

Risk factors for wound complications in midline abdominal incisions related to the size of stitches

D. Millbourn · Y. Cengiz · L. A. Israelsson

Received: 17 September 2010 / Accepted: 25 December 2010 / Published online: 30 January 2011
© Springer-Verlag 2011

Abstract

Background Midline abdominal incisions should be closed continuously with a suture length (SL) to wound length (WL) ratio above 4 using small stitches. The effect on the rate of wound complications of a very high ratio and other potential risk factors when closure is performed with small stitches is unknown.

Methods Patients operated on through a midline incision were randomised to closure with small stitches, placed 5–8 mm from the wound edge and less than 5 mm apart, or with large stitches, placed more than 1 cm from the wound edge. Patient and operative variables were registered. Surgical site infection and incisional hernia were recorded.

Results Three hundred and twenty-one patients were randomised to closure with small stitches and 370 with large stitches. Infection and herniation were less common with small stitches. With small stitches, no risk factors for infection or herniation were identified. With large stitches, wound contamination and the patient being diabetic were independent risk factors for infection, and long operation time and surgical site infection were risk factors for herniation. A very high SL to WL ratio did not affect the complication rates.

Conclusions In midline abdominal incisions closed with small stitches, no risk factors for surgical site infection or incisional hernia were identified. Increasing the ratio very much above 4 had no adverse effects on the rate of wound complications. The higher rates of infection and herniation with an SL to WL ratio over 5 and in overweight patients in previous reports were probably related to wounds being closed with large stitches.

Keywords Suture technique · Post-operative complications · Surgical wound infection · Surgical site infection · Incisional hernia

Introduction

To minimise the risk for incisional hernia, midline abdominal incisions should be closed with a continuous, single-layer technique and a suture length (SL) to wound length (WL) ratio of at least 4, using a monofilament slowly absorbable or non-absorbable suture [1–8]. High tension on the suture should be avoided, as it weakens the wound, impairs collagen synthesis and increases the rate of infection [9–11].

The SL to WL ratio relates to the size of stitches and the interval between them. An equivalent ratio can be achieved with either large stitches or with many small stitches placed at closer intervals. Experimental and clinical studies support that closure should be performed with small stitches, placed 5–8 mm from the wound edge at an interval of less than 5 mm [12–15]. In a randomised trial, the risk of both surgical site infection and incisional hernia was lower with small stitches than with large stitches [16].

The evidence for suturing with an SL to WL ratio of at least 4 is strong [16–20]. However, closure with a ratio

ClinicalTrials.gov ID: NCT00508053, <http://www.clinicaltrials.gov>.

D. Millbourn (✉) · Y. Cengiz
Department of Surgery (Kirurgkliniken),
Sundsvall Hospital (Sundsvalls Sjukhus),
Sundsvall 851 86, Sweden
e-mail: daniel.millbourn@lvn.se

L. A. Israelsson
Department of Surgical and Perioperative Sciences,
Umeå University, Umeå, Sweden

above 5 as well as the patient's overweight have, in previous reports, been associated with an increased rate of wound complications [19, 20]. Since large stitches are more often utilised when the SL to WL ratio is more than 5 and in overweight patients, the large stitch rather than the high ratio or the overweight per se may have been the risk factor [14, 20, 21].

In clinical practise, it is difficult for the surgeon to be as precise, as ending up with a ratio over 4 but not higher than 5 and the effect of suturing with a very high ratio is poorly studied. The effect on the rate of wound complications of a very high SL to WL ratio, overweight and other potential risk factors such as age, sex, diabetes mellitus, wound contamination and operation time [16, 18–22] when closure is performed with small stitches is unknown. The purpose of the present study was to explore potential risk factors for wound complications in midline abdominal incisions in relation to wound closure with small or large stitches.

Materials and methods

The inclusion criteria were patients older than 18 years, emergent or planned surgery through a midline abdominal incision and wounds closed with an SL to WL ratio of at least 4. The exclusion criteria were a previous midline abdominal incision, a former incision crossing the midline or a pre-existing ventral hernia. The study was conducted between January 2001 and January 2006 at the Department of Surgery, Sundsvall Hospital, Sweden.

The incision was closed with a continuous, single-layer technique. Patients were randomised to closure with large stitches using polydioxanone United States Pharmacopeia (USP) 1 on a TP-1 needle (PDS II®, Ethicon, Norderstedt, Germany) or to closure with small stitches using polydioxanone USP 2-0 on an MH-1 needle (PDS II®, Ethicon, Norderstedt, Germany). Randomisation was achieved by using the different techniques on alternating weeks [16]. Surgeons were instructed to always produce an SL to WL ratio of at least 4 and achieving a very high ratio was encouraged. Instructions were to place large stitches at least 10 mm from the wound edge and small stitches 5–8 mm from the wound edge at an interval of less than 5 mm, only incorporating the aponeurosis. Self-locking starting and finishing knots were used [23]. A continuous intra-dermal absorbable monofilament suture USP 4-0 (Monocryl®, Ethicon, Norderstedt, Germany) closed the skin.

Patient-related variables such as age, sex, weight (kilogrammes) and height (metres) were recorded. Patients were registered as diabetic if on treatment with insulin, oral anti-diabetics or food restrictions. The body mass index ($BMI = \text{weight}/\text{height}^2$) was calculated and overweight was defined as a BMI of 25 or higher. Operative variables such

as wound contamination (clean, contaminated by an opened bowel, dirty with faecal contamination or pus), the operation time, the total length of the suture used to close the incision (SL), the wound length (WL) and the number of stitches were recorded. The SL to WL ratio (SL/WL), mean stitch length (SL/number of stitches) and mean stitch interval (WL/number of stitches) were calculated. Stratification was made into groups with an SL to WL ratio of 4.0–4.9, 5.0–5.9, 6.0–6.9 and 7.0 or higher.

Four weeks after surgery, surgical site infection, defined according to the definition of the US Centers for Disease Control and Prevention (CDC), was registered [24]. Superficial and deep infections were together regarded as a surgical site infection. Follow-up examination for the presence of incisional hernia was made after 12 months. Incisional hernia was defined as any palpable defect in the aponeurosis or protrusion beyond the level of the aponeurosis. Patients were examined supine with relaxed and tensed abdominal wall while lifting both legs and in an erect position with relaxed and tensed abdominal wall while straining. Patients and the investigator (DM) were at follow-up examination blinded for the actual randomisation.

The study was approved by the Regional Research Ethics Committee, Umeå University, Umeå, Sweden. The SPSS™ 17.0 (SPSS Inc., Chicago, IL, USA) software was used for the statistical analyses. The means and 95% confidence intervals (CIs) were calculated. Fisher's exact test and the Mann–Whitney *U*-test were used for the univariate analysis, as appropriate. Pearson's two-tailed analysis was used for correlation analysis. A probability of less than 0.05 was regarded as significant. Multivariate analysis was performed with multiple logistic regression. Then, surgical site infection and incisional hernia were dependent variables and all other recorded variables were independent. For the variable estimates, 95% CIs were calculated. A strategy of backward reduction analysis was applied to remove non-significant factors from the model.

Results

Seven hundred and fifty patients were eligible for this study. In 13, the randomisation protocol was not followed due to administrative errors and in 46, an SL to WL ratio of at least 4 was not accomplished. Of the 691 patients analysed, 321 were allocated to closure with small stitches and 370 with large stitches. Patient variables were similar between the groups (Table 1). In those allocated to closure with small stitches, a shorter stitch length, a shorter stitch interval and a lower SL to WL ratio was recorded. For both groups, the maximum SL to WL ratio recorded was 12. The median operation time was about 2 h and patients were in

Table 1 Patient and operative characteristics related to the size of stitches

	Small stitch (<i>n</i> = 321)	Large stitch (<i>n</i> = 370)	<i>P</i> -value
Age, mean, years (95% CI)	65 (64, 67)	64 (63, 66)	0.332
Female, <i>n</i> (%)	143 (44.5)	148 (40.0)	0.247+
Body mass index, mean (95% CI)	26 (25, 27)	26 (25, 27)	0.963
Patient diabetic, <i>n</i> (%)	31 (9.7)	32 (8.6)	0.692
Wound contamination, <i>n</i> (%)			0.560+
Clean	73 (22.7)	89 (24.1)	
Contaminated	220 (68.5)	241 (65.1)	
Dirty	28 (8.7)	40 (10.8)	
Operation time			
Mean, minutes (95% CI)	135 (128, 142)	136 (128, 144)	0.411
Median, minutes	118	126	
Stitch length, mean, millimetres (95% CI)	27 (26, 28)	44 (43, 46)	<0.001
Stitch interval, mean, millimetres (95% CI)	4.5 (4.4, 4.7)	6.8 (6.7, 7.0)	<0.001
SL to WL ratio, mean (range)	5.9 (4.0–12.2)	6.4 (4.0–11.6)	<0.001

Statistical analysis: Mann–Whitney *U*-test; + Fisher's exact test

Table 2 Surgical site infection related to the size of stitches and to the suture length to wound length (SL to WL) ratio

SL to WL ratio	Small stitch	Large stitch	<i>P</i> -value
Total, <i>n</i> (%)	15 of 293 (5.1)	32 of 332 (9.6)	0.034
4.0–4.9, <i>n</i> (%)	5 of 80 (6.3)	4 of 46 (8.7)	0.723
5.0–5.9, <i>n</i> (%)	4 of 88 (4.5)	7 of 98 (7.1)	0.543
6.0–6.9, <i>n</i> (%)	2 of 65 (3.1)	6 of 75 (8.0)	0.285
≥7.0, <i>n</i> (%)	4 of 60 (6.7)	15 of 113 (13.3)	0.213

Statistical analysis: Fisher's exact test. No significant difference within columns

the analysis stratified according to an operation time of up to 120 min and longer than 120 min (Table 1).

The rate of surgical site infection was lower with small stitches than with large stitches. The rate of surgical site infection was similar irrespective of the SL to WL ratio (Table 2). With small stitches, no significant correlation between surgical site infection and registered variables was found (Table 3). With large stitches, surgical site infection was, in the univariate analysis, more common in contaminated or dirty wounds and in diabetic or overweight patients (Table 3). With large stitches, wound contamination and the patient being diabetic were independent risk factors for the development of surgical site infection in the multivariate analysis (Table 4).

The rate of incisional hernia was lower with small stitches than with large stitches. The rate of incisional her-

Table 3 Surgical site infection related to registered variables and the size of stitches

	Small stitch	Large stitch
Sex, <i>n</i> (%)		
Male	10 of 159 (6.3)	14 of 195 (7.2)
Female	5 of 134 (3.7)	18 of 137 (13.1)
	<i>P</i> = 0.428	<i>P</i> = 0.089
Wound contamination, <i>n</i> (%)		
Clean	2 of 70 (3)	3 of 77 (4)
Contaminated	12 of 199 (6.0)	22 of 222 (9.9)
Dirty	1 of 24 (4)	7 of 33 (21)
	<i>P</i> = 0.759	<i>P</i> = 0.020
Patient diabetic, <i>n</i> (%)		
No	13 of 265 (4.9)	25 of 304 (8.2)
Yes	2 of 28 (4)	7 of 28 (25)
	<i>P</i> = 0.643	<i>P</i> = 0.011
Patient overweight, <i>n</i> (%)		
No	5 of 128 (3.9)	8 of 149 (5.4)
Yes	10 of 165 (6.1)	24 of 183 (13.1)
	<i>P</i> = 0.439	<i>P</i> = 0.024
Operation time, <i>n</i> (%)		
≤120 min	11 of 235 (4.7)	27 of 260 (10.4%)
>120 min	4 of 58 (7)	5 of 72 (7%)
	<i>P</i> = 0.517	<i>P</i> = 0.500

Statistical analysis: Fisher's exact test

nia was similar irrespective of the SL to WL ratio (Table 5). With small stitches, no significant correlation between registered variables and incisional hernia was found (Table 6). With large stitches, incisional hernia was, in the univariate analysis, more common if the operation time was longer than 120 min and if a surgical site infection had occurred (Table 6). These factors were independent risk factors for the development of incisional hernia with large stitches in the multivariate analysis (Table 4). Male sex was a confounder for operation time, changing the regression coefficient by more than 10%.

With Pearson's two-tailed analysis, there was a correlation between operation time and incisional hernia with large stitches ($P < 0.001$) but not with small stitches ($P = 0.268$). The only correlation found between operation time and the other registered variables was that the mean operation time was 114 min (95% CI 107, 120) in women and 151 min (95% CI 143, 158) in men ($P < 0.001$).

Discussion

Patients were randomised to closure with either small or large stitches. Patients with wounds closed with an SL to WL ratio lower than 4 were excluded from the analysis as

Table 4 Significant predictors of surgical site infection and incisional hernia with large stitches

Results of logistic regression analysis. All recorded variables were included in the model and removed by a backward reduction strategy if non-significant

	Regression coefficient	Standard error	Odds ratio	95% CI
Surgical site infection				
Wound contaminated or dirty	0.94	0.36	2.57	1.27–5.21
Patient diabetic	1.27	0.49	3.55	1.36–9.27
Incisional hernia				
Operation time >120 min	1.61	0.47	5.01	1.99–12.64
Surgical site infection	1.14	0.36	3.13	1.55–6.34

Table 5 Incisional hernia related to the size of stitches and to the SL to WL ratio

SL to WL ratio	Small stitch	Large stitch	P-value
Total, <i>n</i> (%)	11 of 233 (4.7)	45 of 262 (17.2)	0.001
4.0–4.9, <i>n</i> (%)	4 of 60 (6.7)	7 of 30 (23.3)	0.038
5.0–5.9, <i>n</i> (%)	3 of 70 (4.3)	10 of 83 (12.0)	0.144
6.0–6.9, <i>n</i> (%)	3 of 56 (5.4)	9 of 59 (15.3)	0.126
≥7.0, <i>n</i> (%)	1 of 47 (2.1)	19 of 90 (21.1)	0.002

Statistical analysis: Fisher's exact test. No significant difference within columns

Table 6 Incisional hernia related to registered variables and the size of stitches

	Small stitch	Large stitch
Sex, <i>n</i> (%)		
Male	8 of 127 (6.3)	31 of 153 (20.3)
Female	3 of 106 (2.8)	14 of 109 (12.8)
	<i>P</i> = 0.353	<i>P</i> = 0.136
Patient diabetic, <i>n</i> (%)		
No	10 of 202 (4.9)	42 of 202 (20.8)
Yes	1 of 20 (5)	3 of 15 (20)
	<i>P</i> = 1.000	<i>P</i> = 1.000
Patient overweight, <i>n</i> (%)		
No	3 of 98 (3)	15 of 112 (13.4)
Yes	8 of 35 (5.9)	30 of 150 (20.0)
	<i>P</i> = 0.365	<i>P</i> = 0.187
Operation time, <i>n</i> (%)		
≤120 min	7 of 179 (3.9)	26 of 197 (13.2)
>120 min	4 of 54 (7)	19 of 65 (29)
	<i>P</i> = 0.285	<i>P</i> = 0.004
Surgical site infection, <i>n</i> (%)		
No	10 of 219 (4.6)	35 of 238 (14.7)
Yes	1 of 14 (7)	10 of 24 (42)
	<i>P</i> = 0.502	<i>P</i> = 0.003

Statistical analysis: Fisher's exact test

representing a failure of the suture technique. The groups were similar concerning all registered variables except the mean SL to WL ratio and regarding the intended difference

in the mean stitch length and the mean stitch interval. Surgeons were instructed to place large stitches at least 10 mm from the wound edge and small stitches 5–8 mm from the wound edge at an interval of less than 5 mm. The calculated stitch length reflects the size of tissue bites but is not an exact measure of how far from the wound edge stitches were placed. As the mean SL to WL ratio was about 6 and the maximum was 12, stratification into groups with wounds closed with a very high ratio was possible, permitting an analysis of the effect of closure with a very high ratio. Closure with a ratio of 12 with small stitches may appear astonishing, since it demands placing stitches at extremely short intervals. To surgeons at our department used to always measuring and documenting the ratio, it is, however, quite ordinary. The mean stitch length was, with small stitches, similar irrespective of the SL to WL ratio and did not, with small stitches, increase with a higher ratio. Further, the small needle used when closure was performed with small stitches made it quite impossible to place stitches more than 8 mm from the wound edge, since the small needle could then not be retrieved.

Suturing with a very high SL to WL ratio was not a risk factor for the development of surgical site infection with either small or large stitches. No significant risk factor for the development of surgical site infection was found with small stitches. With large stitches on the other hand, wound contamination and the patient being diabetic were independent risk factors for infection in the multivariate analysis. It is an interesting finding that the patient being diabetic was a risk factor with large stitches but not with small stitches. The higher rate of infection in diabetic patients with large stitches is not surprising but, evidently, utilising small stitches made the wound less susceptible to this potential risk factor.

Thus, closing wounds with a very high SL to WL ratio was not associated with an increased rate of surgical site infection and a lower rate of infection was produced with small stitches. Overweight was, with small stitches, not associated with any increased risk for surgical site infection but with large stitches, it was. These findings support that earlier results of a higher rate of surgical site infection in overweight patients and in patients sutured with an SL to

WL ratio over 5 [19, 20] was an effect of large stitches being used under these circumstances.

Suturing with a very high ratio was not a risk factor for the development of incisional hernia with either small or large stitches. However, with small stitches, there was a trend towards a lower herniation rate with an ascending ratio. No significant risk factors for the development of incisional hernia were found with small stitches. With large stitches, long operation time and an earlier surgical site infection were independent risk factors. It is an interesting finding that long operation time was an independent risk factor for incisional hernia. In previous reports, male sex has been a risk factor for incisional hernia [16, 21, 22] but the present findings indicate that this may have been due to the operation time being longer in men. The rate of incisional hernia was higher in both women and men if the operation time was long and the operation time was longer in men. Thus, the difference in operation time between genders more than the gender per se may, in previous reports, have accounted for the difference in herniation rates. There are indications for surgery associated with long operation time that are more common in men than in women, for example, abdominal aortic aneurysm disease.

Thus, with small stitches, a lower rate of incisional hernia was produced and it was safe, or possibly even beneficial, to close wounds with a very high SL to WL ratio. Overweight was not a risk factor for herniation with either small or large stitches. As herniation was more common with large stitches than with small stitches, these findings support that earlier results of a higher rate of incisional hernia in overweight patients and in patients sutured with an SL to WL ratio over 5 [19, 20] was an effect of large stitches being used under these circumstances.

The present study confirms previous clinical findings of an adverse effect of large stitches [14, 16, 19, 21, 25]. The mechanism for this effect has been illustrated in experimental studies. With a large stitch, other tissue than aponeurosis, such as muscle and fat, is included in each stitch. With increased intra-abdominal pressure post-operatively, the suture may compress or cut through soft tissue included in the stitch [13, 15]. This allows the suture to slacken and the wound edges to become separated with, consequently, a higher risk of developing an incisional hernia [25, 26]. The increased amount of devitalised soft tissue in the wound may relate to the higher risk for surgical site infection with a large stitch. Closing wounds with small stitches considerably diminishes the risk of wound complications. The findings in the present study indicate that it also considerably diminishes the effect of potential risk factors for the development of wound complications, as no risk factors could be identified with small stitches.

It is concluded that, in midline abdominal incisions closed continuously with an SL to WL ratio of at least 4 and

with small stitches, no risk factors for the development of surgical site infection or incisional hernia were identified. Increasing the SL to WL ratio very much above 4 had no adverse effects on the rate of wound complications. The lowest rate of surgical site infection and incisional hernia is achieved with small stitches. The higher rates of surgical site infection and incisional hernia in wounds closed with an SL to WL ratio over 5 and in overweight patients in previous reports were probably related to wounds in these circumstances being closed with large stitches.

Acknowledgments This trial was funded by The FoU-Centre, Västernorrland County Council, Sundsvall, Sweden, and The SJCKMS Foundation, Umeå University, Umeå, Sweden. The funding sources have had no involvement in the work.

Conflicts of interest The authors declare that they have no conflicts of interest.

References

1. Weiland DE, Bay RC, Del Sordi S (1998) Choosing the best abdominal closure by meta-analysis. *Am J Surg* 176:666–670
2. Hodgson NC, Malthaner RA, Ostbye T (2000) The search for an ideal method of abdominal fascial closure: a meta-analysis. *Ann Surg* 231:436–442
3. Rucinski J, Margolis M, Panagopoulos G, Wise L (2001) Closure of the abdominal midline fascia: meta-analysis delineates the optimal technique. *Am Surg* 67:421–426
4. van 't Riet M, Steyerberg EW, Nellensteyn J, Bonjer HJ, Jeekel J (2002) Meta-analysis of techniques for closure of midline abdominal incisions. *Br J Surg* 89:1350–1356
5. O'Dwyer PJ, Courtney CA (2003) Factors involved in abdominal wall closure and subsequent incisional hernia. *Surgeon* 1:17–22
6. Pearl ML, Rayburn WF (2004) Choosing abdominal incision and closure techniques: a review. *J Reprod Med* 49:662–670
7. Ceydeli A, Rucinski J, Wise L (2005) Finding the best abdominal closure: an evidence-based review of the literature. *Curr Surg* 62:220–225
8. Diener MK, Voss S, Jensen K, Büchler MW, Seiler CM (2010) Elective midline laparotomy closure: the INLINE systematic review and meta-analysis. *Ann Surg* 251:843–856
9. Mayer AD, Ausobsky JR, Evans M, Pollock AV (1981) Compression suture of the abdominal wall: a controlled trial in 302 major laparotomies. *Br J Surg* 68:632–634
10. Höer J, Klinge U, Schachtrupp A, Töns C, Schumpelick V (2001) Influence of suture technique on laparotomy wound healing: an experimental study in the rat. *Langenbecks Arch Surg* 386:218–223
11. Höer JJ, Junge K, Schachtrupp A, Klinge U, Schumpelick V (2002) Influence of laparotomy closure technique on collagen synthesis in the incisional region. *Hernia* 6:93–98
12. Cengiz Y, Blomquist P, Israelsson LA (2001) Small tissue bites and wound strength: an experimental study. *Arch Surg* 136:272–275
13. Cengiz Y, Gislason H, Svanes K, Israelsson LA (2001) Mass closure technique: an experimental study on separation of wound edge. *Eur J Surg* 167:60–63
14. Millbourn D, Israelsson LA (2004) Wound complications and stitch length. *Hernia* 8:39–41
15. Harlaar JJ, van Ramshorst GH, Nieuwenhuizen J, Ten Brinke JG, Hop WC, Kleinrensink GJ, Jeekel H, Lange JF (2009) Small

- stitches with small suture distances increase laparotomy closure strength. *Am J Surg* 198:392–395
16. Millbourn D, Cengiz Y, Israelsson LA (2009) Effect of stitch length on wound complications after closure of midline incisions: a randomized controlled trial. *Arch Surg* 144:1056–1059
 17. Jenkins TPN (1976) The burst abdominal wound: a mechanical approach. *Br J Surg* 63:873–876
 18. Israelsson LA, Jonsson T (1993) Suture length to wound length ratio and healing of midline laparotomy incisions. *Br J Surg* 80:1284–1286
 19. Israelsson LA, Jonsson T, Knutsson A (1996) Suture technique and wound healing in midline laparotomy incisions. *Eur J Surg* 162:605–609
 20. Israelsson LA, Jonsson T (1997) Overweight and healing of midline incisions: the importance of suture technique. *Eur J Surg* 163:175–180
 21. Pollock AV, Greenall MJ, Evans M (1979) Single-layer mass closure of major laparotomies by continuous suturing. *J R Soc Med* 72:889–893
 22. Höer J, Lawong G, Klinge U, Schumpelick V (2002) Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years. *Chirurg* 73:474–480
 23. Israelsson LA, Jonsson T (1994) Physical properties of self locking and conventional surgical knots. *Eur J Surg* 160:323–327
 24. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG (1992) CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. *Infect Control Hosp Epidemiol* 13:606–608
 25. Pollock AV, Evans M (1989) Early prediction of late incisional hernias. *Br J Surg* 76:953–954
 26. Burger JW, Lange JF, Halm JA, Kleinrensink GJ, Jeekel H (2005) Incisional hernia: early complication of abdominal surgery. *World J Surg* 29:1608–1613