Thermal Properties of Contemporary Bipolar Systems Using Infrared Imaging

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Key words
- Bipolar electrocoagulation
- Coagulation
- Infrared imaging
- Surgical techniques
- Thermal imaging

Abbreviations and Acronyms
BE: Bipolar electrosurgery
ESG: Ellman Surgitron Generator

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■ BACKGROUND: **Bipolar coagulation has enhanced the capabilities and safety profile of contemporary neurosurgery and has become indispensable in the neurosurgical armamentarium. Nevertheless, significant heat transfer issues remain to be resolved before it can achieve the status of minimal risk.**

■ METHODS: **The Codman irrigating forceps, Codman ISOCOOL forceps, and Ellman bipolar forceps, powered by either Synergy or Ellman generators set at various power levels, were compared to investigate the combinations that would allow for the lowest rate of heat transfer. Using an infrared camera and ThermaGRAM imaging software, the temperature was calculated and used to estimate the degree of heat transfer.**

■ RESULTS: **Codman ISOCOOL forceps powered the Ellman Surgitron generator showed the greatest dissipation (at mid-power, the luminance decreased from 250 units to 80 units within 60 seconds) and the least production of heat after activation. Codman ISOCOOL forceps powered by the Codman SYNERGY MALIS generator showed less heat dissipation (at mid-power, the luminance decreased from 250 units to 195 units within 60 seconds) than the Ellman forceps and Ellman Surgitron generator combination (at mid-power, the luminance decreased from 250 units to 125 units within 60 seconds).**

■ CONCLUSIONS: **These data suggest that the incorporation of the Ellman Surgitron Generator can result in the reduction of thermal transfer with conventional bipolar forceps compared with other generators. The combination with Codman ISOCOOL forceps can maximize the potential safety associated with bipolar coagulation. With regard to the use of comarketed pairs of forceps and generators, the combination of Ellman Surgitron Generator and Ellman bipolar forceps provided the best thermal profile.**

INTRODUCTION

To achieve hemostasis, surgeons have developed and use various methods, including ligatures, clips, monopolar devices, and bipolar devices (2). Cushing (4) wrote about the use of silver clips for achieving hemostasis, but their use has been overshadowed by other innovations. Neurosurgeons currently employ monopolar and bipolar electrocautery and electrocoagulation extensively. These related techniques, first employed in neurosurgery by Bovie and Cushing in 1926, use electrical current designed either to cut or to coagulate tissue (2, 3, 14). Bipolar electrosurgery (BE), pioneered by Greenwood (8, 9) and refined by Malis (13), produced a further refinement in electrosurgery. BE provides several advantages over monopolar electrosurgery, including the ability to manipulate tissue with high precision, to direct current more accurately, to use electrosurgery without the need of grounding the patient, and to operate more efficiently (8, 9). Additionally, BE requires far lower voltages to accomplish satisfactory coagulation, decreasing the risk of excess heat transfer to surrounding tissue (2).

Greenwood's initial article was prescient, identifying many of the disadvantages of BE, including excess heat transfer to surrounding tissues and adherence of the bipolar tip to cauterized tissue (8, 9). Innovations in BE have reduced, but not eliminated, the problems of heat transfer and tissue adherence (14). To add to this body of work, we report our results comparing the heat transfer properties of several commercially available bipolar generators in combination with multiple forceps in common usage. The experiments were designed to reproduce conditions in the operating room, and the results were expressed in a language that could be interpreted and applied by surgeons.

MATERIALS AND METHODS

There were 2 generators used for the study. The first unit was the Ellman Surgitron 4.0 Dual Frequency RF/120 IEC SurgiMax (Ellman International, Inc., Hicksville, New York, USA), where the Mode CUT/COAG was activated at power levels of 3, 4, and 5, defined as low power, mid-power, and high power. The second unit was the SYNERGY MALIS Precision Bipolar Coagulator (Codman Neuro, Raynham, Massachusetts, USA), where coagulation was conducted at power levels of 35, 40, and 45 Malis Units, defined as low power, mid-power, and high power. Bipolar forceps included the standard surgical grade stainless steel bipolar forceps (1-mm tip) by Ellman Innovations (Ellman International, Inc.), ISOCOOL Bipolar forceps (1 mm tips) with Active Heat Transfer technology (Codman Neuro), and the Codman standard stainless steel irrigating bipolar forceps (0.75-mm tip) (Codman Neuro).

Initial thermal exposure with subsequent spread in 9 inch × 5 inch × 0.7 inch fresh bovine muscle tissue at a closure of 1 mm was assessed at common operating settings for 3-second periods by an Indigo Systems infrared camera (version 11A0, 3.21, 0130; Indigo Systems Corp; Goleta, California, USA) using ThermaGRAM imaging software version 2002.2.7.3 (Thermoteknix Systems Ltd.; Waterbeach, Cambridge, UK). The recording and calibration of multiple temperature standards allows for the calculation of temperature by ThermaGRAM (10).

Generator and forceps were assessed in 6 combinations. Thermal recordings were measured at a camera-to-tissue distance of 36.75 cm at 5-second intervals for 60-second periods. Specifically, certain infrared wavelengths are experienced as heat. The time-dependent pattern of infrared emanating from the tissue was quantified and reported as luminance, a value that can be defined as the intensity of light energy propagating in a given direction. The temporal pattern of light energy emanating from the test tissue after activation of the various generator-bipolar forceps combinations was analyzed as a proxy for heat transfer to surrounding tissue.

RESULTS

Data from our experiments are documented in **Table 1**. For the Ellman bipolar forceps (**Figure 1**, row 1), at low power (**Figure 1A**), there was no significant difference in the thermal profile with either generator during the initial 30 seconds after activation. There was a decreased thermal profile for the Ellman bipolar forceps with the Ellman Surgitron Generator (ESG) from 30 to 60 seconds. At mid-power (**Figure 1B**), a similar pattern emerged, although the divergence in heat production occurred at approximately 20 seconds after activation. At high power (**Figure 1C**), the Ellman bipolar forceps coupled with the ESG also showed decreased heat production after 20 seconds post activation, although the amount of divergence between generators used was less than in the trials at low power and mid-power.

Testing the Codman ISOCOOL bipolar forceps (**Figure 1**, row 2) at low power

Table 1. Maximum and Minimum Luminance Values with Bipolar Forceps and Generators Tested

Forceps Type	Generator	Low Power		Mid-power		High Power	
		Maximum Luminance (Time at Occurrence)	Minimum Luminance (Time at Occurrence)	Maximum Luminance (Time at Occurrence)	Minimum Luminance (Time at Occurrence)	Maximum Luminance (Time at Occurrence)	Maximum Luminance (Time at Occurrence)
Ellman bipolar forceps	Ellman Surgitron	250 units (10–30 seconds)	151 units (60 seconds)	250 units (10–20 seconds)	125 units (60 seconds)	250 units (10 seconds)	75 units (65 seconds)
	Codman SYNERGY MALIS	250 units (10–55 seconds)	248 units (60 seconds)	250 units (5–45 seconds)	210 units (55 seconds)	250 units (10 seconds)	165 units (55 seconds)
Codman ISOCOOL Forceps	Ellman Surgitron	250 units (10 seconds)	180 units (50 seconds)	250 units (5–10 seconds)	80 units (60 seconds)	250 units (10–15 seconds)	90 units (60 seconds)
	Codman SYNERGY MALIS	255 units (5–55 seconds)	250 units (60 seconds)	250 units (5–30 seconds)	195 units (60 seconds)	250 units (5–30 seconds)	195 units (60 seconds)
Codman irrigating forceps	Ellman Surgitron	255 units (20 seconds)	180 units (60 seconds)	250 units (10–25 seconds)	190 units (60 seconds)	255 units (15–20 seconds)	180 units (60 seconds)
	Codman SYNERGY MALIS	250 units (10 seconds)	100 units (60 seconds)	250 units (10–20 seconds)	180 units (60 seconds)	255 units (15–20 seconds)	180 units (60 seconds)