Risk of Leukemia in Children Living Near High-Voltage Transmission Lines

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We conducted a study to examine the risk of leukemia between 1987 and 1992 among children living near high-voltage transmission lines (HVTL) in three urban districts of northern Taiwan. Twenty-eight cases of leukemia among some 120,696 children aged 14 years or less were reported to the national cancer registry between 1987 and 1992. Compared with children living in households more than 100 meters away from HVTL, children living in households less than 100 meters from HVTL experienced an essentially elevated risk of leukemia (7 versus 2.88, standardized incidence ratio [SIR] = 2.43, 95% confidence interval [CI] = 0.98–5.01). The elevated risk stands when compared with all children of Taiwan alternatively (7 versus 2.60, SIR = 2.69, 95% CI = 1.08–5.55). Such elevated risk was particularly noteworthy among children aged 5–9 years. The findings suggest that children living near HVTL tend to experience an elevated risk of leukemia. Further investigations are undoubtedly needed to unveil whether such tendency may have implied the putative association between exposure to elevated magnetic fields and risk of childhood leukemia.

We previously reported a significantly elevated risk (standardized incidence ratio [SIR] = 1.49, 95% confidence interval [CI] = 1.16–1.91) of childhood leukemia for the period from 1979 to 1988 in the five districts of Taipei Metropolitan Area, where high-voltage transmission lines (HVTL) (69–345 kilovolts [kV]) pass over at least one elementary school campus.[1] Since our previous study considered all children residing in the five districts to have higher-than-background exposures to power frequency magnetic fields, which is essentially not valid, we used a more precise method in the study presented here to determine the children's residential exposures to magnetic fields and to reassess the potential risk of childhood leukemia in relation to ambient magnetic fields in northern Taiwan. Information from one recent study indicated that Shihlin, Tucheng, and Hsichuh were the districts densely scattered with high-power transmission lines in the Taipei metropolitan area of Taiwan.[2] We therefore selected these three districts as the study area in the study presented here in order to identify an exposed cohort large enough for the purpose of gaining adequate statistical power in risk estimation. In addition, taking into account the annual incidence rate of childhood leukemia in Taiwan and the completeness of the National Cancer Registry, we decided to cover the period between 1987–1992 in order to gain sufficient number of cases of childhood leukemia. Dissimilarity in study period coverage between the present study and our 1994 study (1979–1988)

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TABLE 1
Population and Housing Units in the Study Districts

% of Grids in Each "Li"*	No. of "Li"				No. of Houses†				No. of Children‡			
	Shihlin	Tuchen	Hsichuh	Total	Shihlin	Tuchen	Hsichuh	Total	Shihlin	Tuchen	Hsichuh	Total
91–100	0	0	1	1	0	0	1257	1257	0	0	1210	1210
71–90	0	1	1	2	0	1334	1000	2334	0	1177	315	1492
51–70§	2	5	3	10	1933	7216	3143	12292	730	5490	2880	9100
31–50	2	8	4	14	4693	10916	1800	17409	3815	7408	1888	13111
11–20	5	13	12	30	9939	20254	9886	40079	5350	15643	7938	28931
0–10	41	13	13	67	75463	20922	11485	107870	43024	13857	9971	66852
Total	50	40	34	124	92028	60642	28571	181241	52919	43575	24202	120696

* Within 100-m buffer.
† Annual average no. of houses between 1987 and 1992.
‡ Annual average child (<15 years of age) population size between 1987 and 1992.
§ The "li" within which 50%–70% of grids intersecting with 100-m buffer was considered to be exposed.

also help to avoid selective reporting. This study aims to further examine the risk of childhood leukemia (children aged <15 years) in relation to residential exposure to magnetic fields characterized by residential proximity to HVTL (69–345 kV) in Taiwan.

Methods

Study Populations and Cases of Childhood Leukemia

The three districts (Shihlin, Tucheng, and Hsichuh) in the Taipei Metropolitan area with a heavy presence of HVTL were identified from our previous study[1] and were used as the target study area in this study. A total of 124 "li"s, the smallest administrative region in Taiwan, were encompassed within the boundary of the study area. From 1987 to 1992, the annual average number of 120,696 children aged 14 or less was residing in 181,241 housing units (Table 1). During the same period, a total of 28 pathologically confirmed cases of childhood leukemia from the three districts were newly diagnosed and reported to the National Cancer Registration Center of Taiwan.

Determination of Residential Proximity to High-Power Transmission Lines

The households in the three districts were categorized using utility route maps with a scale of 1 in 5300 (ie, 1.89 mm = 10 meters [m]) into two categories: (1) households within and (2) households outside 100 m on each side of HVTL. The residential proximity to HVTL was determined stepwise. The pre-computerized utility route maps of the three districts (or 124 "li"s), showing the distributions of major power lines and the boundary for each "li", were first supplied by the state-run Taiwan Power Cooperation. The region within 100 m of HVTL was then identified and inscribed as the buffer zone within which all the residences were considered to have elevated indoor exposures to magnetic fields. A grid with 2 mm on each side (ie, a grid of 112 m^2 in area) was then created and mapped. The 112-m^2 grids were used to determine the percentage of the area for each "li" intersecting with the 100-m buffer. The households in each "li" with ≥50%-70% of grids intersecting with the buffer were considered to be less than 100 m from HVTL. It was estimated that some 15,883 households were located and 11,802 children were residing within the 100-m buffer zones, representing 8.8% of all households and 9.2% of all children in the study districts between 1987 and 1992 (Table 1). The annual age-specific (0–4, 5–9, and 10–14 years) populations of the above two household categories between 1987 and 1992 were derived from national census statistics, which provide the annual age-specific population sizes for each "li" of the nation.[3]

Risk Estimation

Children residing within 100 m of HVTL were considered to be "exposed." The expected number of cases (EXP) of childhood leukemia among exposed children was calculated from the person-year approach, using calendar-age (5-year)–specific incidence rate of childhood leukemia in the reference population multiplied by the corresponding calendar and age childhood population in the exposed households. SIRs were estimated by dividing the observed number of leukemia cases (OBS) by the expected (EXP). Two reference populations were used in the study, ie, children living 100 m outside of HVTL in the study districts, and all children in Taiwan.

Results

Between 1987 and 1992, there were seven cases of leukemia among children residing within 100 m of HVTL in the study districts, and 21 cases among children living at least 100 m away from HVTL in the same area. Compared with those living outside 100 m of HVTL, children in households within 100 m of HVTL showed a marginally significant elevation of SIR of leukemia (7 versus 2.88, SIR = 2.43, 95% CI = 0.98–

TABLE 2
Standardized Incidence Ratio (SIR) of Childhood Leukemia Among Households Within 100 Meters of High-Voltage Transmission Lines*

Age (years)	OBS	EXP†	SIR	95% CI
0–4	2	1.57	1.56	0.15–4.60
5–9	4	0.85	4.70	1.28–12.1
10–14	1	0.46	2.17	0.07–12.1
Total	7	2.88	2.43	0.98–5.01

* OBS, observed number of childhood leukemia cases; EXP, expected number of childhood leukemia cases; CI, confidence interval.

† Calendar-age–specific incidence rate among children residing more than 100 meters away from high-voltage transmission lines in the study area was used to compute EXP.

TABLE 3
Standardized Incidence Ratio (SIR) of Childhood Leukemia Among Households in the Study Area by Distance From High-Voltage Transmission Lines (Cutoff Point = 100 m)

Age (years)	Distance From High-Voltage Transmission Lines: <100 m OBS/EXP*	<100 m SIR (95% CI)	≥100 m OBS/EXP*	≥100 m SIR (95% CI)
0–4	2/1.21	2.48 (0.20–5.97)	10/8.47	1.18 (0.57–2.17)
5–9	4/0.79	5.06 (1.38–13.0)	7/6.40	1.09 (0.44–2.30)
10–14	1/0.60	1.67 (0.05–9.28)	4/5.15	0.78 (0.21–1.99)
Total	7/2.60	2.69 (1.08–5.55)	21/20.0	1.05 (0.64–1.58)

* National calendar-age–specific incidence rate of Taiwan area was used for calculation of the expected number of childhood leukemia incidences.

5.01). The SIR was elevated in all of the three ages, with a particularly notable increase among the 5–9–year-old group (4 versus 0.85, SIR = 4.70, 95% CI = 1.28–12.1) (Table 2).

Compared with all children in Taiwan, the children within 100 m of HVTL in the study districts also showed a significantly elevated SIR (7 versus 2.60, SIR = 2.69, 95% CI = 1.08–5.55). The age-specific SIR once again indicated a noteworthy elevation of risk among children of 5–9 years (4 versus 0.79, SIR = 5.06, 95% CI = 1.38–13.0). The children in households outside 100 m of HVTL, on the other hand, do not show any significantly elevated risk of childhood leukemia, as compared with all children in Taiwan (SIR = 1.05, 95% CI = 0.64–1.58) (Table 3).

Discussion

In our earlier publication, we reported an association between the surrogate for residential exposure to power frequency magnetic fields and the risk of childhood leukemia (age <15 years). The surrogate for residential magnetic fields exposure in that particular study was loosely defined, ie, housing units in districts with at least one elementary school campus passed over by HVTL (69–345 kV) were all considered having elevated exposures.[1] We attempted in this study to improve the validity of the surrogate for exposures in which all of the housing units in the study districts were determined with respect to their distance to HVTL, and the exposure levels of children in households were assigned accordingly. With such improvement in exposure assessment, it is believed that the results from the study would be less biased than our previous findings.

Similar to our previous findings, we again noticed an increase in risk of childhood leukemia in relation residential proximity to HVTL. Residential proximity to HVTL has been frequently used as an exposure metric in assessment of the association between exposure to power frequency magnetic fields at home and risk of childhood leukemia[4–6] and has been considered as the most nascent state of assessment of residential magnetic fields, not only because it better captures long-term exposure to electrical utility equipment near residences but also because any biologically important characteristic related to magnetic fields is more likely to be found proximally than distally.[7] Of the three studies of children using proximity to power lines as an exposure metric,[4–6] only Feychting and Ahlbom[5] observed a significantly elevated incidence of leukemia among children residing ≤50 m of major power lines (odds ratio [OR] = 2.9, 95% CI = 1.0–7.3). The other two studies did not reveal any positive result to support the hypothesis that magnetic fields may cause childhood leukemia.[4,6]

Many previous studies of risk of childhood leukemia in relation to magnetic fields exposure suffered from inadequate statistical power to detect the true association.[8,9] In the study presented here, there were only seven exposed children who developed leukemia during the study period, also causing an imprecise risk estimation. What needs to be addressed herein is that the way we used to identify a cohort with potentially elevated exposures is different from those used in previous cohort or nested case-control studies. Although the proportion of the general population living near HVTL is usually small, given the widespread distribution of electrical distribution systems, there must be a substantial number of people with exposures markedly higher than the background exposure in certain regions with a dense population like Taipei. With computerized utility route maps and large-scale residential maps, it is possible that a sufficient size of individuals from large regions can be easily and rapidly identified to meet the need of epidemiological studies.

In this study, we surveyed households located within 100 m of HVTL (presumably with higher-than-background magnetic fields). The selection of a buffer width of 100 m was based on the magnetic fields strength at the edge of the right-of-way. In a study measuring magnetic fields of 407 households in northern Taiwan, it was suggested that the indoor ambient magnetic fields attributable to HVTL were some 2 milli Gauss (mG) for households with a distance of 100 m from HVTL, and a higher exposure can be found in households less than 100 m from HVTL.[10] A magnetic fields strength of 2 mG was considered to be above the background exposure in most of the previous studies.[7–9] Since the exposure assessment of the study was based on the distance of each administrative region, rather than the individual housing unit, to the HVTL, the exposure assessment used in the study may have entailed certain degrees of exposure misclassification, which is believed to alter the risk estimates of the study toward the unity for some extent.

Some studies have reported that children living near certain types of power lines have higher than average rates of leukemia and speculated that power lines might be associated with a cancer risk factor other than magnetic fields.[5,11–13] Several possible confounders have been suggested, including medical history of the family, occupation of parents, traffic density, socioeconomic class, and exposure to chemical substances, but they were ultimately found to produce no confounding at all.[12,13] Thus, in view of the evidence available, results of recent epidemiological studies can hardly be dismissed by arguing a known risk factor for childhood leukemia.[8] However, the possibility of presence of an unknown leukemogen to cause a false-positive association in the studies can not be dismissed. Because of a lack of adjustment of potential confounders in the study presented here, we are unable to draw a conclusion on the role of magnetic fields in the causation of childhood leukemia.

This study provides additional support for the association between residential proximity to HVTL and risk of childhood leukemia. The use of a distance of less than 100 m as a surrogate for magnetic fields is crude in that it also limits the ability of our findings to draw a firm conclusion as to whether the observed association can be attributable to a causal link between magnetic fields exposure at home and the subsequent incidence of leukemia in children. This study also demonstrated one way of identifying a cohort living near HVTL. Although we could not determine the distance of individual housing units to HVTL, we did provide grouped exposure estimates based on reasonable buffer zones. We believe that this method can be useful and efficient in identifying a cohort of sufficient size for further epidemiological studies, at least in regions with dense populations like Taipei. In summary, this study does provide additional support to the association between residential proximity to HVTL and risk of childhood leukemia. We therefore recommend that further studies are warranted in order to uncover what is responsible for such a link. Specifically, the question "If the observed association between residential proximity to HVTL and risk of childhood leukemia is indeed real, then what is to blame?" must be answered by additional scientific research.

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