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The Effects of Distance and Warming Temperature on Intensity of Extremely Low Frequency Electromagnetic Field from Forced-Air Warming System

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Вплив відстані та температури нагрівання на інтенсивність надзвичайно низькочастотного електромагнітного поля від системи примусового повітряного нагрівання

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Introduction

Electric appliances including personal computers and many other medical devices are currently widely used in the operating rooms, and they require connection to mains power by means of electrical wiring. Electricity carried in mains power is the alternating current with voltage and frequency of 120–230 V and 50–60 Hz, respectively. Extremely Low Frequency (ELF) electromagnetic field (EMF), defined by frequencies range 3 Hz – 3 kHz, are emitted from electric appliances as well as electrical wiring connected to mains power [1].

As data have been gathered to investigate the health effects of ELF-EMF since 1960s, its exposure has been found to increase risk of cancer (leukemia and brain tumors), and the International Agency for Research on Cancer (IARC) classified ELF-EMF in 2002 as a Group 2B (possibly carcinogenic to humans) carcinogen [2–5]. It also causes genotoxic effects including DNA damage, mutations and repair [6]. Neurodegenerative diseases including Alzheimer's disease and amyotrophic lateral sclerosis, and infertility are associated with high level exposure to ELF [7; 8]. Neurological effects, such as sleep disorder, headache, anxiety, and fatigue, may be resulted from ELF exposure [8].

Its pathophysiology is not clear, but the high levels of ELF-EMF exposure emitted from medical devices in operating rooms for long durations place health workers at greater risk of potential occupational health hazards. One study found that the average intensity of ELF-EMF measured at 30 cm from the monitoring screens was 2.11 mG across 19 operating rooms [9]. The Swedish Confederation of Professional Employee (TCO) recommended the intensity of ELF-EMF with frequency of 5 to 2 kHz should be ≤ 200 nT (2 mG) at 0.30 m in front of the electric monitor[10]. Several studies on ELF-EMF intensity in operating room have been conducted, revealing relatively high exposure to EMF [9; 11; 12].

Hypothermia is a serious, but preventable perioperative condition, which can lead to possible complications including coagulopathy, cardiac events and wound infection. Hypothermia is defined as core body temperature of less than 36.0°C [13]. Intraoperative hypothermia is caused by thermoregulatory impairment by anesthesia and prolonged exposure to low temperature, which can be prevented by patient warming system. Warming can be achieved with three mechanisms: convection, conduction and radiation. Forced-air warming system is popularly used providing both convective and conductive warming, as warm air is blown into a blanket and escapes through the small holes on one surface towards the patient's body [14].

Despite the beneficial effects of patient warming system, operating room health workers should be aware of the increased risk of ELF-EMF exposure and keep a safe distance from the device. One study investigated the ELF-EMF intensity from a particular convective air warming system, WarmTouch™ (Covidien, Ireland) with varying temperature setting and distance. It concluded that EMF exposure was unexpectedly high and the minimum safe distance from the device was between 0.5 m and 1.0 m according to TCO guideline [15]. EMF emission from a product can vary depending on the manufactures. However, there was no research on another forced-air warming device, 3M Bair-Hugger™ Warming Unit (Model 505, 3M, USA) (Figure 1). This study is to investigate the effects of distance and warming temperature on ELF-EMF intensity from Bair-Hugger™ Warming Unit, in order to find the minimum safe distance from the device

Objectives. A forced-air warming device (3M Bair Hugger™ Warming Unit, Model 505, 3M, USA) (Figure 1) is used to provide a warm environment for patients in operating room in order to prevent hypothermia and its associated adverse effects during surgery. As

mains electricity is required and it emits ELF-EMF, this study is to investigate the effects of distance and warming temperature on ELF-EMF intensity from Bair-Hugger™ Warming Unit, in order to find the minimum safe distance from the device.

Object, materials and research methods

A forced-air warming device (3M Bair Hugger™ Warming Unit, Model 505, 3M, USA) was hung on the side of an operating table in an empty operating room, in order to represent a situation of intraoperative use. All electronic devices including anesthesia machine were turned off except the warming unit under investigation. The size of the operating room was 9.25 x 5.32 m^2. Room temperature (21.9°C) and humidity (33.3%) were measured as they could affect the EMF intensity. The height of the unit was 80 cm from the floor. Measurements were taken at night when other surrounding operating rooms were also empty.

The unit had three temperature settings: low (32°C), medium (38°C), and high (43°C). At each temperature, the intensity of ELF-EMF was measured at 15, 30, and 45 cm from the anterior surface of the warming unit, using an ELF-EMF detector (Triaxial Magnetic Field Meter, TM-192D, Tenmars Electronics Co., Taiwan) (Figure 2). A tape measure was placed on the floor and the detector was held pointing towards the anterior surface of the warming unit. Background EMF intensity with the warming unit turned off was also recorded.

Measurements of 300 data for each combination of temperature and distance were collected at a sampling time of 0.5 times per second for 10 minutes. EMF intensity was measured nine times; three different distances from the warming unit and three different warming temperatures were used to provide nine combinations of distance-temperature. Including 9 combinations and background measurement resulted in 10 sets, 3000 data in total. The ELF-EMF intensity was recorded in mG [16].

Sample size was calculated using MedCalc 12.4.0 (Medcalc software, Ostend, Belgium). A sample size of 110 data in each group was required to detect a difference among different temperatures with a type I error of 0.05 and a power of 80%. Data was calculated for mean and standard deviation for each combination, and compared using Kruskal-Wallis one-way analysis of variance.

Research results

Background ELF-EMF intensity was 1.8451±0.009254 mG. The intensity was greatest, 3.3620±0.0506 mG, when it was measured at 15 cm from the unit and its warming temperature was high (Table 1). At 15 cm, the effect of temperature on EMF intensity was statistically significant. Low temperature emitted statistically significantly reduced EMF compared to high or medium temperature ($p<0.05$, Figure 3). Significantly lower intensity was measured with medium temperature, compared to high temperature ($p<0.05$).

As the distance increased from the device, the intensity rapidly dropped with all ranges of temperature. Similar effects of temperature were observed at 30 cm from the warming unit (Figure 4); higher temperature emitted a statistically significantly greater EMF ($p<0.05$). Further away from the warming device, however, it showed overall reduction in EMF intensity at 45 cm (Figure 5), and only the high temperature emitted a statistically significant amount of EMF (1.9300±0.0110) compared to two lower temperatures (1.9261±0.0102, 1.9260±0.0104, respectively, $p<0.05$). The effects of warming temperature on ELF-EMF intensity became less significant as the distance from the device increased up to 45 cm.

Data was presented as mean standard deviation, in mG.

*,†, ‡,§,‖,¶,**,++ represent statistically significant difference between groups ($p< 0.05$).



Fig. 1. Bair hugger™ warming unit (model 505, 3M, USA)



Fig. 2. Tenmars 3-axis magnetic field meter (TM-192D, Tenmars Electronics Co., Taiwan)

Table 1

Intensity of extremely low frequency electromagnetic field depending on various warming temperatures and distances from the device.

Distance (cm)	Warming temperature	Electromagnetic field intensity (mG)	
15	High	3.3620±0.0506	*†
	Medium	3.2924±0.0404	*‡
	Low	3.1270±0.0424	†‡
30	High	2.1655±0.0404	§‖
	Medium	2.1556±0.0130	§¶
	Low	2.1413±0.0116	‖¶
45	High	1.9300±0.0110	**++
	Medium	1.9261±0.0102	**
	Low	1.9260±0.0104	++

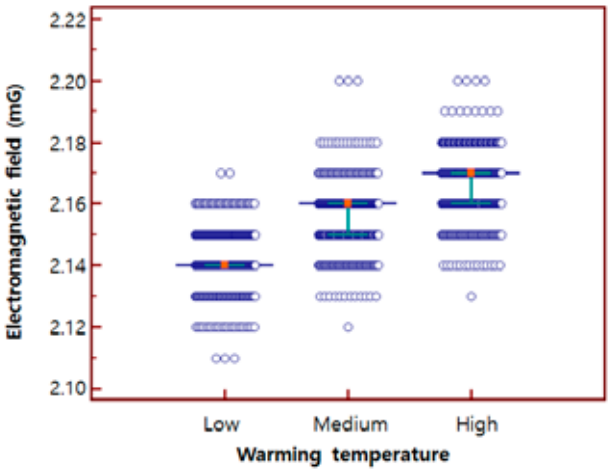


Fig. 4. Effect of warming temperature on intensity of extremely low frequency electromagnetic field at 30 cm from Bair-hugger™ warming unit

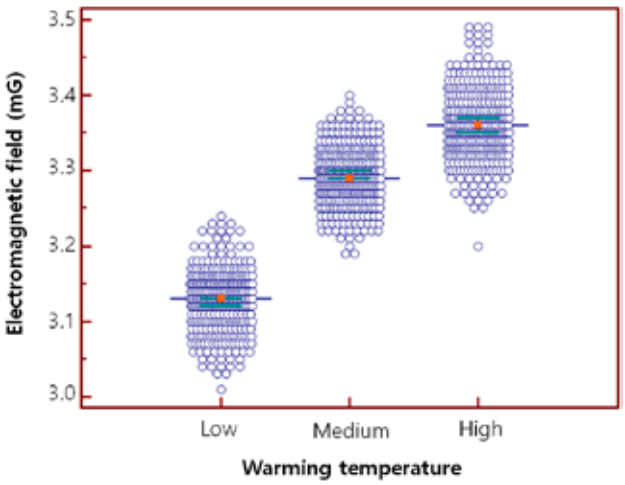


Fig. 3. Effect of warming temperature on intensity of extremely low frequency electromagnetic field at 15 cm from Bair-hugger™ warming unit

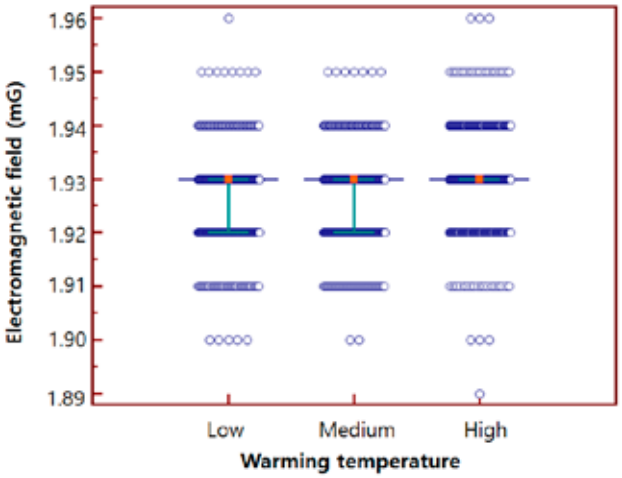


Fig. 5. Effect of warming temperature on intensity of extremely low frequency electromagnetic field at 45 cm from Bair-hugger™ warming unit

Discussion of research results

Modern medicine has been achieved greatly by the advances in technology, which inevitably accompany significant uses of electricity. Each operating room is packed with electric devices for anesthesia as well as for surgical assistance including basic anesthetic monitoring system and ventilators, lamps and electrocautery. When in use, mains power is required and this provides the alternating current with voltage and frequency of 120–230 V and 50–60 Hz, respectively, depending on the countries. The frequency of electromagnetic field emitted from mains power is included within the range of Extremely Low Frequency (ELF) electromagnetic field (EMF), 3 Hz – 3 kHz[1]. Working in operating rooms leads to a prolonged, intensive exposure of ELF-EMF to health workers, resulting in the increased risk of occupational hazards.

The mechanism of ELF-EMF causing health hazards has not been clearly understood, but with studies investigating effect of ELF-EMF on health, International Agency for Research on Cancer (IARC) classified ELF-EMF in 2002 as a Group 2B (possibly carcinogenic to humans) carcinogen. Ahlbom et al. and Greenland et al. reported the high incidence of leukemia in children living near electrical wiring carrying high current [3; 4]. Lai reviewed genotoxicity of ELF causing DNA damage and mutation [6]. Neurologic effects of ELF-EMF were reported, as a history of electrical engineering jobs was associated with a greater incidence of amyotrophic lateral sclerosis [17]. In 1981, Adey suggested that ELF-EMF might act on the cell membrane to cause intracellular activity, and various neurotransmitter receptors, such as dopamine and N-methyl-D-aspartate receptors, seem to interact with ELF [18; 19]. Animal studies conducted with EMF from mobile phone showed oxidative stress, DNA damage, decreased sperm mobility causing infertility [20; 21]. There have been many questionnaire surveys, mostly in Switzerland, and they asked specific health problems or symptoms on EMF exposure, so called Electromagnetic

hypersensitivity [22; 23]. With a varying incidence, they experienced stress, sleeping disorders, fatigue, anxiety and headache, and improved with reducing or avoiding EMF [24].

One of potentially powerful EMF emitter is forced-air warming system to prevent hypothermia, defined as core body temperature of less than 36.0℃, which can lead to severe complications including coagulopathy, cardiac events including arrhythmias and arrest, and wound infection [13]. Thermoregulatory impairment by anesthesia causing redistribution of heat and prolonged exposure to low temperature cause intraoperative hypothermia. During the first hour of surgery, a decrease in core temperature can be as large as 1.6℃, and it is easier to prevent than to reverse unintended hypothermia [25; 26].

Many researches have been conducted on occupational exposure to ELF-EMF in anesthesiology. They revealed the relatively high levels of ELF-EMF were measured in operating rooms. One study reported that the EMF intensity exceeded 2 mG at 30 cm from the monitoring screen, exceeding TCO guidelines, in 8 operating rooms out of 19 rooms [9]. During 8 hour-shift in daytime, 13 operating rooms out of 18 room showed the mean intensity of 5.83 mG, measured at the anesthesiologist's standing position [12]. Even when no electrical device was activated, the measured intensity in an empty operating room was above 2 mG, due to surrounding electricity from other operating rooms during the day [11]. It revealed that forced-air warming system, especially WarmTouch™, could also emit additional EMF, increasing potential hazards.

The 3M Bair-Hugger™ Warming Unit had not been investigated before and this study showed that in order to avoid excessive exposure, the minimum safe distance from 3M Bair-Hugger™ Warming Unit was about 45cm, where the exposure was below 2.0 mG as per TCO guideline recommendations. Measuring the exposure at smaller increments could have provided more insight into more accurate minimum safe distance. However, multiples of 15 cm can be easily converted into feet, which is more practical for real life estimations.

More sophisticated medical devices and computers, which are under development and are increasingly used, generally heavily depend on electrical supply, which may significantly increase occupational exposure to ELF-EMF in operating room. Further studies are needed on other devices in operating room as well as operating room itself.

Prospects for further research

We are planning to conduct a study on human or animal cell in vitro. Research in real biological cells will produce optimal outcomes beyond mere environmental standards.

Conclusions

Health workers should be aware of occupational exposure to ELF-EMF and avoid as much as possible by keeping distance from electrical devices. It is suggested to stay at least 45 cm away when using 3M Bair Hugger™ Warming Unit, which is approximately 2 feet.

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Purpose. Electronic devices, increasingly used in operating rooms, heavily depend on mains electricity. This may significantly increase occupational exposure to extremely low frequency electromagnetic field. As a possible carcinogen as per International Agency for Research on Cancer, Swedish Confederation of Professional Employee recommended it should be below 2 mG. Forced air warming system is used to prevent hypothermia. This study was to investigate the effect of distance and warming temperature on extremely low frequency electromagnetic field intensity from Bair-Hugger™ Warming Unit, in order to find the minimum safe distance from the device.

Materials and methods. The forced-air warming unit was hung on the side of an operating table in an empty operating room, with all other electronic devices turned off. With three different warming temperatures, electromagnetic field was measured at 15, 30, and 45 cm from the anterior surface of the device. Data was collected at a sampling time of 0.5 times per second for 10 minutes. Kruskal-Wallis one-way analysis was used.

Results. Increasing warming temperature and reducing the distance from the device resulted in a significant increase in electromagnetic field intensity ($p < 0.05$). At 45 cm in particular, low and medium warming temperatures showed significantly lower intensity compared to high temperature ($p<0.05$). Exposure below 2.0 mG was achieved only when it was at 45 cm regardless of temperature.

Conclusions. Health workers should be aware of occupational exposure to extremely low frequency electromagnetic field and avoid as much as possible. It is suggested to stay at least 45 cm away from 3M Bair Hugger™ Warming Unit.

Key words: extremely low frequency electromagnetic field, operating room, air warmer.

Мета. Електронні пристрої, які дедалі частіше використовуються в операційних, значною мірою залежать від електромережі. Це може суттєво збільшити професійний вплив електромагнітного поля надзвичайно низьких частот. Як можливий канцероген, за даними Міжнародної агенції з дослідження раку, Шведська конфедерація професійних працівників рекомендувала його нижче 2 мГ. Система примусового нагрівання повітря використовується для запобігання гіпотермії. Це дослідження мало на меті вивчити вплив відстані та температури нагрівання на інтенсивність електромагнітного поля надзвичайно низької частоти від нагрівального блоку Bair-Hugger™, щоб визначити мінімальну безпечну відстань від пристрою.

Матеріали та методи. Нагрівальний пристрій з примусовим повітрям був підвішений на боці операційного столу в порожній операційній, а всі інші електронні пристрої були вимкнені. За трьох різних температур нагрівання електромагнітне поле вимірювали на відстані 15, 30 і 45 см від передньої поверхні пристрою. Дані збиралися з часом відбору вибірки 0,5 раза на секунду протягом 10 хвилин. Було використано односторонній аналіз Крускаля-Волліса.

Результати. Підвищення температури нагрівання та зменшення відстані від пристрою призвели до значного збільшення інтенсивності електромагнітного поля ($p < 0,05$). Особливо у разі 45 см низькі та середні температури нагрівання показали значно нижчу інтенсивність порівняно з високою температурою ($p<0,05$). Експозиція нижче 2,0 мГ досягалася лише у разі 45 см незалежно від температури.

Висновки. Медичні працівники повинні бути обізнані про професійний вплив надзвичайно низькочастотного електромагнітного поля та уникати його дії якомога більше. Рекомендується триматися щонайменше на відстані 45 см від 3M Bair Hugger™ Warming Unit.

Ключові слова: електромагнітне поле надзвичайно низької частоти, операційна, підігрівач повітря.

Conflict of interest: absent.
Конфлікт інтересів: відсутній.

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