Hypothesis: Placing stitches close to the cut wound edge does not produce low wound bursting strength in midline laparotomy incisions closed with a suture length: wound length ratio of 4.

Design: Experimental study in rats.

Methods: Midline incisions were closed with a running suture in 51 Sprague-Dawley rats. A suture length: wound length ratio of 4 was used and stitches were placed at a distance of 3, 6, or 10 mm from the wound edge. Wound bursting strength was studied immediately after and 4 days after wound closure.

Results: Immediately after wound closure, bursting pressure was higher with stitches placed 10 mm from the wound edge than those at a distance of 3 mm. After 4 days, bursting pressure and bursting volume were lower with stitches placed 10 mm from the wound edge than those at a distance of 3 or 6 mm. The abdominal wall ruptured outside the suture line in 14 of 17 wounds closed with 21 stitches, in 11 of 17 wounds closed with 16 stitches, and in 6 of 17 wounds closed with 11 stitches ($P = .02$).

Conclusions: Four days after closure of midline laparotomy incisions using a suture length–wound length ratio of 4, wound bursting strength is higher with stitches placed 3 to 6 mm from the wound edge than those at a distance of 10 mm. Wound bursting strength increases with the number of stitches used.


A N ADEQUATE method of wound closure and an optimal suture technique are important when closing laparotomy incisions. The distance of stitches from the cut wound edge and the interval between stitches can be controlled by the surgeon and may affect the risk of postoperative wound complications.

Experimental studies suggest that wound bursting strength, ie, the force required to burst the sutured wound, increases when stitches are placed at a greater distance from the wound edge.1-5 This has been attributed to weakening of the aponeurosis close to the cut edge during the inflammatory phase of the healing process.1,2,6,7 Based on these findings, it is usually recommended that stitches be placed 10 mm from the cut wound edge to achieve a low rate of wound dehiscence and incisional hernia.5-9 However, the experimental studies have not accounted for a possible effect of the suture length–wound length ratio. For a running-suture technique, this is the ratio of the length of the suture used, calculated by measuring suture remnants, to the length of the wound.10,11

In experimental studies, wound bursting strength increases with higher suture length–wound length ratio.12 In addition, a ratio of less than 4 has been associated in clinical studies with a high rate of wound dehiscence and incisional hernia.10,11 Whether a ratio of more than 4 is accomplished by small tissue bites at short intervals or by large bites at greater intervals has not correlated to the rate of wound dehiscence or incisional hernia.11 Thus, placing stitches close to the wound edge has correlated with low wound bursting strength in experimental studies but not with a high rate of wound failure in clinical studies.

The aim of this experimental study was to investigate bursting strength in midline laparotomy wounds closed with a running suture that produced a suture length: suture length ratio of 4, with stitches placed at different distances from the wound edge. Wound bursting strength was studied immediately after and 4 days after wound closure.
MATERIALS AND METHODS

Fifty-one female Sprague-Dawley rats were used for this study. Those that were randomized to wound bursting strength study immediately after wound closure were killed humanely by carbon dioxide inhalation. Those randomized to study after 4 days were anesthetized by a subcutaneous injection of fentanyl citrate, fluanisone, and midazolam. A 6.6-cm midline laparotomy incision was made after reflecting skin and panniculus carnosus laterally. The incision was closed by a continuous single-layer technique using United States Pharmacopeia 5/0 monofilament suture material (PDS II; Ethicon GmbH, Norderstedt, Germany), placing stitches through sites marked with a template. Three different templates, which determined the distance of stitches from the wound edge and the interval, were used randomly (Table 1 and Figure). A suture length–wound length ratio of 4 was attempted and the ratio produced was calculated. The peritoneum was included in the stitch, and the tension on the suture line was just enough to approximate wound edges. Of the animals randomized to study after 4 days, 3 succumbed to anesthetic complications.

After humanely killing the animals (mean weight, 242 g; SD, 10 g), bursting strength of the wound was studied by inserting a metal trocar with a balloon attached through a vaginal perforation into the peritoneal cavity. To prevent inguinal herniation, a cotton cord was tied around the lower abdomen between the pubic symphysis and the caudad wound edge. The peritoneal cavity. To prevent inguinal herniation, a cotton cord was tied around the lower abdomen between the pubic symphysis and the caudad wound edge. The balloon was gradually distended with water from an infusion pump (IVAC 7201; Alaris Medical, San Diego, Calif) that maintained a constant flow rate of 0.5 mL/s, and the pressure was monitored continuously by a computerized device (PowerLab; AD Instruments Pty Ltd, Castle Hill, Australia). The end point was defined as the occurrence of complete wound dehiscence. Bursting pressure was defined as the highest pressure recorded before dehiscence. Bursting volume was the increase in animal weight at the end point, with 1 g corresponding to 1 mL of infused liquid. The wound was observed during the experiment, and the way the suture cut through the tissues was registered as well as whether dehiscence occurred in the sutured wound or beyond it.

The study design was approved by the Animal Ethics Committee of Lund University, Lund, Sweden, and adhered to the guiding principles in the care and use of animals. Statistical analysis was performed with the Statistical Package for the Social Sciences software (SPSS Inc, Chicago, Ill). The Mann-Whitney test or the χ² test with Yates correction was used for statistical analysis. Probability was accepted as significant at P<.05.

RESULTS

A mean suture length:wound length ratio of at least 4 was produced in all 6 groups of animals studied. In those studied immediately after wound closure, the ratio was lower with stitches placed 10 mm from the wound edge than those at a distance of 6 mm. In those with stitches placed 3 mm from the wound edge, the ratio was higher in the group studied immediately after than the group studied 4 days after wound closure (Table 1).

Immediately after wound closure, bursting pressure was higher with stitches placed 10 mm from the wound edge than those at a distance of 3 mm. Four days after closure, bursting pressure was lower with stitches placed 10 mm from the wound edge than those at a distance of 3 or 6 mm. With stitches placed at a distance of 10 mm from the wound edge, bursting pressure was lower 4 days after than it was immediately after wound closure (Table 2).

Bursting volume was lower with stitches placed 10 mm from the wound edge than those at a distance of 3 or 6 mm 4 days after wound closure. There was no difference in bursting volume between groups studied immediately after and those studied 4 days after wound closure (Table 3).

Knot slippage was not encountered and the suture never broke. The abdominal wall ruptured outside the suture line in 14 of 17 wounds closed with 21 stitches, in 11 of 17 wounds closed with 16 stitches, and in 6 of 17 wounds closed with 11 stitches (P = .02) (Table 1).

Table 1. Characteristics of Templates Used and Suture Length–Wound Length (SL/WL) Ratio

<table>
<thead>
<tr>
<th>Stitches, No.</th>
<th>Distance From Wound Edge, mm</th>
<th>Stitch Interval, mm</th>
<th>SL/WL Ratio Immediately After Wound Closure, Mean (SD)†</th>
<th>4 d After P</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>3</td>
<td>3</td>
<td>4.4 (0.3)</td>
<td>4.0 (0.4) .04</td>
</tr>
<tr>
<td>16</td>
<td>6</td>
<td>4</td>
<td>4.6 (0.4)†</td>
<td>4.5 (0.5) .67</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>6</td>
<td>4.2 (0.2)†</td>
<td>4.5 (0.5) .24</td>
</tr>
</tbody>
</table>

*Each figure represents 8 measurements immediately after and 8 measurements 4 days after wound closure. †Significant difference within columns P< .05.

Illustration of templates used for wounds closed with a running suture and using a suture length–wound length ratio of 4. A, Closure is with 21 stitches; B, with 16; and C, with 11. As stitches are placed closer to the wound edge, their number must increase to achieve a suture length–wound length ratio of 4. Characteristics of these templates are presented in Table 1.
In this experimental study, wound bursting strength in midline laparotomy incisions was studied immediately after and 4 days after wound closure. Wounds were closed by a continuous suture technique, and stitches were placed at a distance of 3, 6, and 10 mm from the wound edge. Templates for a suture length–wound length ratio of 4 were used, and small differences in the tension on the suture may have caused the variability in mean ratios achieved.

Immediately after wound closure, stitches placed 3 mm from the wound edge produced lower bursting pressure than those at a distance of 10 mm. However, there was no difference in bursting volume. Four days after wound closure, stitches placed 10 mm from the wound edge produced lower bursting pressure and volume than those placed closer.

These findings are contrary to previous studies reporting low wound bursting strength with stitches placed close to the wound edge. However, previous studies have not considered a possible effect of the suture length–wound length ratio. In previous studies, the interval between stitches has been constant, and, as a result, placing stitches closer to the wound edge produces a lower suture length–wound length ratio. The reported low wound bursting strength with small tissue bites, therefore, may have been an effect of a low suture length–wound length ratio.

It is also important to consider a possible effect of the inflammatory phase during the first 4 to 5 days of the healing process. A biologically active zone within 15 mm from the cut wound edge with collagen deposition, degradation, and reorganization has been described. Weakening of tissue within 6 mm of the cut wound edge was not associated with low wound bursting strength 4 days after closure in our study. Wound bursting strength was actually higher with stitches placed within this zone. This may have been an effect of the increased number of stitches used when they were placed closer to the cut wound edge. If tension on the sutured wound is distributed to a large number of stitches, the tension on each stitch is low, and with every stitch added to the suture line, the tension on each stitch will be lower. In our study, placing stitches 3 mm from the wound edge corresponded to placing nearly twice as many stitches in the wound than when stitches were placed at a distance of 10 mm (Table 1). Although tissue close to the wound edge may have been weakened, perhaps its suture-holding capacity was not exceeded because wound tension was distributed to more stitches within this zone.

This mechanism also may have relevance for the decrease in bursting pressure 4 days after closure in wounds with stitches placed 10 mm from the wound edge. With the tension on the suture line distributed to fewer stitches, the tension on each stitch is high and may be close to exceeding the suture-holding capacity of the tissue. Even minor weakening of tissue during the inflammatory phase of the healing process may have a detectable effect on wound strength.

Rupture of the abdominal wall outside the suture line indicates that the strength of the sutured wound is close to that of intact abdominal wall. The proportion of wounds that ruptured outside the suture line increased with the number of stitches used, both immediately after and 4 days after wound closure. This is a further indication of tension on each stitch being closer to exceeding the suture-holding capacity of tissues if wound tension is distributed to fewer stitches.

The integrity of the wound depends on the characteristics of the suture during the first days after closure. A suture cutting through suture-holding tissue may cause separation of the wound edges, with subsequent early wound dehiscence or the later development of an incisional hernia. Closure of wounds with a suture length: wound length ratio of at least 4 is essential to the capacity of the suture to support the wound and to prevent such complications. Such a high ratio can be achieved with small tissue bites at short intervals or with large bites at longer intervals.

Experimental models attempt to mimic the clinical situation and, on the basis of such studies, it is usually recommended that stitches be placed at least 10 mm from the cut wound edge. In our experimental study, higher wound bursting strength was achieved 4 days after closure if large tissue bites were avoided and if the tension on the suture line was distributed to many stitches. Whether these findings are applicable in the clinical situation can, of course, be questioned, but our findings in this experimental study are in agreement with previous clinical reports.

Table 2. Relation of Bursting Pressure to Distance of Sutures From Wound Edge

<table>
<thead>
<tr>
<th>Distance From Wound Edge, mm</th>
<th>Bursting Pressure After Wound Closure, Mean (SD), mm Hg*</th>
<th>Immediately After</th>
<th>4 d After</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>227 (15)†</td>
<td>242 (13)†</td>
<td>.11</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>237 (17)</td>
<td>248 (19)†</td>
<td>.20</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>247 (14)†</td>
<td>227 (18)†</td>
<td>.02</td>
<td></td>
</tr>
</tbody>
</table>

* Each figure represents 9 measurements immediately after and 8 measurements 4 days after wound closure. † Significant difference within columns; P < .05.

Table 3. Relation of Bursting Volume to Distance of Sutures From Wound Edge

<table>
<thead>
<tr>
<th>Distance From Wound Edge, mm</th>
<th>Bursting Volume After Wound Closure, Mean (SD), mL*</th>
<th>Immediately After</th>
<th>4 d After</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>172 (12)</td>
<td>175 (6)†</td>
<td>.61</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>172 (11)</td>
<td>172 (8)†</td>
<td>.89</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>165 (12)</td>
<td>162 (8)†</td>
<td>.48</td>
<td></td>
</tr>
</tbody>
</table>

* Each figure represents 9 measurements immediately after and 8 measurements 4 days after wound closure. † Significant difference within columns; P < .05.
matory weakening of tissue is most pronounced, is probably highly relevant, as wound dehiscence occurs most often after 7 days.\(^9\)

We conclude that 4 days after closure of midline laparotomy incisions using a suture length:wound length ratio of 4, wound bursting strength is higher with stitches placed 3 to 6 mm from the wound edge than those at a distance of 10 mm. Wound bursting strength increases with the number of stitches used.

We recommend that a suture length:wound length ratio of 4 be accomplished by placing many stitches in the wound rather than by using big tissue bites, because this may reduce the risk of early wound dehiscence or the development of incisional hernia.

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**REFERENCES**


**IN OTHER AMA JOURNALS**

**ARCHIVES OF INTERNAL MEDICINE**

*The Diagnosis of Cushing’s Syndrome: Atypical Presentations and Laboratory Shortcomings*

Marco Boscaro, MD; Luisa Barzon, MD; Nicoletta Sonino, MD

In the last 3 decades, there have been several advances in understanding the pathogenesis of Cushing’s syndrome and in testing for the diagnosis and differential diagnosis of its various forms. Advanced diagnostic techniques provide useful tools in discovering ectopic adrenocorticotropic hormone sources. However, the occurrence of unusual clinical presentations, laboratory shortcomings, and exogenous compound interference may lead to wrong conclusions. This article reviews the atypical presentations of hypercortisolism and some laboratory shortcomings that may confuse the diagnosis of Cushing’s syndrome. Comments and suggestions are given with the aim of helping the clinician avoid diagnostic mistakes. (2000;160:3045-3053)

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