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Wound strength after midline laparotomy: a comparison of four closure techniques in rats

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ABSTRACT

The primary objective of this study was to determine which closure technique - simple interrupted suture (SIS), simple continuous suture (SCS), interrupted double loop closure (IDLC) or continuous double loop closure (CDLC) - results in stronger wound repair after midline laparotomy. Surgery was performed on 48 male rats. On the 5th postoperative day the rats were sacrificed and wound strength was measured by inserting a balloon into the abdomen and filling it with air until the abdomen burst. Pressure was measured in millimetres of mercury. Abdominal bursting pressure was 281.25 ± 26.5 mm Hg (mean ± SD) in the SIS group, 287.91 ± 29.6 mm Hg in the SCS group, 295.41 ± 31.9 mm Hg in the IDLC group and 314.58 ± 24.7 mm Hg in the CDLC group ($P<0.05$). Closure of the midline abdominal incisions using SCS has almost the same wound strength as SIS or IDLC but it is recommended because of simplicity, speed, and costs. CDLC ensures the greatest wound strength on the basis of the intraperitoneal pressure required to burst the abdomen. The results of the comparison of the SIS to SCS, as well as IDLC to CDLC, show that continuous suture techniques are more favourable than the interrupted suture techniques from which they were derived.

Key words: suture technique, laparotomy, wound strength, rat

Introduction

Wound dehiscence after midline laparotomy in human beings mostly appears between the fifth and eighth postoperative day (HÖGSTRÖM et al., 1990; SEID et al., 1995). Wound

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integrity in this period depends on the mechanical profile of the suture technique (MEEKS et al., 1995). Closure technique involves a choice of continuous versus interrupted suture, the size of fascial bites, distance between consecutive sutures (stitch interval), the length and size of the suture used (CARLSON and CONDON, 1995). The mechanical characteristics of different suture techniques have a direct influence on wound strength (POOLE et al. 1984; MEEKS et al., 1995a). Considering wound strength in interrupted versus continuous suture techniques there are numerous studies with contradictory findings (LARSEN and ULIN, 1970; MAXWELL et al., 1996; SANDERS et al., 1977). Simple interrupted suture (SIS) is a traditionally used technique for closure of laparotomy wounds in human and veterinary surgery (KUMMELING and VAN SLUIJS, 1998; ROSIN, 1985). The disadvantages of SIS are the greater amount of suture material used, and overall time involved in tying and cutting numerous knots (McNEILL and SUGERMAN, 1986). Suture material contained in SIS is mostly in the form of knots which makes that part of the tissue subject to foreign body reaction and wound infection (VAN RIJSSEL et al., 1989). Interrupted double loop closure (IDLC) and simple continuous suture (SCS) techniques are used often. Proponents of the IDLC credit enhanced wound strength to tension on the inner loops of suture, which keeps the incision edges in close approximation (MEEKS et al., 1995a). Wounds closed by IDLC can tolerate higher intra-abdominal pressures than those closed by the SCS technique (NIGGEBRUGGE et al., 1997). POOLE et al. (1984) and SEID et al. (1995) made similar tests and draw the opposite conclusion. The advantages of a continuous suture are speed, an equal distribution of tension, less foreign material in the wound, and less wound trauma (KUMMELING and VAN SLUIJS, 1998). With the aim of combining the advantages of simple continuous suture and interrupted double loop closure, a new suture technique, known as continuous double loop closure (CDLC), was first introduced experimentally in rats and then clinically in humans (NIGGEBRUGGE et al., 1997; NIGGEBRUGGE, 1999). The aim of this study was to compare the bursting strength of a midline laparotomy wound in the rat after closure using four different techniques. For each suture technique the time of suturing and the length of suture required to close the wound were measured.

Materials and methods

Animal model. The study used 48 male Fisher rats weighing 370 g ± 55 g, between 7 and 9 months old, randomized into 4 groups, 12 animals in each group. They were placed in cages, under the same conditions.

Rats were anaesthetized with ketamine hydrocloride (Narketan, Vetaquinol) 80 mg/kg and xylazine (Rompun, Bayer) 8 mg/kg administered intramuscularly.

The skin was incised from xyphoid to pubis, undermined and reflected from the underlying muscle fascias. The rectus sheath was exposed and imprinted with a stamp to demarcate a standardized 5 cm midline incision and loci for suture bites 5 mm and

2.5 mm from the incision edge (MEEKS et al., 1995a; SEID et al., 1995). Distance between sutures or suture interval along the incision line was 10 mm. The 12 stabbing points at 5 mm from the linea alba in SIS and SCS technique and 24 stabbing points at 2.5 and 5 mm from linea alba in IDLC and CDLC technique were marked by the stamp. A longitudinal midline incision was made in the linea alba of the rectus sheath and in the peritoneum.

Suture techniques. Surgical procedures were carried out by the same surgeon. The suturing technique was determined by random assignment. Each time just before wound closure a closed envelope with selected suture technique was opened. The laparotomy wound was closed with one of the following techniques: simple interrupted suture (SIS), simple continuous suture (SCS) (Fig. 1), interrupted double loop closure (IDLC) and continuous double loop closure (CDLC). Wound closure was started from the cranial end of the incision. Suture interval was 1 cm for all techniques. The abdominal wall in the SIS and SCS closure technique was perforated 12 times. Suture bites were 5 mm from the incision edge. In the IDLC and CDLC closure the needle perforated the abdominal wall 24 times. Far bites were placed 5 mm and near bites were placed 2.5 mm from the edge of the incision. All sutures passed through all musculoaponeurotic layers and peritoneum. Interrupted sutures were tied with a 2x1x1 square knot. Continuous sutures were anchored at the cranial pole of the wound with a 2x1x1x1 square knot and at the caudal pole of the wound with a 2×1×1×1×1 square knot. The sutures were tied with just enough tension to loosely approximate the rectus sheath. All knots were positioned away from the incisional region in order not to interfere with the regenerative process. All wounds were closed with USP 4-0 absorbable monofilament polydioxanone (PDS® II, Ethicon) with a swaged on 16 mm tapercut needle. The time for abdominal closure was recorded in seconds from initial suture placement until the last knot was cut. The suture length required to close the wounds was determined by suture length along the wound, in the knots and in the knot ends (ears). The knot end was approximately 3 mm. The skin was closed by SCS, with non-absorbable USP 5-0 monofilament polypropylene suture (Prolene®, Ethicon). The rats received three subcutaneous injections of flunixin meglumine (Fynadine, Essex Tierarznei) 1 mg/kg approximately 8 hours apart for postoperative analgesia.

Abdominal wound strength. On the 5th postoperative day animals were euthanized by carbon dioxide asphyxiation. Abdominal wound strength was determined by combination of the methods reported by POOLE et al. (1984) and UDUPA and CHANSOURIA (1969), partially modified. The first part of the method that concerns corpse preparation for the intra-abdominal pressure measurement relies on the method reported by POOLE et al. (1984). We used an arthrotom for rectal perforation and balloon placement in the abdominal cavity. A rectal perforation was made by a trocar originally used for arthrotomy. The arthrotome was then connected to the trocar, covered with the balloon and placed through the perforated rectum into the abdominal cavity. A nylon cord was tied around the lower abdomen to prevent inguinal herniation (SANDERS et al., 1977; MEEKS et al., 1995a). The other (second) part of the method that concerns intra-abdominal pressure measurement relies on the method reported by UDUPA and CHANSOURIA (1969). A blood pressure manometer was connected to the arthrotome (Fig 4). With a manometer pump normally used for blood-pressure measurement, the balloon was gradually inflated until the abdominal wall ruptured (Fig. 5). The highest intra-abdominal pressure before rupture was recorded in millimetres of mercury (mm Hg). The site and manner of abdominal wound rupture was documented and classified as (1) midline herniation between suture loops, (2) suture tearing through the tissue, (3) midline herniation rupture due to poor knot security and (4) rupture away from the midline incision.

Statistics. Dehiscence pressure, length of suture and surgical time were compared for the four closure techniques with multiple analyses of variance (MANOVA). The minimum level of significance was defined as P<0.05. Significant differences were further investigated using a multiple comparison test (least-square difference -LSD- test).

Results

Dehiscence pressure. Abdominal wall sutured by SIS tolerated the intra-abdominal pressure of 281.25 ± 26.5 mm Hg (mean ± SD) until the moment of rupture. The intraperitoneal pressure required to burst the abdomen closed by SCS was 287.91 ± 29.6 mm Hg; for the one closed by IDLC required pressure was 295.41 ± 31.9 mm Hg, and by CDLC was 314.58 ± 24.7 mm Hg.

The highest intra-abdominal pressure that the abdominal wall sutured by CDLC could tolerate was significantly higher than those sutured by SIS or SCS (P<0.05). Differences between other closure techniques were not significant (Fig. 1).

Table 1. Type of rupture versus closure technique

Type of rupture	SIS	SCS	IDLC	CDLC
Herniation between suture loops		1		1
Suture tearing tissue	12	8	11	7
Poor knot security		1		
Away from the wound		2	1	4

Type of rupture. The site and manner of abdominal wound rupture on the basis of suture technique was recorded (Table 1). In 37 cases the wound dehiscence was caused by suture tearing through the tissue: all 12 in the SIS group, 8 in the SCS group, 11 in the IDLC group and 6 in the CDLC group. Two animals had midline herniation of the balloon between suture loops: 1 in the SCS group and 1 in the CDLC group. Poor knot security as the reason for wound dehiscence occurred only once, in the SCS group. Seven animals were found to have ruptures at sites away from the midline: two in SCS group, 1 in the IDLC group and 4 in the CDLC group (Table 1).

Time of suturing. The time required to close the abdominal incision was significantly different for each tested suture technique (P<0.05). Suturing by SIS required 530.33 ± 37.5 sec (mean ± SD); suturing by SCS required 310.33 ± 20.5 sec; by IDLC 757.66 ± 41.9 sec, and suturing by CDLC required 757.66 ± 41.9 sec.

Length of suture. The length of suture material used was significantly different for each suture technique (P<0.05). Suturing by SIS required 23.7 ± 2.2 cm (mean ± SD) of suture material; by SCS 17.16 ± 0.9 cm; by IDLC 30.04 ± 2.1 cm, and suturing by CDLC required 25.41 ± 1.7 cm.

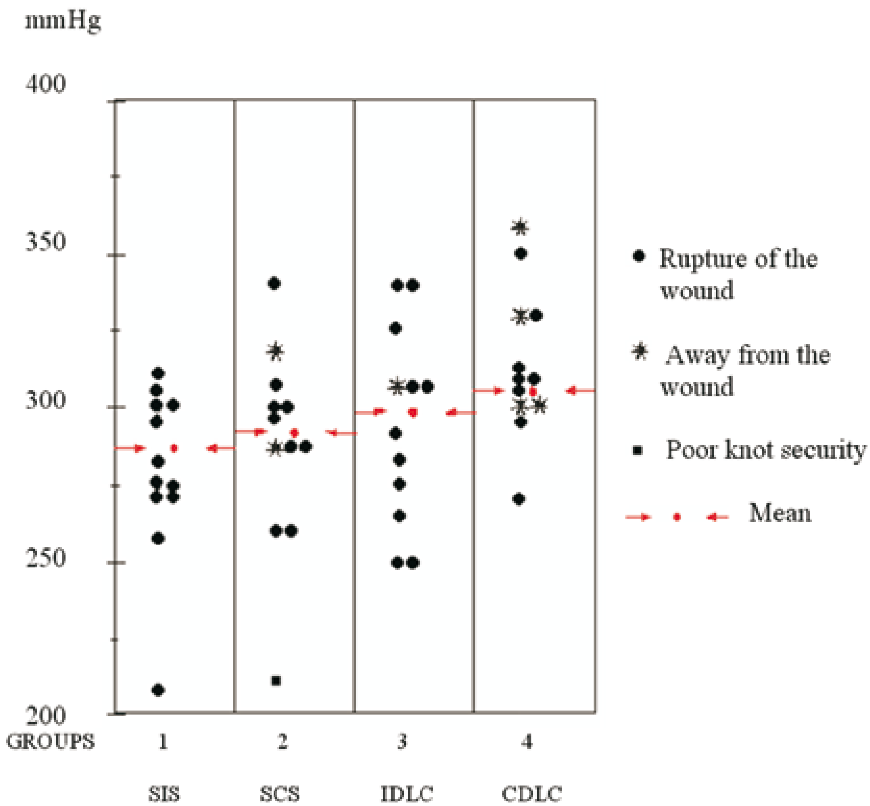

Fig. 1. Maximal intra-abdominal pressure until the rupture of the abdominal wall in all rats divided in four groups (mm Hg)

Fig. 2. SCS technique after midline laparotomy closure

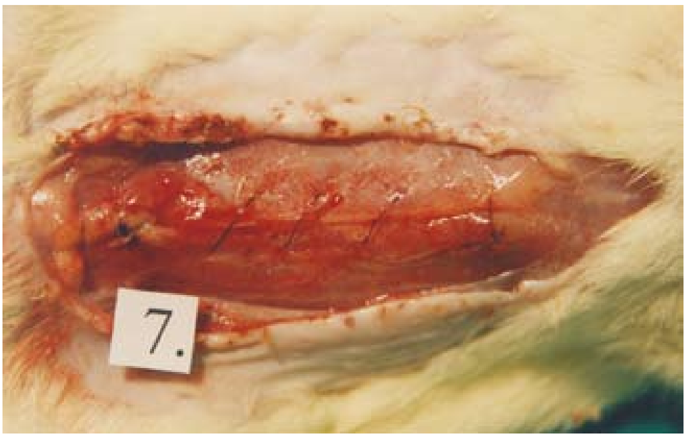

Fig. 3. SCS technique on the 5th postoperative day

Fig. 4. Modification of classic blood pressure manometer connected to the arthrotome and balloon used for measurement of intraabdominal pressure.

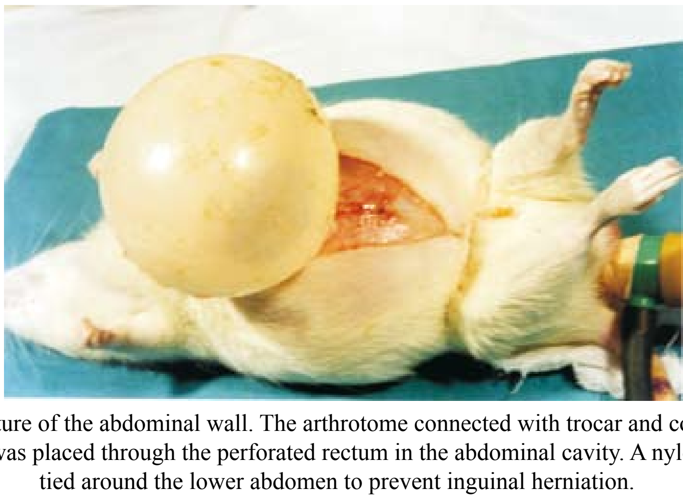

Fig. 5. Rupture of the abdominal wall. The arthrotome connected with trocar and covered with the balloon was placed through the perforated rectum in the abdominal cavity. A nylon cord was tied around the lower abdomen to prevent inguinal herniation.

Discussion

Strength of the healing wound can be measured by several methods (ROSIN and RICHARDSON, 1987). There are two mechanical reasons for abdominal wound rupture: intra-abdominal pressure is too high, or the bursting strength of the wound is too low (EFRON, 1965). This led us to study wound strength of the abdominal midline incision on the basis of intra-abdominal pressure required to burst the abdomen.

The mechanical characteristics of different suture techniques have a direct influence on wound strength (POOLE et al., 1984). Problems in biomechanical testing of soft tissue strips include crushing of tissue and failure at the grip, and variation of mechanical parameters with regard to time after sacrifice, and storage temperatures (ROSIN and RICHARDSON, 1987). Methods of measuring wound strength *in vivo* more closely correspond to clinical situations. Accordingly, we decided to use the methods reported by UDUPA and CHANSOURIA (1969) and POOLE et al. (1984). Both methods use sutured midline laparotomy wounds in rats as a wound model. We think that a placement of needle with an attached balloon through a stab wound in the abdominal wall affects the bursting strength of the abdominal wall. Instead, in that part of study we used the method described by POOLE et al. (1984). Our modification was the use of an arthrotome to make a rectal perforation and to place a balloon in the abdominal cavity, which prove simple and efficient.

The time of abdominal wound dehiscence is usually between the 5th and 8th postoperative day (SANDERS et al., 1977). In similar studies wound strength was measured on the 7th postoperative day (MEEKS et al., 1995a; SEID et al., 1995). The healing process, mainly associated with cross-linking of new collagen, does not really begin until 5-8 days after surgery (HUGH, 1990). Fibroblastic activity begins at approximately the 4th day after wounding (STONE et al., 1986). It is obvious that wound rupture in this period represents a failure of suture technique. On the basis of these facts we decided to measure wound bursting strength on the 5th postoperative day.

Wound studies historically have used rabbits, rats and piglets. Wound strength in rats is most equivalent to humans (MEEKS et al., 1995). We used an investigatory animal that best approximates the human situation. Although caution should be exercised in extrapolating experimental animal data to other species or humans, these results are applicable to clinical situations.

Suture length: wound length (SLWL) ratio depends on the size of tissue bites, the distance between bites and tension on the suture (ISRAELSSON and JONSSON, 1993). In order to compare different suture techniques we kept suture intervals and suture bites the same for all closure techniques. Due to that study design the SLWL ratio in our SCS technique was 3.43, slightly less than the recommended ratio (JENKINS, 1976). The mean SLWL ratio in clinical use of SCS on human midline laparotomy usually amounts to

3.6 (ISRAELSSON and JONSSON, 1993). It could be assumed that strict application of the Jenkins rule in this study would result in greater bursting strength than in our SCS technique. In that case a greater number of stitches and larger suture bites are consequences that would have confounding influences on assessment of suture techniques in this study. That is the object of other similar studies (HÖER et al., 2001).

In this study abdominal wounds sutured by SCS technique withstand higher intra-abdominal pressure than by SIS or by IDLC technique, but those differences had no statistical significance (P>0.05). Reduction in operative time may have a significant impact on morbidity and mortality of the animal (ROSIN, 1985). Suture material makes the tissue subject to foreign body reaction and wound infection (VAN RIJSSEL et al., 1989). Closure with SCS technique according to this study is 41.5% faster and the length of suture is 27.6% reduced in comparison to SIS technique.

Different methods of measuring intra-abdominal pressure showed that wounds closed by CDLC technique could resist higher intra-abdominal pressure than those reconstructed by SCS technique (MEEKS et al., 1995a). Results of this study confirm that conclusion. Wounds closed by CDLC technique can tolerate significantly higher (9.3%) intra-abdominal pressures than wounds closed by SCS. However, the cost of this advantage is 82.9% prolonged time of suturing and 48% greater length of suture material. The mean SLWL ratio was higher in CDLC technique (5 : 1) than in SCS technique (3.4 : 1).

Wounds reconstructed by CDLC can tolerate higher intra-abdominal pressures than those sutured with IDLC, but that difference is not statistically significant (P>0.05). The time of suturing is essentially shorter (33.45%) and length of suture is considerably less (18.2%), both making the CDLC technique favourable.

The type of abdominal rupture provides an additional parameter to compare methods of closure. Wound dehiscence due to sutures tearing through the tissue occurred in 77% of cases. However, this type of rupture was more frequent in interrupted closure techniques. All the cases of SIS and 11 of 12 cases of IDLC group showed this type of rupture. Knots used on the beginning and at the end of continuous sutures are well-disposed to knot slippage and untying (ROSIN and ROBINSON, 1989). Poor knot security appears to be a minor cause of dehiscence if adequate knot tying technique is applied, as we demonstrated in this study. However, one case of rupture with minimal intraperitoneal pressure due to knot slippage in the SCS group suggests that inadequate knot tying could cause wound dehiscence. Rupture of the abdominal wall away from the midline incision is an additional parameter that indicates a stronger wound. Abdominal ruptures have occurred at a site away from the incision in 2 out of 12 tests (16.7%) sutured by SCS technique, and in 4 out of 12 (33.3%) cases sutured by CDLC technique. This indicates that incisions reconstructed by continuous suture could be as strong as the other intact part of the abdominal wall.

Conclusions

On the basis of the intraperitoneal pressure required to burst the abdomen, closure of the abdominal midline incisions using SCS technique has the same wound strength as with SIS or IDLC technique.

The CDLC technique ensures the greatest wound strength, but requires a longer suturing time and more suture material in comparison with SCS technique.

Considering abdominal midline wound strength, time of suturing and length of suture, continuous suture techniques are preferable to the interrupted suture techniques from which they were derived.

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SAŽETAK

Glavna svrha ovog istraživanja bila je određivanje koja od pretraživanih kirurških tehnika šivanja, jednostavnim pojedinačnim šavom (SIS), jednostavnim produžnim šavom (SCS), pojedinačnim šavom s dvije omče (IDCL) ili produžnim šavom s dvije omče (CDLC), dovodi do snažnije rane nakon laparotomije u bijeloj liniji. Operacije su izvedene na 48 štakorskih mužjaka. Petoga dana nakon operacije životinje su žrtvovane, a snaga rane bila je mjerena umetanjem balona u trbušnu šupljinu i upuhivanjem zraka do trenutka rupture trbušne stijenke. Intraabdominalni tlak mjeren je u milimetrima žive. Intraabdominalni tlak u času rupture iznosio je 281,25 ± 26,5 mm Hg u SIS skupini, 287,91 ± 29,6 mm Hg u SCS skupini, 295,41 ± 31,9 mm Hg u IDLC skupini i 314,58 ± 24,7 mm Hg u CDLC skupini ($P<0{,}05$). Šivanjem incizijske rane u bijeloj liniji SCS tehnikom postiže se gotovo ista snaga rane kao šivanjem SIS ili IDLC tehnikom, zato se ona preporučuje osobito zbog jednostavnosti i brzine izvođenja te manjih troškova. CDLC tehnika omogućuje postizanje najveće snage rane s osnove intraabdominalnog tlaka potrebnog za nastanak rupture trbuha. Rezultati usporedbe jednostavnog produžnog šava s jednostavnim pojedinačnim (čvornim) šavom, kao i usporedbe produžnog šava osmice s pojedinačnim šavom osmice idu u prilog produžnih šavova.

Ključne riječi: kirurška tehnika šivanja, laparatomija, čvrstoća rane, štakor