EMFs and Childhood Cancer: Are You Convinced?

In a 1979 study of greater Denver, Colorado, Nancy Wertheimer and Ed Leeper reported a higher occurrence of childhood cancer in residences located near electrical lines capable of carrying high currents as compared to homes located either near low-current capacity lines or far from electrical lines. While there had been a few earlier studies exploring the health effects of electric and magnetic fields (EMFs), the Wertheimer and Leeper report was the first to suggest 50–60 Hertz EMFs as a potential health hazard in residential settings. Not surprisingly, the findings of Wertheimer and Leeper sparked a swell of public concern.

While any potentially dangerous exposure is serious, hazardous exposures found in the home are particularly worrisome. Citizens tend to be less tolerant of residential risks than they are of risks on the job or in external environments (e.g., on the highway or the ski slopes). The Wertheimer and Leeper study implicated a ubiquitous everyday exposure, as nearly every household in this country not only uses but depends upon electricity to carry out commonplace activities. Furthermore, the report focused on childhood cancer, a rare but frightening disease. The vulnerability of the pediatric population, coupled with the widespread nature of the EMF exposure, ignited concern about the potential health effects of residential EMFs.

In response to the Wertheimer and Leeper results, the scientific community conducted additional studies to examine the potential health effects of exposure to EMFs in the home. Since 1979, there have been numerous epidemiologic studies performed in an effort to clarify the issue. The results have been mixed, with much continued debate over whether or not there is a significant association between residential EMFs and childhood cancer.

This issue of RISK IN PERSPECTIVE examines the literature on residential exposure to EMFs and childhood cancer and explores some of the critical questions involved in the debate over the potential health effects associated with that exposure. It also continues the epidemiologic discussion begun in last year's RISK IN PERSPECTIVE on Workers, EMFs, and Cancer (Vol. 3, No. 2, April, 1995). We close with some recent survey findings suggesting that the public is not yet convinced that EMFs from power lines are hazardous to health, especially in comparison to other hazards receiving coverage in the media.

Childhood Cancer

The term, “childhood cancer,” encompasses a variety of diseases. Leukemia is the most common childhood malignancy, accounting for approximately one third of childhood cancers. Brain tumors are the second most common, comprising about 20% of pediatric cancers.

Pediatric leukemia, or cancer of the bone marrow, strikes approximately 2,500 children in this country each year. The most common form of childhood leukemia (80% of such leukemias) is acute lymphocytic leukemia (ALL). Acute myelogenous leukemia (AML), makes up another 15% of pediatric leukemia. The incidence of ALL peaks in young children (2–4 years old), whereas AML has a more even age distribution across children. While leukemia is often fatal, the treatments and prognosis for pediatric leukemia have been steadily improving over the past several decades. The current five-year survival rate for children with ALL is about 70–80%; the five-year survival rate for children with AML approximates 40–50%.
NOTES:
1 = Wertheimer & Leeper (1979); RR for high-configuration code vs. low-configuration code homes.
2 = Fulton (1980); RR for high-configuration code vs. low-configuration code homes.
3 = Tomenius (1986); RR for magnetic fields > 0.3 μT (microtesla).
4a = Savitz et al. (1988); RR for “low power” magnetic fields.
4b = Savitz et al. (1988); RR for high-configuration code vs. low-configuration code homes.
5 = Coleman et al. (1989); RR for distance from overhead line.
6a = London et al. (1991); RR for 24 hour magnetic fields.
6b = London et al. (1991); RR for high-configuration code vs low-configuration code homes.
7 = Feychtling & Ahlbom (1993); RR for magnetic field historical loads ≥ 0.3 μT.
8 = Olsen et al. (1993); RR for magnetic field historical loads ≥ 0.4 μT.
Brain cancer in children is relatively rare and often fatal. Pediatric brain cancer encompasses a variety of tumor types, with astrocytomas, medulloblastomas, and gliomas occurring the most often. As a group, the incidence of brain tumors is fairly evenly distributed across pediatric age groups, but specific tumor types are often concentrated in particular age categories.

While much progress has been made toward improving the diagnosis and treatment of childhood cancers, the causes of the disease are largely unknown. Large doses of ionizing radiation and some rare genetic predispositions (e.g., Li-Fraumeni Syndrome) remain the few established causes of pediatric cancers. A number of environmental agents have been investigated as possible risk factors, from both prenatal and postnatal exposures, but there have been few definitive relationships observed. Furthermore, childhood cancers show no evidence of being related to industrialization (or electric power consumption).

Is There an Association with EMFs?

A number of epidemiologic investigations of residential EMFs and childhood cancers have been completed since the initial Wertheimer and Leeper study. These epidemiologic studies have been conducted largely in U.S. neighborhoods in Denver, Los Angeles, and Seattle, as well as in Scandinavia and England. There are also several large studies currently under way in the U.S., Canada, and England.

The results of these studies have been mixed. Some studies of residential EMFs have reported elevated relative risks of childhood cancer, primarily leukemia and brain cancer. This is particularly the case with studies that used wire code configuration assessments similar to Wertheimer and Leeper's, such as Savitz et al. (1988) in Denver, and London et al. (1991) in Los Angeles. Other studies, however, have found no association with either specific forms of cancer or all childhood cancers taken together. The relative risks observed in the studies lie predominantly in the range of 1.1 to 3, with approximately half of the relative risks achieving statistical significance. Recall that a relative risk of 2.0 means that the occurrence of cancer is twice as common in the exposed group as in the unexposed group. See Figure 1 for a summary of epidemiologic studies examining residential EMF exposure and childhood leukemia. (A full list of epidemiologic references on EMFs and cancer is available from the Center on request.)

While there have also been residential studies focusing on the potential association with residential EMFs and adult cancers — with somewhat mixed results as well — the focus of this discussion is on the pediatric studies. Many experts in the field argue that, at most, the link between power lines and adult cancers is weaker than that shown for children; others argue that there is no evidence of an association for adults. It is possible that children are more susceptible to the effects of EMFs than adults, though this hypothesis is far from proven.

Wire Codes as an Exposure Surrogate to Magnetic Fields

Within the body of epidemiologic literature on EMFs and childhood cancer, one of the most critical and controversial elements is exposure assessment. Attention has focussed largely on the assessment of magnetic fields, since low-frequency electric fields do not penetrate into the body.

The Wertheimer and Leeper exposure metric, repeated in several later studies, did not involve actual measurement of the level of magnetic fields inside homes. The authors used surrogate measures: the likely current load carried by the electrical power lines outside the homes as suggested by different wiring configurations (e.g., the thickness of the wires, the location of transformers and service drops, and the proximity of the sources of current to the house). Since magnetic field intensity is proportional to current, Wertheimer and Leeper categorized the houses into either high-current configuration, suggestive of elevated magnetic field exposure, or low-current configuration homes. More childhood cancers were observed in homes with high-current configurations than in those with low-current configurations.

Many of the studies completed since the Wertheimer and Leeper report have gone beyond the observational wire code surrogate. Later studies have included magnetic field measurements under varying household power use conditions, using both spot measurements and 24-hour exposures to assess
magnetic field levels in the child’s bedroom as well as other areas inside and outside the home. Several of the Scandinavian studies also included assessments of the historical load of power lines, which were used to estimate historical levels of magnetic fields in the home.

The results of studies employing these expanded exposure metrics have been puzzling, often with paradoxical observations. Very high-current configuration wire codes have repeatedly shown a statistically significant positive association with childhood cancer risk. Measured magnetic fields for both spot and 24-hour exposures, on the other hand, have shown little association with cancer incidence. Elevated relative risks — increasing with level of exposure — however, were seen in the Scandinavian studies for leukemia in children that used historical fields to estimate exposure.

The question of why a relationship has been seen between cancer risk and wire code configurations but not actual EMF measurements remains a perplexing one. One explanation is that performing the EMF measurements at the time that the cancer is diagnosed or even later, rather than when the cancer originated, may yield misleading results. Measurements of current EMF exposures may not be an accurate predictor of previous or long term exposures because electrical loads and technology have changed over time. Wire code configurations, on the other hand, may not be good predictors of instantaneous magnetic fields; but, as they remain stable over long periods of time, they might be better predictors of historical field levels and hence previous exposures.

An alternate theory proposes that the negative results seen with EMF measurements suggest that there is no association between EMFs and childhood cancer. The association that has been observed between wire code configurations and childhood cancer may be due to some other variable not yet identified. In other words, wire code configurations may not be acting as a proxy for EMF exposure, but for some other characteristic, such as aspects of the neighborhood or family demographics, which are ultimately responsible for the observed association.

Furthermore, exposure assessment of EMFs in residential environments is difficult. Not only are EMF exposures variable and hard to measure, there are complex factors involved within the homes, such as wiring alignment and grounding or exposure from household appliances. There is also the potential for confounding influences from numerous other variables, including family characteristics and social class, smoking and alcohol, chemical and x-ray exposures, and neighborhood attributes such as urbanity or traffic density. Moreover, there is also the ubiquity of exposure to EMFs in other environments, such as the workplace, schools, or movie theatres and shopping malls.

**Household Appliances**

While not as extensively pursued as the question of exposure from electrical power lines, studies have also explored residential exposures to EMFs from household appliances. Exposures that have been examined include those from electric blankets, water beds, electrical heating sources, hair dryers, sewing machines, televisions, bedside electric clocks, and other appliances. Childhood exposure studies have examined both prenatal and postnatal exposures. Some evidence has been seen for a potentially weak association between childhood leukemia and electric blanket use (for both prenatal and postnatal exposures), sewing machines (prenatal exposures) and hair dryers and black and white televisions, but the data are limited and sketchy.

**Alternative Viewpoints**

What conclusions can be drawn from the existing body of literature on pediatric exposure to EMFs? Proponents of a cancer link cite the positive results from epidemiology as suggesting an association between overhead power lines (and their emitted magnetic fields) and childhood leukemia. The results are consistent with the hypothesis that EMFs may be promoting agents for cancer. These results have also been seen not only in multiple studies, but in studies located in several different countries using divergent electrical wire configurations as well. Furthermore, the Swedish studies evidenced a dose-response relationship, such that the closer the children lived to power lines, the more likely they were to develop leukemia.

Skeptics of the hypothesis believe that the evidence is inconclusive. Several studies show results compatible with no association.
There has also been no association seen with spot or timed measurements of EMFs. Wire code configurations may actually be a proxy for something else that is going on in the neighborhood other than EMFs, such as exposure to PCBs in the power line transformers or high levels of air pollution from urban traffic or industry. Critics also find methodological faults with many of the U.S. studies, such as potential bias in the selection of control subjects, biased assessment of wire codes, or failing to account for elements such as the frequent moves of young families. Furthermore, as everyone is exposed to EMFs at some level from an extensive array of sources, it is impossible to compare exposed to unexposed children; investigators can only compare exposures of greater or lesser amounts.

Few of the elevated relative risks seen in these studies are above 3 and many lie in the 1.5–2 range. Relative risks in this range are considerably lower than those seen in studies of known human carcinogens such as cigarettes. It should be noted, however, that there are other well accepted associations, such as the association between smoking and heart disease, that fall in this range. Furthermore, a relative risk of 2 (a doubling of the risk of childhood cancer), coupled with the widespread exposure to EMFs, could have a potentially significant impact on the population.

The relative risks seen in the EMF studies also lie in a range where epidemiologic study can be difficult. Particularly where the endpoint of interest is a rare disease such as childhood leukemia, extremely large studies are needed to give adequate statistical power to the analysis. Also, when weak associations are studied, it can be difficult to eliminate extraneous effects of bias in study design or confounding by other factors. This is particularly a problem in studies of childhood leukemia, for which the etiology is largely unknown. Moreover, while some laboratory investigations of EMF exposures have seen intriguing effects at the cellular level, there is as yet no clear understanding of a biological mechanism of action for EMFs and human cancer.

Despite — or maybe because of — the inconclusiveness of the literature on EMFs and pediatric cancer, the issue continues to loom large with both the scientific community and segments of the public. Epidemiologic as well as laboratory studies continue to be launched in the direction of EMF study. Scientists continue to debate the interpretation of the results at forums and in the literature. There is also persistent media coverage of the potential effects of power lines and cancer. Some parents and community groups are taking utility companies to court over power line sitings or clusters of pediatric cancers.

In the public sector, the U.S. government has not considered the scientific evidence as sufficient to take public-policy action on EMFs. Various policy and professional organizations (e.g., the American Conference of Governmental and Industrial Hygienists) have recommended safety levels for human exposure to EMFs as well as techniques for measuring the fields, although this response has not been based on the cancer data. Some countries have been even more proactive, as evidenced by the recent endorsement of a policy of “prudent avoidance” by the five Swedish agencies with responsibility for controlling human exposures to EMFs. Yet many countries throughout the world remain skeptical of the “prudent avoidance” approach, given the unsettled science on EMFs and human health.

Is the Public Convinced?

In November, 1995, the Harvard Center for Risk Analysis interviewed 1,000 Americans about a variety of alleged hazards in daily life that have been reported in the media. On a scale from 0 to 10, we asked respondents how confident they were that each item is hazardous to people’s health.

When asked how confident they were that exposure to electric and magnetic fields from large power lines is hazardous to people’s health, 38% of the participants responded with a 7 or higher on the scale. Twenty-seven percent responded with a 3 or less. (See Figure 2.) A sizeable percentage (32%) responded with 4–6, suggesting they were basically undecided.

Interestingly, respondents were less confident that EMFs were a hazard than they were about nearly all the ten potential hazards offered in the survey. See Figure 3 for the survey results.

Overall, the survey results indicate that, while some Americans perceive EMFs to be hazardous, the majority are undecided or
Figure 2. How confident are you that electric/magnetic fields from power lines are hazardous to people’s health?

![Bar Chart showing confidence levels]  

Figure 3. Hazard Confidence Score

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Percent Top Score (^1) (7-10)</th>
<th>Mean Score (^2)</th>
</tr>
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<tbody>
<tr>
<td>Heavy Smoking</td>
<td>90.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Environmental Tobacco Smoke</td>
<td>71.9</td>
<td>7.7</td>
</tr>
<tr>
<td>Ozone Depletion</td>
<td>63.2</td>
<td>7.1</td>
</tr>
<tr>
<td>Particles in Air</td>
<td>59.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Pesticide Residues</td>
<td>59.2</td>
<td>6.9</td>
</tr>
<tr>
<td>Global Warming</td>
<td>51.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Radon</td>
<td>46.7</td>
<td>6.2</td>
</tr>
<tr>
<td>Medical X-rays</td>
<td>38.8</td>
<td>5.6</td>
</tr>
<tr>
<td>Electric and Magnetic Fields</td>
<td>38.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Relaxing Music</td>
<td>5.2</td>
<td>1.0</td>
</tr>
</tbody>
</table>

\(^1\)Percentage of responses equal to 7, 8, 9, or 10 on the 10 point scale.  
\(^2\)Mean score of the 1000 respondents.

believe that they are not a hazard. An interesting question is whether the public and scientific communities are far apart in their perception of this potential hazard. We have a survey of scientists under way to address this question.