TECHNICAL NOTE

Electrical impedance of elk while administering TENS

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Thierman, J.L., Crowe, T.G., Stookey, J.M. and Valentine, B. 1999. **Electrical impedance of elk while administering TENS**. Can. Agric. Eng. **41**:267-269. The output from a commercial device used to administer transcutaneous electrical nerve stimulation (TENS) and the electrical impedance of elk were investigated during the surgical removal of velvet antler. The voltage output from the TENS device, the current through the animal, and the impedance between the animal's ears were all determined and analyzed. The impedance was found to be purely resistive and ranged from 479 to 1185 Ω. Despite the large variation in impedance, the TENS operator was able to administer a consistent current level with a mean of 2.79 mA RMS.

La puissance à la sortie d'un appareil commercial utilisé pour administrer une stimulation électrique transcutanée au nerf (TENS), et l'impédance du wapiti firent l'objet d'un suivi pendant l'enlèvement de la peau qui recouvre les bois de l'animal. Le voltage à la sortie de l'appareil TENS, le courant passant à travers l'animal et l'impédance entre ses oreilles furent mesurés et analysés. L'impédance était purement résistive et allait de 479 à 1185 Ω. Malgré la grande variation dans l'impédance, l'utilisateur du TENS fut capable d'administrer un courant uniforme dont la moyenne était de 2.79 mA RMS.

INTRODUCTION

A common technique of local anesthesia during elk velvet antler harvest includes the use of TENS. Electrodes are attached to each ear and an electrical current is pulsed through the animal's body. It is expected that the pulsed current of TENS masks the pain that is caused during antler removal. When using TENS, the level of pain alleviation is a function of the pulsed current magnitude and waveform. Therefore, the electrical impedance between the ears of each animal will be an important parameter when considering the efficacy of TENS in this application. A better understanding of the electrical impedance between the ears of elk will support the optimization of the use of TENS during velvet antler harvest.

LITERATURE REVIEW

Transcutaneous electrical nerve stimulation is a therapeutic application that is intended to reduce pain perception in a number of clinical conditions (Reeve and Corabian 1995). Reported applications of TENS in humans have included pre- and post-operative pain, post traumatic acute pain, musculoskeletal problems, chronic pain, obstetrical labor and delivery, dental pain, fracture pain and healing, tinnitus, and a multitude of pediatric pain applications (Reeve and Corabian 1995). There has been much skepticism regarding the efficacy of TENS for pain control in humans and gauging the efficacy of the technique for pain control in animals is especially difficult.

TENS treatments are generally characterized by the pulse amplitude, pulse duration, and pulse frequency produced by the device. Reeve and Corabian (1995) suggested that frequencies in the 80 to 120 Hz range are usually applied for acute pain and lower frequencies of 1 to 20 Hz are used in treating chronic pain. The pulse width is usually between 50 and 400 ms and the amplitude of the current usually ranges from 1 to 100 mA. A consensus in the literature suggests that different levels of stimulation are established by varying the level of the current, highlighting the need to understand the electrical system of the subject, including its complex impedance.

Pertovaara (1980) used a TENS pulse width of 0.25 ms with a voltage amplitude and frequency of 20 V and 100 Hz, respectively. Data indicated that the high-frequency TENS elevated the thermal threshold of pain in human subjects. It was thought that the elevated threshold was due to the blockage or fatigue of pain-mediating fibers. Pertovaara (1980) went on to indicate that different species use different physiological mechanisms to block pain. Also, the variability in the necessary level of electrical stimulation to block pain was highlighted. Eriksson et al. (1979) indicated that TENS was effective at levels lower than those needed for inducing muscle twitches. In contrast, Campbell and Taub (1973) and Woolf (1979) showed that thresholds for experimental pain were elevated only when TENS intensity levels surpassed levels inducing muscle activity. These levels of stimulation often caused pain themselves. Burch (1985) indicated that there is an infinite number of operating conditions for TENS, involving voltage, current, pulse width and frequency, and it is logical to assume that different levels of these parameters are required for different applications.

Electrically, the applied voltage and induced current by a TENS device are related by the impedance of the current pathway. Aneshansley and Czarniecki (1990) presented an

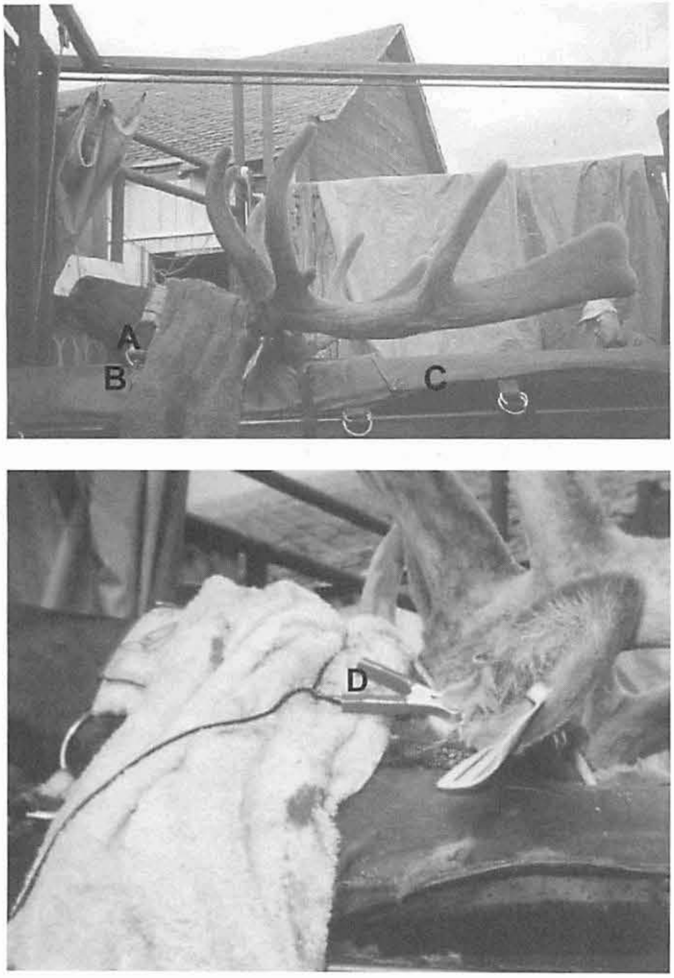

Fig. 1. Animal restraint and TENS electrode. a) Animal restrained in chute. b) Close up of TENS electrode attached to the elk's ear. A - halter; B - tie-down rope; C - padded side panel; D - TENS electrode.

electrical model of two electrodes touching a dairy cow. They showed that capacitance present at the electrodes would decrease the impedance of the current pathway at higher frequencies, allowing higher currents. The researchers showed that contact impedances of the electrical system can contribute more than 2/3 of the total impedance, thus environmental conditions related to electrode contact are important.

Variability in the efficacy of electrical stimulation to control pain in humans still remains after years of research and clinical tests. Not surprisingly, there is a substantial lack of knowledge surrounding the use of TENS on other animals. A better understanding of the electrical properties of elk bodies and the effect of these properties on TENS would help to define requirements of TENS. This would improve the efficacy of TENS in reducing pain levels during velvet antler removal. The objective of this study was to document the electrical impedance of elk while administering TENS during velvet antler removal.

MATERIALS and METHODS

Twenty male elk, ranging in age from three to nine years were used in this study. Figure 1a shows the side view of an animal being restrained. Each animal was captured by moving it into a chute and closing the end door. To restrain the animal, the side panels were contracted, holding the animal's neck below the jaw. Further restraint was provided by a halter that fit over the animal's nose and behind its ears.

Prior to administering the TENS, a towel was placed over the animal's eyes and two electrodes from the TENS device (Vet-EA, Grant, MN) were clamped to the top edge of each unshaven ear (Fig. 1b). The square electrical pulses generated by the TENS device had a width of 240 ms and a frequency of 130 Hz. When administering the local anesthetic, an experienced TENS operator gradually increased the current until the animal's ears twitched and then reduced it slightly. This maximum "dosage" (highest current without causing the ears to twitch) was maintained for two minutes. During this time, the surgical area was disinfected and a tourniquet was applied. At the end of the two minutes, the antlers were removed with an electric reciprocating saw.

To monitor the operating conditions of the TENS device, a 1 kΩ resistor was placed in series with the animal (see Fig. 2). The RMS voltage output from the TENS device (V_1) and the RMS voltage across the resistor (V_2) were measured with a digital multimeter (Model 8060A, Fluke Corporation, Everett, WA). Their waveforms were recorded using a digital oscilloscope (TDS 380, Tetronix Inc., Wilsonville, OR). The current in the circuit was evaluated using:

$$I = \frac{V_2}{R} \tag{1}$$

where:
I = RMS current (A),
V_2 = RMS voltage across the resistor (V), and
R = resistance (Ω).

The sum of voltage drops around a closed circuit must be zero, therefore the voltage drop across the ears of the animal was determined by:

$$V_3 = V_1 - V_2 \tag{2}$$

where:
V_3 = RMS voltage drop across the animal (V), and
V_1 = total RMS voltage drop in the circuit (V).

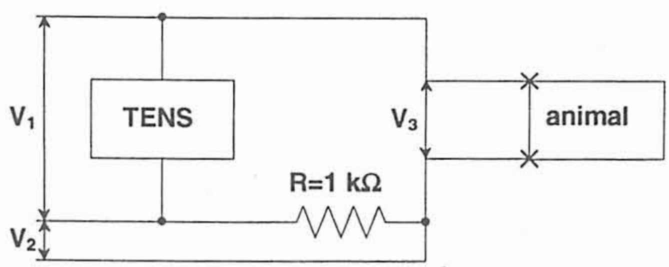

Fig. 2. Electrical configuration for monitoring the performance of the TENS device.

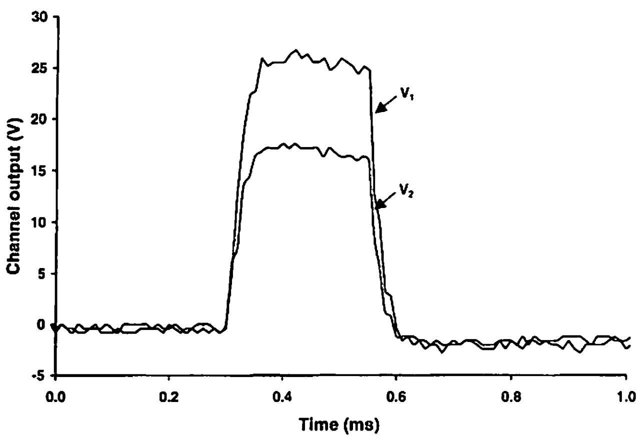

Fig. 3. Voltage waveforms from the monitoring circuitry. V_1 is the voltage output from the TENS device. V_2 is the voltage drop across the resistor and represents the current in the circuit.

The impedance across the animal was then determined by combining the voltage drop and circuit current. Combining equations 1 and 2, the impedance was calculated by:

$$Z = \frac{V_3}{I} = \frac{(V_1 - V_2)R}{V_2} \tag{3}$$

where Z = animal impedance (Ω).

Animal impedance

In an electrical circuit, any non-resistive impedance will cause the current to either lead or lag the voltage. Waveforms of the TENS voltage output (V_1) and voltage across the series resistor (V_2) are shown in Fig. 3. By comparing these two waveforms, it can be seen that the voltage and current were in-phase. Thus, no capacitance was present, and the impedance between the ears was purely resistive.

Table I shows that the average impedance of the 20 animals was 784 ± 540 Ω (± 3 standard deviations). The impedance of the twenty animals studied ranged from 479 to 1185 Ω. The relatively large variation in impedance may have been due to differences in electrode placement, levels of animal hair, or animal body composition.

The voltage output from the TENS device (V_1) showed a range of values. The average RMS voltage was 4.97 ± 1.56 V. This variability was attributed to the inconsistency of the animal impedance. Because the TENS device was designed to produce a current, the voltage increased as the animal impedance increased. The average RMS current through the animals was 2.79 ± 0.43 mA. It is interesting to note that the operator of the TENS provided a consistent level of current based on a muscular response of the animal. This suggests that the ear-twitch response occurred at approximately the same current level for each animal.

Table I. Results of voltage, current, and impedance measurements.

Parameter	Number	Mean	Standard deviation	Minimum	Maximum
TENS voltage, V_1 (volts RMS)	20	4.97	0.52	4.26	6.14
TENS current, I (mA RMS)	20	2.79	0.14	2.53	3.08
Impedance, Z (Ω)	20	784	180	479	1185

CONCLUSIONS and RECOMMENDATIONS

There is a large variability in the impedance between the ears of male elk. Because the animals in this study varied in age, data herein should be indicative of the population. An important factor regarding animal impedance is the conditions at the contact point of the electrodes. Locations of the electrodes and hair density are major factors in the impedance of the animal and subsequent studies should be performed to define their effects. The electrical impedance between the ears of the elk was found to be purely resistive and ranged from 479 to 1185 Ω. The current levels administered by the TENS operator were consistently near 2.79 mA. This may indicate that increasing the current until the ear twitches is an effective method of setting a consistent dosage limit. Although the dosage was consistent, this does not necessarily mean the current was sufficient to block the pain. More information regarding current levels and pain control is necessary to answer this question. It would also be beneficial to examine the effects of frequency and pulse width on the efficacy of TENS in this application.

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