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An Evaluation of Radio Frequency Exposure from Therapeutic Diathermy Equipment

Chung-Yi LI[1]* and Chao-Kang FENG[2]

[1] Department of Public Health, College of Medicine, Fu-Jen Catholic University, 510, Chung Cheng Rd., Hsinchuang, Taipei Hsien 24205, Taiwan, ROC.
[2] Department of Health Care Administration, Hung-Kuang Institute of Technology, Taichung, Taiwan, ROC.

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Abstract: To assess the physiotherapist's exposure to radio frequency electromagnetic fields (RF) leaking from short wave diathermy equipment, we conducted on-site measurements of stray electric and magnetic fields (27.12 MHz) close to continuous wave (CW) short wave equipment. The results show that the operator's knees may have the highest exposure level for both electric field (E-field) and magnetic field (H-field) in the normal operating position, i.e., behind the device console. The whole-body E-field exposure normally does not exceed the 1992 IEEE recommended limit during a normal treatment session. On the other hand, the operator's whole-body exposure to H-field was barely below the recommended limit. Our data suggest little chance of immediate harmful effects of RF leakage from the diathermy. Nonetheless, physiotherapists should still be advised to remain at a distance of at least 20 cm from the electrodes and cables to avoid possible overexposure.

Key words: Radio frequency, Electromagnetic fields, Exposure assessment, Physiotherapists, Short wave diathermy

Radio frequency electromagnetic fields (RF) encompass the spectrum with frequencies of 30 kHz–300 MHz, which have frequently been applied to a variety of modern technologies such as radio communication, radar, satellite communication, medical equipment, and industrial and military applications[1]. Reports of potential health effects in humans from occupational exposure to RF have mainly focused on working groups. These effects consist of a number of health outcomes ranging from general morbidity and mortality to specific end points, such as ocular effects, nervous system and cardiovascular effects and adverse reproductive effects[1]. Because medical facilities including diathermy, hyperthermia, electrosurgical units, magnetic resonance imaging, and a multitude of other applications are all main sources of RF in hospitals, medical personnel in particular physiotherapists have been considered as an important occupational subcategory with potential overexposure to RF[1]. Therefore, the potential health effects of RF exposure among physical therapists have been frequently studied[2–8]. These studies focused on a number of end-points including ocular effects[2, 3], nervous system and cardiovascular effects[2, 3], adverse reproductive effects[4–8], and cancer[3]. A consistent weakness in these studies is the absence of exposure information, which limits the inference of the association between RF exposure and the above selected end points. The study aims to assess the exposure of short wave diathermy operators to RF. The RF from diathermy has been used to heat tissue, thereby increasing blood flow within a region of the body. A general observation is that a single treatment session lasts about 20 minutes[9]. Typically, the physiotherapist will establish the appropriate parameters at the control console, initialize exposure, then go about other responsibilities. Therefore, operator's exposures are estimated to be less than 3 minutes[10].

We conducted on-site measurements of the intensity of electric field (E-field) and magnetic field (H-field),

*To whom correspondence should be addressed.

Table 1. Height specific field intensity and spatial averaging field intensity near the short wave diathermy[1]

Height (cm)[2]	Front site		Back site	
	E-field (V/m)	H-field (A/m)	E-field (V/m)	H-field (A/m)
30	53.73 (3.08)[3]	0.87 (0.020)	46.13 (2.52)	0.91 (0.09)
100	19.24 (2.04)	0.22 (0.004)	46.69 (2.23)	0.25 (0.03)
150	15.96 (1.15)	0.34 (0.007)	6.78 (0.96)	0.21 (0.03)
Spatial averaging	34.21	0.55	38.10	0.56

[1]All measurements were conducted at the surface of 20 cm away from the electrodes. [2]The three selected locations with different heights above the ground, i.e., 30, 100, and 150 cm, represent the exposure for knee, waist, and head, respectively, of operators. [3]Numbers in parenthesis are standard deviations.

respectively, from the short wave diathermy (ENRAF NONUS: model CURAPULS-419) operating at a frequency of 27.12 Mega-Hertz (MHz) and a power of 400 watts. The selected short wave diathermy has twin electrodes and has both E and H-fields of continuous waves (CW). We used *Holaday Model HI-4433 MSE* (with a frequency range of 0.5 MHz–5 GHz, and a measuring range of 10.0–1000 V/m) and *Model HI-4433 LFH* (with measuring frequencies of 0.3–30 MHz, and a measuring range of 0.1–1000 A^2/m^2) to measure E-field and H-field, respectively. Separate measurements of E-field and H-field were recommended by the IEEE C95.1-1991 guideline that suggests the calculation of the respective spatial average for E and H-fields with frequencies of 100 MHz to 3 kHz[11]. With respect to the measurement protocol, we followed the procedure proposed by the IEEE for surveying controlled environment[11]. The IEEE standard requires that measurements be collected at 20 cm, or three probe diameters, from the sources (i.e., electrodes). We measured RF intensities at three locations with different heights above the ground, i.e., 30, 100 and 150 cm, to estimate the exposure for knee, waist, and hand, respectively. For each location, a total of 72 measurements were conducted within six minutes and a six-minute averaging was calculated. Because we assessed CW fields, no time-weighted-average was determined for the applicable averaging time. We also calculated the spatial average derived from the three series of measurements collected over a vertical surface at 30, 100, and 150 cm above the ground. The spatial averaging is calculated as:

$$[(\sum_{i=1}^{n} x_i^2)/n]^{1/2}$$

where x_i is the six-minute averaging electric or magnetic field intensity. The spatial averaging fields were compared with the whole-body exposure standard.

Table 2. Field intensity at selected spatial surface with increasing distance from the electrodes for the short wave diathermy

Distance from the electrodes (cm)[1]	Front site	
	E-field (V/m)	H-field (A/m)
20	15.96 (1.15)[2]	0.34 (0.007)
30	14.94 (1.11)	0.17 (0.018)
100	8.21 (0.87)	0.04 (0.009)
150	0.00 (0.00)	0.00 (0.000)

[1]All measurements were conducted at the surface of 150-cm height above the ground. [2]Numbers in parenthesis are standard deviations.

Our findings are described below. Table 1 shows the six-minute averaging field intensities measured at the three selected vertical surfaces, i.e., 30, 100, and 150 cm above the ground. Measurements taken on the front side of diathermy showed the highest E-field of 53.73 V/m at the 30 cm-high surface, and the lowest E-field at the 150 cm-high surface with a value of 15.96 V/m. The H-field, on the other hand, ranged from 0.22 A/m to 0.87 A/m with the lowest and highest value measured at the surface of 100 cm and 30 cm, respectively. With respect to the intensity measured at the backside of diathermy, the highest intensity of E-field and H-field was 46.69 V/m and 0.91 A/m, respectively, while the lowest intensity for E-field and H-field was 6.78 V/m and 0.21 A/m, respectively. The spatial averaging intensity for E-field and H-field calculated for the front side was 34.21 V/m and 0.55 A/m, respectively. The spatial averaging intensity of E-field and H-field calculated from the backside measurements was relatively higher with a value of 38.10 V/m and 0.56 A/m, respectively. Table 2 shows field intensities measured at selected spatial surfaces with increasing distance from the electrodes. The result showed a dramatic decrease in intensity for both E-field and H-field with increasing distance from the electrodes. For both E-field and H-field, the field intensity decreased almost to zero when measurements were taken at the surface of 150 cm away from the electrodes.

The whole-body exposure standard recommended by the IEEE for E-field and H-field with frequencies of 27.12 MHz is 68.22 V/m and 0.60 A/m, respectively[12]. Our data show that the spatial averaging E-field for the diathermy operators was far below the standard. Because exposure of the operator's knees to H-field could be as high as 0.87–0.91 A/m, the operator's whole-body exposure to H-field was barely below the recommended limit, i.e., 0.60 A/m. Previous studies measuring short wave RF indicated a potential for overexposure for short wave diathermy operators. Hansson[13] reported field intensities of 430 V/m at 80 cm and 1.2 A/m at 60 cm from glass capsule electrodes. The E and H-field intensities decreased by a factor of 10 at distances of, respectively, 170 and 150 cm. Ruggera[9] determined that the greatest exposure near the operator's eye was 140 V/m and 0.33 A/m during the treatment of a thigh with a wing applicator. The highest field intensities near the operator's waist were 250 V/m and 0.47 A/m at the thigh with the same applicator. Stuchly *et al.*[10] found that E-field intensities of 315 V/m were measured near the eye and waist of the operator while treating both knees with two electrodes. The H-fields near the eye and waist of the operator were highest while treating the back. Eye-level values were 0.14 to 0.35 A/m, while those at the waist were 0.5 to 0.95 (A/m). Because these data were based on "spot" measurements which usually concern the maximum RF leakage and do not consider the possible variation in field intensity, they were applicable to the comparison with neither our findings nor the IEEE exposure standard.

In conclusion, we noted that the field intensity of CW short wave is moderately variable. Additionally, this study provides evidence that RF leakage from short wave diathermy are not likely to cause immediate harmful effects during the normal treatment session, and the chance of overexposure for the short wave operators would be limited to H-field only. Despite that, physiotherapists should still be advised to remain at a distance of at least 20 cm from the electrodes and cables to avoid possible overexposure. Future epidemiological studies may consider to utilize the measurement procedure demonstrated in this study for the assessment of occupational exposure to short wave RF.

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