kheifets,[1] Stephanie J. London,[2] and John M. Peters[3]

The authors analyzed data on electric fields from a prior study of occupational magnetic field exposure and leukemia risk conducted in Los Angeles County, California, in 1972–1990. Ranking of exposure differed somewhat for magnetic and electric fields. The odds ratios were 1.22 (95% confidence interval (CI) 0.80–1.86) and 1.15 (95% confidence interval 0.78–1.72) for medium and high exposure categories, respectively, and there was no clear evidence of an exposure-response relation (odds ratio for 10 V/m increase = 1.05, 95% CI 0.95–1.16). Although not conclusive, our analyses provide little support for an association between occupational electric field exposure and leukemia. *Am J Epidemiol* 1997;146:87–90.

electromagnetic fields; leukemia; occupations

Numerous epidemiologic studies have examined the potential influence of electric and magnetic fields on the development of leukemia. Two residential studies of children included measurements of both electric and magnetic fields (1, 2). On the basis of their findings, subsequent residential studies have focused extensively on magnetic fields. The risk of leukemia in electrical workers has been examined in about 40 studies that relied on job title alone to categorize exposure (3). More recent studies have incorporated extensive measurement programs with a focus on magnetic fields (4–7). Recently, Miller et al. (8) reported leukemia risk associated with electric fields. Owing to the paucity of published data on leukemia in relation to electric fields, we analyzed data on electric fields from a study of occupational magnetic field exposure and leukemia by the Los Angeles Cancer Surveillance Program, the comprehensive cancer registry for Los Angeles County, California (9).

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Abbreviation: CI, confidence interval.

[1] EMF Health Assessment and Management, Environment Group, Electric Power Research Institute, Palo Alto, CA.
[2] Epidemiology Branch, National Institute of Environmental Health Sciences, Research Triangle Park, NC.
[3] Division of Occupational and Environmental Health, Department of Preventive Medicine, University of Southern California School of Medicine, Los Angeles, CA.
Reprint requests to Dr. Leeka I. Kheifets, Electric Power Research Institute, 3412 Hillview Avenue, Palo Alto, CA 94303.

MATERIALS AND METHODS

Detailed methods for this study have been presented previously (9, 10). Briefly, electric and magnetic fields were measured in "electrical" occupations modified from the original list of Milham (11) and in a random sample of nonelectrical occupations. Magnetic and electric field exposures for each job title were quantified by personal measurements for specific occupational tasks and by estimating the amount of time spent at each task by workers. Only some of the meters had the capability of measuring electric fields, resulting in fewer electric field measurements. The same standardized protocols were used to collect exposure information for both electrical and nonelectrical occupations. This resulted in a task-weighted exposure estimate for each job title, calculated both for the present and for a period of 15–20 years ago. Only the exposures calculated for the present were used, since the pattern of exposures estimated for the past 15–20 years was very similar (data not shown).

Although we did not have electric field measurements for power line workers in Los Angeles, we classified them as high exposure because, based on all available data (5, 10, 12), power line workers had high electric field exposure measurements. Similar average electric field exposures for power line workers were reported both by us (10) for measurements in Seattle (95.4 V/m) and across other US utilities (12) in the EMDEX occupational study (116 V/m). These levels are in the middle of the range of electric field measurements used by Miller et al. (8) for power linemen.

Average electric field exposures for high-to-medium transmission and distribution power linemen in the Ontario Hydro study ranged from 56 to 174 V/m (5).

The case-control analysis included all men aged 20–64 years with a diagnosis of cancer reported to the cancer registry between 1972 and 1990. The cases were 2,355 men with leukemia. The controls were 67,212 men with other cancers, excluding those with malignancies of the central nervous system because of a possible association with magnetic fields (13). We used odds ratios to estimate associations between categories of electric field exposure and leukemia risk. To test for trend in leukemia risk with increasing electric field exposure, we assigned the mean task-weighted average for that occupation to all subjects in that group and treated this variable as continuous in the logistic regression model. We present the test for trends as the change in odds ratios per 10 V/m increase in exposure. Age and other occupational exposures were the only variables considered as potential confounders. Adjustment for other occupational exposures did not appreciably alter the magnetic field-leukemia association, and therefore, we present results adjusted only for age.

RESULTS

A comparison of electric and magnetic field measurements for different occupations is presented in table 1. We did not have electric fields measurements for power line workers, the group with the highest magnetic field measurements. For the other eight occupations, the ranking of exposures differed somewhat for magnetic and electric fields. While power station operators had high exposures for both magnetic and electric fields, welders had higher magnetic field exposures but were in the low ranking for electric fields. Electricians had the second highest electric field exposure but were in the middle of the ranking for magnetic fields. Projectionists, telephone line workers, and engineers had electric field exposures that were nearly identical to those of the nonelectrical workers.

To assess the risk of leukemia by electric field exposure, we performed two types of analysis. First, we divided the data into ordered categories by using cutpoints of 20 and 10 V/m to distinguish high, medium, and low exposures. The odds ratios were very slightly but nonstatistically significantly elevated, and there was no evidence of an exposure-response relation (table 2). The odds ratios were not altered by using 19 V/m to delineate the high exposure category, thus including television and radio repairmen, or by deleting the power line workers, for whom we did not have measurements in Los Angeles. We also used the mean values for the eight electrical occupations as well as for the nonelectrical occupations we measured in Los Angeles to test for linear trend in relation to leukemia risk. The odds ratio per 10-V/m increase in exposure was 1.07 (95 percent confidence interval (CI) 0.93–1.23). If we included power line workers by giving them the mean value measured at the utility in Seattle, Washington (94.5 V/M), the odds ratio became 1.05 (95 percent CI 0.95–1.16). For completeness, we present an analysis by leukemia subtype. For chronic lymphocytic leukemia, there was an increased risk in the medium exposure category (odds ratio = 1.88, 95 percent CI 1.12–3.17), but the risk went down in the high category (odds ratio = 1.26, 95 percent CI 0.72–2.17). Overall, for the subtype analysis, the risk estimates were unstable due to small numbers and do not show an exposure-response relation in either categorical or continuous analysis.

TABLE 1. Comparison of exposure categorizations for electric and magnetic fields from a study in Los Angeles County, California, 1972–1990

Occupation	Electric field exposure (V/m)			Magnetic field exposure (mG)		
	No.	Mean	(SD)*	No.	Mean	(SD)
Electrical						
Power linemen		n/a*		87	23.6	(4.1)
Engineers	2	5.2	(0.5)	14	1.6	(0.1)
Telephone linemen	21	5.2	(0.8)	32	2.7	(0.4)
Projectionists	14	5.5	(0.9)	15	8.0	(1.9)
Welders	6	6.2	(0.9)	22	19.5	(6.9)
Technicians	4	13.3	(2.6)	13	3.4	(0.3)
Television and radio	17	19.0	(5.6)	25	3.4	(0.4)
Electricians	9	30.6	(13.1)	33	7.0	(1.7)
Power station	6	84.8	(18.4)	37	17.1	(7.7)
Nonelectrical	28	5.5	(0.5)	105	1.7	(0.1)

* SD, standard deviation; n/a, not applicable.

TABLE 2. Odds ratio for leukemia and its subtypes in relation to mean electric field exposure, Los Angeles County, California, 1972–1990

Category	Range (V/m)	Cases	Controls	Categorical		Continuous	
				OR*	95% CI*	OR†	95% CI
All leukemia							
Low	<10	2,296	65,792	1.0			
Medium	10–20	28	627	1 22	0.80–1.86		
High	>20	31	793	1.15	0 78–1.72		
All		2,355	67,212			1.05	0.95–1.16
ANLL*							
Low	<10	831	65,792	1 0			
Medium	10–20	11	627	1 31	0.68–2.53		
High	>20	11	793	1.15	0 59–2.20		
All		853	67,212			1.07	0.93–1.25
CLL*							
Low	<10	517	65,792	1.0			
Medium	10–20	9	627	1.88	1.12–3.17		
High	>20	8	793	1.26	0.72–2.17		
All		534	67,212			1.05	0.88–1.25
CML*							
Low	<10	478	65,792	1.0			
Medium	10–20	2	627	0 39	0.09–1.63		
High	>20	7	793	1 28	0.60–2.76		
All		487	67,212			1 06	0.87–1.29

* OR, odds ratio; CI, confidence interval; ANLL, acute nonlymphocytic leukemia; CLL, chronic lymphatic leukemia; CML, chronic myelogenous leukemia

† Per 10 V/m.

DISCUSSION

Magnetic, rather than electric, fields have been identified as the exposure of potential interest in previous epidemiologic studies, largely on the basis of the lack of an association between childhood leukemia risk and electric fields in the two studies that included both measurements (1, 2). Further, in contrast to magnetic fields, electric fields had a much weaker correlation with wiring configuration code, a risk factor for leukemia in both studies.

Our data are consistent with the original publication from the Canada-France study (5), which did not find significant associations for leukemia or its subtypes and electric fields. Our results appear to be at variance with Miller et al. (8), who reported an odds ratio of 4.45 (95 percent CI 1.01–19.7) for all leukemia in a subset of the Canada-France cohort.

Our detailed, task-based exposure measurements should provide information that is qualitatively similar to the job-title and job-site characterization used by Miller et al. (8). Nevertheless, our data were weakened by a proportional incidence rather than by a general population design and by a job history limited to only one occupation at diagnosis. Further, our job-specific measurements were not made at the companies where subjects were employed. While we were able to rank the jobs on the basis of quantitative data, our reliance on a single job led to our inability to estimate cumulative exposures and the necessity to focus on average exposures. However, these weaknesses apply equally to magnetic field results that were consistent with other studies (3).

The results from the study by Miller et al. (8) should be interpreted with some caution due to the inclusion of only retirees in the first 3 years. However, it is difficult to speculate on the direction of bias that would result without data on the relative exposure profiles of men with short versus long tenure in high-exposure jobs.

Exposure assessment remains a major challenge in all studies of magnetic and electric fields. In addition to the plethora of well-known difficulties in measuring magnetic field exposures today and extrapolating them to workers who held similar jobs in the past, measuring electric field exposure presents unique difficulties. Electric fields are perturbed by conducting objects such as humans and their surroundings. The interaction of the subject with the field affects the reading of a field meter placed on the body. The field that is recorded by the instrument is therefore very dependent on where the device is worn, the posture of the subject, and the relative location of sources of fields. This makes measurements of the electric fields difficult to perform and interpret, often yielding relative, as opposed to absolute, values of exposure for different individuals. Because most of the exposure assessments in the occupational environments have focused on magnetic, rather than on electric, fields, little is known about the reliability and validity of electric field measurements.

While our analyses provide little support for an association between occupational electric field exposure and leukemia, electric field measurements were not examined in most of the previous studies. Exposure misclassification is probably greater for electric than for magnetic fields, thus to be informative, future studies need to focus on developing the methodology and improving exposure assessment for electric fields. Larger studies will also be needed to examine associations with specific leukemia subtypes.

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