Effect of Stitch Length on Wound Complications After Closure of Midline Incisions

A Randomized Controlled Trial

Daniel Millbourn, MD; Yucel Cengiz, MD, PhD; Leif A. Israelsson, MD, PhD

Hypothesis: In midline incisions closed with a single-layer running suture, the rate of wound complications is lower when a suture length to wound length ratio of at least 4 is accomplished with a short stitch length rather than with a long one.

Design: Prospective randomized controlled trial.

Setting: Surgical department.

Patients: Patients operated on through a midline incision.

Intervention: Wound closure with a short stitch length (ie, placing stitches <10 mm from the wound edge) or a long stitch length.

Main Outcome Measures: Wound dehiscence, surgical site infection, and incisional hernia.

Results: In all, 737 patients were randomized: 381 were allocated to a long stitch length and 356, to a short stitch length. Wound dehiscence occurred in 1 patient whose wound was closed with a long stitch length. Surgical site infection occurred in 35 of 343 patients (10.2%) in the long stitch group and in 17 of 326 (5.2%) in the short stitch group (P = .02). Incisional hernia was present in 49 of 272 patients (18.0%) in the long stitch group and in 14 of 250 (5.6%) in the short stitch group (P < .001). In multivariate analysis, a long stitch length was an independent risk factor for both surgical site infection and incisional hernia.

Conclusion: In midline incisions closed with a running suture and having a suture length to wound length ratio of at least 4, current recommendations of placing stitches at least 10 mm from the wound edge should be changed to avoid patient suffering and costly wound complications.

Trial Registration: clinicaltrials.gov Identifier: NCT00508053


MIDLINE INCISIONS ALLOW RAPID AND WIDE ACCESS TO THE ABDOMINAL CAVITY WITH MINIMAL DAMAGE TO MUSCLES, NERVES, AND THE VASCULAR SUPPLY OF THE ABDOMINAL WALL.1 However, wound complications cause patient suffering and generate costs for the health care system.2,3 Surgical site infection, which occurs in up to 16% of patients after major surgery, is a risk factor for the development of incisional hernia.4,6 Herniation often demands repair and occurs in up to 26% of midline incisions.4,6

The quality of the suture technique has a profound effect on the risk of incisional hernia. Incisions should be closed with a running suture and with a suture length (SL) to wound length (WL) ratio of at least 4. When the SL to WL ratio is less than 4, the risk of herniation is 3 times higher.7,8 The ratio (the length of the suture used through the length of the wound) depends on the size of each stitch and the stitch interval. Thus, a ratio of at least 4 can be achieved with many small stitches placed at close intervals or by incorporating a larger amount of tissue into stitches placed at greater intervals. Large stitches are usually recommended because experimental studies have shown that stitches placed at least 10 mm from the wound edge produce a stronger wound.9,11 This has been attributed to inflammatory changes in tissue close to the wound edge diminishing its suture-holding capacity.10 However, in a recent experimental study that also took into account the effect of the SL to WL ratio, stitches placed 3 to 6 mm from the wound edge produced a stronger wound after 4 days—when inflammatory changes would be at their peak—compared with stitches placed at least 10 mm from the wound edge.12

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In clinical reports, long stitches have been associated with a high rate of surgical site infection and incisional hernia. Long stitches may augment the risk of infection because they increase the amount of necrotic tissue in the wound. In an experimental study, long stitches were found to compress or cut through soft tissue included in the stitch, thereby increasing the amount of necrotic tissue. The risk of incisional hernia may be increased with the use of a long stitch length because the stitch slackens, which allows wound edges to separate. Thus, new data indicate that an SL to WL ratio of at least 4 should be achieved with small tissue bites placed at close intervals rather than with large tissue bites placed at greater intervals.

The aim of this randomized trial was to study the effect of stitch length on surgical site infection and incisional hernia in closed midline incisions.

METHODS

Between January 8, 2001, and January 8, 2006, patients older than 18 years who underwent emergent or planned surgery through a midline incision at the Department of Surgery, Sundsvall Hospital, were asked to participate in the trial. Patients with a previous midline incision, a previous abdominal incision crossing the midline, or a preexisting ventral hernia such as an umbilical or epigastric hernia were not eligible. A continuous, single-layer monofilament suture closed the incision, and self-locking anchor knots were used. A continuous, intradermal 4-0 absorbable monofilament suture (Monocryl; Ethicon GmbH, Norderstedt, Germany) closed the skin.

Patients were randomized to wound closure with either a short or long stitch length. Randomization was achieved by using one technique or the other on alternating weeks. In the group randomized to a long stitch length, the previous standard technique for wound closure at the department was used and stitches were placed at least 10 mm from the wound edge. For the short stitch group, a 1-0 polydioxanone suture on a needle with a half-circle, tapered point and a diameter of 41 mm was used (PDS II suture and TP-1 needle; Ethicon GmbH). For the short stitch group, surgeons were urged to place stitches 5 to 8 mm from the wound edge and to include only the aponeurosis in the stitches. In this group, 2-0 polydioxanone suture on a needle with a half-circle, tapered point and a diameter of 20 mm was used (PDS II suture and MH-1 needle; Ethicon GmbH).

Patient age, sex, weight, and height were recorded. The body mass index was calculated as weight in kilograms divided by height in meters squared. Whether patients had previously received a diagnosis of diabetes mellitus was noted. The degree of wound contamination, the operation time, and the incision closure time were recorded. The length of the suture used to close the incision and the length of the wound were measured, and the SL to WL ratio was calculated. The number of stitches placed in the wound was recorded for calculation of the mean stitch length (SL/number of stitches) and the mean stitch interval (WL/number of stitches).

Surgical site infection and wound dehiscence were recorded 4 weeks after surgery. Wound dehiscence was defined as a complete wound disruption that needed emergent reoperation. Surgical site infection was defined according to the criteria of the Centers for Disease Control and Prevention and was classified as deep or superficial. At the 12-month follow-up examination, incisional hernia was defined as any palpable defect in the aponeurosis or protrusion beyond the level of the aponeurosis. Patients were examined supine with a relaxed and tensed abdominal wall while lifting both legs and also were examined in an erect position with a relaxed or tensed abdominal wall while straining. At the follow-up examination, patients and the investigator (D.M.) were blinded to the stitch length used. This study was approved by the regional research ethics committee of Umeå University.

The SPSS statistical software (version 14.0; SPSS Inc, Chicago, Illinois) was used for statistical analysis. The Fisher exact test and Mann-Whitney test were used for univariate analysis as appropriate, and $P < .05$ was regarded as significant. Multivariate analysis was performed with multiple linear logistic regression. Surgical site infection and incisional hernia were considered dependent variables, and all other recorded variables were considered independent variables. We calculated 95% confidence intervals for the variable estimates. A strategy of backward reduction analysis was applied to remove nonsignificant interaction terms from the model. For a difference of 6% in the rate of wound infection and for a power of 80% ($\alpha = .05$), 352 patients were required in each study arm. For a difference of 10% in the rate of incisional herniation, 160 patients were required in each arm.

In all, 750 patients were eligible for the study. In 13, the randomization protocol was not followed because of administrative errors. Of the 737 patients who entered the trial, 381 were allocated to being sutured with a long stitch length and 356 to being sutured with a short stitch length (Figure). Patient characteristics were similar between the groups (Table 1). For the short stitch group, the time spent closing the wound was longer, the stitch length and stitch interval were shorter, and the SL to WL ratio was lower (Table 1).

Wound dehiscence occurred in 1 patient in the long stitch group. Surgical site infection occurred in 52 of 669 patients (7.8%) and was less frequent with a short stitch length (Table 2). Deep surgical site infection occurred in 13 of 343 patients (3.8%) in the long stitch group and in 4 of 326 (1.2%) in the short stitch group ($P = .04$).
cisional hernia was present in 63 of 522 patients (12.1%) and was less frequent in the short stitch group (Table 2). In cases of surgical site infection, incisional hernia was present in 11 of 27 patients (40.7%) in the long stitch group and in 1 of 16 (6.2%) in the short stitch group (P = .02). Incisional hernia was present in 56 of 495 patients (11.3%) sutured with an SL to WL ratio of at least 4 and in 7 of 27 (25.9%) with a lower ratio (P = .03).

In multivariate analysis, wound contamination, diabetes mellitus, and a long stitch length were independent risk factors for a surgical site infection (Table 3). Male sex, higher body mass index, longer operation time, surgical site infection, an SL to WL ratio of less than 4, and a long stitch length were independent risk factors for an incisional hernia (Table 3).

**COMMENT**

In this randomized trial, a short stitch length was associated with a lower rate of both surgical site infection and incisional hernia. Multivariate analysis, which took all registered variables into account, showed that the risk of infection was twice as high and that the risk of herniation was 4 times as high in the long stitch group (Table 3). This is in congruence with previous clinical reports\(^\text{13,14}\) of a correlation between a long stitch length and a high rate of wound complications. Our findings represent a change of paradigm concerning the closure of midline incisions because it has long been recommended to close these incisions with stitches placed at least 10 mm from the wound edge.

The current recommendation of using a long stitch length is based on experimental studies that did not consider the effect of the SL to WL ratio.\(^\text{9-11}\) A recent experiment\(^\text{12}\) has shown that a weaker closure in a wound closed with small stitches was an effect of also reducing the SL to WL ratio. A separate experimental study\(^\text{15}\) has illustrated that, when a long stitch length is used, the suture cuts through or compresses soft tissue included in the

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**Table 1. Characteristics Related to Stitch Length**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Long (n = 381)</th>
<th>Short (n = 356)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patient Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, mean (95% CI), y</td>
<td>64 (63-66)</td>
<td>65 (64-67)</td>
<td>.30(^a)</td>
</tr>
<tr>
<td>Female, No. (%)</td>
<td>153 (40.2)</td>
<td>155 (43.5)</td>
<td>.37(^b)</td>
</tr>
<tr>
<td>BMI, mean (95% CI)</td>
<td>26 (25-27)</td>
<td>26 (25-27)</td>
<td>.94(^a)</td>
</tr>
<tr>
<td>Diabetes mellitus, No. (%)</td>
<td>33 (8.7)</td>
<td>39 (11.0)</td>
<td>.36(^b)</td>
</tr>
<tr>
<td><strong>Operative Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wound contamination, No. (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contaminated</td>
<td>247 (64.8)</td>
<td>245 (68.8)</td>
<td>.44(^b)</td>
</tr>
<tr>
<td>Dirty</td>
<td>42 (11.0)</td>
<td>31 (8.7)</td>
<td></td>
</tr>
<tr>
<td>Operation time, mean (95% CI), min</td>
<td>135 (126-142)</td>
<td>135 (128-142)</td>
<td>.39(^a)</td>
</tr>
<tr>
<td>Suturing time, mean (95% CI), min</td>
<td>14 (13-15)</td>
<td>18 (17-19)</td>
<td>&lt;.001(^a)</td>
</tr>
<tr>
<td>Stitch length, mean (95% CI), mm</td>
<td>44 (42-45)</td>
<td>26 (25-26)</td>
<td>&lt;.001(^b)</td>
</tr>
<tr>
<td>Stitch interval, mean (95% CI), mm</td>
<td>6.9 (6.7-7.0)</td>
<td>4.6 (4.4-4.7)</td>
<td>&lt;.001(^a)</td>
</tr>
<tr>
<td>SL to WL ratio, mean (95% CI)</td>
<td>6.4 (6.3-6.6)</td>
<td>5.7 (5.5-5.8)</td>
<td>&lt;.001(^a)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; SL, suture length; WL, wound length.

\(^a\)Mann-Whitney test.

\(^b\)Fisher exact test.

**Table 2. Wound Complications Related to Stitch Length**

<table>
<thead>
<tr>
<th>Complication</th>
<th>Long</th>
<th>Short</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wound dehiscence, No. (%) of patients</td>
<td>1/381 (0.3)</td>
<td>0/356</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Surgical site infection, No. (%)</td>
<td>35/343 (10.2)</td>
<td>17/326 (5.2)</td>
<td>.02</td>
</tr>
<tr>
<td>Incisional hernia, No. (%)</td>
<td>49/272 (18.0)</td>
<td>14/250 (5.6)</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

\(^a\)Fisher exact test.

**Table 3. Significant Predictors of Surgical Site Infection and Incisional Hernia**

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Regression Coefficient (SE)</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical Site Infection</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wound contamination</td>
<td>1.03 (0.48)</td>
<td>2.81 (1.09-7.25)</td>
</tr>
<tr>
<td>Being diabetic</td>
<td>1.01 (0.38)</td>
<td>2.73 (1.30-5.72)</td>
</tr>
<tr>
<td>Long stitch length</td>
<td>0.77 (0.31)</td>
<td>2.15 (1.17-3.96)</td>
</tr>
<tr>
<td>Incisional Hernia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male sex</td>
<td>0.76 (0.34)</td>
<td>2.14 (1.10-4.15)</td>
</tr>
<tr>
<td>Higher BMI</td>
<td>0.05 (0.02)</td>
<td>1.05 (1.01-1.10)</td>
</tr>
<tr>
<td>Longer operation time</td>
<td>0.005 (0.002)</td>
<td>1.01 (1.002-1.01)</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>1.16 (0.40)</td>
<td>3.18 (1.44-7.02)</td>
</tr>
<tr>
<td>SL to WL ratio &lt;4</td>
<td>1.32 (0.92)</td>
<td>3.73 (1.36-10.28)</td>
</tr>
<tr>
<td>Long stitch length</td>
<td>1.44 (0.34)</td>
<td>4.24 (2.19-8.23)</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); CI, confidence interval; OR, odds ratio; SL, suture length; WL, wound length.

\(^a\)Results of logistic regression analysis. All recorded variables were included in the model and removed by a backward reduction strategy if nonsignificant.
stitch. This increases the amount of devitalized tissue in the wound and may explain the correlation with infection. This also causes slackening of the suture, which allows wound edges to separate and increases the risk of incisional hernia.

Our study confirms that herniation risk is higher when closure is done with an SL to WL ratio of less than 4 (Table 3). Our finding several measurable factors related to the quality of the suture technique—factors that greatly affect the risk of surgical site infection and incisional hernia—has the potential for reducing overall complication rates. Adaptation to these findings is entirely in the hands of the surgeon and it has the potential to substantially reduce patient suffering and lower health care costs.\(^3\) Wound closure took 4 minutes longer with a short stitch length but, when one considers the costs generated by wound complications and the profound effect that use of a short stitch length has on complication rates, this is likely to be cost-effective.\(^2\)

Placing stitches close to the wound edge was not associated with a high risk of wound dehiscence, which was present only in the long stitch group. A short stitch length also was associated with a lower rate of herniation, even when surgical site infection occurred. Infection was associated with a slightly increased herniation rate in the short stitch group but the increase was uncomfortably high in the long stitch group. Thus, placing stitches close to the wound edge was obviously safe, even when wound healing was hampered by an infection.

With the small MH-1 needle, it was almost impossible to place stitches more than 7 to 8 mm from the wound edge and still retrieve the needle. It was not feasible to include tissue other than the aponeurosis into the stitch for the same reason. The 2-0 suture was chosen because it was the longest (150 cm) commercially available polydioxanone suture mounted on such a small needle. To our knowledge, there is no obvious theoretical basis for the needle size or the suture size, per se, to have affected the rate of wound complications.

We recommended that surgeons place stitches 5 to 8 mm from the wound edge; with minimal tension applied to the suture, this corresponds to a mean stitch length of 20 to 32 mm. Surgeons also were instructed to avoid high tension on the suture because clinical studies have shown this to be associated with an increased risk of surgical site infection.\(^18\) Because the mean stitch length was 26 mm in the short stitch group, we believe that our recommendation was followed.

In conclusion, the rate of wound complications for midline incisions closed with a running suture is lower when an SL to WL ratio of at least 4 is accomplished with a short stitch length. Therefore, we recommend that midline incisions be closed with a single-layer, running monofilament suture and that the SL to WL ratio be at least 4. This ratio should be achieved with several small stitches that incorporate the aponeurosis only. Current recommendations of placing stitches at least 10 mm from the wound edge should be changed to avoid patient suffering and costly wound complications.

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Author Contributions: All authors had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Study concept and design: Millbourn, Cengiz, and Israelsson.

Acquisition of data: Millbourn, Cengiz, and Israelsson.

Analysis and interpretation of data: Millbourn, Cengiz, and Israelsson.

Drafting of the manuscript: Millbourn and Israelsson.

Critical revision of the manuscript for important intellectual content: Millbourn, Cengiz, and Israelsson.

Statistical analysis: Cengiz and Israelsson.

Obtained funding: Millbourn.

Administrative, technical, and material support: Millbourn and Israelsson.

Study supervision: Cengiz and Israelsson.

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REFERENCES


