Risks of leukaemia among residents close to high voltage transmission electric lines

Gilles Thériault, Chung-Yi Li

Abstract

Objectives—To reassess the risk of leukaemia associated with residential exposure near high voltage transmission electric lines of 49 kV and above in view of the recent publications.

Methods—Through a review of papers considering the risk of leukaemia among people living near high voltage transmission lines, the combined risks of leukaemia were calculated for distances ≤ 50 m and ≤ 25 m and for exposures at 2 mG, 3 mG, 4 mG, and 10 mG.

Results—The combined analysis of the contributive studies indicated an estimate of risk (odds ratio (OR)) for exposure ≥ 2 mG of 1.3, 95% confidence interval (95%CI) 1.0 to 1.7. The ORs increased with exposures at 3 mG, 4 mG, and 10 mG. The risks were also increased for distances of 50 and 25 m from the lines.

Conclusions—This meta-analysis tends to confirm the presence of an association between exposure to magnetic fields and leukaemia among people who reside in the vicinity of high voltage transmission electric lines of ≥ 49 kV. There is consistency across studies. Measures of exposure used in the studies were either distance from the lines or calculated fields estimated from pertinent line features. The results apply to adults as well as to children.

(*Occup Environ Med* 1997;54:625-628)

Keywords: leukaemia; electromagnetic fields; cancer; environmental health; meta-analysis

Department of
Occupational Health,
McGill University,
Montréal, Québec,
Canada
G Thériault

Department of
Epidemiology and
Biostatistics, McGill
University, Montréal,
Québec, Canada
G Thériault
C-Y Li

Correspondence to:
Dr Gilles Thériault, Joint
Departments of
Epidemiology, Biostatistics
and Occupational Health,
McGill University, 1020 Pine
Avenue West, Montréal,
Québec H3A 1A2, Canada.

Accepted 27 May 1997

Several studies have considered the relation between residential exposure to 50 or 60 Hz magnetic fields and the risk of leukaemia among children and adults who live there.¹ In assessing exposure, authors have used several means: wire code, spot measurements, four corner measurements, bedroom measurements, calculated exposure from circulating current in high voltage overhead power lines, and more recently personal dosimetry.²

So far, these studies have come to a paradoxical result: they found a relation between electrical wiring around the house of leukaemia cases but no such relation with magnetic fields measured directly inside the house.³⁻⁵ To explain this paradox, scientists have proposed that electrical wiring around the house may be a better marker of historical exposure to magnetic fields than direct contemporary measurements, which actually fluctuate continuously with daily and seasonal use of electricity.

tuates continuously with daily and seasonal use of electricity.

This paradox was considered by Feychting *et al*⁶ from further analysis of the results of their study of people living near high voltage transmission lines.^{7,8} They proposed that the measurements that best predicted the risk of leukaemia were those estimated at time of diagnosis calculated from historical information on annual average loads on the power lines which they called the "historical annual average calculation". These calculations explain the increased risk of leukaemia among residents living near high power transmission lines better than spot measurements and they proposed that the difference between these results are attributable to the time interval between diagnosis and contemporaneous estimates of magnetic fields.⁶

We recently conducted a study of 870 cases of adult leukaemia in which we used both distance from high power transmission lines and historical annual average calculation to estimate exposure.⁹ We did find an association between risk of leukaemia and both proximity of residences to high voltage transmission lines and historical annual average calculation of exposure. Our study confirmed the finding made by Feychting *et al* of an association between leukaemia and magnetic fields originating from high power transmission lines and seemed to support their claim that historical annual average calculation is a better marker than spot measurements as the aetiologically relevant exposure.

In view of these recent findings, we reanalysed the studies that have considered leukaemia in people residing in the vicinity of high voltage transmission lines.

Methods

We reviewed the abundant literature on measurements of magnetic fields in residences. We selected papers that considered specifically the exposure resulting from the vicinity of houses to high voltage transmission lines of ≥ 49 kV and in which exposure was expressed either as calculated magnetic fields from lines, or as distance, or both.

With the Mantel-Haenszel method for a summary odds ratio (OR) for a series of 2x2 tables,¹⁰ we calculated the combined risk ratios for leukaemia for distances of ≤ 50 m and ≤ 25 m and for exposure at 2 mG, 3 mG, 4 mG, and 10 mG. For the heterogeneity test of the ORs, we used the Woolf's test for heterogeneity of two or more subgroup ORs.¹¹

Table 1 Percentage of residences exposed to magnetic fields originating from high voltage transmission lines in residential studies of leukaemia

Studies	Distance < 50 m	Exposure	
		≥ 1 mG	≥ 2 mG
Children:			
Coleman <i>et al</i> ¹²	0.6		
Myers <i>et al</i> ^{13†}	5.4	0.7	0.0
Feychting and Ahlbom ⁷	6.0	13.0	8.0
Olsen <i>et al</i> ¹⁴		0.4	0.2*
Verkasalo <i>et al</i> ¹⁵		11.7	5.4
Tynes and Haldoren ¹⁷	9.4	8.1**	3.6***
Adults:			
Youngson <i>et al</i> ^{16‡}	3.4	0.7	0.3****
Feychting and Ahlbom ⁸	6.4	14.7	7.7
Li <i>et al</i> ¹	6.5	14.7	9.7

* ≥ 2.5 mG; **0.5–1.4 mG; ***>1.4 mG; **** ≥ 3 mG; † non-solid tumours; ‡ all haematological cancers.

Table 2 Leukaemia risk in residences ≤ 50 m from high voltage transmission lines

Studies	Exposure			
	≤ 50 m		≤ 25 m	
	OR (95% CI)	n	OR (95% CI)	n
Children:				
Myers <i>et al</i> ^{13†}	1.1 (0.5 to 2.7)	11	1.6 (0.5 to 5.0)	7
Feychting and Ahlbom ⁷	2.9 (1.0 to 7.3)	6		
Tynes and Haldoren ¹⁷	0.6 (0.3 to 1.3)	9		
Adults:				
Coleman <i>et al</i> ¹²	2.0 (0.4 to 9.0)	3	2.0 (0.1 to 31.6)	1
Youngson <i>et al</i> ^{16‡}	1.3 (1.0 to 1.7)	137	1.3 (0.9 to 1.8)	77
Feychting and Ahlbom ⁸	1.2 (0.7 to 2.0)	24		
Li <i>et al</i> ¹	2.1 (1.4 to 3.0)	89	2.5 (1.5 to 3.9)	66
Combined	1.4 (1.2 to 1.7)		1.6 (1.2 to 2.1)	
Heterogeneity test (df)	11.52 (6)		5.69 (3)	
P value	> 0.05		> 0.10	

† Non-solid tumours; ‡ all haematological cancers. >100 m used as comparison group.

Results

There were only nine studies^{7–9, 12–17} that met the inclusion criteria (table 1). Also reported in the table, for each study, are the proportion of residences within 50 m of the lines or exposed to 1 mG and 2 mG. To calculate exposure estimates of magnetic fields, they used several line features—such as current loads, height of the wires, configuration of the wires, and distance between houses and the lines.

Four studies had very few subjects exposed to ≥ 1 mG (<1%). These were the studies by Myers *et al*,¹³ Olsen *et al*,¹⁴ Youngson *et al*,¹⁶ and Coleman *et al*¹² (Coleman *et al* did not use calculated magnetic fields but only distance between residences and high voltage transmission lines). The reason that these studies had such a low proportion of exposed people is that

they were conducted in the general population whereas it is well known that over a whole country, very few residences are within 100 m of overhead high voltage transmission lines particularly in those countries where rights of ways are delineated on both sides of the transmission lines. On the other hand, the other five studies (Feychting and Ahlbom,⁷ Verkasalo *et al*,¹⁵ Feychting and Ahlbom,⁸ Tynes and Haldoren,¹⁷ and Li *et al*¹) were conducted either among residences within predefined corridors along high voltage transmission lines or within densely populated areas where a large proportion of the population live near overhead power lines. That explains why these studies have 12% to 15% of their residences exposed to ≥ 1 mG and 5% to 10% > 2 mG. Only these last studies carry a valuable contribution to information on the relation between exposure to magnetic fields and leukaemia, as the others have too few exposed subjects to do so.

COMBINED ANALYSIS

Table 2 shows the risk of leukaemia by proximity of residences (≤ 50 and ≤ 25 m) to high voltage transmission lines.

Most studies reported risks above 1.0, several had a 95% confidence interval (95% CI) that did not include unity. A combined analysis with the Mantel-Haenszel method¹⁰ shows that the risks are significant, somewhat more so for residences ≤ 25 m (OR 1.6, 95% CI 1.2 to 2.1) than for those ≤ 50 metres (OR 1.4, 95% CI 1.2 to 1.7) from the lines.

Table 3 shows the risks of leukaemia by exposure to ≥ 2 mG resulting from high voltage transmission lines.

Except for the study of Tynes and Haldoren on children¹⁷ and that of Feychting and Ahlbom on adults,⁸ all risks are above 1.0, several of them showing a 95% CI that does not include unity. The combined analysis shows risks that are significant for exposures of 2, 3, 4, and 10 mG compared with exposure to ≤ 1 mG. There is some increase in risk going from 2 mG (OR 1.35, 95% CI 1.05 to 1.74) to 10 mG (OR 1.81, 95% CI 1.14 to 2.87).

VALIDITY OF EXPOSURE ESTIMATES

Some authors have discussed the validity of using exposure estimates calculated from high voltage transmission lines as a method of

Table 3 Leukaemia risks resulting from exposure to ≥ 2 mG originating from high voltage transmission lines

Studies	Exposure			
	≥ 2 mG OR (95% CI) n	≥ 3 mG OR (95% CI) n	≥ 4 mG OR (95% CI) n	≥ 10 mG OR (95% CI) n
Children:				
Feychting and Ahlbom ⁷	2.7 (1.0 to 6.3) 7	3.8 (1.4 to 9.3) 7		
Olsen <i>et al</i> ¹⁴	1.7* (0.3 to 6.7) 3		6.0 (0.8 to 44.0) 3	
Verkasalo <i>et al</i> ¹⁵	1.6 (0.3 to 4.5) 3		1.2 (0.3 to 3.6) 3	
Tynes and Haldoren ¹⁷	0.8** (0.3 to 2.4) 4			
Adults:				
Youngson <i>et al</i> ^{16‡}		1.9 (0.8 to 4.4) 15		3.0 (0.6 to 14.9) 6
Feychting and Ahlbom ⁸	1.0† (0.7 to 1.7) 26			
Li <i>et al</i> ¹	1.4 (1.0 to 1.9) 97	1.4 (1.0 to 2.0) 84	1.4 (1.0 to 2.0) 73	1.7 (1.0 to 2.7) 45
Combined	1.3 (1.0 to 1.7)	1.6 (1.2 to 2.2)	1.5 (1.1 to 2.2)	1.8 (1.1 to 2.9)
Heterogeneity test (df)	3.65 (5)	4.19 (2)	1.74 (2)	0.43 (1)
P value	> 0.10	> 0.10	> 0.10	> 0.10

* 2.5 mG; ** > 1.4 mG; † 20 mG-years; ‡ all haematological cancers; OR = 1.5 (95% CI 1.0 to 2.4); 30 mG-years, OR = 1.5 (95% CI 0.9 to 2.6). < 1 mG used as comparison group.

Deviation of calculated magnetic fields from measured magnetic fields in a sample of 407 houses.

assessing exposure in houses near those lines.^{7 8 18} In a recent study⁹ we compared exposure estimates obtained by calculation based on line with results from direct measurements in 407 residences (figure). In this figure the difference between the two exposures is expressed as the ratio of measured fields minus calculated fields/measured fields. The absence of a difference lies on the zero line.

Information can be extracted from this figure. Firstly, measured magnetic fields yield values that are usually higher than calculated magnetic fields. This is no surprise as measured magnetic fields correspond to the summation of magnetic fields generated from the high voltage transmission lines and the local magnetic fields generated in or around the house. Secondly, when distance increases, the difference between calculated and measured magnetic fields increases. This indicates that with distance the contribution to overall exposure from the local magnetic fields generated in or around the house increases and within a short distance from the line, the exposure from the line contributes to almost all the exposure inside the house. Thirdly, starting at about 90 m, the differences between calculated and measured fields increase and beyond about 100 m, there is poor agreement between measured and calculated exposure, the measured exposure gives higher readings than the calculated ones. It would be false to think that such people are not exposed at all; actually they are exposed like everybody else to the baseline level. For these distances, calculated values from high voltage transmission lines become useless. In summary, magnetic fields calculated from high voltage transmission lines are reliable for distances ≤ 50 m from the centre of the lines, they cannot be relied on when distance is >100 m, and they are of question-

able value for distances between 50 and 100 m. This corresponds to field intensities of ≥ 1.0 mG (≤ 50 m) and ≤ 0.5 mG (≤ 100 m) living near high voltage transmission lines. A corollary to that observation is that exposure calculated from high voltage transmission lines is a reliable marker of a true exposure within 100 m and that exposure in homes located near such lines is less prone to the variations encountered in residences away from the lines.

Discussion

The present comparison tends to confirm the existence of an association between exposure to electromagnetic fields and leukaemia among people who live near high voltage transmission lines. The combined risks are increased for all calculated exposures of ≥ 2 mG.

As it included many subjects, the study by Li *et al*⁹ strongly influenced the combined results. This calls for prudence in interpreting the combined analysis. Furthermore, meta-analyses such as the present one can only serve the goal of increasing sample size and have nothing to do with the validity of the pooled results. One valid study will contribute more to the understanding of an aetiological relation between exposure and disease than the summation or pooling of scores of weak studies. This should keep us from proclaiming that this is definitive evidence that magnetic fields from high voltage power lines cause leukaemia among residents who live near them. Nevertheless, it must be recognised that the study of Li *et al* was planned with the intention of testing the hypothesis, and it avoided the problem of few study subjects.

Our assessment of evidence is based solely on the published literature and consequently the existence of a publication bias cannot be ruled out. We included in the combined analy-

sis all the published articles eligible for inclusion. They are a subset of a much larger set of papers, several of them reporting results of studies conducted recently to test the hypothesis of an association between magnetic fields and leukaemia in which negative findings would have been just as important as positive ones. But there remains the possibility that papers which reported negative results may have been rejected or not published, which may have entailed a bias towards finding an association that actually does not exist.

It has been common practice so far to consider children and adult studies separately. The reason for doing so is that childhood leukaemia is predominantly of the acute lymphoid type whereas adult leukaemias are mostly of the acute myeloid and chronic lymphoid type. These are regarded as separate diseases. In the present analysis, the findings apply equally to both children and adults. Analysing them separately would have yielded similar results with larger 95% CIs and greater instability in rates due to few cases in each category.

If the present comparison is correct, it indicates that contrary to widespread opinion, there is reasonable consistency between studies on the relation between exposure to magnetic fields and leukaemia when exposure is based on calculated fields from high voltage transmission lines at time of diagnosis. The previous studies that have yielded negative results may have been handicapped by not having a large enough exposed population to be able to unveil a true association. When researchers have worked with cohorts defined on the basis of their exposure—such as people living in corridors alongside high voltage transmission lines or cohorts selected from high density populations living close to high voltage lines—they have obtained results that are consistent and do show an association between leukaemia and exposure to magnetic fields.

- 1 Li CY, Thériault G, Lin RS. Epidemiological appraisal of studies of residential exposure to power frequency magnetic fields and adult cancers. *Occup Environ Med* 1996;53:505–10.
- 2 Li CY, Thériault G, Lin RS. A validity analysis of residential magnetic fields estimated from high-voltage transmission lines. *Journal of Exposure Analysis and Environmental Epidemiology* 1997;7.
- 3 Wertheimer N, Leeper E. Electrical wiring configurations and childhood cancers. *Am J Epidemiol* 1979;109:273–84.
- 4 Savitz DA, Wachtel H, Barnes EM, John EM, Tvrdik JG. Case-control study of childhood cancer and exposure to 60 Hz magnetic fields. *Am J Epidemiol* 1988;128:21–38.
- 5 London SJ, Thomas DC, Bowman JD, Sobel E, Cheng TC, Peters JM. Exposure to residential electric and magnetic fields and risk of childhood leukaemia. *Am J Epidemiol* 1991;134:923–37.
- 6 Feychting M, Kaune WT, Savitz DA, Ahlbom A. Estimating exposure in studies of residential magnetic fields and cancer: importance of short-term variability, time interval between diagnosis and measurement, and distance to power line. *Epidemiology* 1996;7:220–4.
- 7 Feychting M, Ahlbom A. Magnetic fields and cancer in children residing near Swedish high-voltage power lines. *Am J Epidemiol* 1993;138:467–81.
- 8 Feychting M, Ahlbom A. Magnetic fields, leukaemia, and central nervous system tumors in Swedish adults residing near high-voltage power lines. *Epidemiology* 1994;5:501–9.
- 9 Li CY, Thériault GT, Lin RS. Residential exposure to 60 Hz magnetic fields and adult cancers in Taiwan. *Epidemiology* 1997;8:25–30.
- 10 Mantel N, Haenszel W. Statistical aspects of the analysis of data from retrospective studies of disease. *J Natl Cancer Inst* 1959;22:719–48.
- 11 Woolf B. On estimating the relation between blood group and disease. *Ann Hum Genet* 1955;19:251–3.
- 12 Coleman MP, Bell CMJ, Taylor HL, Primic-Zakelj M. Leukaemia and residency near electricity transmission equipment: a case control study. *Br J Cancer* 1989;60:793–8.
- 13 Myers A, Clayden AD, Cartwright RA, Cartwright SC. Childhood cancer and overhead powerlines: a case-control study. *Br J Cancer* 1990;62:1008–14.
- 14 Olsen JH, Nilsen A, Schulgen G. Residence near high voltage facilities and risk of cancer in children. *BMJ* 1993;307:891–5.
- 15 Verkasalo PK, Pukkala E, Hongisto MY, Valjus JE, Järvinen PJ, Heikkilä KV, Koskenvuo M. Risk of cancer in Finnish children living close to power lines. *BMJ* 1993;307:895–9.
- 16 Youngson JHAM, Clayden AD, Myer A, Cartwright RA. A case/control study of adult haematological malignancies in relation to overhead powerlines. *Br J Cancer* 1991;63:977–85.
- 17 Tynes T, Haldoren T. Electromagnetic fields and cancer in children residing near Norwegian high-voltage power lines. *Am J Epidemiol* 1997;145:219–26.
- 18 Levallois P, Gauvin D, St-Laurent J, Gingras S, Deadman JE. Electric and magnetic field exposures for people living near a 735-kilovolt power line. *Environ Health Perspect* 1995;103:832–7.