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Don't Touch the Bed! Capacitive Coupling in Electrosurgery Causes Current Loss During Pinch Burning

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Abstract

Background: The commonly used "pinch burn" technique in electrosurgery involves applying current to forceps while grasping tissues for hemostasis. The authors of this study have noticed a reduction in efficacy of pinch burning while touching the surgical table, suggesting that current may be lost through the surgeon's body. Intuitively, surgical gloves should insulate the current, however a phenomenon called capacitive coupling may explain the losses. An experiment was devised to determine if this effect could be measured.

Study Design: A circuit was created to measure the voltage across tissue represented by a 2kΩ resistor. The circuit was shorted with forceps held by a gloved hand. The voltage was measured when holding the forceps in isolation versus touching the table at the waist or forearm.

Results: The measured voltage was 14.4+0.1V but decreased to 12.2+0.1V (16%) when the surgeon touched the table with the waist and to 10.7+0.2V (26%) touching at the forearm ($p<0.0001$). This corresponded to a 1.1 and 1.8mA current drop, and power loss of 28.5mW (29%) and 43.9mW (45%) respectively.

Conclusion: When pinch burning in the OR, the circuit can be shorted from body into the table. Despite the insulating properties of surgical gloves, electrosurgery allows this effect to occur via a phenomenon called capacitive coupling. In a simulated setting this can result in current losses up to 26% and power losses up to 45%. In difficult technical situations where hemostasis is paramount, one strategy to improve pinch burning efficacy is to avoid contact with the surgical table.

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Keywords: Cautery; Electrosurgery; Surgical Hemostasis; Surgical Specialties

Introduction

The commonly used "pinch burn" technique in electrosurgery involves applying current to forceps while grasping tissues and vessels for hemostasis [1]. From anecdotal experience, the authors of this manuscript have noticed a reduction in efficacy of pinch burning while leaning against the surgical table or metal self-retaining retractors, suggesting that current may be lost through this contact. This phenomenon has not been described previously in the literature. Intuitively, insulating surgical gloves should prohibit current loss however, through a phenomenon called capacitive coupling, this may not be true. An experiment was devised to determine whether the observed phenomenon of current loss occurs during pinch burning. A capacitor is a fundamental electrical unit found in essentially all electrical devices [2]. It is comprised of two conductors separated by a thin insulating layer [2]. The relevant property of electrosurgery in this context that high frequency Alternating Currents (AC) are used. In conventional Direct Current (DC) circuits, current cannot flow through insulating layers however in AC circuits, the capacitor will transmit electrical current proportional to the current frequency [2]. A capacitor unit is functionally created during pinch burning whereby the two conductors are the surgeon's hand and the metal forceps, with the glove as the insulating layer in the middle (Figure 1). In simple terms, the glove functions more like a resistor rather than an insulating barrier at the high frequencies of 300 – 500 kHz used in electrosurgery [3]. This phenomenon of capacitive coupling, is described in laparoscopic electrosurgery whereby current can inadvertently flow through the insulated shaft of a cautery tool into adjacent tissues when the tip is not in contact with tissue [3]. A similar phenomenon has not been previously described during open surgery. We hypothesized that when the surgeon holding the forceps while pinch burning is in contact with the OR table, the circuit is "shorted" through the hand and surgeon (Figure 2) and devised an experiment to measure this effect.

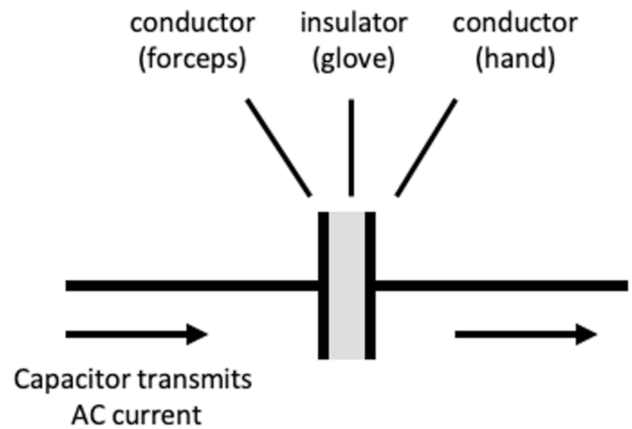

Figure 1: Capacitor Diagram. $C = \varepsilon A/d$ where C is capacitance, ε is the permittivity of the dielectric material (surgical glove material properties), A is the contact surface area (gloved hand with forceps), and d is the distance between the two conductors (glove thickness). The capacitor's ability to transmit current in an AC circuit is directly proportional to the electrical frequency and contact surface area (contact area of the gloved hand to the forceps). It is inversely proportional to the thickness of the insulating material, in this case the glove thickness [2].

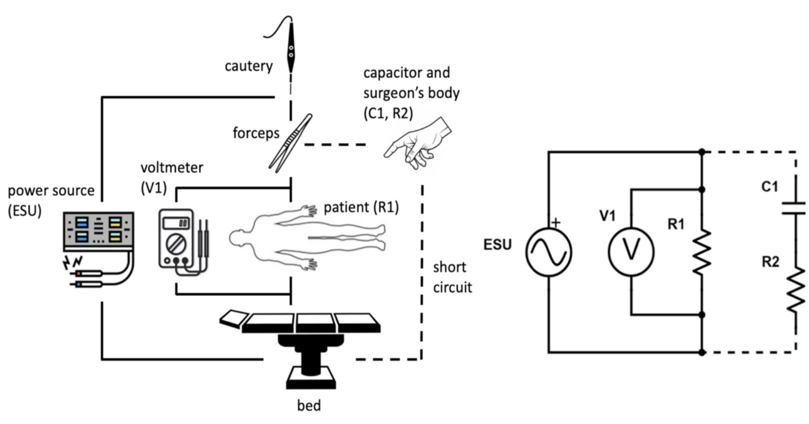

Figure 2A (left): Diagram of hypothesized capacitive coupling phenomenon, where the dotted line denotes the short circuit created between the user holding the forceps and the table.

Figure 2B (right): Testing circuit. ESU: Electrosurgical unit. V1: AC voltmeter. R1: resistor denoting target tissue. C1: capacitance of gloved hand. R2: Resistance of the surgeon holding forceps.

Methods

To test the hypothesis, an electrical circuit (Figure 2) was created to measure the voltage across a 2120Ω resistor, which has similar electrical impedance to human tissues [4]. The electrical surgical unit used was a ForceTriad electrosurgical unit (Valleylab Inc, Boulder, Colorado, USA) set at a power level of 1 W with a Valleylab corded patient return electrode monopolar cautery (Medtronic, Minneapolis, Minnesota, USA). The low power level was used to reduce transient heating of the resistor during testing. The circuit was shorted with steel debakey forceps held by a hand wearing a single latex surgical glove (Triumph LT gloves, Medline Industries, Northfield, Illinois, USA). The voltage across the resistor was measured when the surgeon holding the forceps was standing away from the surgical table versus touching the table at the waist or forearm. Voltages were measured using a digital multimeter with AC voltage measurement sensitivity to 0.1 V (Model 52-0055-6, Mastercraft, Vonore, Tennessee, USA). The experiment was conducted 4 times and the mean and standard deviation of the voltage was recorded and compared using the student's T-test. Current and power were calculated based on the measured voltage and known resistance [2].

Results

The measured voltage was consistently 14.4+0.1V but decreased instantaneously to 12.2+0.1V (16%) when the surgeon touched the table at the waist. The voltage decreased from 14.4+0.2 to 10.7+0.2V (26%) touching at the forearm ($p<0.0001$). This corresponded to a 1.1 and 1.8mA current drop, and power loss of 28.5mW (29%) and 43.9mW (45%) respectively (Table 1) [2].

Touching table with forearm (n = 4)				
	Not touching table	Touching table	Difference (%)	p
Voltage (V)	14.4	10.7	3.7 (26%)	< 0.0001
Current (mA)	6.8	5	1.8 (26%)	< 0.0001
Power (mW)	97.8	53.9	43.9 (45%)	< 0.0001
Touching table with waist (n = 4)				
	Not touching table	Touching table	Difference (%)	p
Voltage (V)	14.4	12.1	2.3 (16%)	< 0.0001
Current (mA)	6.8	5.7	1.1 (16%)	< 0.0001
Power (mW)	97.8	69.3	28.5 (29%)	< 0.0001

Table 1: Measurements from initiating cautery while holding metal forceps connected to circuit and either touching or not touching the table with the forearm or waist. Voltage was measured. Current and power were calculated with a known resistance of 2120 Ω.

Conclusion

When surgeons touch the surgical table or patient during "pinch burning", they can create a short circuit through the forceps, into the surgeon's body and through the table. Despite the insulating properties of surgical gloves, AC electrosurgery allows this effect to occur via a phenomenon called capacitive coupling. We demonstrated, in a simulated setting, that this can result in power losses as high as 30 to 45%, which is directly proportional heat loss, according to Joule's law [2]. This experiment is limited given that it takes place in a simulated setting. During surgery, the degree of current transmission in pinch burning is influenced by a variety of factors including the type of tissue, moisture content, contact area with the forceps, and variable glove thickness. As a proof of concept however, this experiment has confirmed that current can be lost during surgery through capacitive coupling. In difficult technical situations where hemostasis is paramount, one strategy to improve pinch burning efficacy is to avoid direct or indirect contact with the patient or surgical table.

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