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Papers

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Abstract

Objective To determine whether there is an association between distance of home address at birth from high voltage power lines and the incidence of leukaemia and other cancers in children in England and Wales.

Design Case-control study.

Setting Cancer registry and National Grid records.

Subjects Records of 29 081 children with cancer, including 9700 with leukaemia. Children were aged 0-14 years and born in England and Wales, 1962-95. Controls were individually matched for sex, approximate date of birth, and birth registration district. No active participation was required.

Main outcome measures Distance from home address at birth to the nearest high voltage overhead power line in existence at the time.

Results Compared with those who lived >600 m from a line at birth, children who lived within 200 m had a relative risk of leukaemia of 1.69 (95% confidence interval 1.13 to 2.53); those born between 200 and 600 m had a relative risk of 1.23 (1.02 to 1.49). There was a significant ($P < 0.01$) trend in risk in relation to the reciprocal of distance from the line. No excess risk in relation to proximity to lines was found for other childhood cancers.

Conclusions There is an association between childhood leukaemia and proximity of home address at birth to high voltage power lines, and the apparent risk extends to a greater distance than would have been expected from previous studies. About 4% of children in England and Wales live within 600 m of high voltage lines at birth. If the association is causal, about 1% of childhood leukaemia in England and Wales would be attributable to these lines, though this estimate has considerable statistical uncertainty. There is no accepted biological mechanism to explain the epidemiological results; indeed, the relation may be due to chance or confounding.

Introduction

The electric power system produces extremely low frequency electric and magnetic fields. Since 1979 there has been concern that these fields may be associated with cancer. Concern has concentrated on

magnetic rather than electric fields and on childhood leukaemia in particular. A pooled analysis of nine studies that met specified quality criteria found that children living in homes with 24 hour average fields of $\geq 0.4 \mu\text{T}$ have twice the risk of leukaemia.¹ In 2001 the International Agency for Research on Cancer classified extremely low frequency magnetic fields as "possibly carcinogenic" on the basis of "limited" epidemiological evidence and "inadequate" evidence from animals.

Magnetic fields in homes arise mainly from low voltage distribution wiring, house wiring, and domestic appliances. Only a small fraction of homes are close to high voltage overhead power lines (transmission lines), but in these homes the power line is likely to be the main source of magnetic field.

It is not known which period of life, if any, is relevant to induction of cancer by magnetic fields. We investigated whether proximity of home address at birth to transmission lines in England and Wales is associated with increased risks of childhood cancer.

Methods

Cases and controls

We identified nearly 33 000 cases of cancer in children born 1962-95 in England and Wales, diagnosed before age 15 years in England, Wales, or Scotland over the same period, from the National Registry of Childhood Tumours. We obtained birth information for just over 31 000 cases. For each case we selected from birth registers a control matched for sex, date of birth (within six months), and birth registration district. The final dataset comprised 29 081 matched case-control pairs (9700 for leukaemia) that we could map with respect to transmission lines.

Calculation of distance from power lines

We looked at overhead power lines forming the National Grid in England and Wales—that is, all 275 and 400 kV overhead lines (the highest voltages used) plus a small fraction of 132 kV lines. We obtained the grid references of all 21 800 pylons concerned. Using



This is the abridged version the full version is on bmj.com

Table 1 Distance of address at birth from nearest National Grid line for cases and controls in each diagnostic group, and estimated relative risk (RR)

| Distance to line (metres) | Leukaemia | | | CNS/brain tumours | | | Other diagnoses | | |
|---------------------------|-----------|----------|------|-------------------|----------|------|-----------------|----------|------|
| | Cases | Controls | RR | Cases | Controls | RR | Cases | Controls | RR |
| 0-49 | 5 | 3 | 1.67 | 3 | 7 | 0.44 | 7 | 6 | 1.17 |
| 50-99 | 19 | 11 | 1.79 | 4 | 6 | 0.69 | 15 | 16 | 0.91 |
| 100-199 | 40 | 25 | 1.64 | 26 | 32 | 0.82 | 37 | 45 | 0.81 |
| 200-299 | 44 | 39 | 1.16 | 38 | 28 | 1.35 | 66 | 76 | 0.87 |
| 300-399 | 61 | 54 | 1.15 | 35 | 30 | 1.19 | 79 | 65 | 1.21 |
| 400-499 | 78 | 65 | 1.23 | 40 | 42 | 0.96 | 80 | 97 | 0.82 |
| 500-599 | 75 | 56 | 1.36 | 54 | 41 | 1.33 | 86 | 85 | 1.01 |
| ≥600 (reference group) | 9378 | 9447 | 1.00 | 6405 | 6419 | 1.00 | 12 406 | 12 386 | 1.00 |
| Total | 9700 | 9700 | | 6605 | 6605 | | 12 776 | 12 776 | |

CNS=central nervous system.

the postcode at birth we identified subjects living within 1 km of a transmission line. For 93% of these addresses we obtained a 0.1 m grid reference and hence calculated the shortest distance to any of the transmission lines that had existed in the year of birth. We aimed to obtain a complete set of accurate distances for all subjects within 600 m of a line.

Statistical analysis

We used conditional logistic regression on the matched case-control pairs to calculate relative risks and χ^2 values.

Results

Table 1 shows the distribution of distances from the nearest line for cases and controls. Most (97%) of these distances were ≥ 600 m. The relative risk is an estimate of the incidence compared with that at distances ≥ 600 m. For leukaemia, but not for the other diagnoses, the relative risks are greater than 1.0 at each distance category < 600 m; there is some evidence that the leukaemia risk varies according to distance from the line.

In general, emanations from a line source are expected to reduce in strength as the reciprocal of distance, but the magnetic field from a power line generally falls as the inverse square of distance, or sometimes the inverse cube. For each diagnostic group, we tested whether the risk is some function of distance (d) from the nearest line, using three models: that the risk depends on the rank of the distance band, the reciprocal of the distance ($1/d$), or the inverse square ($1/d^2$). For leukaemia the analyses suggest the risk might depend either on the rank of the distance category or on the reciprocal of distance ($P < 0.01$). The latter seems more plausible. We therefore retabulated the results for leukaemia at intervals corresponding to roughly equal intervals of $1/d$ (table 2). This change in the grouping of the data does not change the pattern of relative risk estimates shown in table 1 or the significance of the test for trend with $1/d$.

We examined the possibility that the relation between distance and risk of leukaemia is a consequence of a relation between distance and socioeconomic status. We used the Carstairs deprivation index to allocate socioeconomic status to the census ward in which each child was living at birth and confirmed the previously reported association between affluence and risk of childhood leukaemia (P for trend < 0.01). Adjustment for socioeconomic status had no effect on the relative risks for distance.

Discussion

To date this is the largest study of childhood cancer and power lines. We found an increased risk of leukaemia for children whose home address at birth was within 200 m of a high voltage power line compared with those more than 600 m from the nearest line. There was a smaller increased risk at 200-600 m. The finding that the increased leukaemia risk apparently extends so far from the line is surprising in view of the very low level of magnetic field that could be produced by power lines at these distances.

Possible explanations for findings

There is no obvious source of bias in the choice of cases or controls. The study is based on records of childhood cancer in England and Wales over most of the period that the National Grid has existed. Registration for childhood cancer is nearly complete, and it seems improbable that the likelihood of registration is related to proximity of birth address to transmission lines. Controls were selected from registers compiled through the legally required process of birth registration. No participation by cases or controls was required. We calculated distances without knowing case-control status, and we were able to include 88% of the eligible cases, each with a matched control.

Populations near power lines may have different characteristics from the rest of the population. Adjustment for socioeconomic status of the census ward of birth address did not explain our finding. "Population mixing" has been associated with childhood leukaemia,² but among our cases individual mobility, measured by changes of postcode between birth and diagnosis, was no more common for those whose home at birth was closer to the lines.

Table 2 Relative risk (RR) estimates for leukaemia using revised distance categories (see text)

| Distance, d (metres) | $1/d$ | RR (95% CI) | RR* (95% CI) |
|------------------------|-------|---------------------|---------------------|
| 0-49 | 0.040 | 1.67 (0.40 to 6.97) | 1.65 (0.39 to 6.89) |
| 50-69 | 0.017 | 1.51 (0.48 to 4.79) | 1.53 (0.48 to 4.83) |
| 70-99 | 0.012 | 2.02 (0.76 to 5.39) | 2.00 (0.75 to 5.32) |
| 100-199 | 0.007 | 1.64 (1.00 to 2.71) | 1.64 (0.99 to 2.70) |
| 0-199 | 0.010 | 1.69 (1.13 to 2.53) | 1.68 (1.12 to 2.52) |
| 200-599 | 0.003 | 1.23 (1.02 to 1.49) | 1.22 (1.01 to 1.47) |
| ≥600 (reference group) | 0.000 | 1.00 | 1.00 |

*Adjusted for socioeconomic status.

The results could be due to chance—for example, if the leukaemia controls are not sufficiently representative of the relevant population. Comparison of the leukaemia cases with the non-leukaemia controls still suggests that there is an increased risk for leukaemia but it is much lower than that found using the matched controls. However the use of the matched controls is the most appropriate approach.

Six of the studies included in the pooled analysis referred to above¹ contain, or have been extended to include, analyses of proximity to power lines.³⁻⁸ Of these, a previous UK study found a relative risk of 1.42 (0.85 to 2.37) for acute lymphocytic leukaemia within 400 m for 275 and 400 kV lines.⁴ Studies in Canada⁵ and Sweden³ also found increased risks for childhood leukaemia (Canada: relative risk 1.8 (0.7 to 4.7) for residence within 100 m of transmission lines of 50 kV or more, and 1.3 within 50 m; Sweden: 2.9 (1.0 to 7.3) for residence \leq 50 m versus 101-300 m from 220 and 400 kV power lines, with no increase for other childhood cancers). The others found relative risks below 1.0 but were based on smaller numbers. None of these estimates relates to distances as great as ours.

The most obvious explanation of the association with distance from a line is that it is indeed a consequence of exposure to magnetic fields. For magnetic fields in the home pooled analysis has found a relative risk of 2.00 (1.27 to 3.13) for exposures \geq 0.4 μ T versus $<$ 0.1 μ T; the risks for fields $<$ 0.4 μ T were near the no effect level.¹ Another pooled analysis found a similar result with a threshold of 0.3 μ T.⁹ Our increased risk seems to extend to at least 200 m, and at that distance typical calculated fields from power lines are $<$ 0.1 μ T, and often $<$ 0.01 μ T—that is, less than the average fields in homes from other sources. Thus our results do not seem to be compatible with the existing data. The estimated relative risk was more closely related to the reciprocal of the distance from the line than to the square of the reciprocal of the distance.

Conclusions

While few children in England and Wales live close to high voltage power lines at birth, there is a slight tendency for the birth addresses of children with leukaemia to be closer to these lines than those of matched controls. We have no satisfactory explanation for our results in terms of causation by magnetic fields, and the findings are not supported by convincing laboratory data or any accepted biological mechanism.

Assuming that the higher risk in the vicinity of high voltage lines is indeed a consequence of proximity to the lines we can estimate the attributable annual number of cases of childhood leukaemia in England and Wales (see bmj.com). Of the 400-420 cases of childhood leukaemia occurring annually, about five would be associated with high voltage power lines, though this estimate is imprecise. We emphasise again the uncertainty about whether this statistical association represents a causal relation.

We are grateful to colleagues at the Childhood Cancer Research Group and at National Grid Transco for help with this study and to cancer registries and the United Kingdom Children's Cancer Study Group for notifications of cases of childhood cancer.

Contributors: See bmj.com

What is already known on this topic

Power frequency magnetic fields, produced by the electric power system, are “possibly carcinogenic”

A pooled analysis of case-control studies found that children living in homes with high magnetic fields ($>$ 0.4 μ T) had twice the risk of childhood leukaemia

High voltage power lines are one source of these fields

What this study adds

A UK study of 29 000 cases of childhood cancer, including 9700 cases of leukaemia, found a raised risk of childhood leukaemia in children who lived within 200 m of high voltage lines at birth compared with those who lived beyond 600m (relative risk 1.7)

There was also a slightly increased risk for those living 200-600 m from the lines at birth (relative risk 1.2, P for trend $<$ 0.01); as this is further than can readily be explained by magnetic fields it may be due to other aetiological factors associated with power lines

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Competing interests: JS is employed by National Grid Transco and worked on this project with their permission. A written contract exists between the Childhood Cancer Research Group and National Grid Transco specifying that the Childhood Cancer Research Group has complete control over the conduct, interpretation, and publication of this study; this paper has not been approved by anyone in National Grid Transco other than JS in his capacity as author and does not necessarily represent National Grid Transco's views.

Ethical approval: The Childhood Cancer Research Group has local ethics committee approval and, through membership of the UK Association of Cancer Registries, has approval from the Patient Information Advisory Group with respect to cancer registration function.

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Science commentary: Power to confuse

Geoff Watts

Ever since Nancy Wertheimer of the University of Colorado reported her 1979 findings of an excess of cancer in children living near overhead power lines, seldom has a year passed without a flurry of public debate over the safety or otherwise of these ugly (the one thing all parties agree on) but essential installations.

Much of the argument has been about the very existence of the alleged hazard. As recently as last month, the organisers of the 15 year UK childhood cancer study declared that “perceived risk factors such as living near sources of electromagnetic fields . . . are not principal causes, if at all, of leukaemia in children.” But a clutch of studies reporting a positive association—of which this week’s by Draper and colleagues is the most recent¹—has encouraged researchers to continue investigating possible mechanisms.

Electrical and magnetic fields can induce currents that might alter the voltages across cell membranes. Magnetic fields might cause the movement of ferromagnetic particles within cells. They might also influence free radicals: atoms with unpaired electrons that are highly reactive and play a part in all sorts of biochemical processes. Low frequency electromagnetic fields have been said to alter the progress of cells through the cell cycle and reduce the effectiveness of the immune system. Power lines might even deflect and concentrate cosmic rays on people living within their vicinity. Evidence to support these and other ideas, however, is at best thin and at worst non-existent.

One of the more recent attempts at identifying a mechanism sidesteps the need to invoke direct effects. For the past 10 years or so, Bristol University physicist Dennis Henshaw has been working on the influence of powerful electric fields on the deposition of airborne particles. The relevance of this to power lines entered public consciousness in 1999 with the publication of two papers by Henshaw and colleagues.^{2,3} High energy power systems, they pointed out, cause some breakdown in the surrounding air molecules and so generate positive or negative ions. The systems are designed to minimise this effect, but it does still occur—and any aerosol pollutants that pass through these ion clouds can acquire an electrical charge.

If particles with a charge are inhaled, more of them will stick to the lining of the respiratory system. The data are limited, but one study that used a model of the human airway suggests that deposition could be increased by a factor of around three. A 2004 report by the (then) National Radiological Protection Board conceded the plausibility of the mechanism and suggested some further experiments.⁴ Draper and colleagues refer to the Henshaw hypothesis but add that more work will be necessary to rule it in or out.¹

Like the fluoridation of drinking water and the genetic modification of crops, the debate over power lines seems destined to be with us for a while yet. So, in these risk averse times, and before activists begin blowing up pylons, a bit of perspective might help. In 2002, according to the Child Accident Prevention Trust, more than 36 000 children were hurt in road accidents

and around 200 were killed. Another 32 died in house fires. Draper and colleagues reckon that five cases annually of childhood leukaemia may be associated with power lines.

- 1 Draper G, Vincent T, Kroll ME, Swanson J. Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study. *BMJ* 2005;330:1290-2.
- 2 Fews AP, Henshaw DL, Keitch PA, Close JJ, Wilding RJ. Increased exposure to pollutant aerosols under high voltage powerlines. *Int J Radiat Biol* 1999;75:1505-21.
- 3 Fews AP, Henshaw DL, Wilding RJ, Keitch PA. Corona ions from powerlines and increased exposure to pollutant aerosols. *Int J Radiat Biol* 1999;75:1523-31.
- 4 National Radiological Protection Board. Particle deposition in the vicinity of power lines and possible effects on health. *Documents of NRPB* 2004;15(1).

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Corrections and clarifications

Half of patients in intensive care receive suboptimal care

Several inaccuracies occurred in this News article by Zosia Kmietowicz (*BMJ* 330;2005:1101, 14 May).

The report by the National Confidential Enquiry into Patient Outcome and Death (NCEPOD) on which the article was based was at times somewhat confusing, and this seems to have contributed to the resulting errors. In the second paragraph, we should have said that “Nearly half of all patients admitted to hospital [not “admitted to intensive care” as we implied] who later died in intensive care received care that was judged to be less than good practice.” And the following sentence should have said that poor care may have contributed to the deaths of a third of those whose care was deemed less than good practice. We also reported in the fourth paragraph, rather ambiguously, that “in nearly 6 out of 10 cases, consultants had no knowledge or input into the referral [to intensive care]”—we should have specified “consultant physicians.” In some places in the NCEPOD report, the use of the term consultant was ambiguous—it was not clear whether it meant consultant physician or consultant intensivist. Finally, the graph referred to the standard of care that the patients received in the period from admission to hospital up to, but not including, the first ward round (not, as we said, the standard of care in intensive care only).

Short Cuts: A single computed tomogram can rule out pulmonary embolus

A missing zero in the page reference to the original article described in this item may have confused readers in their search for the article (*BMJ* 2005;330:1045, 7 May). The correct reference is *JAMA* 2005;293:2012-7.

President Bush and Congress intervene in “right to die” case

In this News article by Fred Charatan we should have more correctly described Terri Schiavo as having received tube feeding (not “been on a life support machine”) since a cardiac arrest 15 years previously (*BMJ* 2005;330:687, 26 Mar). We repeated the error in the relevant News article in the following week’s issue.

GMC and the future of revalidation: building on the GMC’s achievements

We slipped up in the spelling of Graeme Catto in his paper in the Education and Debate section (*BMJ* 2005;1205-7, 21 May). The mistake has been corrected on bmj.com.