RISK OF CANCER DUE TO ELECTROMAGNETIC FIELD EXPOSURE: A REVIEW

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ABSTRACT

Background: Electromagnetic field (EMF) spectrum ranges from extremely low frequency electromagnetic field (ELF-EMF) to ultra-high frequency EMF. Increasing use of wireless telecommunication may pose a risk of cancer development due to prolonged EMF exposure. Due to inconclusive evidence from literature, a scoping systematic review was done to determine evidences to support EMF as a determinant of cancer, as well as the type of EMF is implicated in cancer and the type of cancer involved in association with EMF.

Materials and Methods: Full-text articles on Cohort studies and/or randomized controlled trials published from 1st January 2010 to 8th June 2016 were searched using Proquest and other sources. People of all age group and EMF were the type of participant and exposure used for the search strategy, respectively. Data collection was done by 1 reviewer and checked by 2 reviewers for discrepancies. All the papers were critically appraised using the STROBE statement. Qualitative synthesis was done by descriptive comparison, risk of bias comparison and effect of exposure comparison.

Result: 5 out of 29 articles met the eligibility criteria and were selected. Three articles showed low risk of bias due to low confounding bias. Another two articles had unclear risk of bias due to either information bias or using secondary data of uncertain quality. There were 2 high quality, 1 moderate quality and 2 low quality evidences using GRADE. Children under the age of 16 years with medium to ultra-high EMF exposure levels had approximately 0.7 times the rate of all cancer incidence compared to those with low exposure levels. Incidence rate of follicular lymphoma in males who were exposed to ELF-EMF was 300% higher at any given time point studied than the rate in those who were unexposed.

Conclusion: Exposure to medium to ultra-high EMF wavelength lowers the rate of progression of cancer development, due to shorter duration of exposure. Cancer development is only shown to be related to EMF exposure from ELF-EMF but not for shorter-wavelength EMFs, and this is due to longer exposure duration. Due to small number of studies obtained from this scoping systematic review, results from this review should be interpreted with caution.

Keywords: Electromagnetic field, cancer, cohort studies, medium to ultra-high EMF, ELF-EMF
1.0 Introduction

Globally, 14 million new cases and 8.2 million people succumbed to cancer in 2012 (GLOBOCAN, 2012). Cancer is the second most common cause of death after cardiovascular disease. Out of these, about 1% is attributed to radiation. One of the types of radiation is non-ionizing radiation, which includes electromagnetic field (EMF) (Aldrich and Easterly, 1987).

The electromagnetic spectrum extends from waves at low frequency (low energy), referred to as “electric and magnetic fields”, to those at very high frequencies, which are often called “electromagnetic radiation”. Non-ionizing radiation is a general term for that part of the electromagnetic spectrum which has photon energies too weak to break chemical bonds, and includes ultraviolet radiation, visible light, infrared radiation, radiofrequency and microwave fields, extremely low frequency (ELF) fields, as well as static electric and magnetic fields (Aldrich et al., 1987).

Majority of people now use smartphones and appliances radiating EMF. Thus, the risk of exposure truly exists. Exposure depends of dose, duration, shielding, organ targeted, immune system and others. Currently, there is paucity of recent evidences on role of EMF in cancer development. Thus, a scoping systematic review was to ascertain this.

2.0 Materials and Methods

2.1 Objectives

The primary objective of this scoping review is to determine if there are evidences to support EMF as a determinant of cancer. Secondary objectives would be to determine what type of EMF is implicated in cancer and what type of cancer involved in association with EMF.

2.2 Methods

Criteria for considering studies for this review:

a. Types of studies

Cohort and/or randomized controlled trial (RCT) study designs were considered.

b. Types of participants

People of all age groups were considered

c. Types of interventions

EMF exposures as intervention were considered.
2.3 Search methods for identification of studies (including PRISMA flowchart)

Cohort studies and/or RCTs published from 1st January 2010 to 8th June 2016, were searched using Proquest and other sources. Only full text articles were taken. The total search result was 26 in Proquest and 3 from other sources. Three elements of the search strategy were developed using the Boolean term ‘AND’ or ‘OR’:

1. Exposure subject heading: Document text (ft) (Electromagnetic field) AND
2. Disease subject heading: ft ((Cancer OR Neoplasm)) AND
3. Study design subject heading: Document title (ti) ((Cohort OR Randomized controlled trial))

The term searched:

ft(Electromagnetic field) AND ft((Cancer OR Neoplasm)) AND ti((Cohort OR Randomized controlled trial))

The search strategy resulted in a total of 5 cohort studies alone included for this review. The PRISMA flow diagram for the search strategy is summarized in figure below:

2.4 Data collection and analysis

Data collection was done by 1 reviewer and checked by 2 reviewers, comprising of medical doctors from the Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia. All the papers were critically appraised using the STROBE statement.

Qualitative synthesis was done by descriptive comparison, risk of bias comparison and effect of exposure comparison. Meta-analysis was not done due to difficulty in obtaining some of the estimates which were not reported in the articles.

3.0 Result

3.1 Descriptive studies

Table 1: Descriptive studies

<table>
<thead>
<tr>
<th>Author</th>
<th>Study design</th>
<th>Sample size</th>
<th>Population</th>
<th>Period (year)</th>
<th>Exposure</th>
<th>Cancer outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauri et al., 2014</td>
<td>Prospective cohort</td>
<td>1,287,354</td>
<td>Children who were under age 16 years and living in Switzerland on the date of the 2000 census</td>
<td>December 5, 2000 to December 31, 2006</td>
<td>Broadcast transmitters emitting medium-wave (0.5–1.6 MHz), short-wave (6–22 MHz), very high frequency (VHF; 174–230 MHz),</td>
<td>Leukaemia and central nervous system (CNS) tumors</td>
</tr>
</tbody>
</table>
Table 1 depicts the descriptive study on the 5 articles selected for the review.

### 3.2 Risk of bias in included studies

#### Table 2: Risk of bias in reviewed studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Exposure assessment bias</th>
<th>Selection bias</th>
<th>Randomization bias</th>
<th>Confounding</th>
<th>Other bias</th>
<th>Overall risk of bias</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauri et al., 2014</td>
<td>Low due to detailed description given</td>
<td>Low due to all children aged 16 years below living in Switzerland were taken</td>
<td>Not applicable</td>
<td>Low due to all regression models used adjusted for confounders</td>
<td>Non-differential misclassification bias</td>
<td>Low</td>
</tr>
<tr>
<td>Elwood et al., 2012</td>
<td>Low due to specified type and dosage of EMF</td>
<td>Low due to comparison group chosen for their general similarity to Moscow in climate, diet, geographical location, disease</td>
<td>Not applicable</td>
<td>High due to low statistical power and no description on control of confounders</td>
<td>High due to information bias due to reported logical differences between groups rather than numerical differences</td>
<td>Unclear</td>
</tr>
</tbody>
</table>
Table 2 depicts the risk of bias in reviewed studies. The overall risk of bias is based on the author’s judgment and discussion with other reviewers for this systematic review.

### 3.3 Effect of exposure

#### Table 3: Effect of exposure

<table>
<thead>
<tr>
<th>Author</th>
<th>Selected Outcome</th>
<th>Relative effect (95% CI)</th>
<th>No of cases</th>
<th>Quality of evidence using GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hauri et al., 2014</td>
<td>All cancer incidence rate ratio (IRR) from 1996 to 2008</td>
<td>IRR= 0.69 (0.54, 0.87)</td>
<td>2535</td>
<td>High</td>
</tr>
<tr>
<td>Elwood et al., 2012</td>
<td>All cancer mortality</td>
<td>SMR= 0.89</td>
<td>64</td>
<td>Low</td>
</tr>
<tr>
<td>Koeman et al., 2014</td>
<td>Incidence of follicular lymphoma in males</td>
<td>Adjusted hazard ratio (HR)= 2.78 (1.20, 6.44)</td>
<td>49</td>
<td>High</td>
</tr>
<tr>
<td>Frei et al., 2011</td>
<td>All cancer IRR in men</td>
<td>IRR= 0.96 (0.95, 0.98)</td>
<td>122,302</td>
<td>Moderate</td>
</tr>
<tr>
<td>Johansen et al., 2007</td>
<td>Relative risk for brain cancer in men</td>
<td>RR= 0.69 (0.38, 1.25)</td>
<td>32,475</td>
<td>Low</td>
</tr>
</tbody>
</table>

Only 4 studies showed selected outcome results with significant \( P \) value (<0.05) that were chosen for the effect of exposure analysis as in table 3. Another 1 study had no significant selected outcome. For the quality of evidence using GRADE, it is based on the combination of risk of bias judgment and the effect of intervention judgment.
4.0 Discussion

EMF exposure is widespread now with the advent of information technology and borderless world. Coincidently, number of cancer cases is increasing over the years. Thus, it is important to ascertain if cancer does have association with EMF. The systematic review looks upon the evidences to support or refute the association.

4.1 Descriptive studies

Two out of five studies were prospective cohort studies. Out of these two, the larger cohort (involving children under 16 years of age) took medium to ultra-high radiofrequency wave as the exposure and looked at blood cancers (Hauri et al., 2014). Another prospective cohort also studied blood cancers among those aged 55 to 64 years exposed to ELF-EMF. The advantage of the prospective cohort design in environmental cancers such as EMF-induced cancer is that it allows standardized and detailed collection of pre-morbid exposure information, tailored to meet the goals of the study. The assessment of EMF exposure on genetic level, and therefore gene–environment interactions, is typically more extensive and less prone to bias in prospective cohort studies than in retrospective cohort, making the prospective cohort design much more suitable for studying environmental influences on disease risk. Recall bias in particular is avoided by collecting information before disease onset. Another important feature of the prospective cohort design is that all participants are followed in a systematic, forward-looking way, so that all cases of disease have an equal likelihood of being detected. The time of disease onset can also be defined more clearly in prospective cohort studies than in case-control or retrospective cohort, and multiple disease outcomes can be studied. Disadvantage of a prospective design is its higher cost and higher potential for attrition, which could lead to attrition bias. On the other hand, 3 out of 5 studies were retrospective studies. Out of these, 2 of them involved workers, and thus, workplace exposure (Elwood et al., 2012; Johansen et al., 2007). All 3 studies looked at one common cancer which is brain cancer. Only one of the 3 retrospective cohort studies looked at microwave exposure, the type of EMF that have higher frequency and generates heat (Elwood et al., 2012). Advantage is that it cost less than prospective cohort. However, it suffers from poor quality of data when secondary data is taken, frequent absent of potential confounding factors data, difficulty in identifying appropriate exposed cohort and an appropriate comparison group, and there would be differential losses to follow up.

4.2 Risk of bias

There were three articles with low risk of bias (Hauri et al., 2014; Koeman et al., 2014; Johansen et al., 2007). All three articles had low exposure assessment and low confounding bias. Here, it is important that exposure is described in detail. Exposure is the substance in the immediate environment of individuals and populations, but external to them. In environmental and occupational epidemiology, dose is defined as the concentration of the substance of interest in a target internal organ. The incidence and severity of the health effects are related to the rate of radiofrequency energy absorption in the body which is referred to as the specific absorbed radiation (SAR) (Centers for Disease Control, CDC, 2007). Apart from dose, environmental cancers require the exposure level to be dependent on type, duration and shielding. Another important concept is that since EMF is a non-ionizing radiation, inverse square law applies. The farther the person is, the less radiation dose he or she receives. Next,
confounding biases were low for all 3 mentioned articles due to they controlled it during analysis phase. In the paper by Hauri et al. (2014), the author adjusted confounders at three levels. First, during apriori adjustment for leukemia risk due to benzene, natural background ionizing γ radiation, distance to the nearest high-voltage power line, and degree of urbanization. Second, during the survival analysis. Third, during time to event sensitivity analysis all children not living in an area covered by the exposure modeling (>10 km or >20 km from any transmitter) (Hauri et al., 2014). This robustness in controlling for confounders are essential in determining risk of cancer, as environmental cancer have a very long lag time or latent period.

Two articles had unclear risk of bias. One paper had low statistical power as the inference was made through logical explanation rather than doing it quantitatively (Elwood et al., 2012). This creates a type of information bias. One of the reasons is that since the paper was a revised retrospective cohort study of the main 1978 report, the exposure effect from beams of microwaves of 2.5 to 4.0 GHz aimed at the United States embassy building in Moscow could only be crudely associated with the cancer incidence. There were multiple outcome variables, and no corrections for multiple testing were used. Furthermore, it gave a minimum detectable risk ratio. Another paper by Frei et al (2011) used secondary data for its retrospective cohort and no human contact. Thus, the quality of data remains uncertain.

4.3 Effect of intervention

The quality of evidence using GRADE can be classified into high, moderate, low or very low, and it is based on evaluation of both risk of bias and effects of exposure. There were 2 high quality, 1 moderate quality and 2 low quality evidences.

Of the 2 high quality evidences, one had significant decreased effect of exposure from year 1996 to 2008 but not from 1985 to 2008 and 1985 to 1995 (Hauri et al., 2014). Here, the implicated exposure was medium to ultra high electromagnetic wave on all cancer IRR among children aged below 16 years. Children under the age of 16 years with high exposure levels had approximately 0.7 times the rate of all cancer incidences compared to those with low exposure levels. The paper also described that stratifying the analyses for leukemia into different age groups that might represent different etiologies did not indicate effect modification by age. Due to its narrow confidence interval, thus the paper was given high quality of evidence.

Another paper with high quality evidence was measuring incidence of follicular lymphoma in males through exposure from ELF-EMF (Koeman et al., 2014). The incidence rate of follicular lymphoma in males who were exposed to ELF-EMF was 300% higher at any given time point studied than the rate in those who were unexposed. Here, ELF-EMF it is a significant factor that increases the rate of cancer development as “1” is not included in the adjusted hazard ratio 95% CI. The result in this study contradicts the previous high quality evidence paper by Hauri et al. (2014) that tells us medium to ultra high EMF is a factor that decreases the rate of cancer development. Thus, the lower the frequency, the higher the incidence rate. This is probably due to ELF-EMF study had a longer exposure time compared to the medium to ultra high EMF (17 years vs 8 years) for it to have a deterministic (dose-dependent) and/or stochastic (dose independent) carcinogenic effect on the target organ (International Commission on Radiological Protection, ICRP, 1990).
Paper by Frei et al. (2011) showed all cancer IRR due to exposure from radiofrequency EMF. The IRR had a narrow CI. It shows that the incidence rate of all cancer among Danish electric company workers exposed to radiofrequency EMF was 4% lower as compared to the rate for those not exposed to radiofrequency EMF. However, due to possible reporting bias from using secondary data, the quality of evidence was downgraded from high to moderate.

Study by Elwood et al. (2012) used all cancer SMR to obtain relative risk. The SMR reasonably approximates relative risk when it fulfills 2 conditions. First, the mortality rates in the comparison population for the cause of interest are no larger than about 100 per 10,000 workers per year with ten year age bands. Second, the age-specific mortality rates for the study and comparison population are approximately in constant ratio across all age bands (Symons and Taulbee, 1980). The problem in this paper is that the relative risk does not have confidence interval (CI) measurement. Thus, we do not know if it the microwave is a significant risk factor for all cancer mortality or not. Thus, this paper had low quality of evidence.

5.0 Conclusion and recommendation

The authors conclude that there was insufficient evidence to implicate EMF exposure towards cancer. Majority (2 out of 3) of moderate to high quality evidence papers showed that exposure to moderate to ultra-high EMF wavelength lowers the rate of progression of cancer development, due to shorter duration of exposure. Cancer development is only shown to be related to EMF exposure from ELF-EMF but not for shorter-wavelength EMFs, and this is due to longer exposure duration. However, due to small number of studies obtained from this scoping systematic review, results from this review should be interpreted with caution. Meta-analysis could not be done as the studies were too heterogeneous.

Those who are working in radio stations or, specifically, ELF-EMF areas should apply the concept of TDS, which is time, distance and shielding. Workers should wear personal protective equipments (PPEs) as shields especially if they are close to the source of EMF. Shift work is greatly encouraged in order to reduce exposure time. If possible, the community should live far from broadcast stations or even main electric power lines. A surveillance system on EMF detection should be in place.

Further research is warranted using:

i. Different EMF wavelengths
ii. Different target population
iii. Longer duration of follow-up cohorts
iv. Robust statistical analysis to control for most of the confounders
v. Experimental study designs for individual studies
vi. Meta-analysis of high-quality RCTs

In addition, ethical considerations should always be applied here, especially in experimental study designs such as RCTs.
Acknowledgement

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Declaration

Authors declare that there were no conflicts of interest.

Authors contribution

Author 1: Literature review, planning research activities and executing the research activities including data collection

Author 2: Contributing in methodological aspects, planning the research activities and analysis aspect of this research including reviewing for study data discrepancies

Author 3: Contributing in methodological and analysis aspects of the research including reviewing for study data discrepancies

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