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Intensity of Extremely Low-frequency Electromagnetic Fields Produced in Operating Rooms during Surgery at the Standing Position of Anesthesiologists

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Background: **Numerous electronic devices have been introduced into operating rooms. Although little is known about the relationship between exposure to electromagnetic fields and health hazards, several studies have demonstrated causal relationships between electromagnetic fields exposure and various symptoms, cancers, and other diseases.**

Methods: **This study was approved by the Institutional Review Board. The intensity of extremely low-frequency electromagnetic fields was measured during surgery with the extremely low-frequency electromagnetic field strength measurement system at the standing position of anesthesiologists in 18 operating rooms and analyzed with EMDEX analysis and graphical program (EMCALC 95; ENERTECH, Campbell, CA).**

Results: **The average measurement duration per operating room per day was 7.41 ± 0.70 h (mean ± SD). The average sample number of measurements was 888.11 ± 82.75 per operating room. The average magnetic field was 5.83 ± 5.23 milliGuass (mG) (range, 0.10–33.80 mG), with 70% of these levels 2 mG or greater.**

Conclusions: **The authors' results indicate that anesthesiologists in operating rooms are exposed to extremely low-frequency electromagnetic field levels that exceed magnetic field intensity of 2 mG recommended by the Swedish Board for Technical Accrediation for production by computer monitors and detected 30 cm from them. It currently is not clear if this exposure has health effects on anesthesiologists and other operating room personnel.**

A WIDE array of electronic equipment is currently available and often used in operating rooms. This equipment typically produces electromagnetic fields (EMFs). Therefore, anesthesiologists and other operating room personnel are constantly exposed to EMFs of varying strengths. The effects of these EMFs on human health have not been clearly established. Wertheimer and Leeper[1] first reported an increased prevalence of leukemia in children who lived near power lines in 1979. Since then, several studies have been conducted to determine the biologic effects of EMF.

EMF with a frequency of 3,000 Hz or less is defined as extremely low-frequency (ELF) EMF[2] because most electronic devices that are used in everyday life use electricity with a frequency of 50 or 60 Hz. ELF-EMF has been heavily scrutinized in the field of public health, but it is not currently understood if, when, or how ELF-EMF is hazardous to humans either *in vivo* or *in vitro*.[3–6] A few studies have shown a positive relationship between ELF-EMF and diseases.[7–14]

Although numerous studies concerning the biologic effects of ELF-EMF have been conducted, there are few reports evaluating the strength of ELF-EMF in hospitals where there is a variety of sophisticated electronic equipment. Hanada[15] reported that static magnetic fields in some areas of hospitals exceed the International Commission on Non-Ionizing Radiation Protection exposure guidelines.[16] Riminesi *et al.*[17] reported that high ELF-EMFs (above 2 mG) were detected close to medical equipment and inside the open infant warming systems in neonatal intensive care units.

Most anesthesiologists work in operating rooms for extended periods of time every day. Operating rooms usually contain a number of monitors, machines, and computers that produce ELF-EMF. Surprisingly, there are no specific reports regarding the degree that anesthesiologists are exposed to EMF in operating rooms during surgeries. Lee *et al.*[18] measured ELF-EMF in operating rooms at the position of anesthesiologists in vacant operating rooms without the presence of actual anesthesia or surgery. The purpose of this study was to measure long-term ELF-EMF in operating rooms at the anesthesiologist's position during anesthesia and surgeries.

Materials and Methods

This study was approved by the Institutional Review Board of the Yonsei University College of Medicine (Seoul, Korea). On a specific day, the intensities of EMF in 18 operating rooms were measured from the beginning of the day's first operation until the end of the final operation, including periods between surgical cases. All of the monitors and anesthetic machines, including the computers used for measurements, were switched on during measurement of ELF-EMF. The order and date of measurements were randomly allocated within a table of random sampling numbers. The intensity of the ELF-EMF was measured at 30-s intervals with an ELF field strength measurement system (EMDEX II; ENERTECH, Campbell, CA). Anesthesiologists are usually standing in front of anesthetic machines and their attached electronic mon-

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Table 1. The Intensity of ELF-EMF in Operating Rooms

Serial Number of Operating Room	Duration of Measurement, h	Number of Measurement	Intensity of ELF-EMF, mG			Ratio of EMF Above 2 mG in Total Measurements, %
			Minimal	Maximal	Mean ± SD	
1	7.32	878	0.81	12.20	9.44 ± 1.02	99.77
2	8.18	982	0.25	3.47	1.72 ± 0.73	47.86
3	6.81	817	0.49	7.45	5.09 ± 1.09	99.63
4	7.87	944	0.22	30.10	12.21 ± 1.49	99.68
5	7.42	890	0.14	5.64	3.29 ± 0.91	99.78
6	8.34	1001	0.30	14.64	10.72 ± 2.03	99.80
7	7.24	869	0.17	11.89	7.45 ± 2.04	99.31
8	7.08	849	0.14	1.54	0.75 ± 0.11	0
9	7.91	949	0.68	4.75	3.99 ± 0.63	96.52
10	7.60	912	0.44	2.61	2.01 ± 0.26	50.77
11	7.49	899	0.10	2.14	0.79 ± 0.25	0.11
12	8.07	968	0.38	3.92	2.64 ± 0.49	94.32
13	6.23	747	0.25	3.21	1.78 ± 0.34	29.72
14	7.45	894	0.38	33.80	26.02 ± 4.53	99.33
15	5.59	671	0.22	10.64	7.15 ± 2.01	97.32
16	7.94	953	0.25	3.33	1.24 ± 0.34	2.41
17	7.05	846	0.25	4.24	2.90 ± 0.62	96.22
18	7.64	917	0.14	10.60	5.20 ± 3.14	65.10
Total	7.41 ± 0.70	888.11 ± 82.75	0.10	33.80	5.83 ± 5.23	70.98 ± 38.89

ELF = extremely low frequency; EMF = electromagnetic field.

itors; therefore, we put the ELF-EMF measuring machine in the position of the anesthesiologist and elevated it to a height of 120 cm. The mean distance from the main physiologic monitor to the standing position of the anesthesiologist was 85.62 ± 12.45 cm. These measurements were analyzed using an EMDEX analysis and graphical program (EMCALC 95, ENERTECH). The guidelines set forth for computer monitors by the Swedish Board for Technical Accreditation for computer monitors[19] were adopted as the reference values in this study. These guidelines recommend that computer monitors should not produce ELF-EMF of more than 2 mG at 30 cm.

Statistical Analyses

The mean and SD in each room, as well as the total mean and SD were calculated with SPSS 12.0 (Statistical Package for the Social Sciences, Chicago, IL). The ratio of the number of above 2 mG to the total number of measurements was also calculated.

Results

The average duration of measurements in each operating room was 7.41 ± 0.70 h (mean ± SD) (range, 5.59–8.34 h). The average sampling number of EMF measurements taken in each operating room was 888.11 ± 82.75 (671–1001). The average intensity of ELF-EMF in all operating rooms was 5.83 ± 5.23 mG (0.10–33.80 mG). The proportion of ELF-EMF greater than 2 mG were 70.98 ± 38.89% (0–99.77%) (table 1, fig. 1).

Discussion

Every electrical device produces EMF to some extent. Therefore, many populations are constantly exposed to EMF of various strengths.[3] There have consequently been several investigations regarding the health effects of exposure to EMF with particular focus on childhood diseases.

The effects of EMF on human health have been previously studied with a focus on the incidence of cancer and nonmalignant diseases. A few reports have suggested that EMF is associated with cardiovascular and neurodegenerative diseases.[8] Occupational EMF exposure has also been found to increase the risk of testicular and uterine cancers by affecting the endocrine and im-

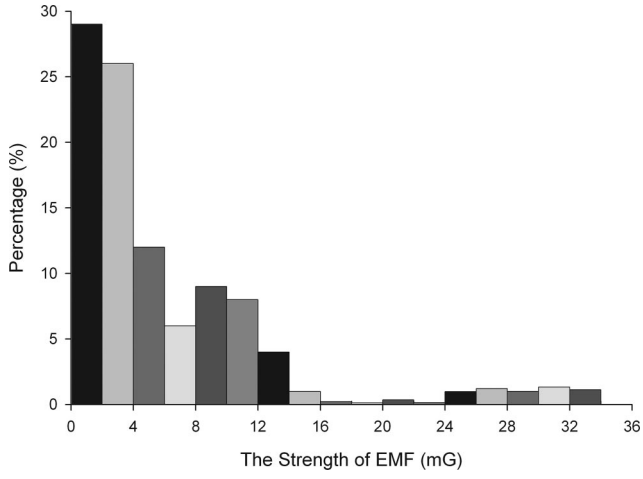

Fig. 1. The distribution of the electromagnetic field of the recorded values. Percentage = (number of measurement/total number of measurement) × 100; EMF = electromagnetic field.

mune systems.[9] It has also been hypothesized that exposure to EMF is associated with breast cancer.[7,10]

However, the majority of studies investigating the association of adverse health outcomes and exposure to EMF have demonstrated negative results. In 1998, the National Institute of Environmental Health Sciences reported a critical review and evaluation of the research data on ELF-EMF exposures and potential biologic and/or health effects in humans.[20] The working group concluded that ELF-EMF is possibly carcinogenic (group 2B by International Agency for Research on Cancer). They also found limited evidence to support the claim that occupational exposure to ELF-EMF is carcinogenic to humans and contributes to chronic lymphocytic leukemia.[21–24] Except for these leukemias, they concluded that there is inadequate evidence to suggest an association between exposure to ELF-EMF and the risk for other cancers including brain,[25] breast,[26] and lung cancer.[27] For noncancer adverse health effects, there was inadequate evidence to associate exposure to ELF-EMF and adverse effects, including birth outcomes, reproductive effects, Alzheimer disease, suicide or depression, cardiovascular diseases, or immune system diseases. For other biologic effects, they concluded that there was no evidence that short-term human exposure to ELF-EMF causes any changes other than heart-rate variability, sleep disturbance, and suppression of melatonin.[20]

Hospitals have a high density of technologically advanced instruments. Medical equipment continues to become more electrically complex with advances in technology. Specifically, operating rooms are often crowded with a large number of electronic devices packed into limited space. Many hospital staffs, including anesthesiologists, work in this environment on a daily basis and for extended periods of time.

In 13 (72%) of 18 operating rooms, the average strength of the magnetic field exceeded 2 mG. The ratio of the number of ELF-EMFs measured above 2 mG to the total number of measurements was also more than 70%. These findings suggest that anesthesiologists may be exposed to magnetic fields exceeding 2 mG, the Swedish Board for Technical Accreditation for computer monitors upper limit for EMF production by computer monitors that is detectable at 30 cm, for more than 70% of their working time.

In a previous study conducted by Lee *et al.*[18] ELF-EMF in operating rooms were measured in the absence of anesthesia and surgery ("empty room" setup). They reported that 10.5% of operating rooms (2 of 19 operating rooms) showed the ELF-EMF above 2 mG. They did not measure ELF-EMF continuously, making it impossible to compare with the results of this study.

In this study, ELF-EMFs were measured at the position anesthesiologists stand during actual work time when surgeries were being performed in operating rooms. The mean distance from the main monitor to the standing position of the anesthesiologist was about 80 cm. One report advises keeping infants at a distance of at least 50 cm from electrical equipment in neonatal intensive care units.[17]

Magnetic field strength in operating rooms is dependent on the number and type of monitors and machines, different types of surgery, the location of the main power input lines, the distance of the anesthesiologist from the operation site, and the illumination of the operating rooms, among other factors.

Almost all anesthesiologists work in operating rooms where they are surrounded by several monitors, medical equipment, and power lines hidden in the walls and floor; all are sources of ELF-EMF. A long-term study should be performed to investigate the effects of exposure to ELF-EMF on anesthesiologists who continuously work in the presence of strong ELF-EMF.

In conclusion, we found that anesthesiologists in operating rooms are exposed to ELF-EMF exceeding the Swedish Board for Technical Accreditation for computer monitors recommended value for more 70% of their work time. Efforts should be made to determine whether there are consequences to such exposures to ELF-EMF.

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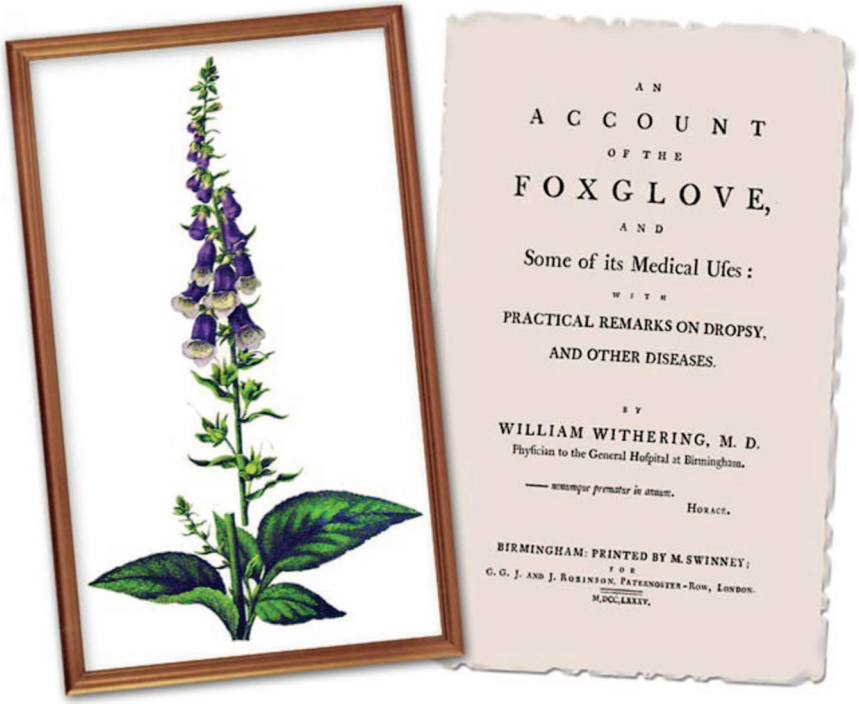
ANESTHESIOLOGY REFLECTIONS

Withering and the Foxglove



An Edinburgh-trained physician, William Withering (1741–1799) had observed successful treatment of congestive heart failure ("dropsy") by a lady herbalist from his native region of Shropshire, England. After isolating foxglove (*Digitalis purpurea*) as the active ingredient in her 20-herb infusion, Withering spent nine years defining the correct dosage of powdered foxglove that would "scatter dropsy" without digitoxic side effects like headache and nausea. Withering's research was nearly lost to the world when pirates pursued his ship back from Portugal during convalescence for "consumption." The year 1785 saw his election as Fellow of the Royal Society and the publication of his classic *An Account of the Foxglove . . .* (depicted above alongside its foldout engraving, courtesy of the Wood Library-Museum). As tuberculosis sapped the strength of foxglove's champion, a visiting punster and well-wisher quipped, "The flower of English physicians is indeed withering." (Copyright © the American Society of Anesthesiologists, Inc. This image appears in color in the *Anesthesiology Reflections* online collection available at www.anesthesiology.org.)

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