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RF Exposure During Use of Electrosurgical Units

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ABSTRACT

Electrosurgical units (ESUs) commonly used in operating suites employ radiofrequency (RF) energy for cutting and coagulation, and operate at different frequencies in the range 0.3–5 MHz. Around the electrode and cables, electric and magnetic fields at similar frequencies will be generated, and the surgeon using the ESU will therefore be exposed to these electromagnetic fields. In this study we have measured the levels of RF fields near the lead wires of two electrosurgical units, BARD 3000 operating at a fixed frequency of 0.5 MHz, and ERBE ICC 350 with a frequency range from 0.3 to 1 MHz. Electric fields were measured at distances from 5–30 cm from the lead wire. Measurements were done with the ESU both cutting and coagulating, and power levels ranging from 10–100 W. The magnetic field outside the lead wire was calculated from the measured current through the leads using standard theory. Using those measurements as a base, the calculated local exposure of the surgeon's hand was estimated to exceed 15 kV/m for the electric field and the

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corresponding value for the magnetic field was 16 μT. These calculations exceed the suggested international reference levels at 0.5 MHz (610 V/m and 4 μT, respectively).

Key Words: Electromagnetic field; Radiofrequency field; Surgical diathermy; Medical personnel.

INTRODUCTION

Electrosurgical units (ESUs) commonly used in operating suites employ radio-frequency (RF) energy for cutting and coagulation, and operate at frequencies between 0.3 and 5 MHz. The monopolar mode in the unit is used for both cutting and coagulation, while the bipolar mode is mainly used for coagulation. In this paper, only the monopolar mode is discussed since it contributes highly to RF emission in the operating room. The output power in the monopolar mode commonly ranges between 50 and 150 W but depends on where in the body the surgeon is operating (Andrén and Hörnblad, 1985; Webster, 1998). The energy is supplied to the cutting tool via an unshielded cable. The voltages reach hundreds of volts and the current is commonly 0.1–0.5 A. Since the lead may pass close to the arm and hand of the surgeon, this results in exposure to RF energy to the surgeon as well as other medical personnel in the operating room.

Exposure to electromagnetic fields during usage of ESUs has been discussed only in a few papers (Paz et al., 1987; Tzima and Martin, 1994), but there are some other types of studies on exposure at these frequencies and health effects. Kolmodin-Hedman et al. (1988) found, in a study on RF plastic sealers, diminished nerve function and numbness in hands and fingers compared to the nonexposed controls. A recently performed study on RF plastic sealers also reported more headache, fatigue, and warmth sensations in the hands compared to controls (Wilén, 2002). Increased prevalence of the above symptoms but also dizziness and difficulties in concentration have also been found among radar workers (Baranski and Czerski, 1976).

It is reasonable to assume that when using ESUs, the surgeon is exposed to RF fields in the same magnitude as RF plastic sealers and radar workers, and it is therefore certainly of interest to measure the RF field during surgical operations.

The aim of this study was to measure the RF emission both under laboratory conditions and during actual surgical procedures. Furthermore, we wanted to compare the results with the international reference levels stated by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (1998).

MATERIALS AND METHODS

The study was divided into two parts: field measurements in the laboratory and three different by-pass surgical procedures at the Umeå University hospital.

In a feigned operation in our laboratory, frequency, the current through the leads, and the electric (E) field at different distance from the active cable were measured at different output power levels of the ESU, when both cutting and coagulating. E-field measurements were done at distances of 5–30 cm (the construction of the probe made

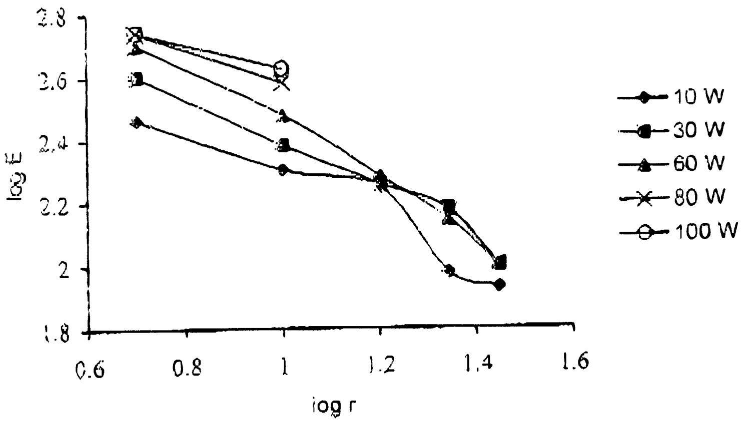

Figure 1. Electrical field strength at different distances from the cable and at various output power for the Bard 3000.

it impossible to measure any closer from the lead wire using a HOLADAY HI-3603 field probe). The current through the leads was measured by using a clamp-on ammeter and an oscilloscope (TEKTRONIX P6021 AC current probe, and Tektronix 2201-oscilloscope with FLUKE 92B scopemeter). The magnetic field near the cable was then calculated using standard theory. Measurements were done on two different ESUs: BARD 3000 and ERBE ICC-350. Similar measurements were also done with a modified ESU (BARD 3000), with the cables shielded in order to reduce the E-field.

The three field measurements at the hospital were done on an ERBE ICC-350, but with three different surgeons. The same parameters as in the laboratory tests but also the time for active ESU and used output power were recorded during the three by-pass operations. The measurements of the E-field were done right on the cable and 1.5 m from the handle with the same equipment as in the laboratory. The current through the leads was measured with a HOLADAY HI-3702 (9 kHz–110 MHz) probe which was read by HOLADAY HI-4460.

For further details, see Liljestrand et al. (2002).

RESULTS

Laboratory Study

The E-field increased with increasing output power as well as decreasing distance to the cable for both tested ESUs. In Figure 1, the results from the Bard 3000, operating at 0.5 MHz, is shown. Making use of the measured values at 30 W output power, the E-field dependence of the distance was found by use of regression analysis to be

$$\log E = 3.1 - 0.75 \log r, \quad \text{where } r \text{ is the distance (in cm)}$$

The E-field generated by Bard 3000 at a distance of 1 and 0.5 cm from the cable was then calculated:

$$E_{1\,cm} \approx 1260\ V/m, \quad E_{0.5\,cm} \approx 2120\ V/m$$

Using the data obtained at 50 W output power for the other ESU (ERBE ICC-350), the same procedure gave

$$\log E = 3.3 - 0.84 \log r$$

and the calculations gave the following results:

$$E_{1\,cm} \approx 2000\ V/m, \quad E_{0.5\,cm} \approx 3600\ V/m$$

The B-field was calculated as the free field from the current in a straight line with an assumption of the current to be approximately 0.3 A (normal range 0.1–0.5 A) for both tested devices.

$$B_{5\,cm} = 1.2\ \mu T, \quad B_{1\,cm} = 6\ \mu T, \quad B_{0.5\,cm} \approx 12\ \mu T$$

Field Measurements in Surgical Operations

Each by-pass operation lasted 3–4 hours. The ESU unit was mostly used during the first hour of the operation. During that time, the power level changed frequently depending on where and in what tissue the surgeon was cutting. During the operations, the surgeons used both cutting modes, coagulation mode as well as a mixture of both. The frequency varied between 0.3 and 1 MHz.

During the first hour in each of the three studied operations, the ESU was activated 35, 30, and 30 min, respectively. The measured E-fields were higher compared to the feigned operation in the laboratory. About half of the time when the ESU was activated, the surgeon's fingers and abdomen were exposed to E-field exceeding 1600 V/m measured 5 cm from the cable. Extrapolated to a distance of 0.5 cm, it will exceed 15 kV/m. With a current of 0.4 A, the calculated B-field will be 16 μT. See Table 1, were the data from the third operation are given.

Table 1. Measured current in the activated electrode cable and E-Field, measured at a distance of 5 cm from the cable during the 3rd operation. In total, the ESU was used for 55 min and with two different output power levels. About 50% of the time the ESU was activated.

	P(W)	
	90	50
Time (min)	28	27
I_{rms} (mA)	250–400	100–300
E-field (V/m)	1200–1800	400–600

Table 2. Measurements with shielded cable on BARD 3000.

Power (W)	E-field without shielded cable (V/m)	E-field with shielded cable (V/m)
30	400	<20
50	480	30
75	500	40

Shielded Cable

In a laboratory set-up, we tested the reducing effect on the E-field by shielding the actual cable (Bard 3000) with a grounded metal shielding. The E-field was reduced to 1/10 of the value observed when using the unshielded cable (Table 2).

DISCUSSION

Both laboratory and field measurements showed rather high electric and magnetic field strengths in air near the ESU cables. When comparing these results with the international reference levels stated by ICNIRP (1998), we found that both E-field and B-field were exceeded. The reference levels at 0.5 MHz are given at 610 V/m and 4 μT for E- and B-field, respectively. As the reference levels are exceeded, it is necessary to make calculations to see if the "basic restrictions" are fulfilled. By using the obtained data from these measurements, an estimation of the induced current was performed by using a two-dimensional finite element program (Hansson Mild et al., 2001). The results of the simulations show a striking enhancement of the electric field in the air between the lead and the body. However, the fields in the tissue were low. Under the conditions of the simulation, the electric current densities in the body ranged up to about 4 A/m^2. The basic restriction stated by ICNIRP is 5 A/m^2 at 0.5 MHz, but if the frequency of operation is 0.3 MHz instead of the assumed 0.5, the basic restriction is 3 A/m^2. Thus, the measured ESUs seem to fulfil the basic restrictions in some cases but may be exceeding them during some conditions.

Taking into account the uncertainty in the measurements, the handling of the ESU equipment, etc., it is possible that also other ESUs exceed the basic restrictions. It is therefore certainly of interest to enlarge the study and include other ESUs operating at other frequencies. Furthermore, it is also of interest to perform an epidemiological study among surgeons in order to find out if the earlier reported increased prevalence of subjective symptoms found among RF plastic sealers and radar workers will also be found among surgeons (Baranski and Czerski, 1976; Wilén, 2002).

Shielding the cables reduced the electric field effectively and is a measure that might be taken into consideration.

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