A scientific translation from the Danish:

Cancer Registry of the Danish Cancer Control Agency

Background Paper

Residence Near High-Voltage Facilities and the Risk of Cancer in Children

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Translator's Note

This "background paper" appears to have been written for a non-scientific audience and cannot be considered to be a comprehensive scientific report. It apparently also reports only preliminary results. The study authors describe three different methods of exposure assessment, but report risk in relation to only one of them (annual average magnetic field exposure). They also allude to planned refinements in their exposure assessment methodology. No schedule information is provided.

Two inconsistencies between the Tables 5a and 5b and the supporting text, respectively, were uncovered. The text appears to be in error, noted by "[*sic*]."

Translator: Jack Brøndum, DVM, MS, University of Minnesota School of Public Health. Dr. Brøndum is a doctoral student in environmental epidemiology and has extensively reviewed the EMF epidemiologic literature. He has also translated a number of Danish short stories, poetry and nonfiction works, which have been published in various English-language literary journals.

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Each year in Denmark, approximately 140 new cases of cancer in children 0–14 years old are found. This is the annual equivalent of 13 cases per 100,000 children, or—put another way—one child in every 8,000 newborns will develop a cancer before 15 years of age. In about one third of the cases, the cancer is of the blood, the medical term for which is leukemia. Childhood cancer, including leukemia, is thus a rare disease.

BACKGROUND

The causes of cancer in the childhood years are largely unknown. It, therefore, caused a great deal of interest when Wertheimer and Leeper reported in 1979 that a study they conducted in Denver, USA, had found that the risk of cancer was increased in children living near to high-voltage facilities. For leukemia, the risk was 2–3 times higher than the background risk in children. A *chance* elevation of leukemia cases in families with residences near high-voltage facilities was considered less likely because of the magnitude of the difference. Since most buildings shield against the electric fields that surround high-voltage lines and transformer facilities, Wertheimer and Leeper concluded that the magnetic fields surrounding the electrical facilities were the cause of this increased risk. Their study was subsequently criticized for lack of clarity in the description of their choice of study subjects and for the fact that those who evaluated the magnetic fields at the residence knew beforehand which of the families being investigated had children with cancer.

Nevertheless, Wertheimer and Leeper's report initiated a series of similar investigations in the USA (1980, 1988 and 1991), England (1990), and Sweden (1986). The results of these studies, however, must be regarded as disappointing in the sense that they produced comparatively different patterns of risk for leukemia and brain tumors, respectively. And, where magnetic field measurements had been taken at the residence {the Swedish stidy, 1986}, one was unable to find a relationship between the magnitude of the measurements and the risk of cancer. In the English study, no relationship could be established between magnetic fields and the risk of any form of childhood cancer.

That was the situation until September 1992, when the study from the Swedish Institute of Environmental Medicine in Stockholm was published. In contrast to the earlier Swedish study from 1986, where an increased risk of brain tumors had been found in children who lived in residences near high-voltage lines as well as a moderately reduced risk of leukemia, the new study found an elevated risk for leukemia and a normal occurrence of brain tumors. Among children experiencing a residential magnetic field of at least 0.2 μT, the new Swedish investigation found seven cases of leukemia, where the expected number was 2.6 (if the risk were the same as it is among Swedish children in general). The difference is statistically significant; i.e., that chance might account for this elevation is considered less likely.

OBJECTIVES

In the Danish study, we wished to evaluate the following two hypotheses:

1. Residence near high-voltage facilities (high-voltage transmission lines, high-voltage cables, and transformer stations) increases a child's risk of developing leukemia, brain tumor and cancer of the lymphatic system (lymphoma).
2. The risk of these types of cancer increases with increasing magnetic field level at the residence.

This study is designed so that it is possible to adjust the results for any potential effects of occupational, socioeconomic, and geographic factors on the risk of childhood cancer.

STUDY GROUPS AND METHODS

Principles of a Case-Control Study

This study is a so-called case-control study. After obtaining the appropriate ethical and legal permissions, we chose groups of patients with predetermined types of cancer from the data base of the cancer registry (case group). Residential history *before* cancer diagnosis was determined for every patient and the proportion of residences near high-voltage facilities was calculated for the group as a whole. In order to assess whether this proportion differed from the population 'norm,' we selected a random, that is, a representative, sample of children from the Central Population Registry (CPR). Their residential histories were investigated as well in order to determine the proportion of residences near high-voltage facilities (the control group). If the proportion of residences near high-voltage facilities is larger for the case group than for the control group, and if this difference in proportions is so large that it is very unlikely to be due to chance, this would support the idea of a causal relationship between the physical location of the residence near electrical facilities and increased risk of cancer (Table 1).

Table 1. Principles of a case-control study

Distance of resience from high-voltage facilities	Case Group (patients with cancer)	Control Group (sample from CPR)
Near	a	b
Far	c	d
Total persons in study	(a+c)	(b+d)

If: a/(a+c) > b/(b+d) (">" means "greater than"), and if the difference is "statistically significant," then residences close to high-voltage facilities are suspected of increasing the risk of cancer.

Case Group

This study includes persons diagnosed with leukemia, brain tumor, or lymphoma in the period 1968–1986, and who were under 15 years of age at the time of diagnosis. The children were identified from Cancer Registry data, a total of 1707 cases (Table 2).

Table 2. Size and distribution of the case and control groups by cancer type

Cancer Type	Case Group	Control Group	Total
Leukemia	833	1666	2499
Brain tumor	624	1872	2496
Lymphoma	250	1250	1500
Total	1707	4788	6495

Control Group

For each child with cancer, control children were selected randomly using CPR records of all Danish children of the same gender and age (as the case child). For each child with leukemia (the most frequent of the three types of cancer), two control children were selected; for each child with brain tumor, three control children; and for each child with lymphoma (the least frequent of the three types of cancer), five control children.

Residential History

The residential histories of all 6495 children were ascertained from the date of cancer diagnosis (corresponding date for the respective control children) retrospectively to nine months before the child's birth. Because some of the children had multiple address changes it was necessary to obtain information on approximately 16,000 addresses, determined according to parish, postal code, street, street number, floor, and side of the building. This information was provided by the CPR and with the enormous assistance of the nation's 276 local population registries. Addresses were sorted in geographic order (by postal code) and distributed to the local divisions of Danish utilities with the objective of evaluating the proximity of each address to existing or former high-voltage facilities. Addresses that met predetermined distance criteria (Table 3) were selected for more detailed description, both in relation to the type of high-voltage facilities and the exact placement of the residence. For each selected address, a sketch was made containing distances, type of electrical facility, tower type, year of construction, and engineering data needed to calculate the size of the magnetic field at the residence during the pertinent period.

Table 3. Distance criteria for addresses with potential magnetic field exposure from existing or former high-voltage facilities.

High-Voltage Facility	220–400 kV	132–150 kV	50–60 kV
Power Lines	150 m	75 m	35 m
Underground Cables	20 m	5 m	2.5 m
Transformer Stations		(Ad - hoc evaluation)	

The sorting and the subsequent description of selected addresses were done in blinded fashion, i.e., with those who did the work having no knowledge of the case or control status of the child living at the address.

Children's Magnetic Field Burden

Addresses that lay within the three distance levels given in Table 3 were subsequently assigned a set of estimated magnetic field levels during the relevant periods in which children had lived there. An example would be a child who from April 1969 to November 1974 lived 20 meters from a 220-kV line with the appropriate engineering specifications (tower type, phase configuration, etc.). On the basis of distance, engineering data for the facility, and an estimated 'duration' graph for the facility's load in the appropriate calendar years, we calculated:

1. field levels under extreme use conditions (minutes to hours per year);
2. field levels during 'normal' maximum and minimum line loads, respectively (days to weeks per year); and
3. field levels at the average annual load.

All measurements are expressed in μT. Only the latter measure (average load) was used in this preliminary analysis.

The exposure estimates will be further refined by incorporating the duration of exposure (e.g., expressed as μT-months), and the child's age during the period of exposure (small children, many hours spent at home). None of these modifications have been incorporated in the analyses presented here.

Other Risk Factors (Confounding)

Parents of the children were all identified in the CPR and their occupational histories determined through data linkage using information in the records of the Labor Market Supplementary Pension system. The child's residences were further classified according to increasing population density, with rural districts at one end of the scale and major metropolitan areas at the other.

Analysis

The results were obtained using a multivariate case-control analysis for paired data with simultaneous adjustment for the potential effects of gender, age, calendar year, urbanization and socioeconomic status on the measure of effect.

RESULTS

Among the 4788 children from the CPR sample (the control group; Table 1), 20 had lived so close to high-voltage lines that they had experienced an average magnetic field at their residence of 0.1 μT or greater. Since the sample is representative of the population, this means that about 0.4 percent of Danish children are exposed to magnetic fields from high-voltage lines at this level, or in actual numbers, 4000 children.

Among the 1707 children with cancer included in the study, ten (0.6%) had lived so close to high-voltage lines that they had experienced 0.1 μT or more. Figure 1 shows the average magnetic field level at the residence for the ten case children and the 20 control children. As can be seen, there is a tendency toward higher values in the values in the case group compared with the control group.

Table 4 shows the relative risk for those cancer types included in the study, given an exposure level to magnetic fields of 0.1 μT or more. For all cancers combined, the increased risk was 40% (RR = 1.4) which was not statistically significantly different from the null value 1.0 (95% confidence interval (CI) = 0.7–3.0). For neither leukemia nor brain tumors was there an increased risk in the interval of 0.1 μT or greater; in contrast, a significantly elevated risk was found in the lymphoma group (RR = 5.0). The latter estimate is based upon only three cases with a correspondingly wide confidence interval (95% C1 = 1.2–21).

Table 4. Relative risk (RR) and 95% confidence intervals (95% CI) for leukemia, brain tumors, and lymphomas among children with exposure of 0.1 μT or greater from high-voltage facilities.

	0–0.09 μT		≥ 0.10 μT			
Cancer Type	n	RR	Cases	Controls	RR	(95% CI)
Combined	1697	1	10	20	1.4	(0.7–3.0)
Leukemia	829	1	4	8	1.0	(0.3–3.3)
Brain Tumor	621	1	3	9	1.0	(0.3–3.7)
Lymphoma	247	1	3	3	5.0	(1.2–21)

Despite the small number of cancer cases found among exposed children (≥ 0.1 μT), we attempted in Tables 5a and 5b to subdivide the exposure interval into high and low levels. Table 5a uses 0.25 μT as a cut point (the *a priori* chosen level) and Table 5b, a value of 0.4 μT. In the exposure category greater than [*sic*] 0.25 μT (Table 5a), a mild elevation in relative risk was seen (RR = 1.5), but the estimate does not differ significantly from the null (95% C1 = 0.6–4.1). On the other hand, in the exposure category greater than [*sic*] 0.4 μT (Table 5b), a significantly increased risk of cancer is seen (RR = 5.6; 95% C1 = 1.6–19), based on six observations (3 cases of leukemia, 2 cases of brain tumor, and 1 case of lymphoma).

Table 5a. Relative risk (RR) and 95% confidence intervals (95% CI) for all cancer among children by magnetic field exposure level: none (< 0.1 μT), low (0.1–0.24 μT), and high (≥ 0.25 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	1697	4768	1	
0.10–0.24	4	9	1.3	(0.4–4.1)
≥ 0.25	6	11	1.5	(0.6–4.1)
Total	1707	4788		

Table 5b. Relative risk (RR) and 95% confidence intervals (95% CI) among children by magnetic field exposure level: none (< 0.1 μT), moderate (0.1–0.39 μT), and very high (≥ 0.4 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	1697	4768	1	
0.10–0.39	4	17	0.7	(0.2–2.0)
≥ 0.40	6	3	5.6	(1.6–19)
Total	1707	4788		

Leukemia

Figure 2 shows the distribution of the four leukemia cases and the eight control children who were exposed to more than 0.1 μT. Two of the four cases had relatively high exposures. Tables 6a and 6b show the relative risks for exposure levels of greater than 0.25 μT and 0.4 μT, respectively. In neither instance is there any evidence of significant risk differences.

Table 6a. Relative risk (RR) and 95% confidence intervals (95% CI) for leukemia among children by magnetic field exposure level: none (< 0.1 μT), low (0.1–0.24 μT), and high (≥ 0.25 μT).

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	829	1658	1	
0.10–0.24	1	4	0.5	(0.1–4.3)
≥ 0.25	3	4	1.5	(0.3–6.7)
Total	833	1666		

Table 6b. Relative risk (RR) and 95% confidence intervals (95% CI) for leukemia among children by magnetic field exposure level: none (< 0.1 μT), moderate (0.1–0.39 μT), and very high (≥ 0.4 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	829	1658	1	
0.10–0.39	1	7	0.3	(0.0–2.0)
≥ 0.40	3	1	6.0	(0.8–44)
Total	833	1666		

Brain Tumor

Figure 3 shows the distribution of the three cases of brain tumor and the nine control persons. Tables 7a and 7b show the situation when the chosen exposure categories are used.

Table 7a. Relative risk (RR) and 95% confidence intervals (95% CI) for brain tumors among children by magnetic field exposure level: none (< 0.1 μT), low (0.1–0.24 μT), and high (≥ 0.25 μT).

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	621	1863	1	
0.10–0.24	1	3	1.0	(0.1–9.6)
≥ 0.25	2	6	1.0	(0.2–5.0)
Total	624	1872		

Table 7b. Relative risk (RR) and 95% confidence intervals (95% CI) for brain tumor among children by magnetic field exposure level: none (< 0.1 μT), moderate (0.1–0.39 μT), and very high (≥ 0.4 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	621	1863	1	
0.10–0.39	1	8	0.4	(0.1–2.8)
≥ 0.40	2	1	6.0	(0.7–44)
Total	624	1872		

Lymphoma

Tables 8a and 8b show the corresponding situation for lymphoma; however, the tables are based upon only three cases of lymphoma and three control persons in these exposure categories.

Table 8a. Relative risk (RR) and 95% confidence intervals (95% CI) for lymphomia among children by magnetic field exposure level: none (< 0.1 μT), low (0.1–0.24 μT), and high (≥ 0.25 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	247	1247	1	
0.10–0.24	2	2	5.0	(0.9–30)
≥ 0.25	1	1	5.0	(0.4–61)
Total	250	1250		

Table 8b. Relative risk (RR) and 95% confidence intervals (95% CI) for lymphoma among children by magnetic field exposure level: none (< 0.1 μT), moderate (0.1–0.39 μT), and very high (≥ 0.4 μT)

Exposure Level (μT)	Cases	Controls	RR	(95% CI)
0–0.09	247	1247	1	
0.10–0.39	2	2	5.0	(0.9–30)
≥ 0.40	1	1	5.0	(0.4–61)
Total	250	1250		

SUMMARY

This population-based case-control study included all cases of leukemia, brain tumor and lymphoma in the 0–14 year age group during the period 1968–1986, a total of 1707 cases.

For every patient with cancer, two (leukemia), three (brain tumor), and five (lymphoma) control persons of corresponding gender and age were selected from the CPR, 4788 persons in all. Exposure to magnetic fields of at least 0.1 μT from 50-Hz high-voltage facilities (transmission lines, cables, and transformer stations) was evaluated blindly for every study subject. A total of ten cancer patients and 20 control persons were previously exposed to average magnetic field levels of at least 0.1 μT, corresponding to a non-statistically significant relative risk of 1.4 (95% C1 = 0.7– 3.0). At an exposure level of 0.4 μT or greater, however, a significant increase in risk of 5.6 (95% C1 = 1.6–19) was found for all cancers combined, based on six cancer patients and three controls.

Even though five of the six cancer patients in the latter exposure category (≥ 0.4 μT) had leukemia or brain tumor, there were no significant increases in risk for these specific cancer types. For the combined exposure category of at least 0.1 μT, the relative

risk in both instances was null; that is, 1.0. In contrast, a significantly elevated relative risk of 5.0 was found for lymphoma on exposure to a ≥ 0.1 μT magnetic field. This risk estimate, however, was based on only three cases of lymphoma and three control persons.

The analyses have been adjusted for socioeconomic status as well as degree of urbanization of the residence.

CONCLUSION

This study demonstrated that the risk of *lymphatic cancer* is increased among children with exposure to magnetic fields from high-voltage lines of 0.1 μT or greater. On the other hand, no increase in risk was found at this exposure level for either leukemia or brain tumor. For all three types of cancer *combined* an increased risk was also found at magnetic field exposures of 0.4 μT or greater, which corresponds to a residential distance of 25–50 meters from the 'most powerful' transmission facilities.

Although a great deal of consideration was devoted to the uncertainties arising from statistical variation, it is important to emphasize that this study is based upon a small number of children with exposure to these types of magnetic fields.

On a national basis, it is estimated that about 4000 children are exposed to magnetic fields from high-voltage facilities of at least 0.1 μT, of which 600 are exposed to 0.4 μT or more.

Figure 1. Average magnetic field level at the residence for exposed case [cases; n = 10] and control children [kontroller; n = 20]

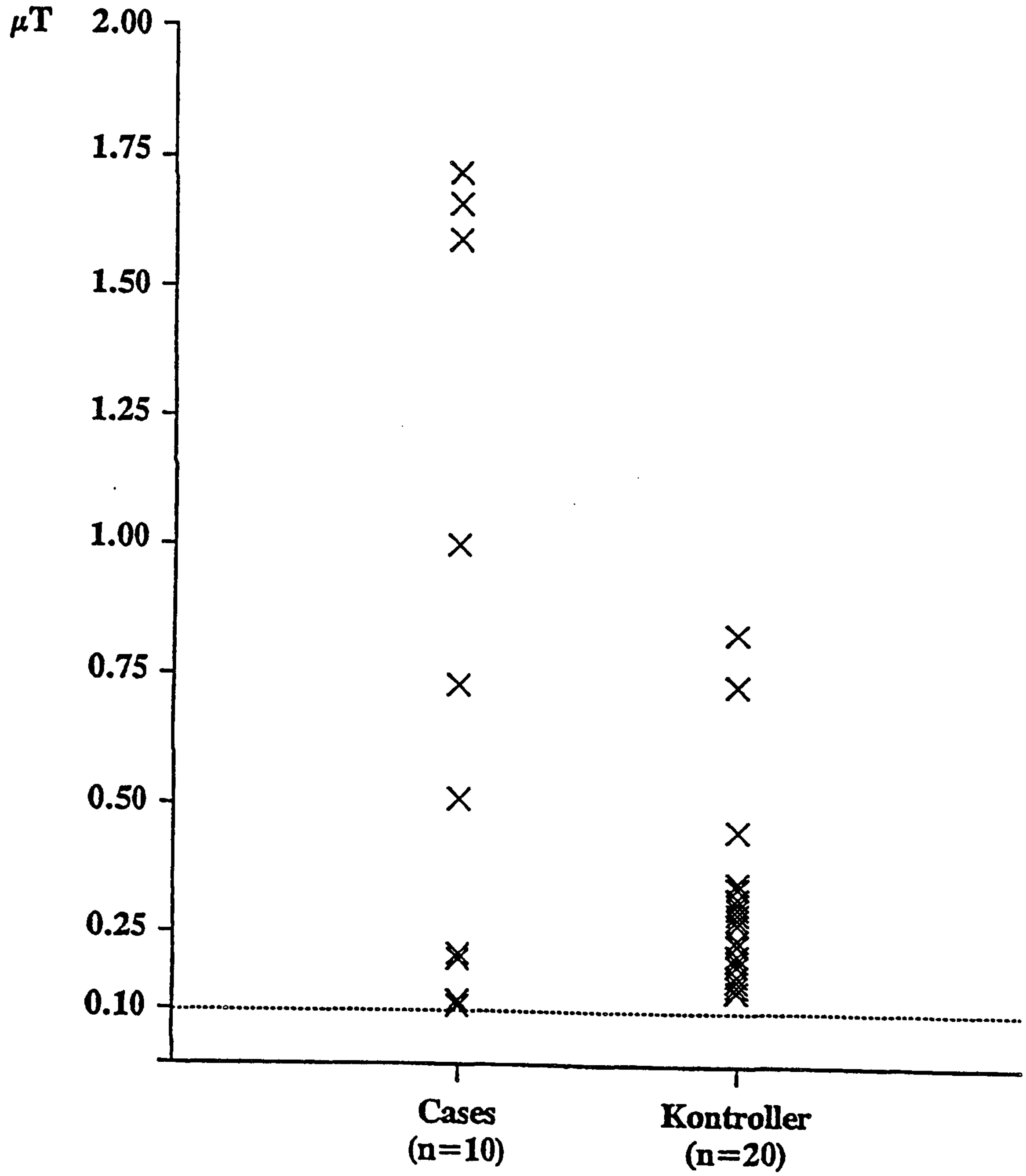

Figure 2. Average magnetic field level at the residence for exposed children with leukemia [leukæmi; n = 4] and exposed children from the control group [kontroller; n = 8]

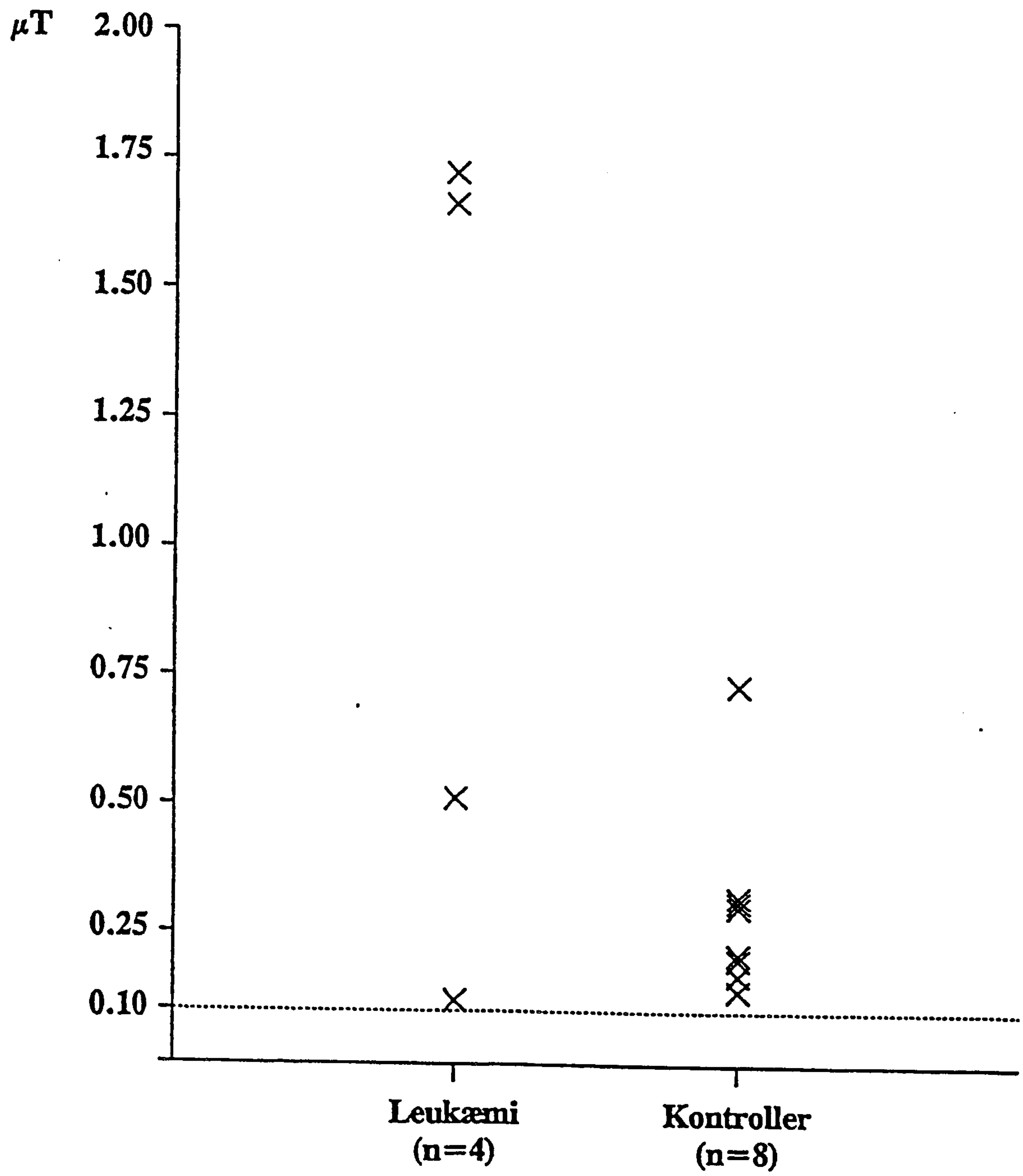

Figure 3. Average magnetic field level at the residence for exposed children with brain tumor [hjernesvult; n = 3] and exposed children from the control group [kontroller; n = 9]