RESEARCH COMMUNICATION

Living Near Overhead High Voltage Transmission Power Lines as a Risk Factor for Childhood Acute Lymphoblastic Leukemia: a Case-control Study

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Abstract

This study aimed to investigate association of living near high voltage power lines with occurrence of childhood acute lymphoblastic leukemia (ALL). Through a case-control study 300 children aged 1-18 years with confirmed ALL were selected from all referral teaching centers for cancer. They interviewed for history of living near overhead high voltage power lines during at least past two years and compared with 300 controls which were individually matched for sex and approximate age. Logistic regression, chi square and paired t-tests were used for analysis when appropriate. The case group were living significantly closer to power lines (P<0.001). More than half of the cases were exposed to two or three types of power lines (P<0.02). Using logistic regression, odds ratio of 2.61 (95%CI: 1.73 to 3.94) calculated for less than 600 meters far from the nearest lines against more than 600 meters. This ratio estimated as 9.93 (95%CI: 3.47 to 28.5) for 123 KV, 10.78 (95%CI: 3.75 to 31) for 230 KV and 2.98 (95%CI: 0.93to 9.54) for 400 KV lines. Odds of ALL decreased 0.61 for every 600 meters from the nearest power line. This study emphasizes that living close to high voltage power lines is a risk for ALL.

Keywords: Acute lymphoblastic leukemia - electromagnetic field - risk factors - case-control study - Iran

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Introduction

During past three decade, researchers have had special concern on relationship between occurrence of cancer and living near overhead high voltage transmission power lines (Sher, 1997). Among different kind of cancers, ALL in children as well as adult has been paid more attention (Li et al., 1996; Verkasalo, 1996). Many studies designed to assess this relationship in Sweden, Denmark, USA, UK, New Zealand, Canada, and others. There was controversy and these studies didn't lead to a common finding. Some of them confirmed living near overhead high-voltage transmission power lines as a risk factor which increases the chance of ALL occurrences almost two folds (Draper et al., 2005) and the others didn't support it (Tynes and Haldorsen, 1997; 2000). Even a meta analysis yielded a pooled relative risk estimate of 1.46 (95% CI 1.05 to 2.04) which is indicating potentially low level of risk (Angelillo and Villari, 1999).

In Tehran, the Capital of Iran, a mixture of overhead high-voltage transmission power lines of 123, 230 and 400 kilo-volts (KV) pass through some neighborhoods in different parts of the city. Researchers found that almost 1.6 million people, 20 percent of total population of capital city, are living near these lines and exposed to extremely low frequency electric and magnetic fields. On the other hand, annual mortality rate of leukemia in Iran estimated 6.1 per 100000 for male and 5.2 per 100000 for female (Mousavi et al., 2009) which is near two fold of ALL incidences in Sweden (Hjalmars and Gustafsson, 1999). This study aimed to investigate whether living near the overhead high voltage transmission power lines is associated with increased risk of childhood ALL and analyze it based on causality principals.

Materials and Methods

Study design

In a case-control study 600 children of less than 18 years old assessed in terms of risk of exposure to high voltage overhead power lines. This study has been approved by the research sub-secretary of Shahid Beheshti University of Medical Sciences and Health Services.

Setting

The study was conducted at all referral hospitals for childhood ALL and also hospitals of acute lymphoblastic leukemia related to NGOs. These include Children's medical center, Ali-Asghar teaching center, children's Mofid teaching center and also Mahak Hospital. The last one is belong to supporting non-governmental organization for cancerous children. The target population

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of these four centers is total population of Tehran province, the capital of Iran that is more than 11.7 million. Also cases from other provinces were referred to these hospitals but this study only focused on Tehran citizens.

Selection of participants

In this study we identified 300 children aged 0-18 years old inclusive with a pathologically confirmed acute lymphoblastic leukemia, all under chemotherapy, and some for relapse. They were diagnosed during last two years and living in Tehran for at least 2 years before diagnosis. Two trained physicians enrolled them through face to face interview with their parents in outpatient oncologic clinics during a period of 5 months, Jan 2009 to May 2009.

The control group consisted of 300 patients selected form clinics that have the same pattern of referral and nonrelated to malignancy or hematologic disease mainly from dialysis ward and orthopedic emergencies which most of the cases in each area have to go to the same hospitals. Controls were from the same hospitals except for Mahak which is a NGO related hospital for only malignant diseases. Both cases and controls were living in Tehran and didn't have any history of other malignancies, neurofibromatosis or Down syndrome. They were individually matched on sex and approximate date of birth (in a range of six months) with cases.

Methods of Measurement

A questionnaire was filled through face to face interview for both cases and controls after getting an informed consent. Age, gender, residential address, family history of acute lymphoblastic leukemia, parent's literacy, history of Down syndrome or neurofibromatosis, history of chemotherapy or radiotherapy for other diagnosis, alcohol consumption during pregnancy were asked. Place(s) of residency during three years before diagnosis of acute lymphoblastic leukemia was asked carefully and registered in the data gathering forms. Then we obtained the grid references of all pylons concerned from the records of National Grid Transco "National Electrical map". Using the subjects' living addresses, we identified subjects' place of residence on the map and calculated the shortest distance to any kind of the overhead high voltage transmission power lines (123, 230 and 400 kilo volts) that existed in the present and the three previous years, by meters. When more than one line was present, we used the distance from the subject's residence to the closest power Line. For calculating distances, we used a GPS-based software and also large scale maps. The person who calculated distances was blinded to situation of cases and controls. We aimed to obtain a complete set of accurate distances for all subjects based on less and more than 600 meters far from power-lines.

Primary Data Analysis

Descriptive statistics were used to explain data summaries. Odds ratio used to clarify the magnitude of the risk in different distances from the power lines and estimated using logistic regression. Different groups' means were compared using paired T-test and relationship between qualitative variables has shown by Chi square.

Results

Totally 600 children, 168 (56%) male and 132 (44%) female in each groups were studied. Mean age of case and control groups were the same (Table 1). Average age of disease onset in cases was 6.2 years, 95% CI for mean was 5.8 to 6.6. The age of disease onset in the youngest case was one year old and in the oldest one were 14. Twenty cases (6.7%) have had lived in the same neighborhood for the past two years before disease onset; the time was at least three years for the other cases and all of the controls (P<0.001). Positive family history detected in 128 (42.7 percent) of cases and only 12 (4 percent) of controls, most

Table 1. Distribution of Age and Sex in cases of ALL and Control Groups

	Cases			Controls		
	Male	Female	Total	Male	Female	Total
Mean	8.88	8.37	8.7	8.87	8.43	8.7
SD	4.21	4.13	4.18	4.21	4.11	4.15
95% CI for mean	8.24- 9.52	7.66- 9.08	8.2 to 9.1	8.23- 9.51	7.72- 9.14	8.2 to 9.1
Minimum(Months)	13	18	13	18	20	18
Maximum(Years)	18	18	18	18	18	18
Total	168	132	300	168	132	300

Table 2. Distribution of Distance of Living Place from High Voltage Power Lines According to Voltage of Power Lines and Groups

Voltage	123 KV		230 KV		400 KV		Nearest power line	
	Case	Control	Case	Control	Case	Control	Case	Control
Mean	1218	1965	1165	1897	1025	1162	1134	2114
SD	757	1181	758	1175	493	825	811	1262
Minimum	48	44	52	134	136	203	48	44
Maximum	3616	3500	3500	3500	2550	3500	3616	3500
Total	219	196	214	201	58	27	300	300
P Value	P< 0.001		P< 0.001		P>0.05		P< 0.001	

Table 3. Distribution of Distance of Living Place from High Voltage Power Lines in Case and Control Groups

Intervals	Case	Control	Total
0-599	89 (29.7%)	42 (14.0%)	131(21.8%)
600-1199	104 (34.7%)	61 (20.3%)	165 (27.5%)
1200-1799	48 (16.0%)	42 (14.0%)	90 (15.0%)
1800-2399	19 (6.3%)	19 (6.3%)	38 (6.3%)
More than 2400	40 (13.3%)	136 (45.3%)	176 (29.3%)
Total	300 (100%)	300 (100%)	600 (100)

Table 4. Frequency of Samples' Exposure to High Voltage Power Lines

	Number of power lines			total
	One (%)	Two (%)	Three (%)	
Cases	140 (46.6)	131 (43.7)	29 (9.7)	300 (100)
Controls	191 (63.7)	94 (31.3)	15 (5)	300 (100)
Total	331 (55.2)	225 (37.5)	44 (7.3)	600 (100)

of them were second degree relationship (P<0.001). None of cases and controls had history of chemotherapy or radiotherapy because of causes other than ALL.

The average distance of living place of cases from all types of high voltage transmission power lines was considerably less than control group (P<0.001)(Table 2). Table 3 shows the frequency distribution of cases and controls around the high voltage power lines in cut points of 600 meters interval (P<0.001). Near two third of cases were living in less than 1200 meters far from the power lines. On the other hand more than half of the controls were living in more than 1800 meters far from them. More than half of the cases were exposed to two or three type of high voltage power lines (P<0.02) (Table 4).

Using logistic regression, odds of acute lymphoblastic leukemia for those who were living in less than 400 meters from high voltage power lines was 2.75 (95%CI: 1.59 to 4.76) times to those living in more distance (P< 0.001). It was 2.67 (95%CI: 1.67 to 4.24) for 500 meters and 2.61 (95%CI: 1.73 to 3.94) for 600 meters far from these lines (P< 0.001). Pure risk of living in less than 600 meters far from each type of high voltage power lines after excluding samples that exposed to the other types of lines, estimated as 9.93(95%CI: 3.47 to 28.48) for 123 KV power lines, 10.78 (95%CI: 3.75 to 31) for 230 KV (P< 0.001) and 2.98 (95%CI: 0.93to 9.54) for 400 KV power lines (P< 0.07).

Odds of ALL decreased 0.61 (95%CI: 0.54 to 0.69) for every 600 meters far from nearest power line. It was 0.47 (95%CI: 0.40 to 0.55), 0.46 (95%CI: 0.39 to 0.54) and 0.46 (95%CI: 0.27 to 0.77) for power lines of 123, 230 and 400 KV respectively. Positive family history of ALL had no added risk of the disease (OR=1.2, 95%CI: 0.82 to 1.77) (P>0.05). Literacy of parents also had no additional risk for ALL (P>0.05).

Discussion

This study found that living near overhead high voltage power lines increases the risk of ALL and this risk is different based on voltage of the power lines which could be 123 KV, 230 KV and 400 KV.

Considering causality criteria, temporality is achieved as all the cases and controls have been lived in the same neighborhood for at least 2 years before disease onset. This is the same time as McBride considered but Myer did not find a significant association based on maximum load during year of birth (Myers et al., 1990; McBride et al., 1999)

Odds ratios of 9.9 and 10.8 for 123 and 230 KV power lines support the strength of association as the second criteria for causal relationship. For 400 KV power lines Odds ratio of 3 may be due to insufficient samples which were living near these lines. Higher odds ratio of different kind of power lines (9.9, 10.8 and 3) in spite of lower odds of nearest power line (2.7) may be due to multiple exposures of more than half of case group and one-third of control group to 123, 230 and 400 KV power lines.

In this study we found that every more 600 meters far from power lines, decreases the risk of ALL by 0.61 folds. Draper also considered 600 meter as the cut-point for calculating risk (Draper et al., 2005). On the other hand exposure to more than one kind of power lines was seen in case group much more than control group. These two finding may support dose-response criteria for causality.

Replication of findings on relationship of ALL occurrence and living close to high voltage power lines is debatable. We found the odds ratio of 2.61 (95%CI: 1.73 to 3.94) for those who living close to overhead power lines. This more than estimation of other studies like Theriault et al which found an increase of 1.3 fold(Theriault and Li, 1997); three other studies estimated 1.7 fold increase in risk of ALL (Hjalmars and Gustafsson, 1999; Greenland et al., 2000; Brain et al., 2003). Angelillo et al calculated a pooled relative risk of 1.46 (95% CI: 1.05 to 2.04) through a meta-analysis (Angelillo and Villari, 1999)and Ahlbom expected two-fold increase in risk of the disease(Ahlbom et al., 2000). On the other hand considerable number of studies didn't find any excess risk (Coleman et al., 1989; Myers et al., 1990; Verkasalo et al., 1993; McBride et al., 1999; 2000; Skinner et al., 2002; Tynes et al., 2003).

Another study from Iran found more similar finding to our study (Feizi and Arabi 2007). They report odds ratio of 8.67 (95% CI: 1.74 to 58.4) which is near to odds ratio of 123 and 230 KV in our study (9.93(95%CI: 3.47 to 28.48) and 10.78 (95%CI: 3.75 to 31) respectively). It may be related to similar pattern of electricity network of these two cities of Iran and other environmental or individual characteristics that not revealed yet. Wider CI in the former is related to small sample size. In these two study children do experience more intensive effects from power lines, and in relatively much far distances, i.e.; 500-600 vs. 50-100 meters, in comparison with their counterparts in developed countries(Lowenthal et al., 2007).

In order to prevent bias, analyzer of distances of living place to power lines blinded to case and control group, control group selected carefully based on the same referral pattern as the cases and all the referral centers for ALL included in the study (by this way the current study can be considered as a field study). Face to face interview in this study provided more accurate data than using existing data as in other studies (Olsen et al., 1993; Tynes

and Haldorsen, 1997; 2000; Skinner et al., 2002). But however, there could be a effect modifiers or confounders that did not known and not measured (Brain et al., 2003) as Bowman (Bowman and Thomas, 2001) mentioned to explain why there is no association in Kleinerman's (Kleinerman et al., 2000) study. In most of the studies the sample size for evaluating the risk was small or the cases of ALL among other cases were too small to be considered (Coleman et al., 1989; Myers et al., 1990; 2000; Skinner et al., 2002; Feizi and Arabi, 2007). In this study we assessed 300 cases of ALL to cover this weak point.

As other criteria of causality, other explanation for this relationship is available as magnetic fields (Feychting and Ahlbom, 1993; Kleinerman et al., 1997; Henshaw, 2002). Other cancers like other lymphomas and brain tumors also may be related to exposure to electro-magnetic fields (Hardell and Sage, 2008). Biologic plausibility of this relationship is explained by Krassowska (Krassowska et al., 2003).

By increasing migration to metropolitans, sub-urban neighborhoods are developing more and more. Most of them have a condensed population and even some of them haven't legal permission to establish home. This situation leads to risky environment that threats health of population. It is important that children don't live very close to high voltage overhead power lines because there is not any competent laws protecting them. There is ALL, other cancers and diseases and also the risk of electrical shock and falling down when they try to climb them.

Considering epidemiologic transition of diseases and increasing rate of cancer mortality and morbidity, especially ALL, the authorities should define harmless zones near the overhead high voltage power lines. The very high voltage electricity stations and lines should be installed enough far from the residential areas or make the power lines underground especially in the densely populated areas. It is reasonable to consider a distance of 600 meters as potentially risky area and no building permits should be issued if the defined safe distance is not respected (Feizi and Arabi, 2007; Mousavi et al., 2009).

This study emphasizes on risk of ALL following living close to overhead high voltage power lines. Authorities should consider legal limitation for building constructions in at least 600 meters from these power lines. Overhead power lines should be changed to under-ground lines in existing risky neighborhoods.

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