Effect of Electrocautery vs. Scalpel on Fascial Mechanical Properties after Midline Laparotomy Incision in Rats

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Abstract

Background: The method of midline laparotomy incision and closure remains a complex surgical problem.

Objective: To compare the mechanical properties at the interface of midline laparotomy incision made by scalpel versus electrocutting current in rats.

Methods: A sharp midline laparotomy incision was made in 60 Wistar female rats using a scalpel or electrocautery to open the fascia. The fascial and skin wounds were closed separately with a continuous nylon. Fascial specimens were analyzed for mechanical properties at the midline incision using a loading machine. The load-extension curve was recorded during tensile loading at a steady extension rate of 15 mm/min.

Results: There was no statistically significant difference between the two groups in either wound-bursting force (P_{PEAK}) or the strain energy spent until the point of measured P_{PEAK}. Each load-extension curve showed a characteristic pattern in all rats. Tissue stiffness was greater in the scalpel group than in the electrocautery group ($P=0.02$). Correlations were found between tissue stiffness and strain energy, between tissue stiffness and bursting force, and between bursting force and strain energy.

Conclusions: While tissue stiffness was greater when a scalpel was used compared to electrocutting to incise the midline abdominal fascia in rats, there was no difference in the bursting force required to disrupt the wound.

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The method of midline laparotomy incision and closure remains a complex surgical problem. The use of electrocautery for tissue incision both reduces blood loss by immediate hemostasis and enables quick and dry separation of tissue [1–4]. The main disadvantage of electrocautery is the increased tissue damage due to the thermal effect [5]. Either the cutting or the coagulating current (or a combination of the two) may be chosen, but the latter may cause greater tissue necrosis [2,6]. A sharp midline laparotomy incision has no thermal effect, but it is time consuming and is associated with blood loss and the need for hemostasis [5].

To prevent early wound dehiscence and late wound hernia, a running polyglyconate suture is the better choice of suture material for closure of the abdominal wall fascia following midline laparotomy [7]. In previous studies, Kumagai et al. [2] and Rappoport et al. [5] assessed the breaking strength of midline wounds, but no other parameters of the abdominal wall fascia were described. The aim of the present study was to compare some mechanical properties related to the interface of midline laparotomy incision using two different techniques in the rat.

Material and Methods

Animals and animal care

Sixty Wistar female rats, weighing 200–250 g, underwent midline incision using general anesthesia with 40 mg/kg ketamine (Ketalar® 50 mg/ml, Parker-Davis, UK), and 6 mg/kg xylazine (Rumpun® Solution 2%, Bayer, Leverkusen, West Germany). Rats were individually housed in standard stainless steel cages and fed with a palette complete rat diet and water *ad libitum*. All animals were cared for according to the National Institutes of Health guidelines for the care of laboratory animals.

Surgical procedure

All surgical procedures were performed by the same surgeon (Y.Z.). The skin was shaved with electric clippers and prepared with 70% isopropyl alcohol before incision with a scalpel. A 3 cm long incision, in a fine white line designating the midline, was made using a surgical scalpel (n = 30) or electrocutting current (n = 30) for opening the fascia. A standard electrosurgical unit was used (ENS Clinic 200, Denver, USA) with the current set at the lowest level to permit division of the fascia. The fascial wounds were closed with continuous 3-0 nylon suture placed 5 mm from the wound edge and 5 mm apart. The skin was closed with a continuous 3-0-nylon suture.

Specimen harvesting procedure and experiment

The rats were anesthetized 6 days after surgery. The skin was separated from the abdominal fascia and removed. Abdominal wall tissue was excised (5x3 cm), with the midline sutured incision in its center and with an adjacent segment of normal tissue. The specimens were transferred in saline solution to the laboratory for mechanical testing. The fascial suture was removed, and a 5x1 cm specimen (length of strip x suture line) was clamped between two custom-made grips that were connected to the loading machine (Instron, model 4502, High Wycombe, UK). The load-extension curve was recorded during tensile loading at a steady extension rate of 15 mm/min. Data were obtained automatically on a PC/AT IBM compatible computer during each experiment using a data acquisition system (A/D card Das 16-F and a Viewdac programme, Kiethley, MA, USA). All specimens were disrupted at the incisional wound. Each load-extension curve showed a characteristic pattern [Figure 1]. From this curve, three mechanical properties of the abdominal wall fascia were determined:

P_{PEAK} The peak load defining the bursting force per 1 cm of tissue width (Newton).

This value is obtained during the experiment and refers to a point where the curve bends, which is related to the resistance of the interface to withstand higher load. From this point, the measured force decreases as the extension of the specimen increases.

$P_{PEAK} = \text{Max}\,[P(e)]$

P = load, e = tissue extension

S The tissue stiffness (Newton/mm) during loading defined as the slope of the initial linear load-extension curve.

$S = \Delta P / \Delta e$

U The strain energy (Joules) required to achieve the incision bursting force defined by the area occupied under the load-extension curve up to e_{PEAK}, P_{PEAK}.

$$U = \int_{e=0}^{e=e_{PEAK}} P\,de \qquad [6]$$

Statistical analysis

Data are presented as mean and standard deviation. The natural logarithmic values of the data were analyzed using the two-tailed Student's *t*-test to compare the two groups of rats. Correlations between these parameters were analyzed using the Pearson test. The statistical significance level was set at 0.05.

Results

Seven rats died (three in the scalpel incision group, and four in the electrocutting incision group). A characteristic load-extension curve [Figure 1] of a specimen was demonstrated in each group. There was no statistically significant difference in wound-bursting force (P_{PEAK}) between the scalpel incision group and the electrocutting incision group ($r = 0.63$, $P < 0.001$). Tissue stiffness was greater in the scalpel than in the electrocutting group 2 ($P = 0.02$), and the strain energy spent until the point of measured P_{PEAK} was not statistically different [Table 1]. Correlations were found between tissue stiffness (S) and strain energy (U), between tissue stiffness (S) and bursting force (P_{PEAK}), and between bursting force (P_{PEAK}) and strain energy (U), as shown in Figures 2 and 3, respectively.

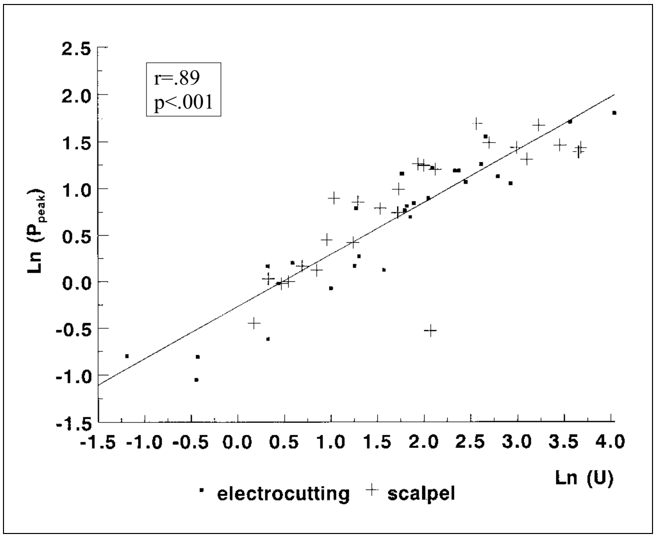

Figure 1. Schematic characteristic presentation of load-extension curve.

Table 1. Comparison of fascial mechanical properties following midline abdominal incision using electocautery-cutting vs. scalpel

Variable	Scalpel incision (n = 27)*	Electrocutting incision (n = 26)*	P**
P_{PEAK} (Newton)	2.63 ± 1.51	2.39 ± 1.52	0.56
Tissue stiffness (Newton/mm)	.53 ± .24	0.4 ± .17	0.02
Strain energy (joules)	10.65 ± 11.78	9.62 ± 12.06	0.75

* Values depicted in mean and standard deviation

** Student's *t*-test

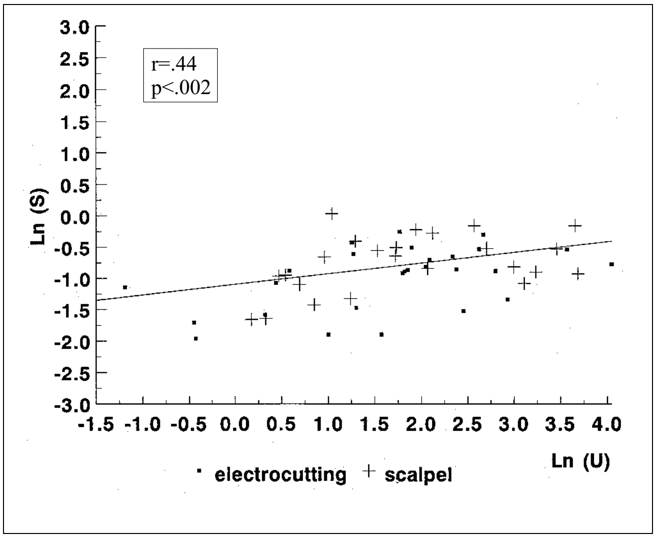

Figure 2. Correlation between tissue stiffness and strain energy in each group of rats.

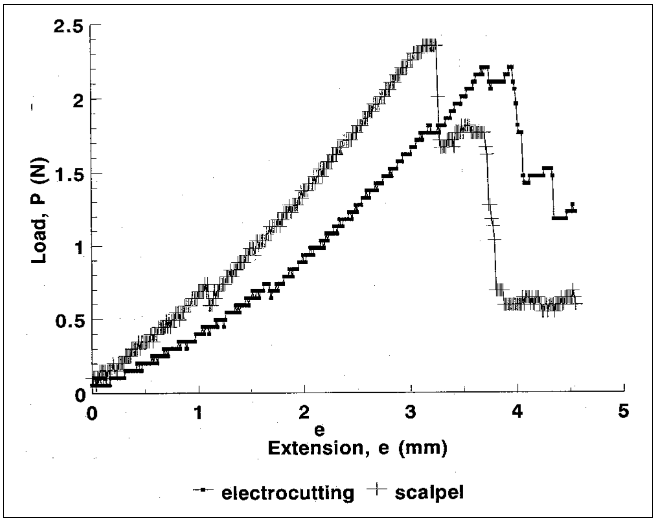

Figure 3. Correlation between tissue stiffness and bursting force in each group of rats.

Discussion

Electrocautery has been used extensively since it was introduced in 1929 [3]. Although electrocautery is widely used in clinical practice, its effect on wound healing is poorly defined. The cutting mode of electrocautery produces intense heat and tissue cells explode into steam. Since the heat is dissipated in the steam it is not conducted through the tissues to dry out adjacent cells. Cutting the current leaves less devitalized, desiccated tissue along the margins of the cut surface than achieved with electrocoagulation [2].

The effect of electrocautery on fascial wound healing has received little attention. Sanders et al. [8] reported a negative correlation between microscopic inflammation and fascial wound strength in rats undergoing laparotomy. Sanz [9] reported wound dehiscence associated with the use of electrocautery for midline fascia incision in six patients. Neither study [7,8] differentiated between electrocoagulation and electrocutting current. Rappaport and co-workers [5] found lower wound-bursting strength at 3, 10 and 21 days when electrocoagulation current was used, but no significant difference was observed when comparing electrocutting current to scalpel-made midline abdominal incisions in rats. Our findings are in accordance with the observation of Rappaport's team [5] when we compared the use of electrocutting to scalpel-made incisions. We found no significant difference between the two groups when we compared the peak force needed to disrupt the tissue. Considering the load-extension curve, the peak force is the simplest parameter determined for both groups: in every specimen examined, the curve showed several declines after the first one (P_{PEAK}), which was always at the highest point of the peak force required to disrupt the tissue at the interface. After reaching the maximal force (P_{PEAK}), the tissue was still joined in a few places at the interface, which then disconnected at a longer tissue extension. This shape of curve was due to the fact that tissue specimens do not disrupt like solid materials, thus few declines and inclines (but not above P_{PEAK}) were seen in the load-extension curves. This phenomenon is equivalent to the clinical setting, when wound disruption in the human begins at one weak point of the incisional wound, resulting in an incisional hernia in most patients, sometimes with complete wound disruption and evisceration.

We also found that the strain energy spent until the peak force disrupts the incisional wound did not differ between the groups. In all tissue specimens, we found a linear behavior between the loading force and tissue extension, defined as tissue stiffness. We found greater ($P = 0.02$) tissue stiffness in rats with scalpel-made midline abdominal incisions compared to electrocutting-made incisions, which is attributed to the thermal effect of electrocutting current on the surrounding tissues. The stiffness characterizes the ability of the tissue to withstand deformation by loading forces. Marked stiffness indicates less stretchable tissue. Although the tissue stiffness was lower in the group of rats with electrocutting- compared to scalpel-made fascial incisions, it did not affect the bursting force (P_{PEAK}) required to disrupt the tissue at the interface, or the strain energy spent reaching that point. We found correlations between tissue stiffness and strain energy, tissue stiffness and bursting force, and bursting force and strain energy, in both groups. More loading force and energy are required to disrupt the incisional wound in a tissue with greater stiffness.

In conclusion, there is no difference between an electrocutting- or scalpel-made incision of midline abdominal fascia in rats, when comparing the bursting force at the interface of the incisional wound. However, other mechanical parameters such as tissue stiffness can be indicative of the surgical procedure used.

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