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Comparative Healing of Rat Fascia Following Incision with Three Surgical Instruments

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Background. **Incisional hernia and fascial dehiscence are associated with significant postoperative morbidity. Electrosurgical devices using pulsed radiofrequency energy and a novel electrode design markedly reduce thermal injury during cutting and coagulation while maintaining equal surgical performance. In this study, we examine fascial healing dynamics in a rat model following incision with a pulsed radiofrequency energy device (PRE), a conventional electrosurgical device, and a standard "cold" scalpel. We hypothesize that incisions made with the pulsed radiofrequency energy device will result in a superior fascial healing profile compared with conventional electrosurgery.**

Materials and Methods. **Full thickness surgical incisions were created in rat fascia using a commercially available PRE device, conventional electrosurgery, and a scalpel. Harvested fascial specimens were analyzed for burst strength testing and healing-associated histologic characteristics at d 7, 14, 21, and 42.**

Results. **PRE incisions were fully healed by 6 wk with normal tissue architecture. By all measures, wounds created by the PRE device were comparable to those made with the standard scalpel. Compared with PRE, conventional electrosurgery incisions exhibited a larger zone of tissue injury (68% greater in Coag mode, $P < 0.0001$; 46% greater in Cut mode, $P < 0.001$), an increased inflammatory response and a less favorable wound architecture. In the immediate postoperative period (1 wk), burst strength testing demonstrated that PRE fascial wounds were significantly stronger than those made by electrosurgery in Coag mode (318%, $P = 0.001$).**

Conclusions. **The favorable fascial healing profile of the PRE device suggests that it is a promising new surgical technology. The early improved strength of wounds made with this device is of particular interest, as wound dehiscence is of greatest concern early in the healing process.** Published by Elsevier Inc.

Key Words: **electrosurgery; electrocautery; fascial healing; thermal injury; pulsed radiofrequency energy.**

INTRODUCTION

Conventional electrosurgical devices have been the mainstay of subcutaneous dissection and hemostatic control since their introduction by Bovie and Cushing in the 1920s [1]. In conjunction with the scalpel, their use is fundamental to the practice of surgery in more than 17.4 million procedures annually in the United States [2]. Central to their design is the use of continuous-waveform radiofrequency (RF) energy, delivered *via* an uninsulated metal electrode, to cut tissue by thermal ablation, thus producing a simultaneous hemostatic effect [3, 4]. While prized for hemostatic control and dissection capability, conventional electrosurgical devices are associated with significant thermal damage to incised tissues, low surgical precision with the potential for injury to adjacent structures (eg, bowel, nerves, blood vessels), and delayed wound healing [5–13].

Accordingly, these limitations have led to improvements in electrosurgical device design including low-stick electrode coatings, ultrasonic blades, sealing

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technology, and feedback controlled RF generators [6–9, 13]. Some of these innovations have demonstrated incremental improvement in reducing thermal damage during dissection while preserving bleeding control; however, the use of continuous RF energy and a large uninsulated electrode has remained unchanged despite many generations of traditional electrosurgical technology. Thus, substantial room for improvement remains to approach the near-atraumatic collateral damage profile of the standard scalpel.

Recently, the use of brief (40-μs range), high-frequency pulses of RF energy to induce the formation of electrical plasma along the edge of a thin (approximately 12 μm wide), flat, 99.5 percent-insulated electrode, has demonstrated the ability to effectively cut and coagulate tissue with significantly decreased thermal damage [14, 15]. By limiting the pulse repetition rate to less than 1 kHz, and the duty cycle (fraction of time that energy is delivered to the electrode) to less than 5%, efficient cooling of the electrode is achieved and the operating temperature remains between 40°C and 100°C (traditional electrosurgery is typically 250°C to 350°C). This reduction in duty cycle combined with the small exposed area of the electrode results in much lower average power output than conventional electrosurgery (CES) and less total energy being used. This technology has been patented and is incorporated into a commercially-available pulsed radiofrequency energy (PRE) device, the PEAK PlasmaBlade (PEAK Surgical, Palo Alto, CA, USA). This device has previously been shown to effectively dissect ophthalmologic tissues as precisely as a scalpel, even while completely submerged in a liquid medium, with minimal thermal collateral damage and the hemostatic control of conventional electrosurgery [16–22].

Prior work comparing the healing dynamics of incisions made in porcine skin using this PRE device, a standard "cold" scalpel, and a conventional electrosurgical device demonstrated that incisions made with PRE produced a significant reduction in thermal injury depth, decreased inflammation with a corresponding increase in wound burst strength and, ultimately, superior scar formation compared with conventional electrosurgery [23]. While these results are scientifically significant, the effects of various forms of electrosurgery on clinically relevant fascial healing are less well understood. When considering surgical laparotomy, adequate fascial healing is essential in preventing incisional hernia, which has been estimated to occur in 2% to 19% of cases [24].

In this study, we hypothesized that decreased thermal injury would lead to improved fascial healing of a midline abdominal fascial incision in a rat model, when comparing conventional electrosurgery (CES), the PRE device, and a traditional "cold" scalpel (SC). We evaluated objective parameters such as healed-wound tensile strength and depth of thermal injury to incised tissue; subjectively, histopathologic scoring of inflammation, collagen deposition, and stage of healing were also evaluated.

MATERIALS AND METHODS

Animals and Study Design

The primary outcome measure for this study was bursting strength of healed fascial incisions; secondary outcomes were depth of thermal injury, inflammation, collagen deposition, and stage of healing. The study was conducted on 90 adult male Sprague-Dawley rats weighing 250 to 300 g. Five (5) rats were allocated to each experimental group (SC, PRE, CES Cut, CES Coag) for time points of 1, 2, 3, and 6 wk; two controls (skin incision only) were allocated to each group in addition to the 0 wk time point. The study protocol was approved by the IACUC committee at the San Francisco Veterans Affairs Medical Center and was conducted in accordance with the requirements of the Animal Welfare Act and the NIH Guide for the Care and Use of Laboratory Animals. The animals were acclimated for a minimum of 96 h prior to the study and fed a standard diet in normal rations *ad libitum*. Following incision and wound closure as described below, animals were allowed to recover under warming lamps and were housed in individual cages with free access to food and water until sacrifice with inhaled CO_2 at 1, 2, 3, and 6 wk following surgery. Each animal was considered to be an independent sampling unit in this study.

Incisional Wound Model Surgical Procedure

Anesthesia was induced and maintained using inhaled 2% isoflurane *via* nose cone for the entirety of the procedure. After shaving the abdomen, the skin was prepped with alcohol and incised sharply with a scalpel to expose the midline abdominal wall. Following careful dissection to the midline abdominal fascia, a small entry incision was made sharply at the inferior portion of the abdominal fascia to allow access to the abdominal cavity. A plastic retractor was then placed under the abdominal wall to facilitate a single, smooth 5 cm midline fascial incision and to prevent injury to abdominal organs. Incisions were made with a No. 10 scalpel blade ("SC"; Bard-Parker, Franklin Lakes, NJ), the Valleylab Electrosurgical Pencil (E2516) with standard tip (E1551) using a Force 2 Generator (Valleylab, Boulder, CO) on Cut (40 W, Blend 2) and Coagulation (40 W, Spray) modes ("CES-Cut" and "CES-Coag", respectively), and the PRE device, the PEAK PlasmaBlade with PULSAR Generator (PEAK Surgical, Palo Alto, CA) on Cut setting 3 (6 W). Although future generations of the Valleylab CES generator (Force 4, Force FX, etc.) offer optional coagulation settings including low (soft), medium (fulgurate), and high (spray) the Force 2 model only features the spray mode. Neither the radiofrequency energy waveforms, nor the standard electrode design have changed in future revisions of the generator.

For each instrument, the pass rate was approximated to that used during traditional human laparotomy. The CES electrode tip chosen was the standard, uncoated stainless steel electrode used in conventional surgery. The PRE device electrode has nearly the same dimensions as the standard CES blade tip, although the construction is different to reflect the technological differences as described in the introduction.

The settings for the CES and PRE devices were chosen based on commonly used operating room settings and tested in a pilot study to ensure their ability to effectively divide tissue at the same approximate pass rate, in a single stroke. The fascial wound was closed with a running 4-0 nylon suture (Johnson & Johnson/Ethicon, Somerville, NJ) followed by closure of the skin with a running 5-0 nylon suture (Ethicon) and covered with bacitracin-neomycin-polymyxin (BNP) ointment (MWI Veterinary Supply, Meridian, ID).