Incisional Hernia

New approaches and aspects

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Contents

1

Introduction and thesis outline

INTRODUCTION

This thesis is about the anatomy, diagnosis, treatment and outcome of incisional hernia. New approaches and aspects are discussed in the following chapters.

Definitions

The following definitions were derived from Butterworth's medical dictionary [1]. A hernia is the protrusion of an internal organ through a defect in the wall of the anatomical cavity in which it lies. An abdominal hernia is the protrusion of abdominal content through the abdominal wall. A ventral hernia is any hernia protruding through the abdominal wall. An incisional hernia is a hernia protruding through an operation scar. Incisional hernias can be classified according to their localization [2].

Abdominal hernias include groin (i.e. inguinal and femoral) hernias and ventral hernias. Ventral hernias include umbilical, incisional, epigastric and spigelian hernias. This thesis is restricted to incisional hernias through midline incisions.

Anatomy

The ventral abdominal wall consists of two rectus abdominis muscles on each side of the linea alba. The rectus muscle is enveloped in a fascial layer consisting of the anterior and posterior rectus fasciae, which join in the median line with the other side to form the linea alba. The deepest layer of the abdominal wall is the parietal peritoneum, which is separated from the posterior rectus sheath by preperitoneal fat. However, the posterior rectus fascia does not extend to the pubic symphysis. This limit of the posterior layer of the rectus abdominis muscle sheath is called the semicircular or arcuate line of the rectus sheath. Below the semicircular line, the preperitoneal space contains a bilaminar fascia complex [3]. The ventral component of this bilaminar fascia complex is also known as the posterior lamina of the transversalis fascia.

Diagnostic tools such as ultrasonography (US), computed tomography (CT) and magnetic resonance imaging (MRI) are commonly used for imaging of the ventral abdominal wall [4-6].

In chapter two, US and CT results are discussed to pre- and post-operatively identify the separate layers of the abdominal wall in relation to hernia surgery [7].

Incidence

The published incidence of primary incisional hernia varies; it depends not only on the study type but also on patient characteristics. For instance, morbidly obese patients have a high incidence of primary incisional hernia. Another important factor is whether the incisional hernia diagnosis is made clinically or based upon imaging techniques. A prospective study with a follow-up time of ten years showed a clinically established incisional hernia incidence of 11% (37 cases out of 337 patients)[8]. These patients had undergone elective major abdominal surgery of the gastrointestinal tract, biliary tree or colon. On the other hand, Sugerman et al.

prospectively observed 19% (n=198) clinically diagnosed primary incisional hernias in a group of 968 morbidly obese gastric bypass patients with an 87% follow-up rate after one year [9].

The use of imaging techniques yields a higher incidence of incisional hernia; for instance, in a study [10] comparing ultrasonography (US) and magnetic resonance imaging (MRI), an incisional hernia incidence of 31.7% was found following reconstruction for abdominal aortic aneurysms after a mean follow-up time of 48.6 months. Because of this high incidence, we chose to compare computed tomography (CT) and ultrasonography (US) in the diagnosis of incisional hernia in patients after reconstruction of abdominal aortic aneurysms. This study is described in chapter three of this thesis [11].

Prevention

Initially, the incision type is significant for prevention of incisional hernias. In this regard, the lateral paramedian incision is superior to the median incision [12]. A Cochrane review showed no difference between transverse and midline incisions in the occurrence of incisional hernia [13]. This conclusion was confirmed in a recent randomized controlled trial (RCT) [14]. However, Fassiadis et al. found a higher incidence of incisional hernia after full-length midline incisions as compared to transverse incisions for aortic aneurysm repair [14]. Halm et al. reported an incisional hernia incidence of 14% after midline incisions versus 2% after transverse incisions for cholecystectomy after a minimum follow-up time of 12 months [15].

In addition to incision type, the abdominal wall closure method is important for prevention of incisional hernias. A number of meta-analyses have shown that mass closure with a continuous non- or slowly absorbable suture is the best technique for preventing incisional hernias [16-19]. Although there is no strong evidence from randomized clinical trials, prospective clinical studies and experimental evidence support the use of a suture length:wound length ratio of at least 4:1 [20;21]. To arrive at a closure suture length of four times the incision length, the bites must encompass one centimeter of tissue at one-centimeter intervals.

When using a simple cost comparison in the decision analysis model of Cheng et al., the higher incidence of incisional hernia following open versus laparoscopic abdominal surgery results in additional treatment costs [22].

The topic of this thesis is restricted to incisional hernias after midline incisions.

Risk factors and etiology

There are many risk factors associated with the occurrence of a primary incisional hernia. The major risk factors are either patient-related, such as obesity, wound infection, chronic lung disease, type II diabetes mellitus, male gender, age, smoking, malnutrition, steroids, chemotherapy, anemia and relaparotomy, or surgeon-related, such as the wound closure method [23;24].

The association between inguinal and incisional hernia and abdominal aortic aneurysms suggests a collagen disorder. An abnormal collagen I/III ratio and reduced MMP-1/MMP-2 ratios have been found in the fascia of patients with (recurrent) incisional hernias [25;26]. Primary closure

of midline incisions using mesh in operations with a high risk of incisional hernia reduces the incidence of incisional hernia[27-29]. According to reports by Irvin et al. [30] and Bucknall et al. [31], dehiscence and herniation occur significantly more common in wounds that are closed by surgeons in training.

Hesselink et al. retrospectively studied the risk factors for developing a recurrent incisional hernia in patients who mainly underwent direct open suture techniques. The only risk factor for recurrent incisional hernia was hernia size: hernias smaller than four centimeters had a lower recurrence rate than hernias larger than four centimeters (25% versus 41%) [32]. Langer et al. also found hernia size to be a risk factor for recurrent incisional hernia, but stronger risk factors were BMI > 25 and the surgeon's experience [33;34]. In a retrospective study, Anthony et al. found obesity to be a risk factor for recurrent incisional hernia [35].

The most important risk factor for recurrence, however, is the technique used for repairing the incisional hernia. In a randomized clinical trial, the 10-year cumulative recurrence rate was 63% for suture repair and 32% for mesh repair [36]. Even for small hernias (less than 10 cm^2), the recurrence rate is high when direct suture repair is used (67% after 10 years) [36]. We performed a meta-analysis of different open surgical procedures for incisional hernias using recurrence rate as the primary outcome measure. This Cochrane review is described in chapter four of this thesis [37].

Signs and symptoms

Incisional hernia has been clinically defined as "a bulge, visible and palpable when the patient is standing, and often requiring support or repair" [38]. This bulge, which is located over or near the scar of a ventral abdominal wall incision and enlarges during standing, is the usual clinical presentation. In time, incisional hernias become larger. The signs and symptoms of incisional hernias have not been studied systematically. In a literature review concerning the natural course of incisional hernia, this lack of information was underscored [39]. According to this review, many incisional hernias (47-88%) are asymptomatic. In this review, strangulation or incarceration in incisional hernias was mentioned as an indication for operation in 6-14.6% of cases. Trophic ulcers were observed in 3.25% of giant incisional hernias (33 out of 1018 cases) [40]. Courtney described the presentation of 60 incisional hernias, of which 82% were primary incisional hernias [41]. The indications for operation in this study were pain in 83%, incarceration in 5% and enlargement in 3% of cases. In 3% of these patients, the indication for operation was not specified. Ramirez et al. observed severe back pain in four out of 11 patients with large abdominal wall defects [42]. The back pain disappeared after Ramirez' components separation technique was used to close the defects.

Pulmonary function is seldomly used as an outcome parameter in surgical repair studies for incisional hernias. However, preoperative ventilatory function has been described in some reports. Munegato et al. studied preoperative spirometry in 10 patients with large median incisional hernias and found restrictive and obstructive bronchopneumopathy (vital capacity and

forced expiratory volume in one second = FEV_1 reduced) [43]. Rives et al. examined pulmonary function prior to operation in 33 patients with large ventral hernias [44]. In 14 cases, a reduced expiratory vital capacity (reduction of the Tiffeneau value = FEV_1/IVC = ratio between forced expiratory volume in one second and inspiratory vital capacity) was found. No RCTs regarding simple pulmonary function tests or spirometry in a group of patients before and after surgical repair of incisional hernias could be found in the literature.

Operative treatment of large incisional hernias increases intra-abdominal pressure (IAP). This elevation in IAP results in a decrease in cardiac output, which is caused by a decrease in the venous return [45]. High IAP can decrease cardiac and pulmonary function during and after repair of large incisional hernias, especially in patients with obesity and chronic obstructive pulmonary disease. This increased IAP and changes in respiratory function should be avoided during surgical repair of incisional hernias, which can initially be achieved by punctual monitoring of hemodynamic parameters to detect a fall in cardiac output. Then, if necessary, the systematic venous return can be increased by infusion with crystalloids and colloids, and cardiac output can be improved with a dopamine infusion.

Treatment and outcome

In general, an incisional hernia is considered an indication for operation [46], but some surgeons prefer a wait-and-see policy [47].

Incisional hernia repairs can be performed using either open or laparoscopic techniques [48]. The open technique may consist of a simple hernioplasty (e.g., Mayo duplication or fascia-adaptation), components separation technique or mesh repair. The components separation technique is based on enlargement of the abdominal wall surface by separation and advancement of the muscular layers. The mesh can be placed using onlay (prefascial/subcutaneous, Sandwich or Chevrel technique), sublay (retromuscular or preperitoneal) or inlay ("bridging") techniques. The mesh can be used for augmentation in combination with closure of the fascia or as a bridging mesh between the fascial edges. The sublay technique has been described and popularized by Flament, Rives and Stoppa and has been adopted by the European Society of Hernia Surgery as the standard open repair procedure. In an inlay ("bridging") repair, the fascia is not approximated, but the gap is closed by mesh. Laparoscopic ventral hernia repair is an intraperitoneal underlay technique with placement of mesh that is secured with a tagging device and/or transabdominal sutures. Recently, sealants have been used for mesh fixation. Advocates of the laparoscopic technique emphasize low recurrence rates, shorter hospital stays, decreased infection rates and reduced wound complications. Opponents of the laparoscopic approach refer to the restoration of normal abdominal wall function and cosmetic improvement of the abdomen (e.g., excision of excess tissue and scar tissue), which are not accomplished by laparoscopic repair [46]. The aforementioned advantages of laparoscopic incisional hernia repair, such as reduced lengths of hospital stay and lower wound infection rates, were confirmed by a meta-analysis in 2006 [49]. A more recent meta-analysis found that laparoscopic repair of ventral

and incisional hernias is at least as effective (in terms of hernia recurrence, seroma formation, hemorrhagic complications, bowel injury and infection requiring mesh removal) if not superior (in terms of wound infection without mesh removal) to the open approach for a number of outcomes [50]. The operation time for laparoscopic incisional hernia repair was significantly longer (p=0.009) than for open repair in randomized controlled trials [49;51]. However, this conclusion was not confirmed by the meta-analysis of Sajid et al [52]. The RCT with the largest sample size (n=170) in this meta-analysis showed a significantly shorter time for laparoscopic repair [53].

In two randomized, controlled trials, no difference was found in operation duration between lightweight and heavyweight mesh, and between onlay and sublay techniques in open hernia repairs with mesh [54;55]. Data from a cohort study of ventral hernia outcomes from the Veterans Affairs Medical Center showed a shorter duration time of surgery for open suture as compared to open mesh repair (60 versus 105 minutes) [56].

The mesh used for incisional hernia repair consists of either autoplastic or alloplastic material. In an autoplastic graft, a cutis flap is used (skin autograft hernioplasty). Synthetic mesh can be further classified into three types [57]. Prosthetic meshes are divided into macro- and microporous meshes according to their pore sizes. Type I mesh is a totally macroporous prosthesis consisting of monofilament or double filament polypropylene. Type II mesh is a completely microporous prosthesis, such as expanded polytetrafluoroethylene (PTFE). Type III mesh is a mixed prosthesis consisting of a macroporous prosthesis with multifilamentous or microporous components, such as PTFE mesh. In a retrospective cohort study of 200 patients undergoing open repair of incisional hernias with different prosthetic materials, the long-term complications were chronic infection/sinus tract in 6% of patients, small bowel obstruction in 5% and enterocutaneous fistula in 4% [58]. Halm et al. reported a complication rate of 76% after intraperitoneal placement of polypropylene mesh [59]. Therefore, for the intraperitoneal mesh position in laparoscopic repair, a composite mesh with coating is advisable.

A Cochrane review in 2007 regarding wound drainage after incisional hernia repairs concluded that there is insufficient evidence to determine whether wound drains are associated with better or worse outcomes [60].

Little is known about abdominal wall function after abdominal surgery. No studies were found in the literature describing rectus abdominis function in relation to hernia correction. Assessment of the rectus abdominis muscle can be performed by ultrasound and isokinetic strength measurements [61-64]. The theoretical advantage of placing the rectus muscles in their normal median position during three-layered closure repair is that they can perform their normal function.

Israelsson concluded in a prospective cohort cost analysis study that the costs for suture repair were higher than for mesh repair (6.122 versus 5.458 Euro) [65]. In a cost-utility analysis by Finan et al., open mesh repair was a more effective treatment than open suture repair based on small incremental costs of 1.878 dollars for prevention of one recurrent incisional hernia [66]. For this study, data retrieved from the literature were used in a decision analysis model (recurrence

rate mesh versus suture repair, 26% and 44%, respectively). In a randomized, controlled trial with a one-year follow-up time, the most cost-effective strategy in terms of recovery and return to work was laparoscopic hernia repair [51].

In chapter four of this thesis, a Cochrane review is presented [37]. The primary objective of this review was to identify the best available open operative techniques for repairing incisional hernias.

Chapter five is a retrospective analysis of open suture repairs of incisional hernias without using mesh [67]. This analysis was performed because we had the clinical impression that their results were better than those reported in the literature.

The muscular function of the abdominal wall after open and laparoscopic incisional hernia repairs was studied, and the results are presented in chapters six and seven.

Quality of life is rarely used as an outcome measure for hernia repair. For this reason, we conducted a study comparing pre- and long-term post-operative quality of life. This study is introduced in chapter eight.

Chapter nine is a case report describing a patient with an acute traumatic abdominal wall hernia (TAWH). Case reports are classified as the lowest level of evidence for making clinical decisions. However, case reports and case series can still play important roles in "the recognition and description of new diseases, detection of drug side effects (adverse or beneficial), study of the mechanism of disease, medical education and audit and the recognition of rare manifestation of disease" [68]. This case report is important because of the difficulties in diagnosing TAWH after a high-energy trauma as well as the discussion about the best available treatment for this extensive abdominal wall rupture. It is also interesting and important for educational purposes and for reviewing the performance of the involved surgical team.

THESIS OUTLINE

Chapter one presents the introduction and thesis outline.

Chapter two presents an ultrasonography study of the abdominal wall in controls and patients with incisional hernias before and after suture repair.

Chapter three presents a comparison between computed tomography (CT) and ultrasonography (US) in the diagnosis of incisional hernia in patients after reconstruction of abdominal aortic aneurysms.

Chapter four is a systematic Cochrane review that identified the best available open operative techniques for repairing incisional hernias.

Chapter five consists of a retrospective analysis of open suture repair of primary and recurrent incisional hernias without using mesh.

Chapter six presents a prospective study evaluating the muscular function of the abdominal wall by isokinetic strength measurements after open incisional hernia repair without using mesh.

Chapter seven describes the muscular function of the abdominal wall by isokinetic strength and ultrasound measurements after open and laparoscopic incisional hernia repair using mesh.

Chapter eight presents a study comparing pre-operative and long-term post-operative quality of life in patients after open suture repair of incisional hernias.

Chapter nine is a case report about an acute traumatic abdominal wall hernia caused by a high-energy trauma.

Chapter ten includes the discussion.

Chapter eleven includes the summary.

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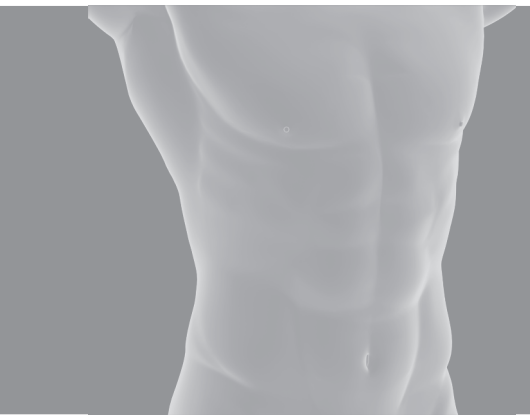

2

Pre-, intra-, and postoperative sonography of the abdominal wall in patients with incisional hernias repaired via a three-layered operative suture method

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ABSTRACT

We illustrate the various sonographic (US) appearances of the abdominal wall following this type of repair, including partial and complete recurrences. Correlation is made with CT imaging. The three-layered anatomical reconstruction of an incisional hernia is described.

INTRODUCTION

Incisional hernias, which are hernias that occur through a surgical scar in the anterior abdominal wall, are serious complications of abdominal surgery. Incisional hernias occur in 11%-23% of laparotomies[1] and can lead to serious morbidity from strangulation or incarceration in 6%-14.6% of cases.[2] Frequently, their diagnosis can be made through clinical examination, but small hernias and hernias in obese patients can be difficult to diagnose, which makes sonography (US) or CT imaging critical. The recurrence rate of incisional hernias after open suture repair may be as high as 54%,[3] and for open mesh repair specifically, recurrence rates can be up to 32%.[4] To decrease the recurrence rate, we developed a method that combines three-layered closure repair with extensive adhesiolysis. Using this repair method without mesh, we achieved recurrence rates that are comparable with the mesh procedure.

To determine the feasibility of this operation, however, it is important to examine and assess the quality and anatomic position of each abdominal wall layer. Five patients from our surgical department were selected between November 2006 and January 2008 for this pictorial essay. All US examinations were performed with an Aplio XG, model SSA-796A scanner (Toshiba Medical Systems, Tokyo, Japan) and 5-12 MHz PLT-1204AX linear transducer. CT examinations were performed with an Asteion 4-slice helical scanner (Toshiba Medical Systems) with typical acquisition protocols and sagittal and coronal reconstructions.

The aim of this pictorial essay is to describe US anatomy of the abdominal wall before, during and after the three-layered anatomic reconstruction of an incisional hernia.

NORMAL ANATOMY OF THE ABDOMINAL WALL

The normal anatomy of the abdominal wall is shown a 55-year-old male who had not previously undergone abdominal surgery and was admitted for resection of a colonic carcinoma. He underwent preoperative CT and US examinations of the abdominal wall (Figure 1).

The abdominal wall was opened through a midline incision. After opening the abdominal cavity, intraoperative US (IOUS) was performed to examine the abdominal wall adjacent to the incision. The median portion of the ventral abdominal wall consists of the two rectus sheaths. Each rectus sheath includes a rectus muscle between the anterior and posterior rectus fasciae, which join with the other side at the median line to form the linea alba. IOUS could differentiate between the peritoneum and the posterior rectus fascia after opening the rectus sheath and placing a forceps between the peritoneum and the rectus sheath (Figure 2).

US and CT were repeated postoperatively to show the healed median incision (Figure 3). After a midline incision, the linea alba usually heals, and the 2 rectus muscles remain separated.

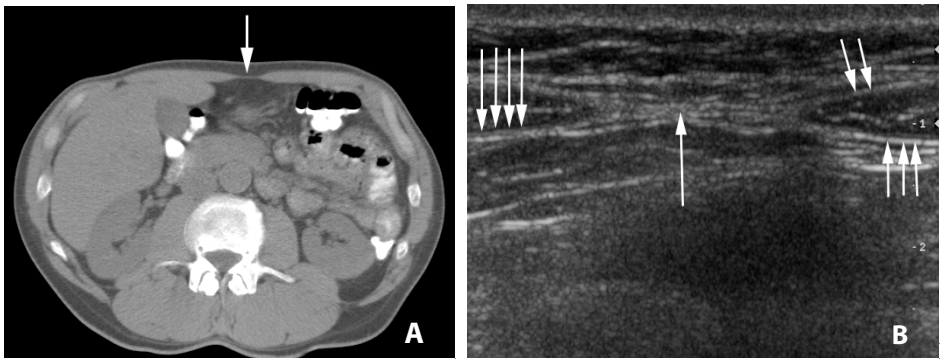

Figure 1 (A) Preoperative CT scan of a 55-year-old male shows the anatomy of the ventral abdominal wall and the linea alba (arrow) on the midline. On both sides of the linea alba are the rectus muscles. **(B)** Preoperative transverse sonogram shows the linea alba (arrow) on the midline. On both sides of the linea alba are the rectus muscles with anterior rectus fascia (two arrows). The peritoneum is marked with triple arrows, and immediately in front of the peritoneum is the posterior rectus fascia, a thinner line marked with four arrows.

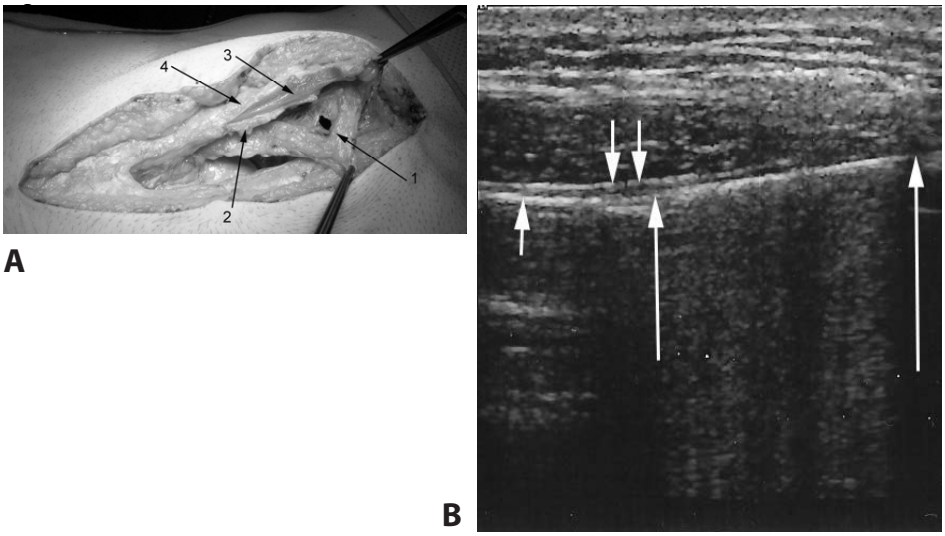

Figure 2 (A) Intraoperative photograph shows the anatomy of the abdominal wall through a midline incision. The lower forceps are holding the peritoneum with preperitoneal fat (arrow 1), which is separate from the posterior rectus fascia (arrow 2). The opened rectus sheath shows the rectus muscle (arrow 3) and the anterior rectus fascia (arrow 4) towards patient's head. **(B)** Intraoperative sonogram. The transducer is placed on the skin, in a transverse position to the right of the midline incision. The rectus sheath has been cut, and forceps (straight white line between the two long arrows) is shown between the posterior rectus fascia (two small arrows) and the peritoneum (one small arrow). The forceps was used to ensure that the anterior interface was the rectus fascia and the posterior one was the peritoneum.

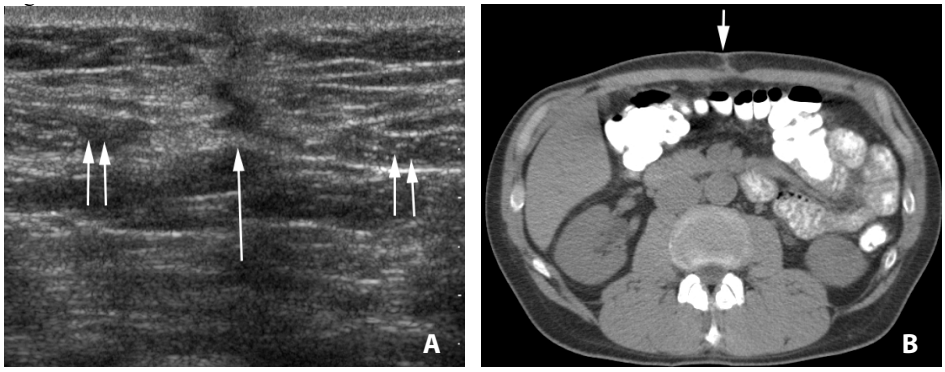

Figure 3 (A) Postoperative sonogram shows the anatomy of the midline abdominal wall after closure, the healing of a median incision, the healed linea alba (one arrow) within the midline, and scar tissue above the fascia of the linea alba. On both sides of the linea alba are the rectus muscles (double arrow) with their anterior and posterior rectus fasciae. **(B)** Postoperative CT shows the anatomy of the ventral abdominal wall after closure and healing of a median incision, the healed linea alba within the midline, and scar tissue (arrow) above the fascia of the linea alba.

INCISIONAL HERNIA AFTER MEDIAN INCISION

Incisional hernia after a median incision is shown in a 67-year-old male who had developed an incisional hernia after undergoing aortic-iliac reconstruction for arterial occlusive disease 5 years earlier (Figure 4).

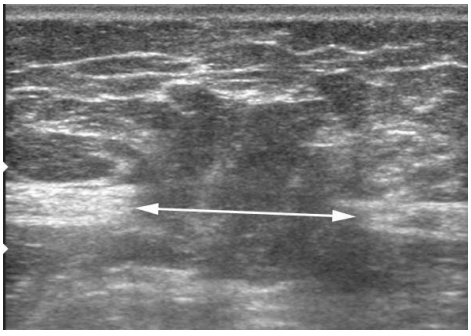

Figure 4. Preoperative transverse sonogram of an incisional hernia after reconstruction of an aortic-iliac occlusion that occurred 5 years previously shows a defect of the linea alba (double arrow) with a protrusion of the hernial sac consisting of preperitoneal fat.

The progressive enlargement of the hernial sac shifts the rectus muscles laterally. During real-time US examination, the protrusion of the hernial sac can be augmented when the patient performs a Valsalva maneuver.

THREE-LAYERED DIRECT SUTURE REPAIR OF INCISIONAL HERNIA AFTER MEDIAN INCISION

Our three-layered closure repair technique for incisional hernias consists of dissecting the retracted midline edges of the anterior and posterior sheath of the rectus abdominis muscle after extensive adhesiolysis. The peritoneum and posterior sheath are closed together in the first layer. The rectus abdominis muscles are placed in contact in the second layer, and the anterior sheath is closed in the third layer (Figure 5).

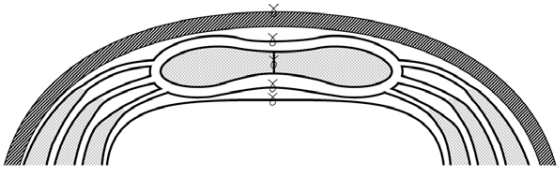

Figure 5. Diagram showing the 3-layered closure technique. The anterior/posterior rectus fasciae and the rectus muscles are sutured in separate layers, forming the three layers of the repair. In reality, the peritoneum, posterior rectus fascia and pieces of the rectus muscle are sutured together continuously, and the anterior rectus fascia and pieces of rectus muscle are also sutured continuously. This type of closure prevents the muscle from tearing. Thus, the three-layered closure consists of the apposition of three layers with two sutured layers.

The second phase of this reconstruction consists of suturing the two rectus muscles together along the median line by including pieces of rectus muscle ½ centimeter from the median edge and including the anterior or the posterior fascia. On US, the linea alba has disappeared and the two rectus muscles are in continuity on the median line (Figure 6).

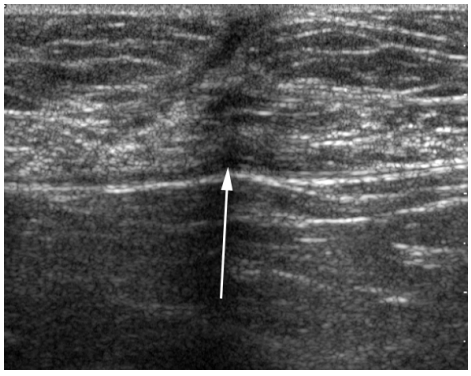

Figure 6. Postoperative transverse sonogram 2 years following the three-layered direct suture repair of an incisional hernia. The rectus muscles are attached to each other, and the linea alba has disappeared. Scar tissue (arrow) separates the rectus muscles. The posterior fasciae of both rectus muscles are continuous.

RECURRENCE AFTER THREE-LAYERED DIRECT SUTURE REPAIR OF AN INCISIONAL HERNIA FOLLOWING MEDIAN INCISION

US appearances of recurrent incisional hernias after the three-layered direct suture repair of a hernia through a median incision are shown in Figures 7 and 8. Recurrences can be partial and total (Figure 7). There is complete breach through the three sutured layers with possible protrusion of a hernial sac.

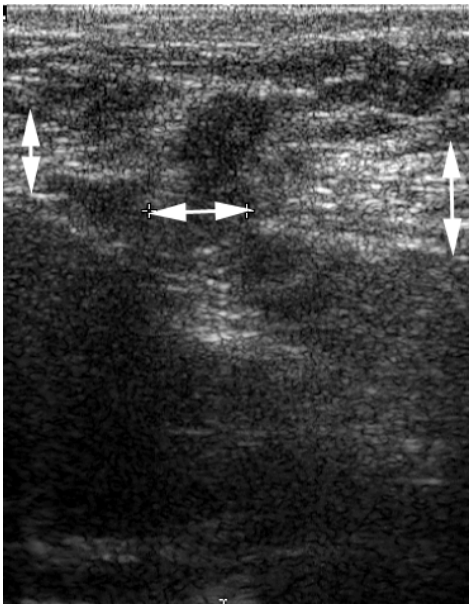

Figure 7. Complete recurrence 2 years after a three-layered direct suture repair of an incisional hernia. Transverse sonogram shows a complete discontinuity (horizontal double arrow) between the two rectus muscles (vertical double arrows) with protrusion of a small hernial sac.

A partial recurrence is defined as a defect of only the posterior fascia of the rectus sheath with an intact anterior fascia (Figure 8). In a partial defect, the outer layer of the repair (anterior rectus fascia) remains intact.

DISCUSSION

Repairs of incisional hernias can be performed using either open or laparoscopic techniques.[5] Open techniques include a simple hernioplasty (Mayo duplication or fascia-adaptation), component separation, or mesh repair. The recurrence rate of incisional hernias after open suture repair may be as high as 54%,[3] and for open mesh repair specifically, recurrence rates can be up to 32%.[4] However, the infection rate is higher in patients with open mesh repair and was, for instance, 10.1% in a Cochrane review, which pooled data from two studies.[6] Recurrence rates

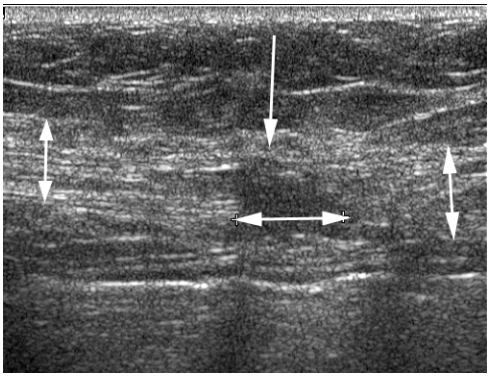

Figure 8. Partial recurrence of an incisional hernia 2 years after a three-layered direct suture repair. Transverse midline sonogram shows the partial defect (horizontal double arrow) and no protrusion of a hernial sac. The anterior rectus fascia is intact (vertical arrow). Vertical double arrows indicate the rectus muscles.

for laparoscopic repair are comparable with those obtained with the open mesh procedure but offer a shorter hospital stay.[1] High incidence rates of incisional and recurrent incisional hernias make imaging modality very important for this condition. Whereas the CT features of incisional hernias have been clearly described,[7-9] the US characteristics of ventral hernias have not been reported in detail.[10,11] An observational study compared US with CT in the diagnosis of incisional hernias,[12] but in general, the previous studies did not focus on the abdominal wall layers following the repair of an incisional hernia. This type of description is necessary to evaluate the concept of closure across all three layers, including the anterior fascia, the rectus abdominal muscles and the posterior fascia.

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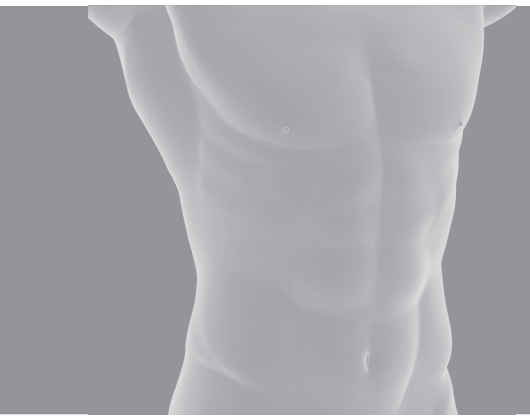

3

Comparison of ultrasonography with computed tomography in the diagnosis of incisional hernias

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W.E. Tuinebreijer
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Hernia 2009;13(1):45-8

ABSTRACT

Background The objective of this study was to determine the reliability and validity of ultrasonography (US) in diagnosing incisional hernias in comparison with computed tomography (CT). The CT scans were assessed by two radiologists in order to estimate the inter-observer variation and twice by one radiologist to estimate the intra-observer variation. Patients were evaluated after reconstruction for an abdominal aortic aneurysm or an aortoiliac occlusion.

Methods Patients with a midline incision after undergoing reconstruction of an abdominal aortic aneurysm or aortoiliac occlusion were examined by CT scanning and US. Two radiologists evaluated the CT scans independently. One radiologist examined the CT scans twice. Discrepancies between the CT observations were resolved in a common evaluation session between the two radiologists.

Results After a mean follow-up of 3.4 years, 40 patients were imaged after a reconstructed abdominal aortic aneurysm (80% of the patients) or aortoiliac occlusion. The prevalence of incisional hernias was 24/40 = 60.0% with CT scanning as the diagnostic modality and 17/40 = 42.5% with US. The measure of agreement between CT scanning and US expressed as a Kappa statistic was 0.66 (95% confidence interval [CI] 0.45-0.88). The sensitivity of US examination when using CT as a comparison was 70.8%, the specificity was 100%, the predictive value of a positive US was 100%, and the predictive value of a negative US was 69.6%. The likelihood ratio of a positive US was infinite, and that of a negative US was 0.29. The inter- and intra-observer Kappa statistics were 0.74 (CI 0.54-095) and 0.80 (CI 0.62-0.99), respectively.

Conclusions US imaging has a moderate sensitivity and negative predictive value and a very good specificity and positive predictive value. Consistency of diagnosis, as determined by calculating the inter- and intra-observer Kappa statistics, was good. The incidence of incisional hernia after aortic reconstructions is high.

INTRODUCTION

Incisional hernias, ventral hernias that manifest themselves through an operation scar, are a serious common complication of abdominal surgery. Incisional hernias occur in 11-23% of laparotomies and can give rise to serious morbidity, such as strangulation and incarceration [1]. Often the diagnosis can be made on clinical examination. However, small hernias and hernias in obese patients can be difficult to diagnose.

Diagnostic tools such as ultrasonography (US) and computed tomography (CT) are commonly used for imaging hernias. Most incisional hernias noted at cross-sectional imaging are incidental findings encountered during radiological examination for unrelated clinical problems. However, accurate demonstration of the size and location of the hernial orifice may be useful in assessing the success of hernia repair. The accuracy of these methods and their place in the clinical management of hernias have not been fully determined.

In cases in which there is clinical uncertainty of the diagnosis of an incisional hernia, US or CT scanning can be used. The validity and inter-observer reliability of CT in the diagnosis of incisional, inguinal, and femoral hernias have been described in a preliminary study of 24 patients [2]. In this study, the gold standard was the situation found at operation. For two observers, the sensitivity was 0.83 and 0.83, the specificity 0.83 and 0.67, the positive predictive value 0.94 and 0.88, and the negative predictive value 0.63 and 0.5, respectively. The inter-observer Kappa statistic was 0.87. Although the ultrasonographic features of ventral hernias have been described, the reliability and validity of US in the diagnosis of ventral hernias have not been systematically studied [3-5]. A literature search did not reveal the existence of any systematic comparisons of CT scanning and US for use in the diagnosis of incisional hernias. However, an observational study compared ultrasound with CT scanning without describing reliability and validity [6].

The objective of this study is to determine the reliability and validity of US in the diagnosis of incisional hernias. CT scanning was used as a comparison in the determination of the validity. A gold standard was lacking because these patients were not operated after the diagnosis of an incisional hernia. The study population was composed of a group of patients who had previously undergone open reconstruction for abdominal aortic aneurysm or aortoiliac occlusive disease. Patients with an abdominal aortic aneurysm have a high incidence of ventral hernias. For instance, in a study comparing US and magnetic resonance imaging (MRI), the incidence of incisional hernias was 31.7% after reconstruction for abdominal aortic aneurysm after a mean duration of follow-up of 48.6 months [7]. In a systematic literature review, the pooled incidence of a postoperative incision hernia was 21% in abdominal aortic aneurysm patients and 9.8% in patients with aortoiliac occlusive disease [8].

MATERIALS AND METHODS

Forty patients (38 men, two women) who had undergone reconstruction for an abdominal aortic aneurysm or an aortoiliac occlusion between January 2002 and December 2006 at one single institution were selected for this study through the hospital administration system. The operation was required to have occurred at least one year prior to the study, because most incisional hernias develop in the first year after surgery [9, 10]. Patients had undergone surgery through a midline incision by one of the two vascular surgeons. No other inclusion or exclusion criteria were used. These patients were examined by both CT scanning and US in November and December 2007. All US examinations were done by the same radiologist. This radiologist and another evaluated the CT independently. These radiologists were blinded to the outcome of the other diagnostic modality. One radiologist assessed the CT scans twice, with an interval of four weeks between assessments. In a common evaluation session, the two radiologists resolved the discrepancies between the three CT observations in order to develop a standard for comparison.

US examinations were performed using high-end ultrasound equipment (Aplio XG, model SSA-796A, Toshiba Medical Systems Corporation 1385, Shimoishigami, Otawara-Shi, Tochigi-Ken 324-8550, Japan and ATL 5000, Philips, ATL-factories, Bothell, USA) and linear transducer 5-12 MHz.

CT scanning was performed on a four-slice helical CT system (Asteion, Toshiba Medical Systems Corporation 1385, Shimoishigami, Otawara-Shi, Tochigi-Ken 324-8550, Japan) with the following protocol: 120 kVp, 200 mA, 0.75-s scan time, 3-mm slice thickness, 5.5 pitch.

The statistical methods assessed were the sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios. The kappa coefficient was used to estimate the inter-observer variation between the two radiologists who examined the CT scans independently and the intra-observer variation between the two observations of one radiologist. The kappa coefficient is an expression of the reproducibility of test results and can range from +1 to –1. If the agreement is perfect, the Kappa statistic has the value +1. Kappa gives the degree of agreement that has occurred over and above that which would have occurred by chance alone.

RESULTS

After a mean follow-up of 3.4 years (standard deviation [SD] = 1.6), 40 patients were imaged after reconstruction for an abdominal aortic aneurysm (80% of the patients) or an aortoiliac occlusion (20%). Ninety-five percent of the patients were male. The mean age was 72.5 years (SD = 8.9). The prevalence of incisional hernias with CT scanning as the diagnostic modality after achieving consensus between the two radiologists was for 24/40 = 60.0%. The prevalence

was 59.4% in the abdominal aortic aneurysm group and 62.5% in the occlusive disease group. With US as the diagnostic modality, the prevalence was 17/40 = 42.5%.

In Table 1, the results of the CT scan and US are presented in cross-tabular form. CT scanning revealed the presence of seven hernias that were not found during US imaging, while on US, no hernia was seen that was not found on CT scanning. The measure of agreement between CT scanning and US, expressed as a Kappa statistic, was 0.66 (95% confidence interval [CI] 0.45-0.88).

Table 1. Results of CT scan and ultrasonography in the diagnosis of incisional hernias.

	CT positive for hernia	CT negative for hernia	Total
ULTRASOUND positive for hernia	17	0	17
ULTRASOUND negative for hernia	7	16	23
Total	24	16	40

In Table 2, the results of US in the diagnosis of incisional hernia are presented using CT scanning as a comparison. The sensitivity of a US examination was 70.8% and the specificity was 100.0%. The predictive value of a positive US was 100.0%, and that of a negative US was 69.6%. In other words, 100% of the patients with a positive US had a positive CT scan and 69.6% of the patients with a negative US had a negative CT scan.

The likelihood ratio of a positive US was infinite, which means that the probability of a positive US being associated with a positive CT scan is an infinite number of times greater than the probability of a positive US associated with a negative CT scan. The likelihood ratio of a negative US is 0.29, which means that the probability of a negative US coupled with a positive CT scan is 0.29 less than the probability of a negative US associated with a negative CT scan.

Table 2. Results of ultrasonography in the diagnosis of incisional hernia when CT scan is used as comparison.

	Ultrasound	CT
Incidence (incisional hernia)	17/40 = 42.5%	24/40 = 60.0%
Sensitivity	17/24 = 70.8%	
Specificity	16/16 = 100.0%	
Positive Predictive Value	17/17 = 100.0%	
Negative Predictive Value	16/23 = 69.6%	
Likelihood ratio Positive (Sens ÷1-Spec)	~	
Likelihood ratio Negative (1-Sens ÷ Spec)	0.29	

Table 3 presents the results of the two radiologists in the diagnosis of incisional hernias with CT scanning. The inter-observer variation for CT scanning between the two radiologists expressed as a Kappa statistic was 0.74 (95% CI 0.54-0.95).

Table 3. Results of the CT scan for radiologists A and B as a measure of inter-observer variation.

Radiologist A \ Radiologist B	CT positive for hernia	CT negative for hernia	Total
CT positive for hernia	21	1	22
CT negative for hernia	4	14	18
Total	25	15	40

Table 4 shows the results of one radiologist in the diagnosis of incisional hernias with CT scanning on two occasions with an interval between assessments of 4 weeks. The intra-observer variation for CT scanning between the two examinations, expressed as a Kappa statistic, was 0.80 (95% CI 0.62-0.99).

Table 4. Results of the CT scan evaluated twice by one radiologist as a measure of intra-observer variation.

Second occasion \ First occasion	CT positive for hernia	CT negative for hernia	Total
CT positive for hernia	19	1	20
CT negative for hernia	3	17	20
Total	22	18	40

DISCUSSION

The sensitivity and negative predictive value of US in the diagnosis of incisional hernia were moderate in this study, because US yielded seven false negative cases in the 24 patients who were CT positive for incisional hernia (29.2%). Nevertheless, the specificity and positive predictive value were very high, because no false positive cases were diagnosed by US examination. Højer et al. [2] found a lower specificity but a higher sensitivity in the diagnosis of hernias by CT examination. However, they examined a smaller combined group of groin and incisional hernias. Moreover, their gold standard was the situation at operation and they used CT as their imaging study.

In our group of patients, the majority of which had undergone an abdominal aortic aneurysm reconstruction, we found a very high incidence (60.0%) of incisional hernias after a mean follow-up of 3.4 years. In comparison, the pooled analysis of Takagi et al. yielded an incidence of 21% in a total of 719 abdominal aortic aneurysm reconstruction patients [8]. However, most of the diagnoses included in the analysis were made clinically. Musella et al. [7] found an incidence of 31.7% for incisional hernias after a follow-up of 4 years in their patients, who were diagnosed by MRI and US. They concluded that US was unreliable in the early detection of anterior wall hernias and that US was more accurate in detecting normal rather than abnormal abdominal walls. This conclusion contradicts with our finding of high specificity and moderate sensitivity of US imaging.

Rodriguez et al. [11] found an incidence of 23% for abdominal wall hernias with CT scanning after open abdominal aortic aneurysm repair. Importantly, they concluded that clinical events and reinterventions related to these radiographic abnormalities are rare and that only 8% of the patients had clinical evidence of an incisional hernia.

Our inter-observer Kappa of 0.74 is lower than the value of 0.87 found by Højer et al. [2], but the confidence intervals are wide in studies with such small samples. The intra-observer consistency (Kappa = 0.80) is satisfactory in the light of the difficulty of reproducible, reliable clinical measurements [12].

A drawback of our study is that no measurements of the size of the hernias were made. Therefore, the influence of the hernia size on the sensitivity could not be determined.

In conclusion, abdominal wall US is an effective method for identifying incisional hernias but it is only moderately accurate in detecting normal abdominal walls. The inter- and intra-observer reliability of CT examination for the diagnosis of incisional hernias is sufficient.

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4

Open surgical procedures for incisional hernias

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ABSTRACT

Background

Incisional hernias occur frequently after abdominal surgery and can cause serious complications. The choice of a type of open operative repair is controversial. Determining the type of open operative repair is controversial, as the recurrence rate may be as high as 54%.

Objectives

To identify the best available open operative techniques for incisional hernias.

Search strategy

Electronic databases MEDLINE, EMBASE, LILACS, and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched from 1990 to 2007 and trials were identified from the known trial reference lists.

Selection criteria

Studies were eligible for inclusion if they were randomized trials comparing different techniques for open operative techniques for incisional hernias.

Data collection & analysis

Statistical analyses were performed using the fixed effects model. Results were expressed as relative risk for dichotomous outcomes and weighted mean difference for continuous outcomes with 95% confidence intervals.

Main results

Eight trials comparing different open repairs for incisional hernias were identified; one trial was excluded. The included studies enrolled 1,141 patients. The results of three trials comparing suture repair versus mesh repair were pooled. Hernia recurrence was more frequent, wound infection less frequent in the direct suture group compared to the onlay or sublay mesh groups. The recurrence rates of two trials comparing onlay and sublay positions were pooled. This comparison yielded no difference in recurrences (two studies pooled), although operation time was shorter in the onlay group (one study). No difference was found in recurrence, satisfaction with cosmetics, or infection between the onlay standard mesh and skin autograft groups, following analysis pooling the two treatment arms. However, the analysis demonstrated less pain in the skin autograft group. Other trials comparing different mesh materials or different positions of the mesh, or comparing mesh with the components separation technique are described individually. The comparison between lightweight and standard mesh showed a trend for more recurrences in the lightweight group. The comparison between onlay and intraperitoneal mesh positions resulted in non significant fewer hernia recurrences, less seroma formation and more

postoperative pain in the intraperitoneal group. No differences in the recurrence rates between the components separation and the intraperitoneal mesh technique.

Authors' conclusions

There is good evidence from three trials that open mesh repair is superior to suture repair in terms of recurrences, but inferior when considering wound infection. Six trials yielded insufficient evidence as to which type of mesh or which mesh position (on- or sublay) should be used. There was also insufficient evidence to advocate the use of the components separation technique.

PLAIN LANGUAGE SUMMARY

Open surgical procedures for incisional hernias.

An incisional hernia is a bulge of tissue or an organ through an operation scar in the abdominal wall. Incisional hernias occur in 10 to 23 percent after abdominal operations.

This review question the choice of open operative repair technique, somehow controversial due to a high failure rate, reported as high as 54%. Open mesh repair has a lower failure rate (recurrence) than open suture repair, but mesh repair are complicated by more wound infections. No conclusions could be drawn on which type of mesh should be used because of lack of trials. Also no inference was drawn about the position of the mesh (below or above the fascia). More randomized clinical trials are needed to answer all the remaining questions.

BACKGROUND

Incisional hernias are ventral hernias through an operation scar and are a serious complication of abdominal surgery. Incisional hernias occur in 11 to 23 percent of laparotomies (Cassar 2005). Incisional hernias enlarge over time and can result in serious complications such as pain, bowel obstruction, incarceration and strangulation, and enterocutaneous fistula. Furthermore, the quality of life and chances for employment are reduced in patients suffering from incisional hernias.

The repair of such hernias can be performed through either an open or laparoscopic technique (Korenkov 2001). The open technique may be a simple hernioplasty (Mayo duplication or fascia-adaptation), a components separation, or a mesh repair. The components separation technique is based on enlargement of the abdominal wall surface by separation and advancement of the muscular layers. The mesh can be placed using onlay (prefascial), sublay (subfascial or preperitoneal) or inlay techniques. In an inlay repair, the fascia is not approximated but the gap is closed by the mesh. The mesh consists of either autoplastic or alloplastic material. In

an autoplastic graft, a cutis flap is used (skin autograft hernioplasty). Synthetic mesh can be further classified into three types (Amid 1997). Type I mesh is a totally macroporous prosthesis consisting of monofilament or double filament polypropylene. Type II mesh is a completely microporous prosthesis, such as expanded polytetrafluoroethylene (PTFE). Type III mesh is a mixed-prosthesis consisting of a macroporous prosthesis with multifilamentous or microporous components, such as PTFE mesh.

The recurrence rate following open suture repair may be as high as 54% (Paul 1998) and as high as 32% for open mesh repair (Burger 2004). Recurrence rates for laparoscopic repair appear to be comparable to the open mesh procedure, but require a shorter hospital stay (Cassar 2005). In a Swedish cost analysis study (including sick leave), the costs for incisional hernia repair were 6,122 Euro and 5,458 Euro for suture and mesh repairs, respectively (Israelsson 2003). The quality of life, as assessed by physical function scores obtained through a questionnaire (SF 36), improved four months after mesh repair (Conze 2005).

Several conditions are associated with the development of incisional hernia: suture technique, wound infection, increased abdominal wall tension and metabolic connective tissue disorder, specifically, abdominal aortic aneurysms (Klinge 2000; Klinge 2001). A Cochrane Review found no difference in the risk of incisional hernia comparing midline with transverse incisions (Brown 2005).

Although incisional hernias result from a process that initiates within weeks of surgery, clinical appearance may take years (Burger 2005; Pollock 1989).

OBJECTIVES

The primary objective of this review was to identify the best available open operative techniques for repairing incisional hernias.

METHODS

Criteria for considering studies for this review

Types of studies

We included only randomized controlled studies that compared different open techniques for closure of incisional hernias. All included studies reported at least a half year follow-up, and at least 70 percent of the study participants had a mean follow-up of one year. We did not restrict the type of incision (midline, transverse, paramedian, lumbar, etc.) used in the trials.

Types of participants

We included trials that compared the interventions of interest in adult patients of both genders. Mixed studies that also included patients with other types of hernias (e.g., primary epigastric, umbilical, parastomal) were excluded. Patients with elective and emergency care were also included.

Types of interventions

Included trials compared the open primary closure technique procedure with either another technique or the same open primary closure technique with a prosthesis. We also included trials that compared different prosthetic materials. No studies investigating laparoscopic techniques were included.

We included trials that compared any of the following interventions separately or in combination:

Open suture repairs as simple adaptation of fascia, duplication of fascia (Mayo procedure) and components separation.

Open mesh repairs with allo- and autoplastic materials.

Types of outcome measures

The primary outcome for the review was the number of participants who developed a recurrent incisional hernia as defined in the included studies. We reported the primary outcome at different follow-up times, as available from the individual studies, although the primary outcome of interest was the rate of recurrence of incisional hernia after at least a one-year follow-up.

The secondary outcomes for the review were defined by the individual investigators and were as follows:

Length of hospital stay in days, enterocutaneous fistula, cosmesis, patient satisfaction, operating time (minutes) and wound pain. Acute postsurgical pain due to the incision was distinguished from chronic pain (possibly due to mesh reaction). Wound complications including acute infections, and chronic infections such as sinus/fistula tracts, mesh infection, and seroma/haematoma formation were also secondary outcomes.

Search methods for identification of studies

See: Colorectal Cancer Group methods used in reviews.

Electronic search included MEDLINE, EMBASE, LILACS, and the Cochrane Central Register of Controlled Trials (CENTRAL). There was no limitation based on language or date of publication.

Manual searches including reference lists of all included studies were used to identify randomized trials that the electronic search may have failed to identify.

We used the following search terms in different combinations as MeSH (Medical Subject Heading) terms and as text words: incisional hernia, ventral hernia, and surgical treatment outcome.

Data collection and analysis

Selection of studies

Two reviewers independently assessed the title and abstracts of all reports identified by electronic and manual searches. Each report was labeled as (a) definitely exclude, (b) unsure or (c) definitely include. Full text articles of abstracts labeled as "unsure" were reassessed according to the inclusion criteria for this review. Any differences were resolved through discussion. Studies labeled as "definitely exclude" were excluded from the review, while studies labeled as "definitely include" were further assessed for methodological quality.

Abstract publications were only selected when a full manuscript was obtained from the study authors.

Data extraction and management

Two reviewers independently extracted the data for the primary and secondary outcomes and entered the data into paper data collection forms developed for this purpose. Discrepancies were resolved by discussion. Authors of included studies were contacted for missing data. One reviewer entered all data into RevMan 4.2. The second reviewer independently re-entered the data, using the double data-entry facility in order to verify the data entered

Assessment of methodological quality of included studies

Two reviewers independently assessed the included studies for sources of systematic bias in trials, according to the guidelines in section 6 of the Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 (Higgins 2005). The studies were evaluated for the following criteria: allocation concealment (selection bias), rates of follow-up and intention to treat analysis (attrition bias). Allocation concealment was graded as (a) adequate, (b) inadequate or (c) unsure. Authors of studies labeled "unsure" were contacted for further clarification. Differences between the two reviewers were resolved by discussion. Masking of outcome assessors in the included studies was assessed.

Measures of treatment effect

Data analysis followed the guidelines outlined in Section 8 of the Cochrane Handbook for Systematic Reviews of Interventions 4.2.5 (Deeks 2005).

Dichotomous outcomes:

Dichotomous outcomes (e.g., presence/absence of recurrence, complications) were reported as proportions and were directly compared (difference in proportions). We used these proportions to calculate risk ratios (RRs) and absolute risk reductions (risk differences) with 95% confidence intervals (CIs). Data from survival curves comparing different treatments were extracted to calculate hazard ratios (Parmar 1998).

Continuous outcomes:

For continuous data (e.g., operating time, length of hospital stay, quality of life, pain scores) results are presented as weighted mean differences (WMD).

We used Review Manager 4.2 software (RevMan 4.2, Cochrane software) for generating the figures and statistical analyses.

Assessment of heterogeneity

We explored heterogeneity using the chi-squared test with significance set at a p-value less than 0.10. The quantity of heterogeneity was estimated by the I-squared statistic.

Because prior statistical evidence existed for homogeneity of effect sizes, the planned analysis used a fixed effect model.

Sensitivity analysis

Sensitivity analyses were conducted to determine the impact of exclusion of studies with lower methodological quality. The sensitivity analysis was performed for the recurrence rate in order to test the effect of removing studies. The methodological quality of studies was inadequate in the following situations: when the allocation sequence was not generated by a computer or random number table, when the reasons for dropouts and withdrawals were not described, or when the analysis was not performed on intention to treat basis.

RESULTS

Description of studies

A total of seven trials comparing different open surgical procedures for incisional hernias were included (see 'Characteristics of included studies' table for further details) with a total enrolment of 1,141 patients. In addition, one study with 65 patients was excluded (see 'Characteristics of excluded studies') because follow-up in one of the groups was limited to only four months (Schumpelick 1999). From all studies a full publication from a journal or a copy of the original poster was retrieved (Baracs 2007; Köhler 2004).

Risk of bias in included studies

Results of the quality assessment are given in the 'Characteristics of included studies' table. In general, the study quality was assessed as fair to moderate with regard to methodology and all trials were large enough to detect useful clinical differences between groups.

Randomization

Allocation concealment was described in four trials (Afifi 2005; Conze 2005; Korenkov 2002a; de Vries 2007a) but was absent in three others (Burger 2004; Köhler 2004; Baracs 2007). Allocation

concealment was verified by e-mail correspondence with one of the authors of the study of Köhler. Incomplete information about the randomization procedure was completed by the authors of the Baracs study.

Participants lost to follow up

All studies, except one (Baracs 2007), reported losses at follow-up. In four studies, the intention-to-treat analysis was explicitly undertaken (Burger 2004; Conze 2005; Korenkov 2002a; de Vries 2007a), which could be concluded from the Köhler 2004 study from the flow diagram. In the Afifi 2005 study, there was no loss of follow-up and the interventions were given following the random allocation. Thus, the intention-to-treat analysis was secure in six of the studies and was unable to be determined only in the Baracs 2007 study.

Blinding

Five of the studies did not provide enough information to determine the strategies used to blind participants or outcome assessors (Afifi 2005; Burger 2004; de Vries 2007a; Köhler 2004; Baracs 2007). For these studies, the blinding strategy was verified by direct e-mail correspondence with one of the authors. In the Köhler study, blinding was reported not to be possible. In one study, the patients were informed about the operation they received and subsequently notified the assessors, who were thus unblinded (Korenkov 2002a). The patients and outcome assessors were blinded to the treatment group in the 2005 study by Conze (Conze 2005). In the Baracs 2007 study postoperative monitoring was done by a surgeon who had not operated on the patient.

Length of follow-up

The Afifi 2005 study had a follow-up length of 30 months (median), the Baracs 2007 study had a minimum of 3 years and a maximum of 5 years of follow-up, the Burger 2004 study had a median follow-up of 75 months for the suture repair patients and 81 months for the mesh repair group, the Conze 2005 study had a follow-up of 2 years, the de Vries 2007a study had a mean follow-up of 22 months, the Korenkov 2002a study had a mean follow-up of 16 months and the Köhler 2004 study a mean follow-up of 1 year. This last study was included because 70% of the patients had a minimal follow-up time of one year.

Effects of interventions

Statistical analyses were performed using the fixed effects model, since we assumed that all variation between studies was caused by chance and that studies measured the same overall effect. Even if a random-effects model was used, our conclusions remained the same. The results were expressed as relative risk (RR) for dichotomous outcomes and weighted mean difference (WMD) for continuous outcomes with 95% confidence intervals (CI).

Data from three studies comparing suture repair with mesh repair in onlay or sublay position could be pooled (Burger 2004; Korenkov 2002a; Baracs 2007). From two of these studies, hazard ratios for recurrences were calculated and pooled with the Peto odds method (Burger 2004; Korenkov 2002a). The Luijendijk 2000 study is a prior version of the study of Burger 2004. The publication of Weber 2002 is a description of the planned design of the Baracs 2007 study. Data from two studies comparing the sublay versus the onlay position could be pooled for the recurrence rate outcome (Köhler 2004; Baracs 2007), but not for the outcome operation time (standard deviations missing).

Data from the five studies comparing different types of mesh and different positions of these types of mesh could not be pooled due to clinical and methodological heterogeneity, and thus are described individually. One study is a double trial and is included as two separate trials (Korenkov 2002a; Korenkov 2002b). Korenkov 2002a is a three-armed trial on simple hernias comparing suture repair, mesh repair and skin autograft. Korenkov 2002b is a two-armed trial on complex hernias comparing mesh repair with skin autograft. Part of the three-armed trial was pooled with the two-armed trial. Hazard ratios for recurrences could also be calculated for the Köhler 2004 and de Vries 2007a studies.

One trial with 65 patients was excluded because follow-up in one of the groups was limited to only four months (Schumpelick 1999).

Suture repair versus mesh repair in the onlay or sublay position

Recurrence

Korenkov 2002a, Burger 2004, and Baracs 2007 data were pooled for the analysis of recurrences.

Hernia recurrence was more frequent in the suture repair group than in the mesh group (Comparison 01:01: RR 1.85, 95% CI 1.33 to 2.56; p=0.0002). These three studies included small hernias defined as being smaller than 10 cm, smaller than 6 cm and smaller than 25 cm2, respectively. In contrast with Korenkov 2002a and Burger 2004 , who compared mesh in the onlay position with suture repair, Baracs 2007 compared mesh repair in the sublay position with suture repair. Omitting the Baracs 2007study from the analysis did not change the outcome (sensitivity analysis).

The pooled recurrence rate was 33.3% for the suture repair group and 16.4% for the mesh group. The number needed to treat to benefit (NNTb) was 6 for the suture group patients.

The calculated hazard ratio for recurrences in the Burger 2004 study was 2.08 (CI 1.35 to 3.22) and it was 1.36 (CI 0.31 to 6.03) for the Korenkov 2002a study. Pooling of these two studies yielded a hazard ratio of 2.01 (CI 1.32 to 3.06; p=0.001).

Korenkov 2002a and Burger 2004 data were pooled for the following analysis.

Chronic wound pain

The frequency of chronic wound pain was not statistically different between the groups (Comparison 01:02: RR 1.02, 95% CI 0.62 to 1.68; p=0.92). The pain outcome in the Korenkov 2002a

study was defined as the presence of wound pain measured on a visual analogue scale (VAS) after one year, therefore corresponding to a VAS score greater than one. However in the Burger 2004 study chronic wound pain was scored positively when the patient had experienced scar pain during the last month prior to follow-up (median follow-up for suture repair was 75 months and 81 months for mesh repair patients).

Satisfied with cosmetic result

The satisfaction with the cosmetic result was not statistically different between the groups (Comparison 01:03: RR 0.90, 95% CI 0.68 to 1.20; p=0.48).

Wound Infection

Wound infection was more frequent in the mesh group than in the suture repair group (Comparison 01:04: RR 0.09, 95% CI 0.01 to 0.70; p=0.02). In the Burger 2004 study, six of the 60 mesh repair patients were scored as having deep infection: three patients had a fistula from mesh to skin, one patient a mesh infection and two patients an enterocutaneous fistula. In the Korenkov 2002a study, four of the 39 mesh repair patients were scored as having local infectious complications. Two meshes had to be removed.

The pooled infection rate was 0% for the suture repair group and 10.1% for the mesh group. The number needed to treat to harm (NNTh) was 10 for the mesh group patients.

Lightweight mesh versus standard mesh in sublay position

The Conze 2005 study investigated lightweight mesh versus standard mesh in the sublay position with closure of the peritoneum, posterior rectus sheath and reconstruction of the line alba in hernias larger than 4 cm. The recurrence rate was 17% for the lightweight mesh and 7% for the standard mesh (Comparison 02:01: RR 2.31, 95% CI 0.93 to 5.71; p=0.07). No difference was observed between the groups in the frequency of chronic wound pain after 24 months (Comparison 02:02: RR 0.59, 95% CI 0.15 to 2.40; p=0.46), rates of deep infection (Comparison 02:03: RR 0.99, 95% CI 0.30 to 3.28; p=0.98), hospital stay in days (Comparison 02.04: WMD 0.80, 95% CI -1.78 to 3.38; p=0.54) or operation time in hours (Comparison 02.05: WMD 0.00, 95% CI -0.21 to 0.21; p=1.00). The infections in this study were mostly subcutaneous and no mesh removals were necessary.

The onlay versus sublay mesh positions

The Köhler 2004 and Baracs 2007 studies investigated the onlay position and sublay positions in mesh repair. In the Köhler 2004 study, the recurrence rate was 10% for the onlay position and 9% for the sublay position. The recurrence rates in the Baracs 2007 study were 7.4% and 13.6% in the onlay and sublay mesh groups, respectively. The pooled comparison was not significant (Comparison 03:01: RR 0.66, 95% CI 0.35 to 1.25; p=0.21). A post hoc power calculation on these proportions with G*Power software (version 3.03, Kiel, Germany) yielded only a

power of 23%. In the Köhler 2004 study the operation time was significantly shorter in the onlay group compared with the sublay group (Comparison 03:02: WMD -22.50, 95% CI -38.72 to -6.28; p=0.007). In the Baracs 2007 study the mean operation times in the sublay and onlay mesh group were comparable with 72.2 (minimum 25, maximum 210 minutes) and 74.2 (minimum 30, maximum 210 minutes) minutes, respectively. In the Köhler 2004 study no difference was found for hospital stay in days (Comparison 03.03: WMD 0.30, 95% CI -1.63 to 2.23; p=0.54), for overall complication rate (Comparison 03:04: RR 0.77, 95% CI 0.35 to 1.68; p=0.51) or for postsurgical pain on the first postoperative day measured with a VAS score (Comparison 03.05: WMD -0.20, 95% CI -1.03 to 0.63; p=0.64). The calculated hazard ratio for recurrences in the Köhler 2004 study was 1.16 (CI 0.31 to 4.3).

Mesh (polypropylene) versus skin autograft in the onlay position

In a double trial Korenkov 2002a studied mesh (polypropylene) versus skin autograft in the onlay position with closure of the fascia in simple hernias compared to mesh (polypropylene) versus skin autograft in the onlay position in complex hernias (hernia larger than 10 cm in diameter or a re-recurrence) with closure of the fascia (Korenkov 2002b). The results of this double trial were pooled. The recurrence rate was 8.6% for the mesh group and 12.3% for the skin autograft group (Comparison 04:01: RR 0.70, 95% CI 0.25 to 1.94; p=0.49). The calculated hazard ratio for recurrences in the simple hernia group was 0.73 (CI 0.16 to 3.27) compared to 0.56 (CI 0.11 to 2.79) in the complex hernia group. Pooling yielded a hazard ratio of 0.65 (CI 0.22 to 1.93; p=0.43). Pain was significantly less in the skin autograft group (Comparison 04:02: RR 1.94, 95% CI 1.05 to 3.58; p=0.03). This pain outcome was defined as the presence of wound pain measured on a VAS after one year. No difference was found in the cosmetic result (Comparison 04:03: RR 1.18, 95% CI 0.80 to 1.76; p=0.41) or in the rates of deep infection (Comparison 04:04: RR 0.70, 95% CI 0.24 to 2.04; p=0.52) between the two groups after one year. Four polypropylene meshes had to be removed.

Onlay mesh repair versus double mesh intraperitoneal repair for recurrent large ventral hernias

Afifi 2005 studied the onlay mesh repair versus intraperitoneal double mesh repair. The recurrence rate was 27% for the onlay mesh group and 0% for the intraperitoneal mesh group (Comparison 05:01: RR 11.30, 95% CI 0.68 to 188.39; p=0.09). A non significant difference was found for seroma formation: 32% in the onlay group and 0% in the intraperitoneal group (Comparison 05:02: RR 13.04, 95% CI 0.79 to 214.34; p=0.07). A post hoc power calculation on these proportions with G*Power software (version 3.03, Kiel, Germany) showed a power of 58%. No difference was found for chronic postoperative wound pain after 6 months: 4.5% in the onlay group and 31.6% in the intraperitoneal group (Comparison 05:07: RR 0.14, 95% CI 0.02 to 1.09; p=0.06). Likewise, no difference was observed between groups in superficial wound infection (Comparison 05:03: RR 0.86, 95% CI 0.06 to 12.89; p=0.92), wound hematoma (Comparison 05:04: RR 2.61, 95% CI 0.11 to 60.51; p=0.55), deep venous thrombosis (Comparison 05:05: RR

0.29, 95% CI 0.01 to 6.72; p=0.44), fatal pulmonary embolism (Comparison 05:06: RR 0.29, 95% CI 0.01 to 6.72; p=0.44) or mesh removal (Comparison 05:08: RR 2.61, 95% CI 0.11 to 60.51; p=0.55). Only one mesh was removed from the onlay mesh repair group.

The components separation technique versus the intraperitoneal prosthetic repair in giant hernias

De Vries 2007a studied the components separation technique versus prosthetic repair in giant hernias and found that the closure of the fascia was not possible because of the large defect in the fascia. The recurrence rate was 56% for the components separation technique and 58% for the prosthetic repair (Comparison 07:01: RR 0.96, 95% CI 0.55 to 1.69; p=0.89). The calculated hazard ratio for recurrences was 0.79 (CI 0.34 to 1.86). No difference was found for reoperations due to wound complications (Comparison 07:02: RR 0.30, 95% CI 0.07 to 1.26; p=0.10). The seven reoperations for wound complications in the mesh repair group were removals of infected meshes. Differences in the operation time could not be analyzed because the standard deviations were not published, although the authors stated that the operation time was significantly shorter in the components separation technique group.

DISCUSSION

This review has included data from seven trials. One trial made comparisons between three different types of hernia repairs (Korenkov 2002a). When considering the comparison of direct suture repair versus mesh repair, only three randomized trials were found (Burger 2004; Korenkov 2002a; Baracs 2007). Mesh repair was associated with fewer hernia recurrences and with more infection compared with direct suture repair. Most surgeons seem to have accepted the superiority of mesh repair for an average patient. For example, in a population based study of 10,822 patients in the USA Flum 2003 observed an increase in the frequency of synthetic mesh use from 35% in 1987 to 65% by 1999. The NNTb was 6 patients for recurrences and the NNTh was 10 patients for infection. Thus, for every six mesh repairs, one recurrence is prevented in comparison with direct suture repair, but one infection is seen for every 10 mesh repairs. Therefore, the balance between the benefit of a lower recurrence rate and the risk of a higher wound infection rate should be considered. Another minor consideration that has to be made are the additional direct costs of the mesh. In a Swedish observational study, however, the total costs (including sick leave costs) of open mesh repair were not higher than the costs of open suture repair (Israelsson 2003).

These three studies comparing suture repair with mesh repair included small hernias which were defined as being smaller than 10 cm, smaller than 6 cm and smaller than 25 cm2, respectively. So these studies also included hernias smaller than 4 cm, which had for instance a lower recurrence rate in a retrospective observational study with the suture technique (Hesselink 1993). In an experts' meeting it was recommended to use fascia-duplication only in small

incisional hernias (Korenkov 2001). These different hernia sizes in the included studies are a source of clinical heterogeneity. In large incisional hernias the NNTb for recurrences is probably higher. However in the study of Burger 2004 a subgroup analysis of 50 patients with hernias smaller than 10 cm2 showed a significant different 10 years recurrence rate of 67% after suture repair and 17% after mesh repair.

A comparison of different types of synthetic mesh or the use of a skin autograft was performed by Conze 2005 and Korenkov 2002a. Conze 2005 compared lightweight mesh and standard mesh in the sublay position. Although not significant, there was a trend towards more recurrences in the lightweight mesh group, which the authors explained as a technically related difference. Korenkov 2002a compared standard mesh (polypropylene) with skin autograft in the onlay position in simple ventral hernias and in complex hernias. No differences were found for the recurrence rate, satisfaction with cosmetic result and infection. Chronic wound pain was significantly more frequent in the mesh group than in the skin autograft group.

Afifi 2005 compared the onlay position with the intraperitoneal position. Fewer hernia recurrences and seroma formations were observed in the intraperitoneal group, although the 95% confidence intervals were large and insignificant. This study lacked power to find a significant difference in recurrence rate.

Köhler 2004 and Baracs 2007 studied the onlay and the sublay mesh positions. The recurrence rate was not different, however the operation time was shorter in the onlay group in the Köhler 2004 study, but equal in the Baracs 2007 study. Also this studies lacked power to find a significant difference in recurrence rate.

In comparing the onlay and sublay positions, we are comparing the different positions of the mesh, but also the difference in fascia closure. In the onlay position, the fascia remains open (Burger 2004) or is closed in one layer (linea alba), while in the sublay position, the fascia is closed in two layers (anterior and posterior rectal sheath).

A study by de Vries 2007a compared the components separation technique with intraperitoneal prosthetic repair in giant hernias. The recurrence rates were high and equal in both groups. The recurrence rate in the intraperitoneal group (58%) was not comparable with that found in Afifi's study (recurrence rate 0%), as the size of the hernia defect was different, the fascia closure was different and the 95% confidence intervals in Afiifi's study were large and insignificant.

In all included studies, the direct suture repairs were inappropriately described. For instance the different possibilities in direct closure technique such as the use of which suture material (absorbable versus non-absorbable or slowly absorbable), continuous versus interrupted closure of the fascia, suture to wound length ratio and in relation with this ratio the size and interval of the fascial bites, were incompletely described. Furthermore, recurrences were not objectively defined and were generally diagnosed by clinical examination rather than through imaging techniques.

Infection was either not objectively defined or was not comparable between the different studies, such as the distinction between superficial and deep graft infection. The same critique

can be used for pain, either wound pain or abdominal pain. For example, Burger 2004 found a significant difference in abdominal pain but not in wound pain.

The limited number of available trials has resulted in an inadequate comparison of the different techniques for ventral hernia repair. Thus, more randomized trials are needed.

AUTHORS' CONCLUSIONS

Implications for practice

There is good evidence from three trials included in this review that open mesh repair is superior to suture repair in terms of recurrences, but inferior in the occurrence of wound infection. There is insufficient evidence from five trials in this review as to which type of mesh or which position of the mesh (on- or sublay) should be used in open ventral hernia repair. Also, insufficient evidence was found to advocate the use of the components separation technique.

Implications for research

Given its ongoing use, further randomized trials of high methodological rigor are needed in order to define the true extent of benefit from the use of different types of mesh and the different positions the mesh are placed. Further trials are needed to study the newer bioprosthetic meshes (de Vries 2007b). Specifically, more information and research is needed to compare more complicated abdominal wall reconstructions with mesh repair. Further information is needed to delineate the relationship between clinical and radiological recurrences, and to determine the most appropriate measure of functional outcomes that relate to a generic measure of health-related quality of life and the outcome pain in relation with the use of different types of mesh.

Acknowledgements

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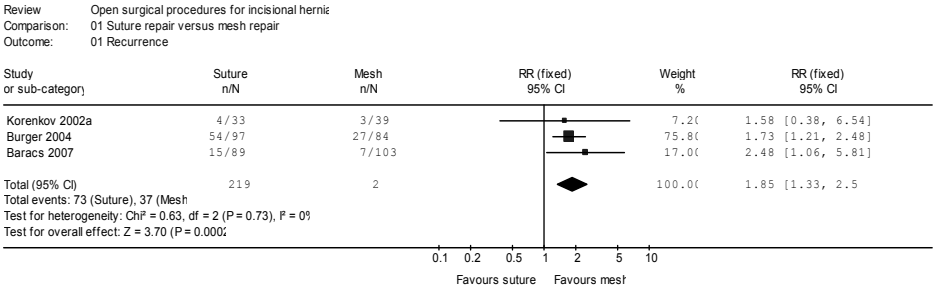
* *Indicates the major publication for the study*

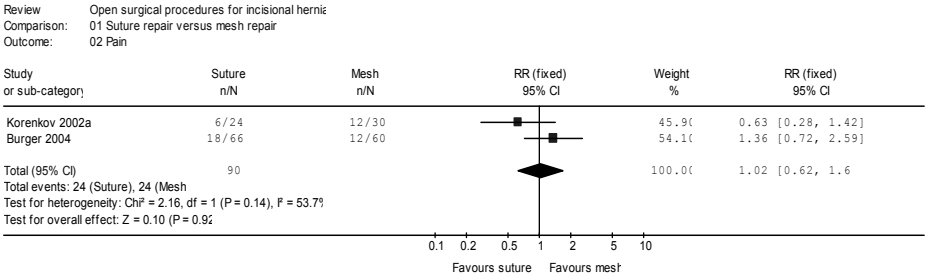
DATA AND ANALYSES

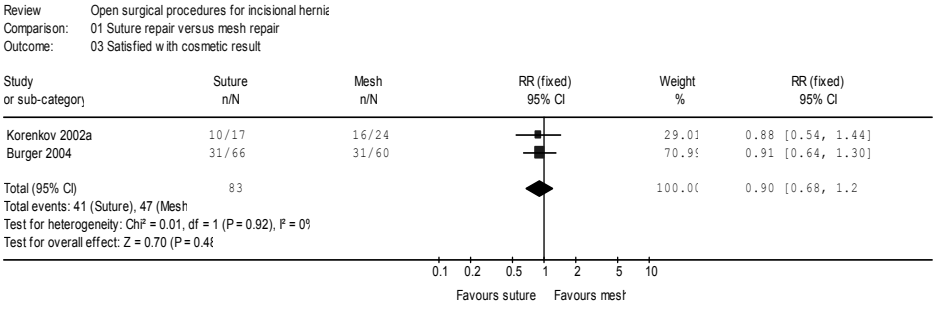
Outcome or Subgroup	Studies	Participants	Statistical Method	Effect Estimate
1.1 Recurrence	3	445	Risk Ratio (M-H, Fixed, 95% CI)	1.85 [1.33, 2.56]
1.2 Pain	2	180	Risk Ratio (M-H, Fixed, 95% CI)	1.02 [0.62, 1.68]
1.3 Satisfied with cosmetic result	2	167	Risk Ratio (M-H, Fixed, 95% CI)	0.90 [0.68, 1.20]
1.4 Infection	2	198	Risk Ratio (M-H, Fixed, 95% CI)	0.09 [0.01, 0.70]
2 Lightweight mesh versus standard mesh in sublay position				
Outcome or Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**
2.1 Recurrence	1	165	Risk Ratio (M-H, Fixed, 95% CI)	2.31 [0.93, 5.71]
2.2 Pain	1	165	Risk Ratio (M-H, Fixed, 95% CI)	0.59 [0.15, 2.40]
2.3 Deep infection	1	165	Risk Ratio (M-H, Fixed, 95% CI)	0.99 [0.30, 3.28]
2.4 Hospital stay in days	1	165	Mean Difference (IV, Fixed, 95% CI)	0.80 [-1.78, 3.38]
2.5 Operation time in hours	1	165	Mean Difference (IV, Fixed, 95% CI)	0.00 [-0.21, 0.21]
3 Onlay versus sublay mesh				
Outcome or Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**
3.1 Recurrence	2	353	Risk Ratio (M-H, Fixed, 95% CI)	0.66 [0.35, 1.25]
3.2 Operation time in minutes	1	93	Mean Difference (IV, Fixed, 95% CI)	-22.50 [-37.74, -7.26]
3.3 Hospital stay in days	1	93	Mean Difference (IV, Fixed, 95% CI)	0.30 [-1.63, 2.23]
3.4 Overall complication rate	1	93	Risk Ratio (M-H, Fixed, 95% CI)	0.77 [0.35, 1.68]
3.5 Postsurgical pain	1	93	Mean Difference (IV, Fixed, 95% CI)	-0.20 [-1.03, 0.63]
4 Mesh (polypropylene) versus skin autograft in onlay position				
Outcome or Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**
4.1 Recurrence	2	127	Risk Ratio (M-H, Fixed, 95% CI)	0.70 [0.25, 1.94]
4.2 Pain	2	103	Risk Ratio (M-H, Fixed, 95% CI)	1.94 [1.05, 3.58]
4.3 Satisfied with cosmetic result	2	79	Risk Ratio (M-H, Fixed, 95% CI)	1.18 [0.80, 1.76]
4.4 Deep infection	2	127	Risk Ratio (M-H, Fixed, 95% CI)	0.70 [0.24, 2.04]
5 Onlay mesh repair versus double mesh intraperitoneal repair				
Outcome or Subgroup	**Studies**	**Participants**	**Statistical Method**	**Effect Estimate**
5.1 Recurrence	1	41	Risk Ratio (M-H, Fixed, 95% CI)	11.30 [0.68, 188.39]
5.2 Seroma	1	41	Risk Ratio (M-H, Fixed, 95% CI)	13.04 [0.79, 214.34]
5.3 Superficial wound infection	1	41	Risk Ratio (M-H, Fixed, 95% CI)	0.86 [0.06, 12.89]
5.4 Wound hematoma	1	41	Risk Ratio (M-H, Fixed, 95% CI)	2.61 [0.11, 60.51]
5.5 Deep venous thrombosis	1	41	Risk Ratio (M-H, Fixed, 95% CI)	0.29 [0.01, 6.72]
5.6 Fatal pulmonary embolism	1	41	Risk Ratio (M-H, Fixed, 95% CI)	0.29 [0.01, 6.72]
5.7 Postoperative pain (> 6 mths)	1	41	Risk Ratio (M-H, Fixed, 95% CI)	0.14 [0.02, 1.09]
5.8 Mesh removal	1	41	Risk Ratio (M-H, Fixed, 95% CI)	2.61 [0.11, 60.51]
6 Components separation technique versus intraperitoneal prosthetic repair (giant hernias)				

Outcome or Subgroup	Studies	Participants	Statistical Method	Effect Estimate
6.1 Recurrence	1	37	Risk Ratio (M-H, Fixed, 95% CI)	0.96 [0.55, 1.69]
6.2 Reoperation for wound complications	1	37	Risk Ratio (M-H, Fixed, 95% CI)	0.30 [0.07, 1.26]

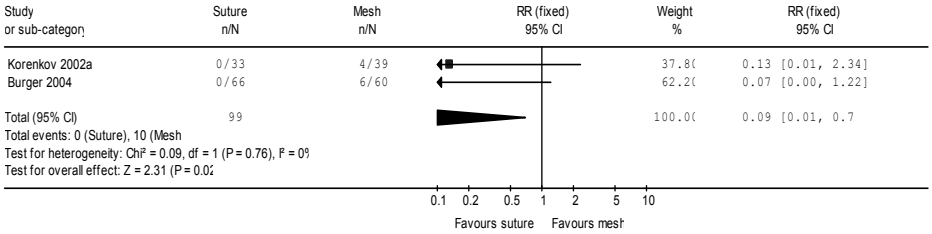
1 SUTURE REPAIR VERSUS MESH REPAIR



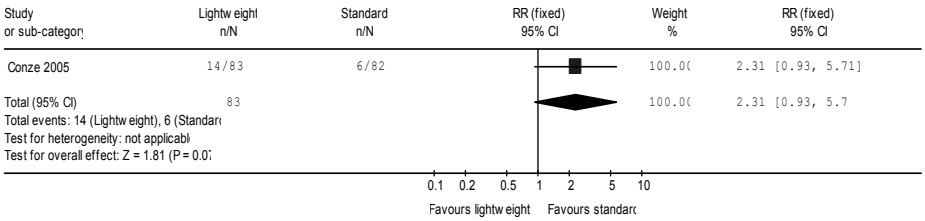




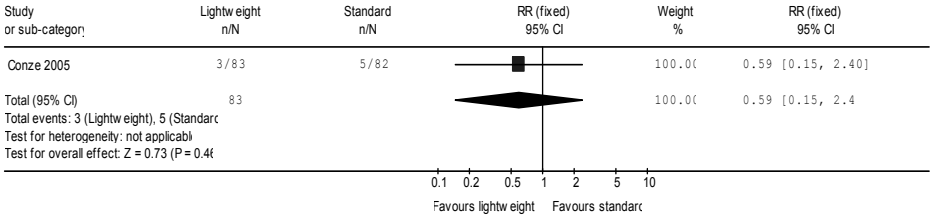
Review Open surgical procedures for incisional hernia
Comparison: 01 Suture repair versus mesh repair
Outcome: 04 Infection



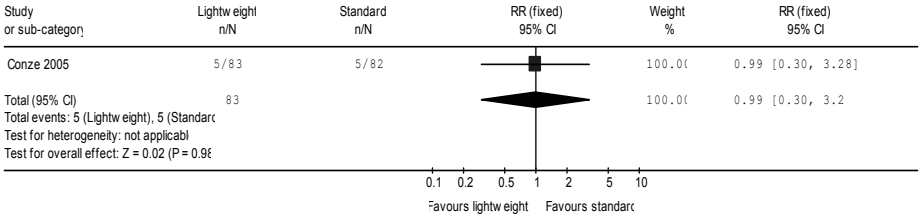
Review Open surgical procedures for incisional hernia
Comparison: 02 Lightweight mesh versus standard mesh in sublay position
Outcome: 01 Recurrence



Review Open surgical procedures for incisional hernia
Comparison: 02 Lightweight mesh versus standard mesh in sublay position
Outcome: 02 Pain



Review Open surgical procedures for incisional hernia
Comparison: 02 Lightweight mesh versus standard mesh in sublay position
Outcome: 03 Deep infection



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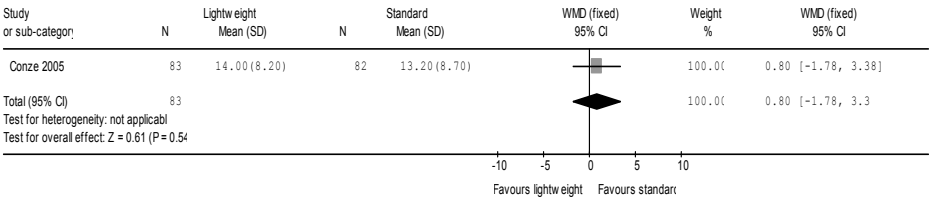
Comparison: 02 Lightweight mesh versus standard mesh in sublay position
Outcome: 04 Hospital stay in days



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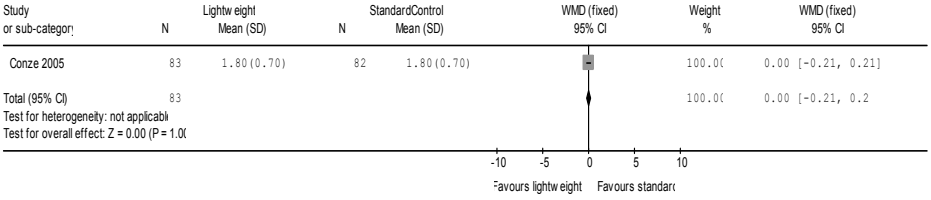
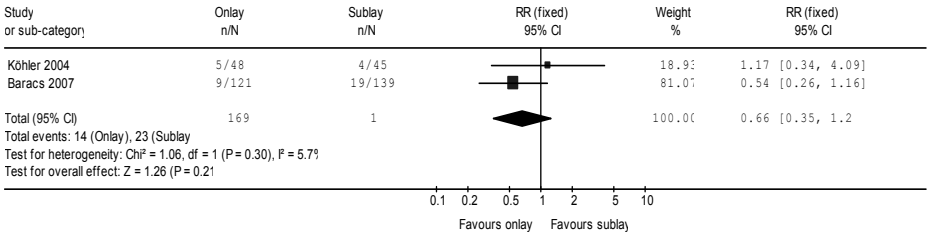
Comparison: 02 Lightweight mesh versus standard mesh in sublay position
Outcome: 05 Operation time in hours



Review Open surgical procedures for incisional hernia
Comparison: 03 Onlay versus sublay mesh
Outcome: 01 Recurrence



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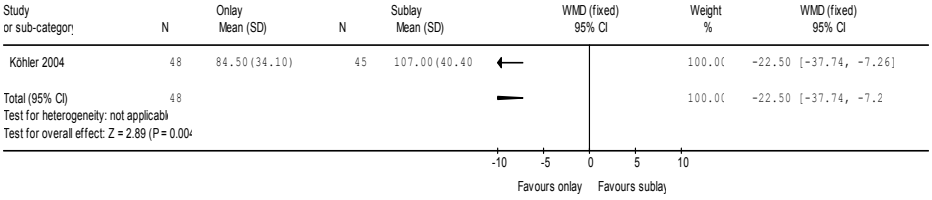
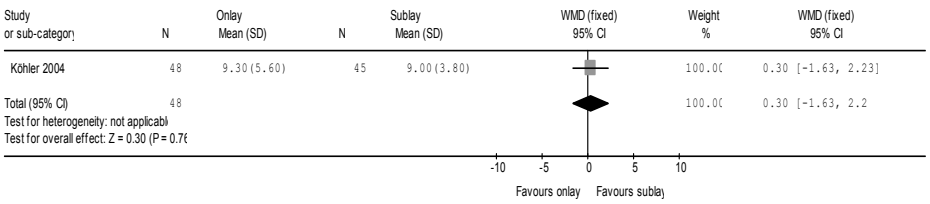
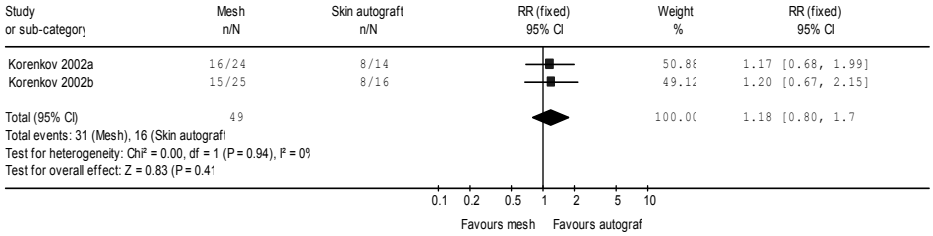
Comparison: 03 Onlay versus sublay mesh
Outcome: 02 Operation time in minutes



Review Open surgical procedures for incisional hernia
Comparison: 03 Onlay versus sublay mesh
Outcome: 03 Hospital stay in days



Review Open surgical procedures for incisional hernia
Comparison: 04 Mesh (polypropylene) versus skin autograft in onlay position
Outcome: 03 Satisfied with cosmetic result



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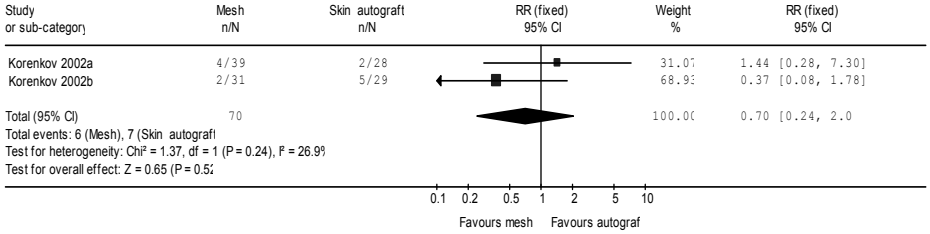
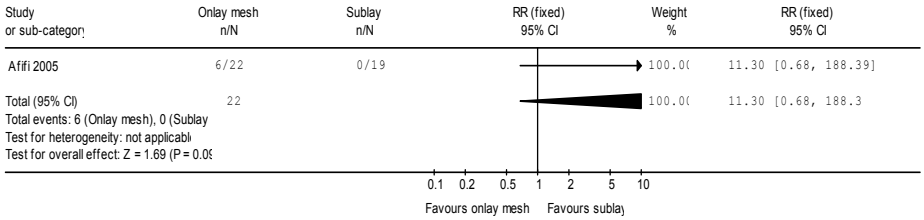
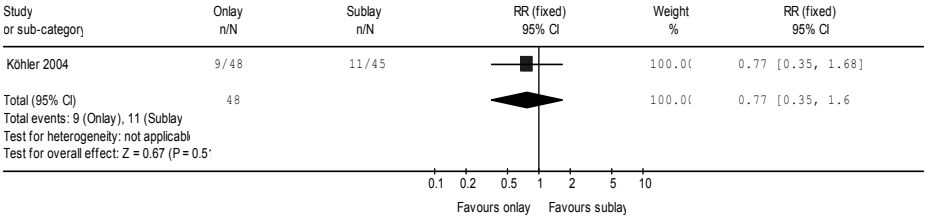
Comparison: 04 Mesh (polypropylene) versus skin autograft in onlay position
Outcome: 04 Deep infection



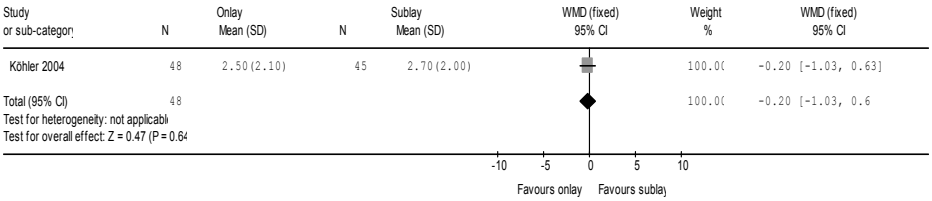
Review Open surgical procedures for incisional hernia
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 01 Recurrence



Review Open surgical procedures for incisional hernia
Comparison: 03 Onlay versus sublay mesh
Outcome: 04 Overall complication rate



Review Open surgical procedures for incisional hernia
Comparison: 03 Onlay versus sublay mesh
Outcome: 05 Postsurgical pain



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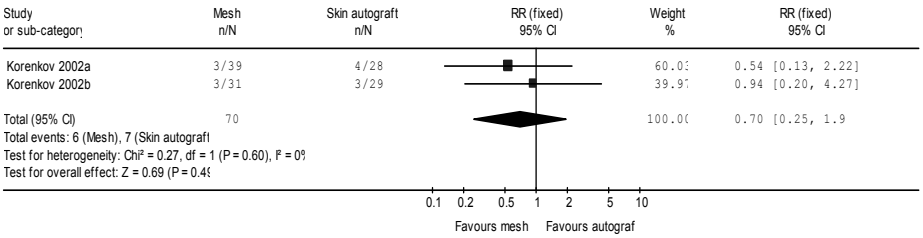
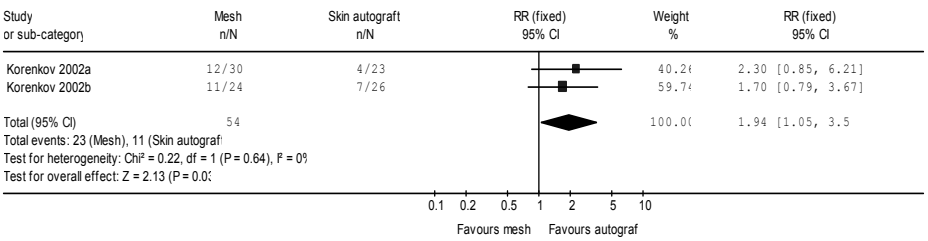
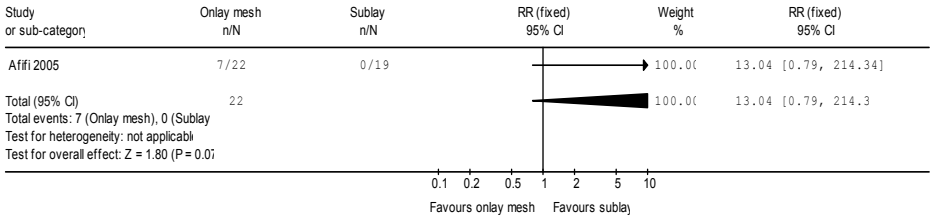
Comparison: 04 Mesh (polypropylene) versus skin autograft in onlay position
Outcome: 01 Recurrence



Review Open surgical procedures for incisional hernia
Comparison: 04 Mesh (polypropylene) versus skin autograft in onlay position
Outcome: 02 Pain



Review Open surgical procedures for incisional hernia
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 02 Seroma



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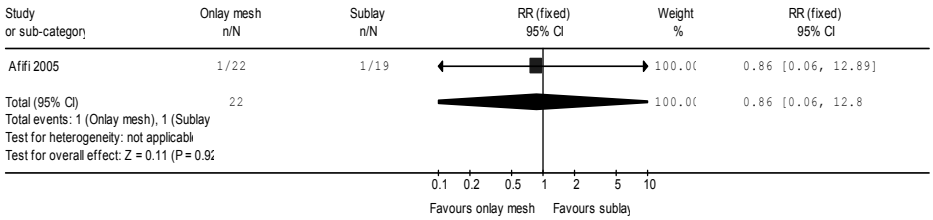
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 03 Superficial wound infection



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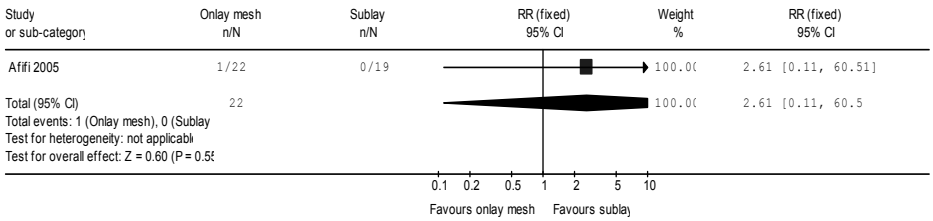
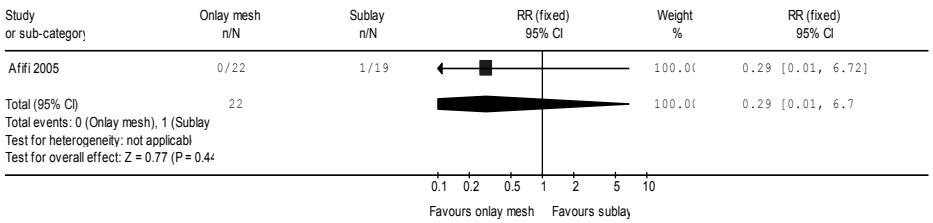
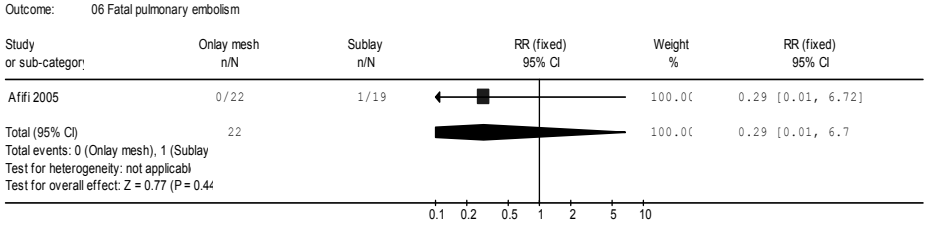
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 04 Wound hematoma



Review Open surgical procedures for incisional hernia
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 05 Deep venous thrombosis



Review Open surgical procedures for incisional hernia
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 06 Fatal pulmonary embolism



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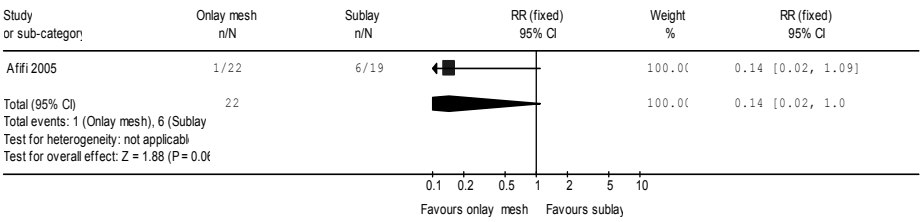
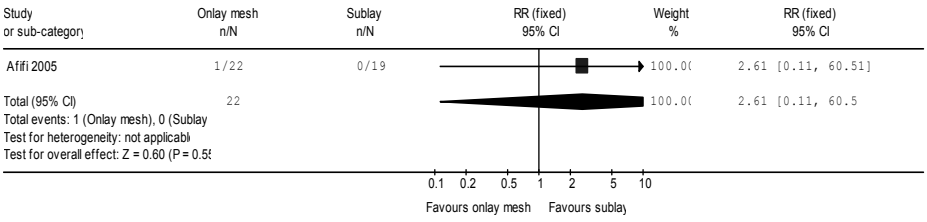
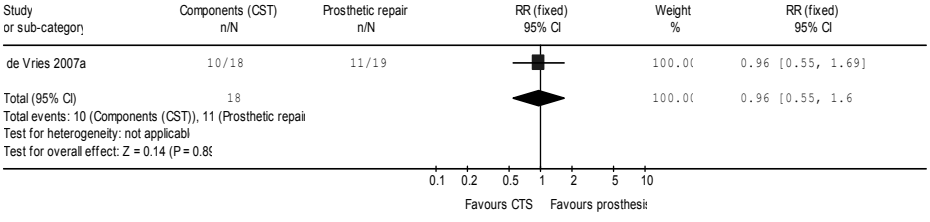
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 07 Postoperative pain (> 6 mths)



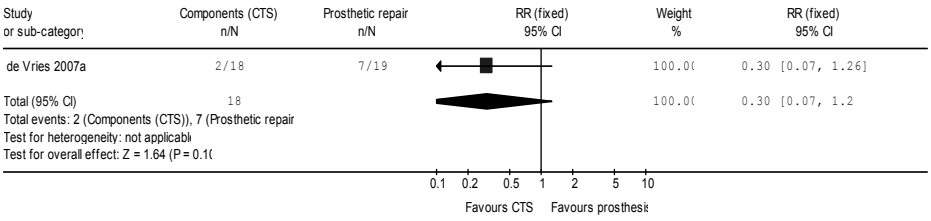
Review Open surgical procedures for incisional hernia
Comparison: 05 Onlay mesh repair versus double mesh intraperitoneal repair
Outcome: 08 Mesh removal

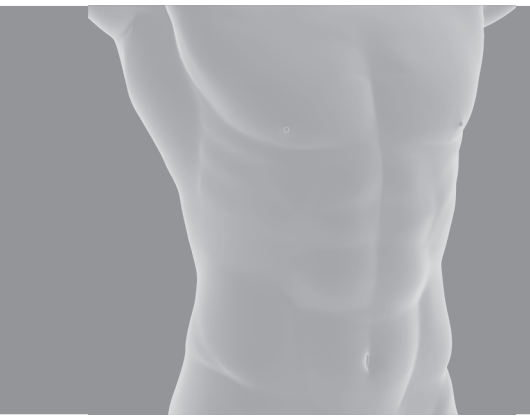


Review Open surgical procedures for incisional hernia
Comparison: 06 Components separation technique versus intraperitoneal prosthetic repair (giant hernias)
Outcome: 01 Recurrence



Review Open surgical procedures for incisional hernia
Comparison: 06 Components separation technique versus intraperitoneal prosthetic repair (giant hernias)
Outcome: 02 Reoperation for wound complications





5

Low recurrence rate of a two-layered closure repair for primary and recurrent midline incisional hernia without mesh

A.H.M. Dur
D. den Hartog
W. E. Tuinebreijer
R. W. Kreis
J.F. Lange

Hernia 2009;13(4):421-6

ABSTRACT

Background Incisional hernia is a serious complication after abdominal surgery and occurs in 11-23% of laparotomies. Repair can be done, for instance, with a direct suture technique, but recurrence rates are high. Recent literature advises the use of the mesh repair. In contrast to this development we studied the use of a direct suture repair in a separate layer technique. The objective of this retrospective observational study was to assess outcomes (recurrences and complications) of a two-layered open closure repair for primary and recurrent midline incisional hernia without the use of mesh.

Methods In an observational retrospective cohort study, we analysed the hospital and outpatient records of 77 consecutive patients who underwent surgery for a primary or recurrent incisional hernia between 1st May 2002 and 8th November 2006. The repair consisted of separate continuous suturing of the anterior and posterior fascia, including the rectus muscle, after extensive intra-abdominal adhesiolysis.

Results Forty-one men (53.2%) and 36 women (46.8%) underwent surgery. Sixty-three operations (81.8%) were primary repairs and 14 (18.2%) were repairs for a recurrent incisional hernia. Of the 66 patients, on physical examination, three had a recurrence (4.5%) after an average follow-up of 2.6 years. The 30-day postoperative mortality was 1.1%. Wound infection was seen in five patients (6.5%).

Conclusions A two-layered suture repair for primary and recurrent incisional hernia repair without mesh with extensive adhesiolysis was associated with a recurrence rate comparable to mesh repair and had an acceptable complication rate.

INTRODUCTION

Incisional hernias are ventral hernias through an operation scar and are a serious complication of abdominal surgery. Incisional hernias occur in 11-23% of laparotomies [1]. Incisional hernias enlarge over time and can give rise to complications such as pain, discomfort, bowel obstruction, incarceration and strangulation. Furthermore, incisional hernias reduce the quality of life and the chances for employment.

The repair can be done by either an open or a laparoscopic technique. The open technique can be a simple hernioplasty (Mayo duplication or fascia-adaptation), a components separation technique or a mesh repair. Laparoscopic correction is always performed with a mesh. The recurrence rate after open suture repair may be as high as 54% [2], and for open mesh repair, up to 32% [2, 3]. The recurrence rate for laparoscopic repair appears to be comparable to the open mesh procedure, but with a shorter hospital stay [1]. In a Swedish cost analysis study (including sick leave), the costs for incisional hernia repair by suture were 6122 Euro and for repair with mesh, they were 5458 Euro [4].

In a recent Cochrane review, the authors conclude that mesh repair is superior to suture repair in terms of recurrences [5]. Burger et al. [6] stated that suture repair of incisional hernias should be completely abandoned. However, in our experience, dedicated surgery for incisional hernias justifies the direct suture repair in a separate layer technique without the use of mesh. In contrast to the mesh repair, the infection rate after suture repair is lower [6]. Furthermore, the clinical relevance of (partial) radiological recurrences is uncertain [5] because in the literature imaging techniques are only used in case of doubt.

The objective of this retrospective observational study is to assess recurrences and complications of our two-layered closure repair for primary and recurrent incisional hernia and to delineate the relationship between clinical and radiological recurrences.

PATIENTS AND METHODS

We conducted a retrospective study of incisional hernias repaired with a two-layered closure method at the Red Cross Hospital, Beverwijk, The Netherlands, between 1st May 2002 and 8th November 2006. The hospital information system was used to find all patients who had undergone an operation for primary or recurrent incisional hernia. We obtained all of the information from the hospital and outpatient medical records. We identified 77 consecutive cases. Six patients were deceased, of which one death was related to the operation (30-day mortality). In January 2008, 71 patients were asked to attend for a physical and an ultrasound (US) examination. Fifteen patients were unable to attend the ultrasound examination, despite repeated attempts. Four patients reached the endpoint of the study because of a re-operation

for a reason other than recurrence. These patients were included in the physical examination group for calculating the recurrence rate.

A two-layered closure repair was performed without the use of mesh in 77 patients: 36 women (46.8%) and 41 men (53.2%). The mean age of these patients was 62.2 years (standard deviation [SD] =14.4). The mean body mass index (BMI) was 28.8 kg/m^2 (SD=6.5). The indication was a primary incisional hernia in 63 patients (81.8%) and a recurrent incisional hernia in 14 patients (18.2%). The primary hernia repair in the 14 patients with a recurrent repair was a suture repair in nine patients and a mesh repair in five patients. A history of smoking was found in 19 patients (24.7%), diabetes in nine patients (11.7%), and corticosteroid use in two patients (2.6%). A wound infection was found in 15 patients (19.5%) after the primary operation after which the incisional hernia developed. In nine patients, a history of a burst abdomen was found (11.7%).

The hernias were measured during operation and classified according to size in three categories: small (<5 cm in width or length), medium (5-10 cm in width or length) and large (>10 cm in width or length) [7].

All US examinations were done by one radiologist. Ultrasound examinations were performed using high-end ultrasound equipment (Aplio XG, model SSA-796A, Toshiba Medical Systems Corporation 1385, Shimoishigami, Otawara-Shi, Tochigi-Ken 324-8550, Japan and ATL 5000, Philips, ATL-factories, Bothell, USA). A total recurrence was defined as a defect in both the posterior and the anterior fascia.

Operations were performed either by one of two surgeons or by surgical residents under supervision of these two surgeons.

Operative technique

The abdomen is opened through the midline incision scar. The incision is equal to the length of the scar and does not depend on the size of the hernia. All scar tissue is excised. The mutual bowel adhesions and adhesions between the bowel and the ventral abdominal wall are removed. In this manner, there is no retraction of the abdominal wall and the bowels are divided equally over the whole abdominal cavity. The hernia sac and scar tissue are excised from the fascia rims. On both sides of the incision, the rectus sheath is opened from the midline to develop a free anterior and posterior fascia of the same length. The rectus muscles become exposed during this manoeuvre. With a running polydioxanone suture (PDS-loop, Ethicon, Johnson & Johnson Medical), the posterior fascia is closed together with the peritoneum, and parts of the rectus muscle are included. The suture technique is done with a short stitch length and a suture-length-to-wound-length ratio of four or more, as described by Millbourn and Israelsson [8]. Next, the anterior fascia is closed with a running polydioxanone suture, and parts of the rectus muscle are included. The rectus muscles are not sutured together separately, but always with the anterior or posterior fascia. At the end of this procedure, two separate layers are identified: the anterior and posterior fascia with the rectus muscles. Mesh and drains are not used as a standard procedure. If the tension on the fascia is too tight, the anterior and posterior

fasciae are closed simultaneously to reduce the tension on the posterior fascia. Additionally, the closure is simultaneously started superiorly and inferiorly to divide the tension over the entire wound. In most of our cases, it is not a tension-free technique. Subcutaneous tissue and skin are closed with interrupted sutures. Surplus skin arising as a consequence of this anatomical repair is excised. The surgical technique is shown in Figs. 1-4.

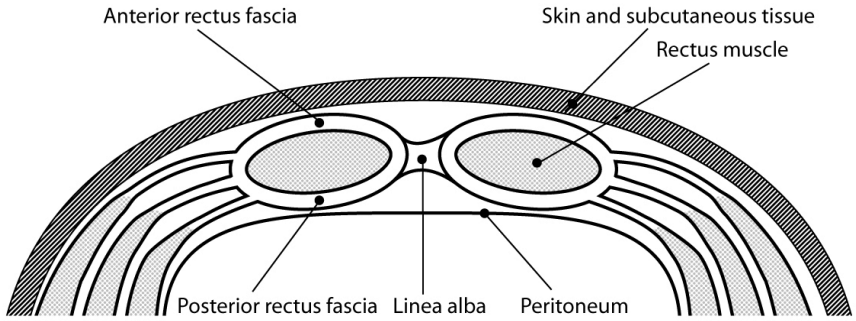


Fig. 1 Diagram of the anatomy of the median ventral abdominal wall. In front of the rectus muscles are the anterior rectus fasciae and on the backside the posterior rectus fasciae. The anterior and posterior rectus fasciae join medially to form the linea alba

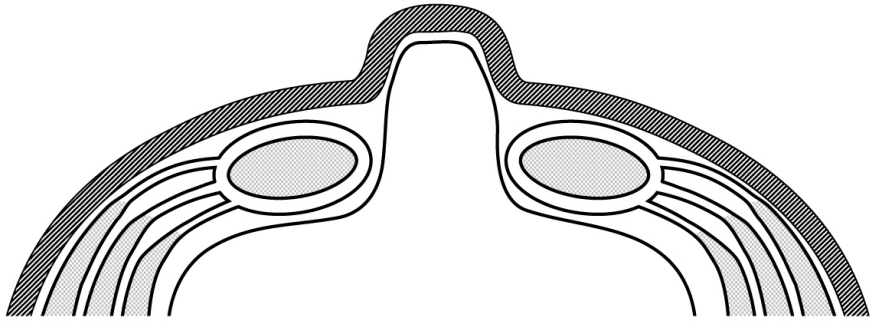


Fig. 2 Diagram of the anatomy of an incisional hernia through a midline abdominal incision. The hernial sac consists of the peritoneum, which is covered by skin and subcutaneous tissue

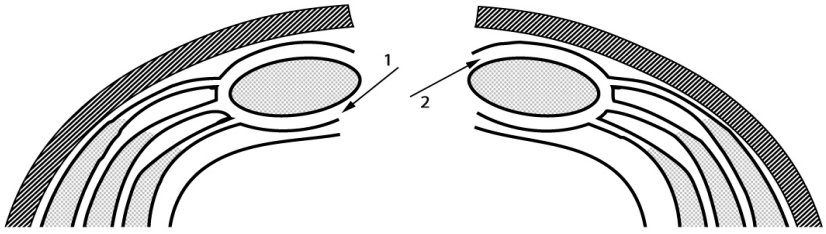


Fig. 3 Diagram of the surgical situation after resection of the scar tissue and hernial sac. The rectus sheaths are opened through the posterior rectus fasciae (arrow 1) on the medial sides. Then, the rectus muscles and anterior rectus fasciae (arrow 2) are exposed

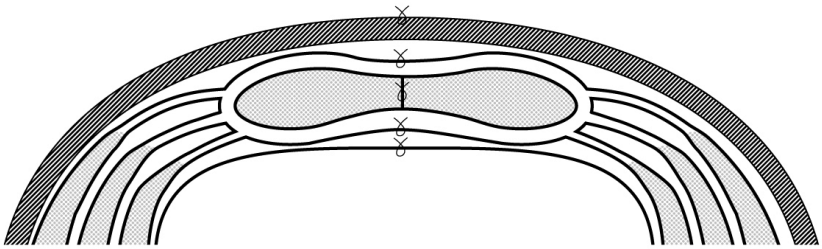


Fig. 4 Diagram of the three-layered closure. Anterior and posterior rectus fasciae and rectus muscles are sutured in separate layers and form the three layers of the repair

Statistical analysis

The statistical analysis was performed with SPSS (version 11.0) on a personal computer. Categorical data are presented as the number of subjects in the category, along with the percentages. All continuous data are given as means with SDs.

The Chi-square test and Fischer's exact test were used to compare the patients with and without an ultrasound follow-up examination and the patients with and without a recurrence. The independent Student's *t*-test was used to compare the length of follow-up of the patients with and without an ultrasound follow-up examination. A *P*-value <0.05 was taken as the threshold of statistical significance.

RESULTS

The mean operation time was 114.5 minutes (SD=65.7). Mean blood loss was 438.2 ml (SD=842.7). The mean postoperative stay in the hospital was 9.0 days (SD=13.4) and the mean stay in the intensive care unit (ICU) was 1.1 days (SD=4.4). The mean ventilation time in days in the ICU was 0.68 days (SD= 2.9). Seven patients (9.1%) were ventilated and 14 patients (18.2%) were admitted to the ICU. Admission to the ICU was often preoperatively planned by the anaesthesiologist because of preoperatively estimated comorbidity. The mean length of follow-up for the ultrasound examination was 3.1 years (SD=.94, range 1.2-5.2 years).

The primary operation after which the incisional hernia developed was a median upper abdominal incision in 18 patients (23.4%), a median lower abdominal incision in 13 patients (16.9%) and a combined upper and lower incision (59.7%) in 46 patients.

The size of the hernia was small in 20 patients (26.7%), medium in 41 patients (54.7%) and large in 14 patients (18.7%). Information about the size of the hernia was missing in two patients.

The complications are stated in Table 1. The 30-day postoperative mortality was 1.3% (*n*=1). The cause of mortality was aspiration followed by pneumonia and multiple organ failure. Wound infection was seen in five patients (6.5%) and wound haematoma was seen in two patients (2.6%). Respiratory insufficiency was seen in four patients (5.2%) and pneumonia was seen in five patients (6.5%), leading to artificial ventilation in three patients, with full recovery.

Table 1 Complications

Mortality		1 (1.3%)
Wound infection		5 (6.5%)
Wound haematoma		2 (2.6%)
Respiratory insufficiency		4 (5.2%)
Pneumonia		5 (6.5%)
Cardiovascular complications		6 (7.8%)
Bowel obstruction		2 (2.6%)
Wound fistula		1 (1.3%)
Abdominal compartment syndrome		1 (1.3%)
Recurrence		
By physical examination:	Yes	3 (4.5%)
	No	63 (95.5%)
By ultrasound examination:	Yes	7 (13.5%)
	No	44 (84.6%)

Cardiovascular complications were seen in six patients (7.8%) and were treated with medication and follow-up by the cardiologist. Three patients experienced cardiovascular complications with respiratory insufficiency, including pneumonia. Temporary bowel obstructions were seen in two patients (2.6%) and were treated conservatively. Wound fistula developed in one patient (1.3%). The wound healed without further complications after exploration with the removal of a suture granuloma. An abdominal compartment syndrome was seen in one patient (1.3%), which necessitated immediate open-abdomen treatment and successive closure with sublay mesh technique.

Of the 77 patients, six deceased, one was unable to attend follow-up physical examinations and 15 were unable to attend the ultrasound examination, despite repeated attempts. Four patients reached the endpoint of the study because of re-operation for a reason other than recurrence. These four patients were included in the physical examination group for calculating the recurrence rate. In this group, one recurrence was diagnosed during surgery.

No significant differences were found between the patients with and without an ultrasound follow-up examination for the variables examined, except for a significant difference for sex and length of follow-up of the physical examination. More women than men had an ultrasound follow-up examination (P=.002). The mean length of follow-ups for the physical examination in the ultrasound and non-ultrasound groups were 3.1 years (SD=0.94) and 1.15 years (SD=1.23), respectively (P=0.000). Recurrences were diagnosed by physical examination in three patients out of 66 patients examined (4.5%) after a mean follow-up of 2.6 years (SD=1.3), and by ultrasound in seven patients out of 52 patients examined (13.5%) after a mean follow-up of 3.1 years (SD=.94). All of these patients had a partial defect in the length of the fascia. One patient had only a small defect of the posterior fascia of the rectus sheath with an intact anterior fascia diagnosed by ultrasound. There were no symptoms and no recurrence diagnosed by physical examination in this patient, and the data of this patient were not used for the calculation of the recurrence rate after ultrasound, given our definition of recurrence.

Predictor variables of hernia recurrences were not found and probably could not be estimated because of the low recurrence and complication rates. For instance, no correlations were found between recurrence and hernia size, BMI, age, sex, diabetes and smoking.

DISCUSSION

Our two-layered suture repair of incisional hernias without mesh showed a clinical recurrence rate of 4.5% after a mean follow-up of 3.1 years. We found a discrepancy between the clinical and ultrasound recurrence rates. Of 52 patients, examination with ultrasound identified seven with a recurrence (13.5%) after a mean follow-up time of 3.1 years. Most publications only report the lower clinical recurrence rates, which will be more strongly correlated with the complaints and symptoms of the patient. In four recent randomised clinical trials (RCTs) investigating incisional hernias, the outcome of recurrence was measured by physical examination, and radiological examination was done only on indication, but recurrence rates by these examinations were not reported [6, 9-11].

Our complication rate was acceptable. For instance, our wound infection rate was 6.5%. A recent Cochrane review calculated a pooled infection rate for mesh repair of 10.1% [5]. In mesh repair, wound infection can lead to infection of the prosthesis, sometimes necessitating mesh removal.

The Cochrane review found solid evidence to advocate for the use of mesh repair for the open repair of incisional hernias [5]. The pooled recurrence rate was 33.3% for the suture repair group and 16.4% for the mesh group. In the RCT of Burger et al., the recurrence rate in the suture group was 56% after a median follow-up of 75 months, and in the RCT of Korenkov et al., the recurrence rate was 12% after 13 months [6, 11].

On a poster, Baracs et al. [12] reported the results of a multicentre RCT. The recurrence rate was 16.9% in the suture group (*n*=89) compared with 6.8% in the sublay mesh group (*n*=103) after a follow-up of 3-5 years; this difference was significant.

In their study of giant hernias with a length of at least 20 cm, de Vries Reilingh et al. [9] described a high recurrence rate of 56% in the components separation group. The authors could not close the fascia in their patients with a mesh repair. With the two-layered closure technique, it was possible to close the fascia in our patients. Our study group included different hernia sizes, but most hernias (54.7%) were between 5-10 cm in width or length and 18.7% were larger than 10 cm in width or length. This distribution was caused by the fact that our patients are a continuous series and that our hospital is a referral centre for incisional hernias. This diverse distribution of the hernia sizes and our inclusion of patients consecutively in this study allowed us to conclude that there was no patient selection.

What makes our technique so successful? The following reasons might explain our success. First, the two-layered suture repair consists of an extensive adhesiolysis, which prevents

retraction and gives space to move the abdominal wall to the midline. In addition, the adhesiolysis makes it possible for the bowels to move freely instead of moving as a block, and they adjust more easily to the reduction in the abdominal cavity. Second, the abdominal wall is anatomically reconstructed. It is very important that the rectus muscles are placed in their normal median position. In our technique, they are attached to each other at the midline and, as a result, they can exert normal function. It is important to note that we do not suture the rectus muscles separately to each other, but always together with the anterior or posterior fascia to prevent tension and, thus, necrosis of the muscle.

Muscle can not stretch as fascia does, and muscle can keep an isometric state during different loads, such as lifting. Furthermore, the two-layered fascia closure is stronger than a one-layered repair. Another explanation relies on theoretical arguments that fibroblasts from the rectus muscle positively influence the fascia healing in the midline. All scar tissue and the hernia sac are additionally removed up to the median border of the rectus fascia. Finally, the entire primary incision is explored independent of the size of the hernia, so we are treating future recurrences along these parts of the fascia. Often, weak spots and small defects are found in the fascia that are distinct from the repaired hernia. As a result, we only use healthy functional tissue and simultaneously identify non-diagnosed small hernias within the remainder of the scar. Because the anterior and posterior fascia are often sutured under tension, we abandon the important surgical principle in hernia surgery of tension-free repair. Our low recurrence rate shows that this is possible. However, the disadvantage of this technique under tension can be the occurrence of an abdominal compartment syndrome, which, in our series, was treated by open abdomen and successively closed with the mesh technique.

An important observation to explain our low recurrence rate is the low incidence rate of incisional hernias (less than 1%) in the so-called lateral paramedian incision [13]. In this incision, the anterior and posterior rectus sheath are incised at a point not less than two-thirds of the width of the rectus sheath from the midline. The sutured rectus sheaths are covered by rectus muscle and, therefore, are comparable with our two-layered suture repair.

All of our surgeries were done by or under the direct supervision of experienced surgeons, using a strict protocol for the surgical technique. Our good results could be due, in part, to this method of dedicated surgery. In contrast, in all of the referenced RCTs, the open suture repairs are inappropriately described in this regard [6, 11, 12].

This operation is a major procedure that can result in a longer hospital stay, intensive care stay and time on a ventilator.

Significantly more women than men attended the ultrasound examination, which we explained as a better compliance and cooperation of the female patients. The longer length of follow-up for the physical examination of the patients with an ultrasound examination can be explained by the fact that the ultrasound examination was always preceded by a physical examination by the surgeon. So the willingness of the patient to come to the hospital for the ultrasound examination was used to perform a physical examination. The ultrasound

examination was performed at the end of this study and can be looked upon as the prospective part of our study. However, these two significant findings could also be false-positive results of the subgroup analysis.

Because our study is retrospective, it could be open to bias. For this reason, it is necessary to perform an RCT comparing our technique with mesh repair. In contrast to our technique, the latter can be done laparoscopically with less blood loss and a shorter hospital stay [14, 15]. An important advantage of the direct suture repair is avoidance of using a mesh. This avoids the risk of prolonged pain, seroma and mesh-related infections, which often require mesh removal [14]. In one study, extensive laparoscopic adhesiolysis was the major cause of an enterotomy rate of 3.3%, which often necessitates conversion to an open procedure [14]. The complications of the mesh repair should be weighed against the risk of 1.3% occurrence of an abdominal compartment syndrome in our study. By avoiding the use of a mesh prosthesis, which will often be represented by an expensive intraperitoneally positioned composite mesh, a very important cost reduction can be accomplished. In contrast with our anatomical repair the laparoscopic repair has as a common problem, the surplus of skin that remains and chronic postoperative seroma.

We advocate the use of the two-layered closure technique for primary and recurrent incisional hernias without a mesh.

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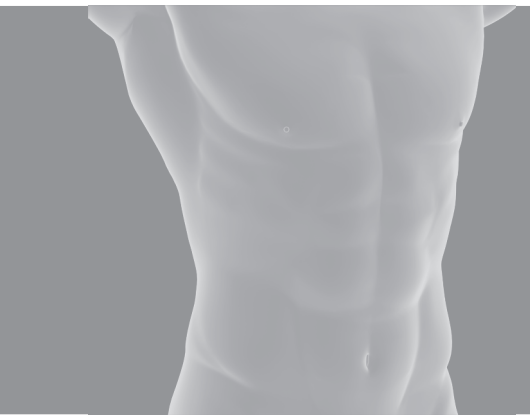

6

Isokinetic strength of the trunk flexor muscles after surgical repair for incisional hernia

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ABSTRACT

Purpose The repair of incisional hernias can be accomplished by open or laparoscopic techniques. The Biodex® dynamometer measures muscle strength during isokinetic movement. The objectives of this study were to compare the strength of the trunk flexors between patients who underwent repair for incisional hernia and a control group, and to compare trunk flexion after two kinds of operative techniques for incisional hernias with and without approximation of the rectus abdominis muscles.

Methods The trunk flexion of 30 patients after different operative techniques for midline incisional hernias and of 12 healthy subjects was studied with the Biodex® isokinetic dynamometer.

Results The mean torque/weight (Nm/kg) for trunk flexion was significantly higher in the control group compared to the patient group after incisional hernia repair. A significantly higher peak torque/weight [coefficient 24.45, 95% confidence interval (CI) -0.05; 48.94, *P*=0.05] was found in the two-layered suture technique without mesh compared to the laparoscopic technique after adjusting for gender.

Conclusions The isokinetic strength of the trunk flexor muscles is reduced after an operation for incisional hernia. There is some evidence that a two-layered suture repair with approximation of the rectus abdominis muscles results in higher isokinetic strength of the trunk flexor muscles compared to the laparoscopic technique.

INTRODUCTION

Incisional hernias are a serious complication of abdominal surgery and they occur in 11-23% of laparotomies [1]. After abdominal aortic resection, the incidence of incisional hernia can be as high as 60% [2]. The hernia can be repaired by either open or laparoscopic techniques. Laparoscopic correction is always performed with a mesh. The open technique can be simple herniorrhaphy (Mayo duplication or fascia adaptation), component separation technique after Ramirez or a mesh repair with (Rives-Stoppa) or without approximation of the rectus abdominis muscles. The open technique can be performed using a separate-layer technique without the use of mesh [3]. In this two-layered suture repair, the abdominal wall is anatomically reconstructed and the rectus muscles are placed in a normal median position. In this technique, the rectus muscles are attached to each other at the midline; as a result, they are thought to retain normal strength. However, muscle strength studies of the trunk flexors after abdominal operations are rarely performed. Zauner-Dungl et al. studied trunk flexion strength after rectus abdominis muscle flap transfer in reconstructive surgery with an isokinetic dynamometer [4]. The same group studied trunk flexion strength comparing a laparoscopic technique with open cholecystectomy [5].

The Biodex® dynamometer studies muscle strength during isokinetic movement, which is a movement with a constant angular velocity (given by the dynamometer) within a certain range against a changing resistance, given by the subject [6-8].

The object of this study is to compare trunk flexion strength between patients who underwent surgical repair for incisional hernia and a healthy control group. The second objective is to compare trunk flexion strength after two different kinds of operative techniques for incisional hernia.

PATIENTS AND METHODS

This study consisted of 30 patients who underwent midline incisional hernia operations and 12 healthy subjects without any abdominal operation. Fifty-five percent of the subjects were male and their mean (standard deviation [SD]) age, height, body weight and body mass index were 60 (15) years, 173 (11) cm, 81 (18) kg and 27 (4) kg/m^2, respectively. The mean age was significantly lower in the control group than in the patient group (49 vs. 64 years, $P<0.01$). The patients had undergone operations in either an academic (n=14) or a teaching hospital (n=16). Sixteen (53.3%) patients had operations with an open technique and 14 (46.7%) by laparoscopic access. In the laparoscopic technique, a mesh was used and the fascia was left open. In the open repair, the fascia was closed in a two-layered technique without using a mesh [3]. The mean follow-up time between the Biodex® examination and the operation was 5.8 (1.8) years.

Trunk flexion strength measurements were conducted on a Biodex® isokinetic dynamometer (Model 2000, Multijoint System 3, Biodex Corporation, Shirley, NY, USA). Each subject

Fig.1 . Set-up of Biodex® isokinetic dynamometer

was seated on a chair with his or her body strapped to the back of the chair. The mechanical stops were positioned with an amplitude of 60° to prevent the subject from working in non-conventional zones (Fig. 1). One session of flexions and extensions was performed to get the subject accustomed to the exercise before testing. The second test session was used for collecting data measurements.

Trunk flexor muscles were assessed at 60°/s angular velocities. The subjects performed six flexions and extensions and were encouraged to generate maximal effort through the entire range of motion for all repetitions. The peak torque was expressed in Newton metres (Nm) and

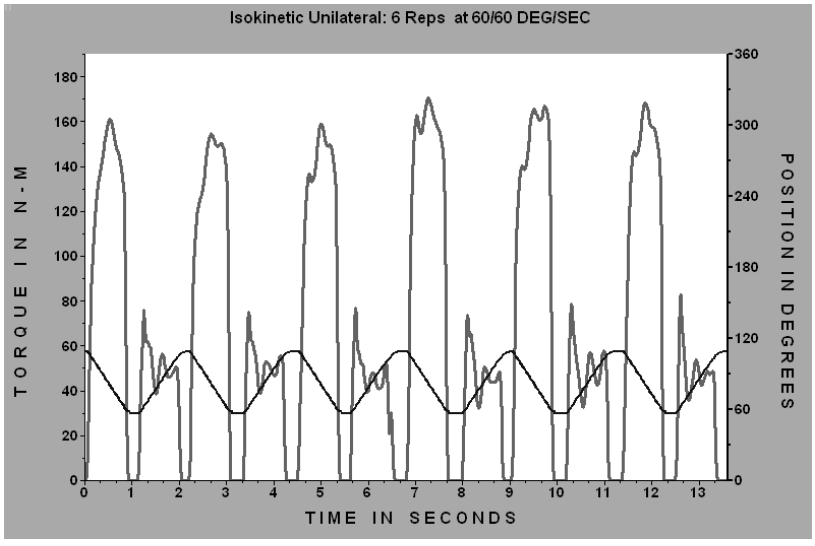

Fig. 2. Example of the torque course of six flexions and extensions as a function of time

was normalised to body weight (Nm/kg x 100%). Torque was proportional to power and the peak torque was the highest value within the range of motion (Fig. 2).

Statistical analysis

Statistical analysis was performed with the PASW Statistics 17.0 package on a personal computer. All continuous data were given as means with SDs.

The two-sample *t*-test was used to compare the control and operative groups for age, weight and length. The Chi-square test was used to compare the control and operative groups for gender.

The two-sample *t*-test was used to compare the Biodex® measurements in the controls and patients after operative repair for incisional hernia. This test was also used to compare the Biodex® measurements among themselves in patients after two operative techniques for incisional hernia, two-layered closure repair and laparoscopic repair with a mesh. A *P*-value <0.05 was taken as the threshold of statistical significance.

The relationship between the peak torque (Nm) and the operative technique (open or laparoscopic) was estimated using multiple regressions allowing for body weight, age and gender. Non-significant variables were removed one by one, removing the largest *P*-value first, until all of the remaining variables in the model were significant.

Because values of the Biodex® measurements with standard deviations from patients after incisional hernia operations could not be retrieved from the literature, sample size calculations could not be performed.

RESULTS

Gender, height and weight were not significantly different between the patients and controls or between the open and laparoscopic groups.

The mean torque/weight (Nm/kg) for trunk flexion was significantly higher in the control group than in the total patient group after incisional hernia repair (Table 1). This difference with the control group existed for both kinds of operative techniques, namely, the two-layered closure and the laparoscopic repair.

Table 1 Mean peak torque related to body weight in Nm/kg (standard deviation [SD]) in trunk flexion comparing two different operations for incisional hernia with the control group (n=12)

Peak torque/weight (Nm/kg)	Operation group	Control group (n=12)	Confidence interval of the difference	*P*-value
Total operation group (n=30) versus control	84.4 (38.9)	202.4 (88.6)	60.5; 175.4	<0.01
No mesh = two layered technique (n=16) versus control	95.8 (39.7)	202.4 (88.6)	47.9; 165.3	<0.01
Laparoscopic (n=14) versus control group	71.4 (34.8)	202.4 (88.6)	72.6; 189.4	<0.001

Table 2 Mean peak torque related to body weight in Nm/kg (SD) in trunk flexion comparing the two operations for incisional hernia

Peak torque/weight (Nm/kg)	Laparoscopic group (n=14)	Two-layered technique (n=16)	Confidence interval of the difference	*P*-value	Power post-hoc
Laparoscopic versus two-layered technique	71.4 (34.8)	95.8 (39.7)	-52.5; 3.6	0.086	0.41

Table 3 Regression coefficients of peak torque related to body weight in Nm/kg with respect to gender and laparoscopic access versus the two-layered suture technique

Variable	Coefficient	95% confidence interval (CI)	*P*-value	Standardised coefficient
Gender[a]	-37.58	-62.02; -13.14	0.004	-0.49
Laparoscopic versus two- layered suture technique[b]	24.45	-0.05; 48.94	0.050	0.32

[a] Male gender is the reference category

[b] Laparoscopic access is the reference category

The mean torque/weight (Nm/kg) for trunk flexion was not significantly different in a mutual comparison of the two operative techniques (two-layered closure repair and laparoscopic repair with a mesh) (Table 2). The post-hoc power calculation is presented in the last column of Table 2.

A significantly higher peak torque/weight (coefficient 24.45, 95% confidence interval [CI] -0.05; 48.94, *P*=0.05) was found in the two-layered suture technique compared to the laparoscopic technique after adjusting for gender (Table 3).

DISCUSSION

In this study, we compared the isokinetic muscle strength of the trunk flexor muscles measured with the Biodex® isokinetic dynamometer between patients who underwent repair for incisional hernia and a control group without any abdominal operation. The mean peak torque, as a measure of the isokinetic strength of trunk flexor muscles, was significantly lower in the patients with incisional hernia operations than in the healthy controls. We also compared the trunk flexion strength after two kinds of operative techniques for incisional hernias with and without approximation of the rectus abdominis muscles. A significantly higher peak torque/weight was found in the two-layered suture technique compared to the laparoscopic technique after adjusting for gender.

Midline incisional hernias displace the rectus muscles laterally. This lateral position might be the cause of a weakened abdominal muscle strength. In a study comparing laparoscopic with open cholecystectomy, the open technique resulted in reduced muscle strength of the trunk flexor muscles compared to controls and the laparoscopic approach [5]. The open cholecystectomy was performed subcostally with transections of the right rectus abdominis muscle. This

is in contrast with the laparoscopic technique through small incisions, which leave the rectus abdominis muscles intact. So, a scarred rectus abdominis muscle lowers the muscle strength of trunk flexion measured with an isokinetic dynamometer.

In contrast to the two-layered closure repair for incisional hernia, in which the rectus muscles are medially positioned and, as such, can exert greater strength, in the laparoscopic mesh technique, the rectus muscles remain in their lateral displaced position.

Despite the considerable academic interest, the clinical relevance of a reduced isokinetic strength of the trunk flexors is not exactly known and correlations between strength, signs and symptoms have not been studied. Significantly lower mean strength values have been found in patients with chronic back pain [7]. It will be interesting to study the relationship between the reduced muscle strength of trunk flexors in patients with incisional hernia and the patients' symptoms before and after surgical repair. Overall, incisional hernia symptoms have not been systematically studied [9]. The reduced muscle strength of trunk flexors in patients after laparoscopic techniques for incisional hernia could cause a higher prevalence of back pain than in patients after the two-layered closure repair with approximation of the rectus abdominis muscles.

The statistical power for finding a significant difference between the two operative techniques was low and was caused by the small sample sizes of the groups. Because we only rented the Biodex® isokinetic dynamometer for a limited time, more patients could not be examined. The small sample size of our study is a flaw for making strong conclusions. Measuring the same patients before and after operation will increase the power of the study.

Another limitation of our study is the use of healthy controls. A better and more interesting study group for comparison would be a patient group with a well-healed scar after a median laparotomy or patients with a large primary incisional hernia. Our healthy controls were also younger than the incisional hernia patients. This could have resulted partly in the large difference between the controls and the patients. We did not examine the trunk flexor muscles in patients after a midline laparotomy and in patients with an incisional hernia. Balogh et al. studied isokinetic muscle strength of the trunk flexor muscles with the Cybex® isokinetic dynamometer 6 months to 1.5 years after open subcostal cholecystectomy and in healthy volunteers [5]. Their controls consisted of 10 men and 12 women, but these volunteers had a mean age of 23.5 years younger than our controls. Their mean peak torque at 30°/s angular velocity was 221.7 Nm/kg. Keeping account of the higher age of our controls, this is comparable with the mean peak torque at 60°/s of 202.4 Nm/kg. The mean peak torque at 30°/s of the open cholecystectomy group (13 men, 12, female, mean age 58 years) of Balogh et al. was 170.7 Nm/kg, which is much higher than in our incisional hernia group (84.4 Nm/kg). So, having an incisional hernia and incisional hernia surgery affects the peak torque more than having a laparotomy, such as an open subcostal cholecystectomy.

Moreover, it will be necessary to replicate the significant difference in peak torque between the laparoscopic group and the two-layered closure repair in larger sample sizes. It is important

and interesting to establish whether the difference in trunk flexor torque also exists in other open procedures, in which the fascia is closed; this question should also be studied in larger sample sizes than those used in this study.

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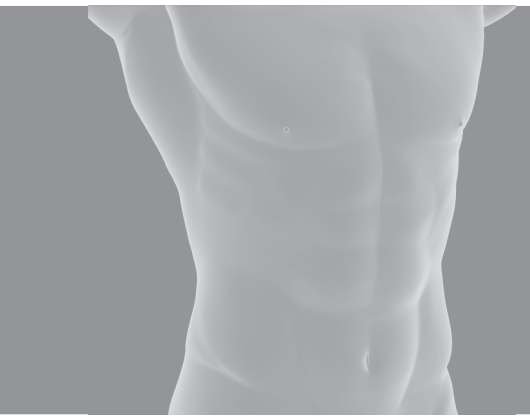

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Functional outcome after laparoscopic and open incisional hernia repair

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ABSTRACT

Background:
The debate about the advantages of laparoscopic versus open incisional hernia repair is still ongoing. The primary outcomes of already published studies are mainly recurrence, pain and quality of life. Data on postoperative abdominal wall function after these corrections is still lacking. In this single center study muscle strength and transverse abdominal muscle thickness were analysed with regard to open and laparoscopic techniques.
Methods:
Thirty-five patients that underwent open and laparoscopic midline incisional hernia correction were included. Approximation of the rectus muscles was included in some open procedures but never in laparoscopic correction. Twelve healthy subjects without any abdominal operation functioned as a control group. Trunk flexion muscle strength of all operated patients and 12 healthy subjects was studied with the Biodex® isokinetic dynamometer and conventional abdominal muscle trainers for the rectus and oblique abdominal muscles. All patients underwent ultrasound examination of the abdominal wall for analysing transverse abdominal muscle thickness.
Results:
The mean torque/weight (%) for trunk flexion, measured with the Biodex®, was significantly higher in the control compared with the total patient group. Comparing trunk flexion with the Biodex® after either laparoscopic or open incisional hernia repair showed a trend in favour of the open group after adjusting for gender. The muscle strength measured by the conventional abdominal muscle trainers showed no differences between the operation groups. The transverse abdominal muscle thickness difference between rest and contraction was significantly higher in the open repair group.
Conclusions:
The isokinetic strength of trunk flexor muscles is reduced after an operation for incisional hernia. There is some evidence that open repair with approximation of the rectus abdominis muscles results in higher muscle strength of the rectus muscles and higher thickness differences between rest and contraction of the transverse abdominis muscles compared to laparoscopic technique.

INTRODUCTION

Despite extensive research on the optimal closing technique for midline laparotomy, the risk for incisional hernia still remains about 5-20% [1, 2]. After abdominal aortic resection, the incidence of incisional hernia can be as high as 60% [2, 3]. Accordingly incisional hernia is the most frequently observed long-term complication in surgery, causing high morbidity and even mortality rates [4-8]. Complaints, such as pain, discomfort and respiratory restriction, subsequently lead to surgical repair in a large number of patients [9, 10].

Incisional hernias can be repaired by either open or laparoscopic techniques. As a rule laparoscopic correction is performed with a mesh. The open technique can be a simple hernioplasty (Mayo duplication or fascia-adaptation), component separation technique after Ramirez or a mesh repair with (Rives-Stoppa) or without approximation of the rectus abdominis muscles.

However, muscle strength studies of the trunk flexors after abdominal operations are rarely performed. Zauner-Dungl et al. studied trunk flexion strength after rectus abdominis muscle flap transfer in reconstructive surgery with an isokinetic dynamometer [11]. The same group studied trunk flexion strength comparing a laparoscopic with open cholecystectomy [12].

Using the Biodex® dynamometer muscle strength is measured during isokinetic movement, which is movement with a constant angular velocity (given by the dynamometer) within a certain range against a changing resistance given by the subject [13-15].

Another way to assess dynamic strength is to determine how much weight an individual can lift for one repetition. This one repetition maximum strength can be calculated from how many repetitions a person can perform with a certain sub-maximal weight [16]. Ultrasound of the abdominal wall can be used to measure the transverse abdominal muscle thickness in rest and during contraction. The change between rest and contraction can be used as a measure of abdominal wall muscle function [17-19].

The object of this study was to compare trunk flexion muscle strength between patients who underwent surgical repair for incisional hernia and a healthy control group. Secondary objectives were to compare trunk flexion strength and transverse abdominis muscle thickness after open and laparoscopic techniques for incisional hernia.

MATERIALS AND METHODS

This study consisted of 35 patients who underwent midline incisional hernia correction and 12 healthy subjects without any abdominal operation. All patients had undergone operations at an academic center. Twenty-one (53.3%) patients had operations with an open technique and 14 (46.7%) by laparoscopic access. In the laparoscopic technique, a mesh was used, and the hernia ring was left open. In the open repair, the fascia of the rectus abdominis muscle was closed after placement of a mesh in seven patients. The fascia was left open after placement of

a mesh in fourteen patients. The mean follow-up time between the operation and the Biodex® examination was 5.8 years (1.8).

Biodex® measurements

Trunk flexion muscle strength measurements were conducted on a Biodex® isokinetic dynamometer (Model 2000, Multijoint System 3, Biodex® Corporation, Shirley, NY, USA). The dynamometer evokes a variable resistance with a fixed speed. Each subject was seated on a chair with the body strapped to the back of the chair. The mechanical stops were positioned with an amplitude of 60° to prevent the subject from working in non-conventional zones. One session of flexions and extensions was performed to get the subject accustomed to the exercise before testing. The second test session was used for collecting data measurements.

Trunk flexor muscles were assessed at 60°/sec angular velocities. The subjects performed six flexions and extensions and were encouraged to generate maximal effort through the entire range of motion for all repetitions. The peak torque was expressed in Newton meters (Nm) and was normalised to body weight (Nm/kg x 100%). Torque is proportional to power, and the peak torque is the highest value within the range of motion.

One repetition maximum measurements

To evaluate the maximum strength of the abdominal muscles, one maximum repetition test was performed. Two different devices were used for the exercises. One of the devices was designed to exercise the rectus abdominis and the other to exercise the oblique and transverse abdominal muscles (Enraf-Nonius, Rotterdam, The Netherlands). None of the patients had training experience and were instructed before doing the exercises. After measuring how many times patients could perform standardized exercises on the devices, the one repetition maximum (1RM) was calculated using the formula of Brzycki [16]. The formula is as follows: 1RM = weight lifted / (1.0278 – 0.0278 * number of repetitions). The maximum weight a person can lift is expressed in grams. The unit of the one repetition maximum is expressed in kilogram-force or gram-force, which is the magnitude of the force exerted on 1 kilogram (or gram) of mass by a 9.81 m/s^2 gravitational field (standard gravity).

Ultrasound imaging

Changes in muscle thickness during rest and after muscle contraction were assessed with ultrasound imaging. Unilateral measurements of the transverse abdominal muscle were performed using a portable ultrasound unit (SonoSite®, Seattle, USA). The measurements were performed by positioning the transducer at the level of the umbilicus horizontally and thereafter moving it laterally until the proximal edge of the transverse abdominal muscle was aligned to the left side of the onscreen display.

In the resting position, two images were taken from the transverse abdominal muscle to assess the rest thickness. Subsequently patients were asked to strain the abdominal wall at

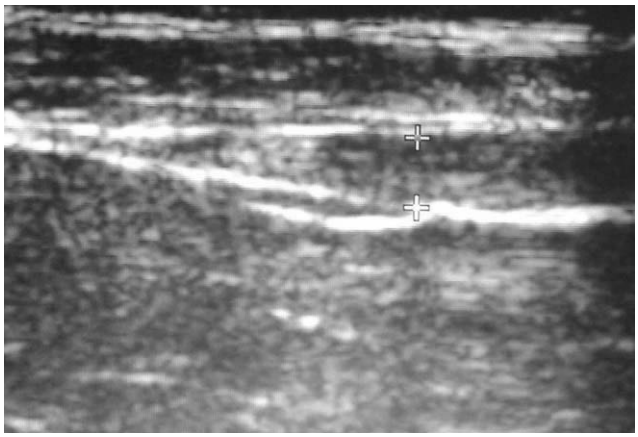

Fig. 1. Example of an ultrasound still frame of the transverse abdominal muscle

maximum strength. During contraction of the abdominal wall, two images were again taken after aligning the proximal edge of the transverse abdominal muscle to the left side of the onscreen display (Figure 1).

The thickness of the transverse abdominal muscle was obtained using the measurement software of the ultrasound device. The proximal edge of the muscle was digitally callipered, whereupon the thickness of the muscle 25 mm laterally from this calliper was measured. Every measurement was repeated two times to reduce intra-observer variability. The mean of these two measurements was calculated and used for comparison between the subjects.

Statistical analysis

Statistical analysis was performed with PASW Statistics 17.0 on a personal computer. All continuous data were given as means with standard deviations (SD).

The two-sample t-test was used to compare the control and operative groups for age, weight and length. The chi-square test was used to compare the control and operative groups for gender.

The two-sample t-test was used to compare the Biodex® measurements in the controls and patients after operative repair for incisional hernia. This test was also used to compare the measurements amongst themselves in patients after the three included operative techniques for incisional hernia: open technique with fascia closure, open technique without fascia closure and laparoscopic repair. A *P*-value <0.05 was taken as the threshold of statistical significance.

The relationship between the one repetition maximum lift and the operative technique (open or laparoscopic) was estimated using multiple regressions allowing for body weight, age and gender. Non-significant variables were removed one by one, removing the largest p-value first, until all remaining variables in the model were significant.

The strength of the relationship between the measurements of the different measurement techniques was estimated by the product-moment correlation coefficient.

RESULTS

Fifty-five percent of the subjects were male, and their mean (SD) age, height, body weight and body mass index were 60 (13) years, 173 (10) cm, 83 (19) kg and 27 (5) kg/m^2, respectively. The mean age was significantly lower in the control group than in the patient group (50 versus 64 years, P<0.01). The patient groups were similar in age, sex ratio, mean BMI (body mass index) and recurrence rate.

Biodex®

A significantly higher peak torque/weight was found in the control group compared to the operated group (84 versus 202 nm, P<0.01). After splitting up the operated group in open and laparoscopic repair, the comparison with the controls remained significant (*P*<0.01, Table 1).

Table 1. Mean peak torque/weight in % (SD) in trunk flexion comparing three different operations for incisional hernia with the control group (n=12) measured with the Biodex® isokinetic dynamometer.

Peak torque/weight (%)	Measure device	Operation group	Control group (n=12)	Confidence interval of the difference	P-value
Total operation group (n=35) versus control	Biodex®	83.7 (46.1)	202.4 (88.6)	61.0; 176.4	<0.01
Laparoscopic technique (n=14) versus control group	Biodex®	71.4 (34.8)	202.4 (88.6)	72.6; 189.4	<0.01
Open technique with fascia left open (n=14) versus control group	Biodex®	97.0 (59.3)	202.4 (88.6)	45.2; 165.6	<0.01
Open technique with fascia closed (n=7) versus control group	Biodex®	81.9 (32.6)	202.4 (88.6)	60.1; 180.9	<0.01

The mean torque/weight was not significantly different between the open and laparoscopic groups. Comparison between patients in which the fascia was closed over the mesh with patients where the fascia was left open after open incisional hernia repair showed no difference in outcome (82 versus 97, P=0.54, Table 2).

After adjusting for gender, a trend could be observed with regard to the mean one-repetition maximum lift in favour of the open group (coefficient –136.6, [95% CI –284.9; 11.6], P =0.07, Table 3).

Table 2. Mean peak torque/weight in % (SD) or maximum strength (gram-force) in trunk flexion comparing the three operations for incisional hernia with three different devices.

		Operation group			
Peak torque/weight (%) or maximum strength (gram-force)	**Measure device**	**Group 1**	**Group 2**	**Confidence interval of the difference**	**P-value**
Open group (n=21) versus laparoscopic group (n=14)	Biodex®	92.0% (51.5)	71.4% (34.8)	-11.5; 52.6	0.20
Open group fascia open (n=14) versus laparoscopic (n=14)	Biodex®	97.0%(59.3)	71.4% (34.8)	-12.1; 63.4	0.18
Open group fascia closed (n=7) versus laparoscopic (n=14)	Biodex®	81.9% (32.6)	71.4% (34.8)	-22.5; 43.6	0.51
Open group fascia closed (n=7) versus open group fascia open (n=14)	Biodex®	81.9% (32.6)	97.0% (59.3)	-65.8; 35.6	0.54
Open group (n=20) versus laparoscopic group (n=14)	Abdominal muscle trainer Rectus	560.5 (237.7)	423.9 (257.8)	-38.0; 311.3	0.12
Open group fascia open (n=14) versus laparoscopic (n=14)	Abdominal muscle trainer Rectus	576.7 (261.0)	423.9 (257.8)	-48.7; 354.4	0.13
Open group fascia closed (n=6) versus laparoscopic (n=14)	Abdominal muscle trainer Rectus	522.7 (187.5)	423.9 (257.8)	-147.6; 345.2	0.41
Open group fascia closed (n=6) versus open group fascia open (n=14)	Abdominal muscle trainer Rectus	522.7 (187.5)	576.7 (261.0)	-302.9; 194.8	0.65
Open group (n=19) versus laparoscopic group (n=13)	Abdominal muscle trainer Transverse	461.6 (208.7)	375.6 (162.3)	-54.8; 226.8	0.22
Open group fascia open (n=13) versus laparoscopic (n=13)	Abdominal muscle trainer Transverse	444.9 (158.3)	375.6 (162.3)	-60.5; 199.0	0.28
Open group fascia closed (n=6) versus laparoscopic (n=13)	Abdominal muscle trainer Transverse	497.8 (307.3)	375.6 (162.3)	-102.0; 346.5	0.27
Open group fascia closed (n=6) versus open group fascia open (n=13)	Abdominal muscle trainer Transverse	497.8 (307.3)	444.9 (158.3)	-169.0; 275.0	0.62

Abdominal muscle trainer

Analysis of the one repetition maximum strengths, measured with the abdominal muscle trainer for the rectus abdominis, showed no significant differences between the open and laparoscopic groups (561 versus 424, P=0.12, Table 2). Splitting up the open repair group in fascia closed or left open, showed comparable results between the two groups (523 versus 577, P=0.65). The same analyses were made for the one repetition maximum strengths measured

Table 3. Regression coefficients of maximum strength with respect to gender measured by one repetition maximum measurement (rectus muscle).

Variable	Coefficient	95% CI	P-value	Standardised coefficient
Gender[1]	-263.2	-409.1; -117.3	0.001	-0.53
Laparoscopic versus open incisional hernia repair[2]	-136.6	-284.9; 11.6	0.07	-0.27

[1] Men is reference category.
[2] Open access is reference category.

with the abdominal muscle trainer for the oblique and transverse muscle. No significant differences were found between the open and laparoscopic groups or between the two different open techniques (Table 2).

Ultrasound measurement transversus abdominis (TrA)

Resting thickness of the transversus abdominis (TrA) was comparable between the open and laparoscopic techniques. The average thickness of the TrA was 4.4 mm for the open and 4.0 mm for the laparoscopic technique (P=0.40). Changes of the TrA muscle thickness after straining were significantly different between the open and laparoscopic technique, 3.3 mm and 1.7 mm, respectively (P=0.02), shown in Table 4. Comparing the open approximated fascia and the left open fascia groups with the laparoscopic patients, the TrA muscle thickness differences were significantly higher for both open groups (both P=0.05). The increase of the transversus abdominis muscle thickness was similar, whether the fascia was closed or left open in the open repair technique (3.3 mm versus 3.3 mm, P=0.98).

Table 4. Ultrasound measurements of the transversus abdominis muscle comparing the three operations for incisional hernia.

	Operation technique			
Changes of mean transversus muscle thickness (mm)	**Group 1**	**Group 2**	**Confidence interval of the difference**	**P-value**
Open (n=20) versus laparoscopic (n=10)	3.3 (1.8)	1.7 (1.4)	0.22; 2.9	0.02
Open fascia - open technique (n=13) versus laparoscopic (n=10)	3.3 (1.9)	1.7 (1.4)	0.04; 3.1	0.05
Closed fascia - open technique (n=7) versus laparoscopic (n=10)	3.3 (1.6)	1.7 (1.4)	-0.003; 3.1	0.05
Closed fascia - open technique (n=7) versus open fascia - open technique (n=13)	3.3 (1.6)	3.3 (1.9)	-1.8; 1.8	0.98

The Pearson's correlations between the five different measurement techniques for abdominal muscle function are presented in Table 5. For the correlations, the Biodex® peak torque flexion was not corrected for body weight like in the other measurements.

Table 5. Pearson correlations (P-values) between five measurements of abdominal function.

	Biodex® (no correction for body weight)	1RM rectus	1RM oblique	Ultrasound in rest	Ultrasound during contraction
Biodex®	1.00				
1RM rectus	0.86 (<0.001)	1.00			
1RM oblique	0.54 (0.002)	0.65 (<0.001)	1.00		
Ultrasound in rest	0.22 (0.23)	0.40 (0.03)	0.54 (0.003)	1.00	
Ultrasound during contraction	0.24 (0.21)	0.40 (0.03)	0.35 (0.07)	0.58 (<0.01)	1.00

DISCUSSION

In this study we compared the isokinetic muscle strength of the trunk flexor muscles measured with the Biodex® isokinetic dynamometer between patients who underwent open and laparoscopic correction for incisional hernia and a control group without any abdominal operation. The mean peak torque, as a measure of the isokinetic strength of trunk flexor muscles, was significantly lower in the patients with incisional hernia corrections than in the healthy controls.

We also compared the abdominal wall function after the included three kinds of operative techniques for incisional hernia: the laparoscopic technique and the open technique with or without closure of the fascia. No difference was found between the different kinds of operations measured with the Biodex® dynamometer. A significantly higher maximum strength measured with the abdominal rectus muscle trainer was found in the open operations compared to the laparoscopic technique after adjusting for gender. All the open operations compared with the laparoscopic technique had higher thickness changes of the transversus abdominal muscle after contraction using ultrasound measurement.

Midline incisional hernias displace the rectus muscles laterally. This lateral extra-anatomical position might be the cause of weakened abdominal muscle strength. In a study comparing laparoscopic with open cholecystectomy, the open technique resulted in reduced muscle strength of trunk flexor muscles compared to controls and the laparoscopic approach [12]. The open cholecystectomy was performed subcostally with transection of the right rectus abdominis muscle. This is in contrast with the laparoscopic technique that is made through small incisions, leaving the rectus abdominis muscles intact. So a scarred rectus abdominis muscle lowers the muscle strength of trunk flexion measured with an isokinetic dynamometer.

In contrast to the open repair with fascia closure for incisional hernia, in which the rectus muscles are medially positioned, in the laparoscopic mesh technique the rectus muscles remain in their lateral displaced position. In the open repair with the fascia left open, the abdominal muscle function is probably better than in the laparoscopic technique, because the fascia is put on tension in the open technique. In the laparoscopic technique, the hernia is enlarged by the

pneumoperitoneum during the operation. After desufflation of the pneumoperitoneum, the risk of the mesh hanging floppy in the abdominal cavity is increased.

The ultrasound measurements showed a significant increase of the transversus abdominis (TrA) muscle after contraction in the open techniques compared to the laparoscopic technique. Probably because of the better anatomical repair in the open technique, the TrA muscle does not become atrophic or even enlarges after the repair. In the open technique, the abdominal muscles remain on tension, which is necessary for a good muscle function.

The clinical relevance of a reduced isokinetic strength of the trunk flexors is not known, and correlations between strength, signs and symptoms were not studied. Significantly lower mean strength values have been found in patients with chronic back pain [15]. It will be interesting to study the relationship between the reduced muscle strength of trunk flexors in patients with incisional hernia and the patients' symptoms before and after surgical repair. Overall, incisional hernia symptoms have not been systematically studied [20]. The reduced muscle strength of trunk flexors in patients after the laparoscopic technique for incisional hernia could cause a higher prevalence of back pain than in patients after open repair.

A good correlation was found between the Biodex® dynamometer and the one repetition measurement of the rectus muscles and also between the one repetition measurements of the rectus and oblique abdominal muscles. The measurements of the one repetition maximum tests and the ultrasounds at rest showed a moderate correlation. A moderate correlation was also shown with the measurements of the one repetition and the ultrasound at rest and during contraction. These correlations mean at least that these three techniques all measure abdominal function but at different levels. The Biodex® dynamometer measures the torque or moment of force, which is the tendency of a force to rotate an object about an axis. It is expressed in Newton meter (Nm), and it was corrected for body weight in our analysis. The one repetition maximum is a measure of maximal strength, representing the maximum amount of weight a person can lift in a single repetition. This lifted weight is expressed in kilograms or grams. The good correlation between the Biodex® and the one repetition rectus muscles indicates, that the Biodex® measures rectus muscle function more than oblique abdominal muscle function. The ultrasound examination yields a measure of the thickness of the transverse abdominal muscle before and after contraction and is expressed in millimetres. It has a low correlation with the Biodex®, because the ultrasound measured the transverse muscle, and the Biodex® mainly measures the rectus muscle function.

The statistical power for finding a significant difference between the three operative techniques was low and was caused by the small sample sizes of the groups. The small sample size of our study is a limitation for making strong conclusions. Measuring the same patients before and after the repair of their incisional hernia would increase the power of the study.

Another limitation of our study is the use of healthy controls. A better and more interesting study group for comparison would be a patient group with a well-healed scar after a median laparotomy or patients with a large primary incisional hernia.

Moreover, it will be necessary to replicate the significant difference in abdominal muscle function between the laparoscopic group and the different open techniques with larger sample sizes. It is important and interesting to establish whether the difference in abdominal muscle function also exists in other open procedures, in which the fascia is closed and the rectus muscles are more or less approximated; this question should also be studied with larger sample sizes than those used in this study.

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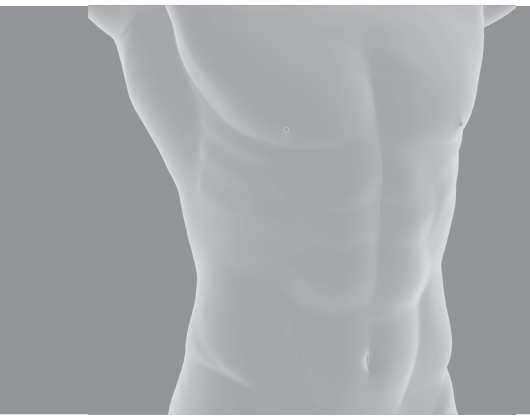

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Quality of life after suture repair for incisional hernia: long-term postoperative and retrospective preoperative evaluations

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ABSTRACT

Purpose: The aim of this observational study was to examine postoperative and retrospective preoperative evaluations of multiple dimensions of patient quality of life after a three-layered closure repair for incisional hernia.

Methods: After suture repair of an incisional hernia (mean follow-up of 4.6 years), 72 patients (32 female, 40 male, mean age 63.6 years) completed the SF-36 Health Survey Questionnaire to evaluate their current postoperative as well as their past preoperative quality of life.

Results: All domains improved significantly after the operation. Relative to age-matched controls, the preoperative quality of life was evaluated negatively in seven domains, while the postoperative quality of life was evaluated negatively for only two domains.

Conclusions: In this study, patients retrospectively evaluated their physical and mental health as poor before an incisional hernia repair. After the operation, patient quality of life improved, but the perceived quality of life did not completely normalize. Further prospective studies will be useful to examine the quality of life before and after ventral hernia repairs..

INTRODUCTION

Incisional hernias, ventral hernias that manifest themselves through an operation scar, are a serious common complication of abdominal surgery. In the literature, quality of life is seldom examined as an outcome parameter in studies of surgical repair for incisional hernias [Korenkov et al, 2002; Mussack et al, 2006]. Korenkov et al. (2002) used the Gastrointestinal Quality of Life Index (GIQL) one year postoperatively in a randomized controlled trial comparing suture repair, polypropylene mesh or autodermal skin graft for incisional hernias. These authors found no differences in GIQL scores at one year among the different groups, although pain visual analogue scores at one year were different, but not statistically significant. Preoperative GIQL scores were not reported. Mussack, et al. (2006) compared open with laparoscopic incisional hernia repair using the Medical Outcome Study SF-36 Health Survey (SF-36). Pre- and postoperative scores were compared with the age-stratified mean scores of the German population. Preoperatively, all eight domain scores of the SF-36 were significantly lower than the mean scores. After open and laparoscopic incisional hernia repair, all eight scores increased significantly, but remained lower than the mean scores.

Our clinic has developed a method of three-layered closure repair in combination with extensive adhesiolysis for primary or recurrent incisional hernias. Rates of recurrence were low, and complication rates were acceptable (den Hartog et al, 2002). The aim of this observational study was to examine postoperative and retrospective preoperative evaluations of multiple dimensions of the quality of life (SF-36) in patients with incisional hernia after three-layered closure repair.

PATIENTS AND METHODS

We conducted a retrospective study of incisional hernias repaired with our three-layered closure method at the Red Cross Hospital, Beverwijk, Netherlands. These patients were operated on between 1997 and 2006. The hospital information system was used to identify all patients who had undergone an operation for primary or recurrent incisional hernia. All information was retrieved from the hospital and outpatient medical records, resulting in a total of 77 identified cases.

To measure the quality of life, the Dutch version of the SF-36 was employed (van der Zee et al, 1996). This questionnaire contains eight different health-quality domains: physical and social functioning (PF and SF), body pain (BP), general health perception (GH), physical and emotional role limitations (RP and RE), vitality (VT), and mental health (MH). The scores for each domain can range from 0 to 100, with higher scores indicating a better quality of life. Additionally, the SF-36 Physical Component Summary (PCS) and the Mental Component Summary (MCS) scales were applied, with scores ranging from zero (lowest well-being) to 100 (highest well-being).

All patients were requested to complete two SF-36 questionnaires. The first was intended to represent the current point of view (called the postoperative evaluation). The second was rephrased in order to make a retrospective evaluation of the preoperative quality of life possible (called the retrospective preoperative evaluation).

Statistical analysis

The statistical analysis was performed with SPSS (version 11.0) software. Demographic and clinical data and SF-36 scores are presented as means and standard deviations.

The paired t-test was used to compare the pre- and postoperative scores. The age-stratified norm scores from the Dutch population were subtracted from the pre- and postoperative patient scores. The differences were used in the one-sample t-test to compare whether they deviated significantly from zero.

In order to detect a possible response shift, the questionnaires were divided into two equal groups on the basis of the median follow-up time, and were denoted as short-term and long term postoperative evaluations. The SF-36 domain scores of the two groups were compared using the two sample t-test. Statistical significance was set at $p < 0.05$.

For every item of the SF-36 the effect size was calculated by dividing the mean difference between the postoperative and preoperative score by the standard deviation. An effect size greater than 0.5 was recognized as a medium and important effect.

RESULTS

From 1997 to 2006, a three-layered closure repair was performed in 77 patients. These 77 patients were sent postoperative ands well as retrospective preoperative SF-36 questionnaires by mail, and a return envelope was included. Seventy-two patients returned the questionnaires, 32 women and 40 men (56%). The mean age was 63.6 years (SD = Standard deviation = 12.7). The mean follow-up duration was 4.6 years (SD = 2.8). The scores of the eight domains and the summary scores are reported in table 1. Significant differences between pre- and postoperative scores were observed for all dimensions and both summary scores. In table 2, comparisons with age-stratified mean Dutch scores are reported. The scores are expressed as differences from these mean scores. Significant negative differences were observed for the preoperative scores versus the mean Dutch scores for all domains except physical functioning and change in health. Significant negative difference was found between the postoperative and mean Dutch score for social functioning and a significant negative trend for role limitations due to physical and emotional problems, and a significant positive difference was found for physical functioning, mental health and change in health.

A significant difference (p=.039) was observed for the retrospective preoperative pain scores between the short-term (mean follow-up 2.4 years, mean 67.1, SD=30.2) and long-term (mean

Table 1. Mean scores of the retrospective preoperative and postoperative evaluations of quality of life (SF-36). The p values compare retrospective pre- and post-operative scores.

SF-36	Retrospective preoperative scores (SD)	Postoperative scores (SD)	P value
Physical functioning	66.4 (26.0)	80.9 (25.2)	.000
Social functioning	67.1 (27.8)	79.0 (21.8)	.001
Role limitations due to physical problems	39.9 (45.8)	65.7 (42.5)	.000
Role limitations due to emotional problems	56.9 (45.2)	79.0 (34.6)	.000
Mental health	71.0 (20.8)	82.2 (15.9)	.000
Vitality	57.0 (23.1)	67.5 (20.8)	.000
Pain	60.1 (29.3)	72.5 (27.1)	.000
General health	58.2 (21.7)	65.0 (21.9)	.000
Change in health	48.3 (27.6)	70.1 (26.7)	.000
Physical component summary	59.5 (22.5)	79.6 (22.1)	.000
Mental component summary	64.2 (21.1)	77.2 (16.2)	.000

SD: standard deviations

Table 2. Retrospective preoperative and postoperative scores of quality of life (SF-36) dimensions expressed as differences from the mean scores of the age referenced group from the general Dutch population. P values compare pre- and postoperative difference scores with zero.

SF-36	Retrospective preoperative scores (SD)	P value	Postoperative scores (SD)	P value
Physical functioning	-5.0 (26.6)	.143	6.8 (26.9)	.046
Social functioning	-17.4 (27.6)	.000	-5.5 (21.5)	.036
Role limitations due to physical problems	-33.6 (45.2)	.000	-9.7 (42.9)	.072
Role limitations due to emotional problems	-28.0 (45.5)	.000	-7.4 (35.9)	.092
Mental health	-6.2 (21.2)	.017	5.2 (15.8)	.008
Vitality	-8.9 (23.7)	.002	1.9 (20.8)	.440
Pain	-15.7 (29.3)	.000	-3.0 (27.4)	.362
General health	-6.4 (21.6)	.019	-.15 (21.3)	.955
Change in health	-.26 (28.0)	.936	21.6 (27.2)	.000

SD: standard deviations

follow-up 6.8 years, mean 52.9, SD=26.8) preoperative evaluations and a trend for a difference (p=.099) was observed for the retrospective preoperative physical component summary scores between the short-term (mean 64.9, SD=22.4) and long-term (mean 55.0, SD=21.6) evaluations and a trend (p=.061) for a difference for the preoperative general health perceptions scores between the short-term (mean 63.0, SD=22.7) and long-term (mean 52.8, SD=20.5) evaluations.

A significant difference (p=.011) was observed for the postoperative general health perceptions scores between the short-term (mean follow-up 2.4 years, mean 70.8, SD=22.8) and long-term (mean follow-up 6.8 years, mean 57.6, SD=19.1) postoperative evaluations and a trend for pain (p=.061) between the short-term (mean 78.8, SD=25.2) and long-term (mean 66.9, SD=28.0) postoperative evaluations.

Medium positive effect sizes (>.50) between the postoperative and retrospective preoperative score were found for the following items of the SF-36: general health; actual health at this moment; pain during last week; how much did pain interfere with normal work; vigorous activities; bending, kneeling or stooping; climbing one flight of stairs; spending less time on labour; did you feel satisfied; did you feel tired and did you feel worn out?

DISCUSSION

A recent review noted a relative paucity of randomized clinical trials comparing different repairs of incisional hernias (Cassar and Munro, 2002). This shortage necessitates a careful evaluation of the different procedures. For this reason, and because of the lack of quality of life studies, we examined postoperative and retrospective preoperative evaluations of multiple dimensions of quality of life (SF-36) in patients with incisional hernia after open three-layered closure repair. The SF-36 is a well validated generic instrument. In our study, all domains except physical functioning and change in health of the retrospective preoperative SF-36 were significantly lower than the mean scores of the age-stratified Dutch population. Postoperatively, all domains showed significant improvement, mental health and change in health were higher than the mean scores of the age-stratified Dutch population, but scores remained lower than the mean for social functioning and role limitations due to physical and emotional problems. These findings are partly in agreement with those of Mussack et al (2006), who also found an improvement in scores, but an incomplete normalization after the operation.

Studying the effect sizes of the different items of the SF-36 marked improvement was seen for pain, labour, vitality items and physical activities such as bending, kneeling or stooping. This specific improvement is not only interesting but also important because little is known of the natural course of incisional hernias (Nieuwenhuizen et al, 2007).

The difference between the actual and retrospective evaluations of preoperative quality of life is called a response shift, and refers to changes in the meaning of a self-evaluation of the quality of life. For instance, this shift could be the result of a change in the respondent's internal norms (i.e., recalibration) (Schwartz et al, 2007). In a study of quality of life after gastric banding, a response shift was observed. The preoperative quality of life tended to be perceived to improve over time (Schok et al, 2000). In comparing early postoperative (mean follow-up 2.4 years) and late postoperative responders (mean follow-up 6.8 years), we found a response shift in the opposite direction for the preoperative score for pain, which was evaluated worse by the late postoperative responders. Thus with passage of time patients evaluated their preoperative pain as poorer. This unexpected worsening could be due to comorbidity which deteriorated in the long postoperative period. However most of the scores were not subject to a response shift. This could be due to our long mean follow-up period of 4.6 years, since the response shift could have occurred in the early postoperative years. It is remarkable that patients can still evaluate

their quality of life retrospectively after such a long period. The retrospective evaluation of the quality of life may not necessarily be a reliable perception. This perception could be altered over time because of changes in internal standards, values and conceptualization. However, our long follow-up period could also have influenced the postoperative scores negatively, as a result of the postoperative occurrence of chronic disease. The worsening for postoperative general health perceptions might be indicative for this, because with passage of time patients evaluated their postoperative general health perceptions as poorer.

The SF-36 is a useful generic instrument to evaluate the quality of life after incisional hernia repair. Specific instruments are not currently available to examine the quality of life of incisional hernia patients.

In this study, patients retrospectively evaluated their physical and mental health as poor before an incisional hernia repair. After the operation, patient quality of life improved, but the perceived quality of life did not completely normalize. Further prospective studies will be useful to examine the quality of life before and after ventral hernia repairs.

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9

Acute Traumatic Abdominal Wall Hernia

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ABSTRACT

Although blunt abdominal trauma is frequent, traumatic abdominal wall hernias (TAWHs) are rare. We describe a large TAWH with associated intra-abdominal lesions that were caused by high-energy trauma. The diagnosis was missed by clinical examination but was subsequently revealed by a computed tomography (CT) scan. Repair consisted of an open anatomical reconstruction of the abdominal wall layers with reinforcement by an intraperitoneal composite mesh. The patient recovered well and the results of a post-operative CT scan are presented.

INTRODUCTION

Blunt trauma of the abdominal wall can lead to a traumatic abdominal wall hernia (TAWH). Damschen et al. defined TAWH as the "herniation through disrupted musculature and fascia associated with adequate trauma, without skin penetration, and no evidence of a prior hernia defect at the site of injury".[1] Although this type of hernia is unusual, it has been described in some reviews. [2-7] Two reviews studied TAWH, especially in the lumbar position. [8;9] The increased abdominal pressure and shearing forces likely cause disruption of the abdominal wall muscles and fasciae. Although the skin can be bruised, it normally remains intact. [10] We describe the history and imaging of a patient with a traumatic abdominal wall hernia and the operative treatment.

CASE REPORT

A 59-year-old male sustained a fall from a height of nine metres onto a pile of steel bars, landing on his right flank. Upon arrival of helicopter emergency medical services, the patient was alert and complained of pain in the abdomen. The Advanced Trauma Life Support (ATLS) survey revealed a right-sided pneumothorax, which was treated with a chest tube. After this intervention, the patient was respiratorily and haemodynamically stable and transported to the emergency department. Upon arrival, the initial assessment according to the ATLS protocol was performed without any new findings according to the A, B, C and D approaches. During the secondary survey, the effects of the blunt abdominal trauma were observed. Inspection revealed a large swelling at the right side of the abdomen, with abrasions of the overlying skin (Figure 1). Palpation of the right abdominal wall was extremely painful.

Focused assessment with sonography for trauma identified the presence of free intraperitoneal fluid around the spleen. An orbital fracture with eyelid laceration was also diagnosed.

In addition, a computed tomography (CT) scan of the abdomen showed a traumatic hernia of the right lateral abdomen (Figure 2), with protrusion of bowel and laceration of the spleen.

The patient was transported to the operating theatre, and exploration of the abdomen through a median incision revealed a transverse rupture of the total abdominal wall, including rectus muscle and external, transverse and internal abdominal muscles, with a length of 30 cm from the midline to the vertebral column on the right side (Figure 3). The small bowel, ascending colon and the right lobe of the liver were herniated due to this defect. A non-vital part of the small bowel (10 cm) was resected, and haemorrhages from the mesentery and spleen were treated. The skin and subcutaneous tissue of the lower lateral abdomen showed deglovement. The ruptured layers of the abdominal wall were sutured separately. This anatomical reconstruction was reinforced with an intra-abdominal polyester composite mesh (Parietex®) with at least four cm overlap and fixed with sutures and taggers. After closure of the linea alba, the

Figure 1. Patient after blunt abdominal trauma with swelling of the right hemi-abdomen

overstretched median fascia below the umbilicus was protected by an absorbable polyglactin mesh (Vicryl®).

Post-operatively, the patient developed superficial skin necrosis in the area of the abdominal wall with deglovement, which healed by secondary intention assisted by a vacuum assisted

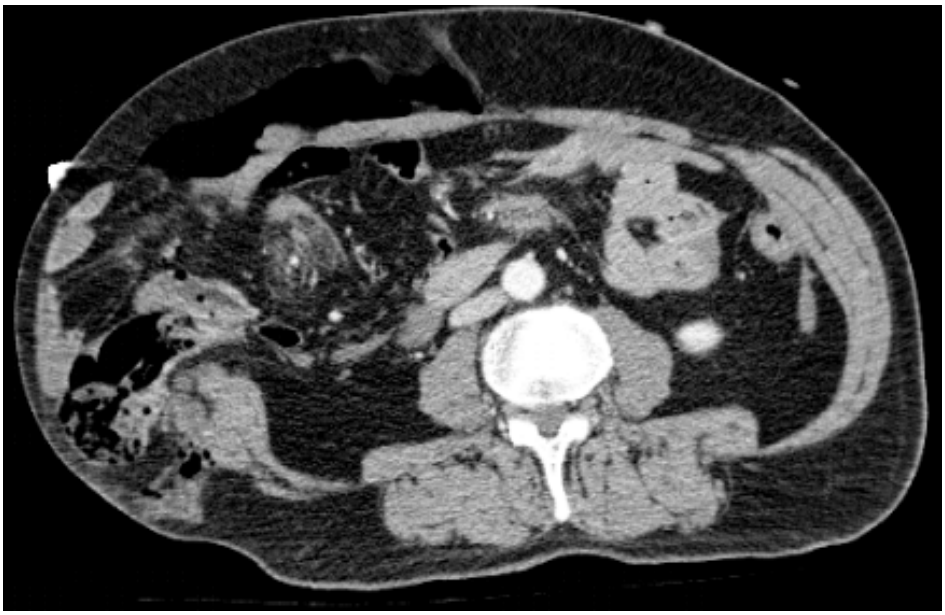

Figure 2. Preoperative abdominal CT scan demonstrating three ruptured muscle layers on the right side

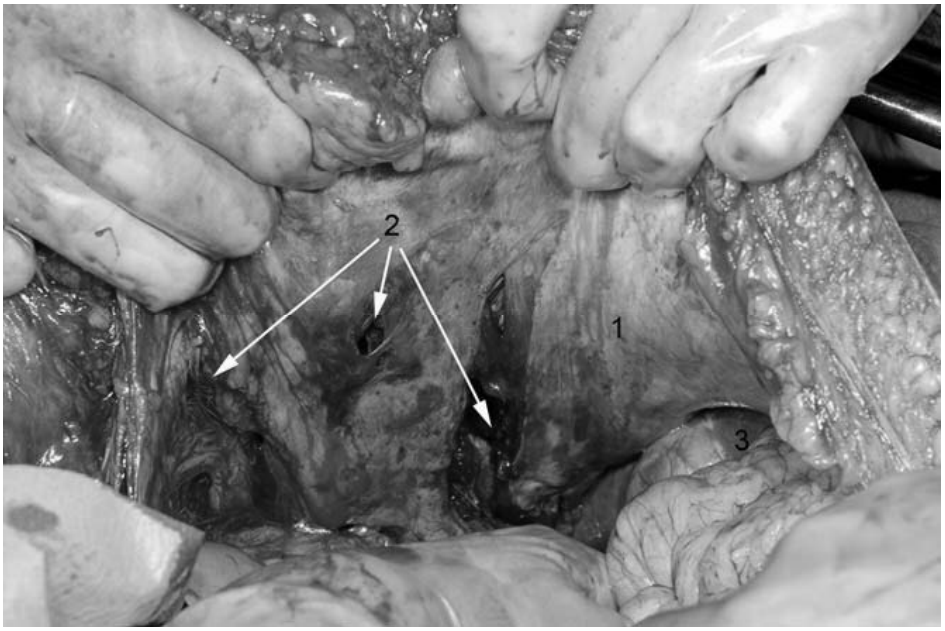

Figure 3. Intra-operative picture of the right inner abdominal wall with rupture of all muscle layers. Head of patient at right side of the picture.
1: parietal peritoneum; 2: rupture of abdominal muscle layers; 3: liver

Figure 4. Post-operative abdominal CT scan demonstrating anatomical restoration of the right abdominal wall with the use of an intra-abdominal mesh fixated with taggers

closure system. A CT scan of the abdomen four months after the operation (Figure 4) showed the anatomical reconstruction of the right abdominal wall with the use of an intra-abdominal mesh fixed with taggers. Physical examination in the outpatient department showed no hernia recurrence after one year.

DISCUSSION

Our patient sustained a high-energy trauma caused by a fall from a large height. This trauma gave rise to the TAWH and associated devascularisation of the small bowel, necessitating bowel resection. Low energy trauma can lead to smaller TAWHs, which can easily be missed on physical evaluation. Handlebar injury is an example of a low energy trauma that can lead to TAWH. [2;11;12] This smaller TAWH can and often will be treated secondarily due to delayed diagnosis. The diagnosis of a TAWH on physical examination can be difficult; because of its rare occurrence, a diagnosis of TAWH is not often considered. With TAWHs, the elastic skin remains intact. In our patient, the TAWH was not diagnosed by physical examination, and the very tender right hemi-abdomen was thought to be associated with intra-abdominal lesions. Because life-threatening intra-abdominal injuries can occur after high-energy trauma, a CT scan should be used as a

diagnostic method. [13] The CT scan in this case led to the diagnosis of TAWH after careful examination of the abdominal wall and also to multiple haematomas in the mesentery and a spleen laceration. The strong shear forces had split the three layers of the lateral abdominal wall and the peritoneum. With the routine use of CT scans after blunt trauma, TAWH will be accurately diagnosed more often. TAWH can be operated on by an incision overlying the defect, but in this case, a midline exploratory laparotomy was necessary for the associated intra-abdominal injuries. A late diagnosed TAWH has also been operated on laparoscopically. [14] In addition, because of the associated intra-abdominal injuries, delayed exploration of the TAWH was not a treatment option in our case. [15] We combined the primary closure in the anatomical layers with an intraperitoneal mesh because the fascia was stretched out by the trauma and the hernia was very large. We used a composite mesh because the inner side was in direct contact with the bowels. In a recent review of the open treatment of incisional hernia, the pooled infection rate for mesh use was 10.1%. [16] Also, in a recent retrospective study of 206 open sublay mesh repairs with intraperitoneal placement of a composite mesh, the infection rate was 10.2% in a 9.5-year period. [17] In our case, resection of a small bowel section could have increased the risk of a mesh infection. The high infection rate has to be weighted against the risk of recurrence. In a series of eight acutely repaired TAWHs without mesh, three developed a recurrent hernia after eight months. [6] In another series of seven acute repairs of TAWHs, the repair attempt was only successful in two patients. [18] Thus, the acute repair of a large TAWH should not be underestimated because of the associated injuries and the risk of a recurrence.

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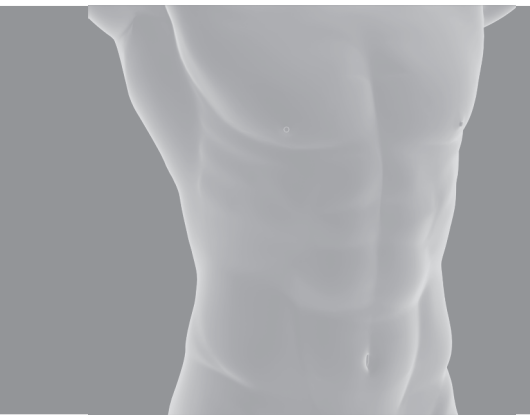

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Discussion

DISCUSSION

This dissertation revolves around one important contradiction: in a Cochrane review, we identified mesh repair as the best available open operative technique for repairing incisional hernias[1]. However, we always had the clinical impression that the results of our two-layered suture repairs of incisional hernias without mesh were better than the results reported in the literature. In the randomized clinical trials, direct suture repair was inappropriately described. For instance, the different possibilities for direct closure techniques, including the suture material (absorbable versus non- or slowly absorbable), use of continuous versus interrupted closure of the fascia, suture:wound length ratio and, in relation to this ratio, the size and interval of fascial bites, were incompletely described. Furthermore, it is possible that the direct suture repair techniques described in trials were not performed by dedicated surgeons, which could have influenced the outcomes. At present, however, most surgeons seem to have accepted the superiority of mesh repair for incisional hernias. For example, in a population-based study of 10,822 patients with incisional hernias in the US, Flum et al. observed an increase in the frequency of synthetic mesh application from 35% in 1987 to 65% by 1999[2]. The use of mesh, however, results in more infectious complications[3]. From these data, it was concluded that the number needed to treat (NNTb) was six patients for recurrences, and the number needed to harm (NNTh) was ten patients for infections. Thus, for every six mesh repairs, one recurrence is prevented as compared to direct suture repair, but one infection is observed for every ten mesh repairs. Our three-layered suture repair for incisional hernia without mesh showed a clinical recurrence rate of 4.5% and a recurrence rate of 13.5% as assessed by ultrasound after a mean follow-up time of 3.1 years. Most studies only report the lower clinical recurrence rates. In this thesis, we demonstrated that ultrasound is an effective method for identifying incisional hernias[3]. The wound infection rate of three-layered suture repair was 6.5%[4]. The complications of mesh repair should also be weighed against the increased risk of abdominal compartment syndrome, which had a 1.3% incidence in our study. Another important advantage of three-layered suture repair with regard to the medially positioned rectus muscles is the higher muscle strength of the trunk flexor muscles as compared to the laparoscopic technique (chapter 6 of this thesis). In addition, patients were satisfied with three-layered suture repair, as determined by the postoperative improvement in quality of life (SF-36) evaluations[5].

Several factors might have contributed to the apparent success of the mesh-less technique. First, three-layered suture repair utilizes extensive adhesiolysis, which prevents retraction and gives space to move the abdominal wall to the midline. In addition, adhesiolysis makes it possible for the bowels to move freely instead of moving as a block, allowing them to adjust more easily to the reduction in abdominal space after repair. Second, the abdominal wall is anatomically reconstructed. It is very important that the rectus muscles are positioned in their normal median position. Ultrasound and computed tomography examinations after repair confirmed this anatomical position[6]. In this technique, the muscles are attached to each other

at the midline; as a result, they can exert their normal function (chapter 6 of this thesis). It is important to note that the rectus muscles are not separately sutured, but are always together with the anterior or posterior fascia to prevent tension and subsequent necrosis of the muscles.

Muscle cannot stretch like fascia, and muscles can retain an isometric state during different loads, such as lifting. Furthermore, a three-layered fascia closure is stronger than a one-layered repair. Another explanation relies on theoretical arguments that fibroblasts from the rectus muscles might positively influence fascia healing in the midline. All scar tissue and the hernia sac are additionally excised up to the median border of the rectus fascia. Finally, the entire primary incision is explored independently of hernia size, so future recurrences along these parts of the fascia are also treated at the same time. This idea is supported by the observation that the recurrence rate after incisional hernia repair is associated with multiple fascia defects, so-called Swiss-cheese defects[7]. Often, weak spots and small defects are found in the fascia that is distinct from the repaired hernia. As a result, only healthy functional tissue is used, and non-diagnosed small hernias within the remainder of the scar tissue are identified. Because the anterior and posterior fasciae are often sutured under tension, with our technique, the surgical principle of tension-free repair in hernia surgery is abandoned. The low recurrence rate showed that this is possible. However, a disadvantage of this technique under tension might consist of the occurrence of an abdominal compartment syndrome, which in our series was treated by an open abdomen technique and successively closed using the mesh technique. However, in a rat model of chronic incisional hernia, induced herniation decreased abdominal wall compliance via oblique muscle atrophy and fibrosis[8]. Restoration of the abdominal wall anatomy using the three-layered technique could reverse this atrophy and fibrosis. Moreover, fibroblast homeostasis is likely to be dependent upon mechanical signals such as intrinsic and extrinsic loads; in this way, the tension of three-layered repair could be beneficial[9].

An important observation that might explain the low recurrence rate is the low incidence of incisional hernias (less than 1%) in the so-called lateral paramedian incision[10]. In this practically obsolete incision technique, the anterior and posterior rectus sheath is incised at a point not less than two-thirds of the width of the rectus sheath from the midline. The sutured rectus sheaths are covered by rectus muscle and thus are comparable with three-layered suture repair.

All operations were performed by or under the direct supervision of experienced surgeons using a strict protocol for the surgical technique. Our satisfying results could be due in part to this dedicated surgery. Consequently, incisional hernias should be operated by surgeons certified for these procedures based on training level and volume of operated incisional hernias.

Because our study of three-layered closure repair was a retrospective study, it could be subject to (serious) bias. For this reason, it is necessary to perform a randomized clinical trial comparing our technique with mesh repair, with the prosthesis covering the entire incision.

An important secondary finding of the study comparing ultrasound and computed tomography was the high prevalence of incisional hernia (60% with CT) in patients with a midline incision after undergoing reconstruction of an abdominal aortic aneurysm or aorta-iliac

occlusion[3]. Such a high risk should not be accepted and should be prevented in a convenient way. To fortify the wound in patients after reconstruction of an abdominal aortic aneurysm, a prosthetic mesh might be applied above or below the fascia after the wound is sutured in a normal fashion[11-13]. This procedure is being compared to the standard method of closing the abdomen in the Netherlands in a double-blind, randomized, controlled trial, the so-called PRIMA trial[14]. Three-layered suture repair can also be used to prevent incisional hernias in high-risk patients (those with obesity or aortic aneurysm); this possibility should also be tested in a randomized clinical trial.

Biodex® examination of the trunk flexor muscles cannot be recommended yet for routine diagnostic workup or postoperative follow-up because of its unclear clinical relevance. It will be necessary to examine abdominal muscle function for different techniques in which the fascia is left open or closed and the rectus muscles are more or less approximated; this question should also be studied using adequately large sample sizes.

In conclusion, the problem of incisional hernia is significant and as yet unresolved. Data from the research represented in this dissertation, however, will help to define clear directions of future research, which can mainly be performed in clinical settings under good clinical practice (GCP) conditions.

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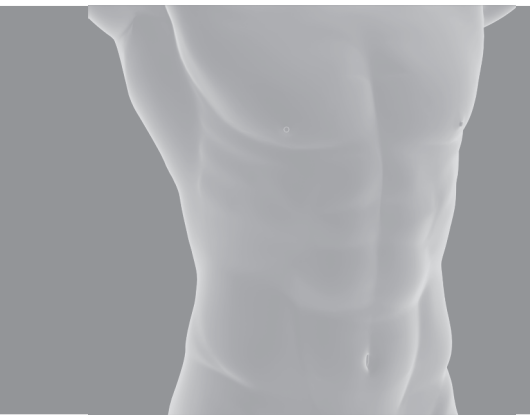

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Summary

SUMMARY

Chapter one introduces primary and recurrent incisional hernia as the subject of this thesis. This thesis is restricted to midline incisional hernias, which is defined as a hernia through an operation scar.

Knowledge of the anatomy of the abdominal wall is important for understanding the different types of hernia repair that are described in the following chapters. The ventral abdominal wall consists of two rectus abdominis muscles on each side of the linea alba. The rectus muscle is enveloped in a fascial layer, the anterior and posterior rectus fasciae, which join in the median line with the other side to form the linea alba. However, the posterior rectus fascia does not reach the pubic symphysis. This limit of the posterior layer of the rectus abdominis muscle sheath is called the semicircular or arcuate line of the rectus sheath. The deepest layer of the abdominal wall is the parietal peritoneum, which is separated from the posterior rectus sheath or bilaminar fascia complex by preperitoneal fat.

The incidence of primary incisional hernia depends on its definition. According to the literature, the clinically diagnosed ventral hernia incidence is 11% in contrast to the incidence diagnosed using imaging, which is 31.7%. The incision type and closure method of the abdominal wall prove to be influencing factors for prevention of incisional hernias. A lower incidence was found for transverse incisions and closure with continuous non-absorbable sutures in a suture:wound ratio of at least 4:1.

Many risk factors for developing a *primary* or *recurrent* incisional hernia were studied. The type of collagen, expressed as a I/III ratio, and the hernia size are patient-related factors. However, the repair technique and surgeon's experience are probably the most important risk factors influencing the occurrence of incisional hernias.

The signs and symptoms of incisional hernia have not been studied systematically. Many incisional hernias are asymptomatic, with the exception of cases of strangulation or ulceration in giant hernias. There is less evidence regarding the relationship of hernia with back pain and pulmonary function.

Incisional hernia repairs can be performed through either open or laparoscopic techniques. The open technique may consist of simple hernioplasty (e.g., Mayo duplication or fascia-adaptation), components separation or mesh repair. Ramirez' components separation technique is based on enlargement of the abdominal wall surface by separation and advancement of the muscular layers. The mesh can be used for augmentation in combination with closure of the fascia or as a bridging mesh between the fascial edges. The mesh can be placed using onlay (prefascial/subcutaneous, Sandwich or Chevrel technique), sublay (retromuscular or preperitoneal) or inlay ("bridging") techniques.

The mesh that is used for incisional hernia repair consists of either autoplastic or alloplastic material. Prosthetic meshes are divided into macro- and micropore meshes depending on their pore sizes.

According to the literature, the advantage of laparoscopic repair versus open repair is the occurrence of fewer wound infections in the laparoscopic technique. However, the operation time of laparoscopic incisional hernia repair is longer and does not result in cosmetic improvement of the abdominal wall. The recurrence rates for open and laparoscopic hernia repairs are not significantly different.

Taking into account the recovery time, time needed to return to work and reoperations for recurrences, open mesh repair is more cost-effective than open suture repair.

The study in **chapter two** describes the anatomy of the abdominal wall using ultrasonography (US) and computed tomography (CT) before, during and after a midline abdominal surgical incision for resection of a colon tumor to study the normal anatomy of the abdominal wall. US and CT scanning were also performed before and after three-layered direct suture repair of an incisional hernia after a median incision. This repair consists of closure of the anterior and posterior fasciae with approximation of the abdominal rectus muscles. The normal rectus sheath shows three layers in US imaging: anterior rectus fascia, posterior rectus fascia and abdominal rectus muscle. However, the posterior rectus fascia does not reach the pubic symphysis. This limit of the posterior layer of the rectus abdominis muscle sheath is called the semicircular or arcuate line of the rectus sheath. The three layers above the semicircular line are separately closed in direct suture repair of incisional hernias. After a successful repair, the abdominal rectus muscles become attached in the median line, which is necessary for the dynamic function of the abdominal muscles. Two types of recurrences were seen with US: partial and total defects of the three layers. In contrast to a total defect, a partial defect retains at least one intact layer.

The objective of the study in **chapter three** was to determine the reliability and validity of ultrasonography (US) in diagnosing incisional hernias as compared to computed tomography (CT). CT scans were assessed by two radiologists to estimate the inter-observer variation. The intra-observer variation was determined by examination of CT scans twice by the same radiologist. Patients with a midline incision after undergoing reconstruction of an abdominal aortic aneurysm or aorta-iliac occlusion were examined by CT scanning and US. Discrepancies between CT observations were resolved in a common evaluation session between the two radiologists. After a mean follow-up time of 3.4 years, 40 patients were imaged after reconstruction of an abdominal aortic aneurysm (80% of patients) or aorta-iliac occlusion. The prevalence of incisional hernias was 24/40 (60.0%) with CT scanning as the diagnostic modality and 17/40 (42.5%) with US. The measure of agreement between CT scanning and US, expressed as a Kappa statistic, was 0.66 (95% confidence interval [CI] 0.45 – 0.88). The sensitivity of US examination, using CT as a comparison, was 70.8%, and the specificity was 100%. The predictive value of a positive US was 100%, and the predictive value of a negative US was 69.6%. The likelihood ratio of a positive US was infinite, and that of a negative US was 0.29. The inter- and intra-observer Kappa statistics were 0.74 (95%CI 0.54-095) and 0.80 (95%CI 0.62-0.99), respectively.

In summary, US imaging has moderate sensitivity and negative predictive value, and very good specificity and positive predictive value. Consistency of diagnosis, as determined by calculating inter- and intra-observer Kappa statistics, was good. The incidence of incisional hernia is high after aortic aneurysm reconstruction.

Chapter four shows a Cochrane systematic review regarding open surgical procedures for incisional hernias. Incisional hernias occur frequently after abdominal surgery and can cause serious complications. Determining the type of open operative repair is controversial, as the recurrence rate may be as high as 54%.

The objective of this review was to identify the best available open operative techniques for incisional hernias. The electronic databases MEDLINE, EMBASE, LILACS and the Cochrane Central Register of Controlled Trials (CENTRAL) were searched from 1990 to 2007, and trials were identified from known trial reference lists. Studies were eligible for inclusion if they were randomized trials comparing different open operative techniques for incisional hernias. Statistical analyses were performed using the fixed effect model. Results were expressed as relative risk for dichotomous outcomes and weighted mean difference for continuous outcomes with 95% confidence intervals.

Eight trials comparing different open repairs for incisional hernias were identified; one trial was excluded. The included studies enrolled 1,141 patients. The results of three trials comparing suture repair versus mesh repair were pooled. Hernia recurrence was more frequent and wound infection less frequent in the direct suture group as compared to the onlay or sublay mesh groups. The recurrence rates of two trials comparing onlay and sublay positions were pooled. This comparison yielded no difference in recurrence (two studies pooled), although operation time was shorter in the onlay group (one study). No difference was found with regard to recurrence, satisfaction with cosmetic appearance or infection between the onlay standard mesh and skin autograft groups following an analysis pooling the two treatment arms. However, this analysis demonstrated less pain in the skin autograft group. Other trials comparing different mesh materials, and positions, or comparing mesh with the components separation technique, are described individually. There tended to be more recurrences in the lightweight mesh group than the standard group. There were non-significantly fewer hernia recurrences, less seroma formation and more postoperative pain in the intraperitoneal group than in the onlay group. No differences in recurrence rates between the components separation and intraperitoneal mesh techniques were observed.

In summary, there is good evidence from three trials that open mesh repair is superior to suture repair in terms of recurrence, but inferior when considering wound infection. Six trials yielded insufficient evidence as to which type of mesh or which mesh position (onlay or sublay) should be used. There was also insufficient evidence to advocate the use of the components separation technique.

In **chapter five**, a cohort study is presented. Incisional hernia is a serious complication after abdominal surgery and occurs in 11-23% of laparotomies. Repair can be accomplished, for instance, with a direct suture technique, but recurrence rates are high. Recent literature advises the use of mesh repair. In contrast to this development, we studied the use of direct suture repair in a separate layer technique. The objective of this retrospective observational study was to assess outcomes (i.e., recurrences and complications) of two-layered open closure repair for primary and recurrent midline incisional hernia without using mesh.

In an observational retrospective cohort study, we analyzed hospital and outpatient records of 77 consecutive patients who underwent surgery for a primary or recurrent incisional hernia between 5 January 2002 and 11 August 2006. Repair consisted of separate continuous suturing of the anterior and posterior fasciae, including the rectus muscle above the semicircular line, after extensive intra-abdominal adhesiolysis. Below the semicircular line, instead of the posterior fascia, the bilaminar fascia complex was included in the suture.

Forty-one men (53.2%) and 36 women (46.8%) underwent surgery. Sixty-three operations (81.8%) were primary repairs and 14 (18.2%) were repairs for recurrent incisional hernias. Of the 66 patients, three had a recurrence (4.5%) upon physical examination after an average follow-up time of 2.6 years. Thirty-day postoperative mortality was 1.1%. Wound infection was observed in five patients (6.5%).

In conclusion, two-layered suture repair for primary and recurrent incisional hernia repair without mesh with extensive adhesiolysis was associated with a recurrence rate that was comparable to that of mesh repair, as well as an acceptable complication rate.

Chapter six is a study on the isokinetic strength of the trunk flexor muscles after surgical repair for incisional hernia. Incisional hernia repairs can be accomplished by open or laparoscopic techniques. The Biodex® dynamometer measures muscle strength during isokinetic movement. The objectives of this study were to compare trunk flexor strength between patients who underwent incisional hernia repair and a control group as well as to compare trunk flexion after two kinds of operative techniques for incisional hernias with and without approximation of the rectus abdominis muscles.

Trunk flexion of 30 patients who underwent different operative techniques for midline incisional hernias and 12 healthy subjects was studied using the Biodex® isokinetic dynamometer.

The mean torque/weight (%) for trunk flexion was significantly higher in the control group as compared to the patient group after incisional hernia repair. A significantly higher peak torque/weight (coefficient 24.45 [95% CI -.05; 48.94], p=0.05) was found for the two-layered suture technique without mesh as compared to the laparoscopic technique after adjusting for gender.

In summary, the isokinetic strength of the trunk flexor muscles is reduced after an incisional hernia operation. There is some evidence that two-layered suture repair with approximation of the rectus abdominis muscles results in higher isokinetic strength of the trunk flexor muscles as compared to the laparoscopic technique.

Chapter seven is a study comparing laparoscopic versus open ventral incisional hernia repair with regard to abdominal muscle strength and thickness of the transverse abdominal muscle.

The debate about the advantages of laparoscopic versus open incisional hernia repair is ongoing. The primary outcomes of previously published studies mainly include recurrence, pain and quality of life. Data regarding postoperative abdominal wall function is still lacking. In this single center, case-control trial, muscle strength and transverse abdominal muscle thickness were analyzed.

Thirty-five patients who underwent open and laparoscopic midline incisional hernia correction were included in this study. Approximation of the rectus muscles was included in some open procedures but never in laparoscopic correction. Twelve healthy subjects without any abdominal operation functioned as the control group. Trunk flexion of all operated patients and 12 healthy subjects was studied using the Biodex® isokinetic dynamometer and conventional abdominal muscle trainers for the rectus and oblique abdominal muscles. All patients were examined for recurrence at the outpatient department, undergoing ultrasound examination of the abdominal wall for analysis of transverse abdominal muscle thickness.

The mean torque/weight (%) for trunk flexion, as measured with Biodex®, was significantly higher in the control group than in the patient group after either type of incisional hernia repair. A comparison of trunk flexion of the two groups using Biodex® after either laparoscopic or open incisional hernia repair showed a trend in favor of the open group after adjusting for gender. Muscle strength, as measured by conventional abdominal muscle trainers, showed no differences between the operation groups. The difference in transverse abdominal muscle thickness between rest and contraction was significantly higher in the open repair group.

In conclusion, the isokinetic strength of the trunk flexor muscles is reduced after incisional hernia operation. There is some evidence that open repair with approximation of the rectus abdominis muscles results in higher muscle strength of the rectus muscles and thicker transverse abdominis muscles as compared to the laparoscopic technique.

The aim of the observational study shown in **chapter eight** was to examine postoperative and retrospective preoperative evaluations of multiple dimensions of patient quality of life after three-layered closure repair for incisional hernia. After suture repair of incisional hernia (mean follow-up time of 4.6 years), 72 patients (32 female, 40 male; mean age 63.6 years) completed the SF-36 Health Survey Questionnaire to evaluate their current postoperative and past preoperative quality of life. All domains improved significantly after operation. Relative to age-matched controls, preoperative quality of life was evaluated negatively in seven domains, while postoperative quality of life was evaluated negatively for only two domains.

In summary, in this study, patients retrospectively evaluated their physical and mental health as poor before incisional hernia repair. After operation, patient quality of life improved, but the perceived quality of life did not completely normalize. Further prospective studies will be useful for examining quality of life before and after ventral hernia repairs.

Chapter nine is a case report regarding an acute traumatic abdominal wall hernia (TAWH). Although blunt abdominal trauma is frequent, TAWHs are rarely encountered. We describe a large TAWH with associated intra-abdominal lesions that was caused by high-energy trauma. The diagnosis was missed by the clinical examination but was subsequently revealed by computed tomography (CT). Repair consisted of open anatomical reconstruction of the abdominal wall layers with reinforcement by an intraperitoneal composite mesh. The patient recovered well, and the results of postoperative CT are presented.

SAMENVATTING

In **hoofdstuk een** wordt de primaire en recidiverende littekenbreuk als onderwerp van dit proefschrift gepresenteerd. Dit proefschrift is beperkt tot de littekenbreuk na een mediane laparotomie. Een littekenbreuk wordt gedefinieerd als een breuk in een operatielitteken.

Kennis van de anatomie van de buikwand is belangrijk om de verschillende chirurgische technieken van littekenbreukcorrectie, beschreven in de volgende hoofdstukken, te begrijpen. De voorste buikwand bestaat uit de twee rectus abdominis spieren aan weerszijde van de linea alba. De rectus is craniaal van de linea semicircularis begrensd door een voorste en achterste fascie blad, die samensmelten in de mediaan lijn als de linea alba. De diepste laag van de buikwand is het peritoneum, gescheiden van het achterste fascie blad door het preperitoneale vet. Caudaal van de linea semicircularis gaat het achterste fascie blad over in het bilaminaire fascie complex.

De incidentie van een primaire littekenbreuk hangt af van de definitie. Volgens de literatuur is de incidentie van een klinisch gediagnosticeerde littekenbreuk 11% in tegenstelling tot de 31.7% incidentie, gediagnosticeerd met beeldvorming . De aard van de incisie en de wijze van sluiten van de buikwand na een laparotomie zijn van invloed op het voorkomen van een littekenbreuk. Een lagere incidentie werd gevonden voor dwarse incisies en sluiten met een doorlopende niet-resorbeerbare hechting in een wond-hechting lengteverhouding van tenminste één staat tot vier.

Veel risicofactoren voor het ontwikkelen van een *primaire* littekenbreuk of een *recidief* littekenbreuk werden onderzocht. Het type collageen, uitgedrukt in een I / III ratio en de grootte van de hernia zijn patiënt-gerelateerde factoren, maar de operatietechniek en ervaring van de chirurg zijn waarschijnlijk de belangrijkste risicofactoren voor het ontwikkelen van een littekenbreuk.

De symptomen van de littekenbreuk zijn niet systematisch onderzocht. Veel littekenbreuken verlopen asymptomatisch. Klachten kunnen echter ontstaan ten gevolge van huidulceraties bij zeer grote littekenbreuken en strangulatie van breukinhoud. Er is weinig onderzoek gedaan naar de relatie tussen littekenbreuk en rugpijn of verminderde longfunctie.

De behandeling van een littekenbreuk kan via open of laparoscopische benadering. De open techniek kan een eenvoudige hernioplastiek (bijv. Mayo duplicatie of fascie-adaptatie), een "componenten separatie techniek", of een correctie met mesh zijn. De "componenten separatie techniek" is gebaseerd op de vergroting van het oppervlak van de buikwand door scheiding en verschuiving van de spierlagen. Indien een correctie wordt verricht met mesh, kan deze toegepast worden als onlay (prefasciaal, Sandwich, of Chevrel techniek), sublay (retromusculair of preperitoneaal,) of inlay techniek ("bridging").

De kunststof mesh, die wordt gebruikt voor littekenbreukcorrectie, bestaat uit hetzij autoplastisch of alloplastisch materiaal. De autoplastische meshes zijn onderverdeeld op basis van de grootte van de poriën in meshes met macro- en/of microporiën.

Het voordeel van de laparoscopische boven de open benadering van littekenbreukcorrectie is volgens de literatuur gelegen in minder wondinfecties, maar het nadeel is de langere operatietijd en het niet cosmetisch herstel van de huid bij een laparoscopische correctie. De kans op recidief littekenbreuk na open of laparoscopische correctie is niet significant verschillend.

Met het oog op het herstel na de operatie, werkhervatting en reoperaties in verband met recidief breuken is de open techniek met mesh kosteneffectiever dan zonder mesh.

De studie in **hoofdstuk twee** beschrijft onder andere de anatomie van de buikwand door middel van echografie en computer tomografie vóór, tijdens en na primaire mediane laparotomie. Deze beelden worden vergeleken met de echografie en computer tomografie beelden vóór en na een drie-lagige anatomische reconstructie van een littekenbreuk zonder mesh, een techniek beschreven in hoofdstuk vijf. Deze drie-lagige reconstructie bestaat uit het separaat sluiten van de voorste en achterste fascie van de musculus rectus abdominis met adaptatie van de musculus rectus in de mediaanlijn. De normale rectus schede toont drie lagen craniaal van de linea semicircularis bij echografie: anterieure rectus fascie, posterieure rectus fascie en musculus rectus abdominis. Caudaal van de linea semicircularis gaat het achterste fascieblad over in het bilaminaire fasciecomplex. Na een succesvol herstel worden de rectus spieren in de mediaan lijn gepositioneerd. Deze positie is noodzakelijk voor de functie van de buikspieren. Twee typen van recidief littekenbreuk werden geïdentificeerd met echografie: gedeeltelijke en totale onderbreking van de drie lagen. In tegenstelling tot een totale onderbreking, heeft een gedeeltelijk defect nog een intacte fascielaag.

Het doel van de studie in **hoofdstuk drie** was de betrouwbaarheid en validiteit van echografie te bepalen in vergelijking met computer tomografie (CT) voor het stellen van de diagnose littekenbreuk. De CT-scans werden beoordeeld door twee onafhankelijke radiologen om de inter-observer variatie te berekenen. De intra-observer variatie werd vastgesteld door een radioloog de CT-scans tweemaal te laten beoordelen. Voor dit onderzoek includeerden wij patiënten na een reconstructie voor abdominaal aneurysma van de aorta (80% van de patiënten) of een aorta-iliacale occlusie via mediane laparotomie. Wij onderzochten alle patiënten postoperatief met CT en echografie van de buikwand. Discrepanties in de CT uitkomsten werden door de twee radiologen in een consensus bespreking opgelost. Na een gemiddelde follow-up van 3.4 jaar werden 40 patiënten onderzocht. De prevalentie van littekenbreuk was 24/40 (60%) met CT en 17/40 (42.5%) met echografie. De mate van overeenkomst tussen CT en echografie, uitgedrukt in Kappa was 0.66 (95% betrouwbaarheidsinterval [bti] 0.45 tot 0.88). De sensitiviteit van het echografie onderzoek met CT als gouden standaard was 70.8%, de specificiteit was 100%, de voorspellende waarde van een positieve echografie was 100%, en de voorspellende waarde van een negatieve echografie was 69.6%. De likelihood ratio van een positieve echografie was oneindig, en van een negatieve echografie 0.29. De inter- en intra-observer Kappa's waren respectievelijk 0.74 (bti 0.54-095) en 0.80 (bti 0.62-0.99).

Concluderend: echografie heeft een matige sensitiviteit en negatief voorspellende waarde en een zeer goede specificiteit en positief voorspellende waarde voor het stellen van de diagnose littekenbreuk. De inter- en intra-observer variabiliteit is goed. Opmerkelijk is de hoge incidentie (60%) van littekenbreuken bij patiënten na reconstructie voor een aneurysma van de aorta abdominalis.

Hoofdstuk vier is een Cochrane systematische review over open chirurgische behandeling van de littekenbreuk. Littekenbreuken komen na abdominale chirurgie vaak voor en kunnen leiden tot ernstige complicaties. De keuze van de operatietechniek staat in de literatuur ter discussie, omdat het recidief percentage van een primair geopereerde littekenbreuk kan oplopen tot 54%.

Het doel van dit onderzoek was het identificeren van het kwalitatief hoogst beschikbare bewijsmateriaal uit de literatuur over de beste open operatieve techniek voor de littekenbreuk. Elektronische databanken MEDLINE, EMBASE, LILACS en de Cochrane Central Register of Controlled Trials (CENTRAL) werden doorzocht van 1990 tot 2007 en artikelen werden geïdentificeerd. Artikelen werden tevens geselecteerd uit de referenties van de gevonden publicaties. Studies kwamen in aanmerking voor inclusie als ze voldeden aan de criteria van gerandomiseerde studies, waarin verschillende open operatieve technieken voor littekenbreuken met elkaar werden vergeleken. Statistische analyses werden uitgevoerd met behulp van het fixed-effect model. De resultaten werden weergegeven als relatief risico voor dichotome uitkomsten en als een gewogen gemiddelde van de verschillen voor continue uitkomsten (met 95%-betrouwbaarheidsintervallen).

Acht trials, die verschillende open technieken voor littekenbreuken vergeleken, werden geïdentificeerd; één trial werd niet gebruikt. De gebruikte trials omvatten 1141 patiënten. De resultaten van drie trials, die primair sluiten van de buikwand zonder mesh vergeleken met sluiten door middel van een mesh, werden samengevoegd. Een recidief littekenbreuk kwam frequenter voor na primair sluiten vergeleken met een correctie met kunststofmesh in onlay of sublay positie. Het gebruik van een mesh in deze trials ging wel gepaard met meer wondinfecties. De recidiefcijfers van de twee trials, die onlay en sublay posities vergeleken, werden samengevoegd. Deze vergelijking leverde geen verschil op voor recidiefcijfers (twee gepoolde studies), hoewel de operatie korter was in de onlay groep (één studie). Er werd geen verschil gevonden in recidief, esthetiek, of een infectie tussen de onlay standaard mesh (alloplastisch) groep en de huid (autotransplantaat) groep, volgens de analyse van de twee gepoolde behandelingsopties. Uit de analyse bleek echter minder pijn voor te komen bij de patiënten met een huid-autotransplantaat. Andere trials, die verschillende materialen of verschillende posities van de mesh, of mesh met de "componenten separatie techniek" volgens Ramirez vergeleken, werden individueel beschreven. De vergelijking tussen lichtgewicht en standaard mesh liet een trend voor meer recidieven in de lichtgewicht groep zien. De vergelijking tussen onlay en intraperitoneaal geplaatste mesh leidde tot een niet significante daling van recidief

littekenbreuken, minder seroomvorming en meer postoperatieve pijn in de intraperitoneale groep. Geen verschil werd gevonden in het aantal recidief littekenbreuken tussen "componenten separatie techniek" volgens Ramirez en de techniek met de intraperitoneaal geplaatste mesh.

Kortom, er is voldoende bewijs uit drie trials, dat de open techniek met mesh superieur is aan primair sluiten zonder mesh wat betreft recidief, maar inferieur wat betreft wondinfectie. Zes studies leverden onvoldoende bewijs op om te beslissen welk type mesh of welke mesh positie (on- of sublay) het best kan worden gebruikt. Er was ook onvoldoende bewijs om het gebruik van de "componenten separatie techniek" volgens Ramirez te bepleiten.

In **hoofdstuk vijf** wordt een cohortstudie gepresenteerd. Een littekenbreuk is een ernstige complicatie na abdominale chirurgie en komt in 11 tot 23% na laparotomie voor. Herstel van een littekenbreuk kan worden verricht door primair sluiten van het defect, maar de recidiefpercentages zijn hoog. In de recente literatuur wordt daarom het gebruik van een mesh bij het sluiten van een breuk geadviseerd. In tegenstelling tot deze ontwikkeling analyseerden wij de techniek zonder mesh waarbij de verschillende buikwandlagen separaat worden gesloten. Het doel van deze retrospectieve observationele studie is om de resultaten (recidieven en complicaties) te beoordelen van deze drie-lagige reconstructie voor primaire en recidiverende mediane littekenbreuken zonder het gebruik van een mesh.

In dit observationele retrospectief cohortonderzoek, analyseerden wij de klinische en poliklinische dossiers van 77 opeenvolgende patiënten, die een operatie ondergingen voor een primaire of recidief littekenbreuk. De techniek bestond uit het afzonderlijk doorlopend hechten van de voorste en achterste rectus facie of het bilaminaire fasciecomplex met inbegrip van de rectus spier na uitgebreide intra-abdominale adhesiolysis.

Een en veertig mannen (53.2%) en 36 vrouwen (46.8%) ondergingen een operatie. Drie en zestig operaties (81.8%) waren primaire correcties en 14 (18.2%) waren correcties voor recidief littekenbreuk. Bij lichamelijk onderzoek kregen drie van de 66 patiënten een recidief (4.5%) na een gemiddelde follow-up van 2.6 jaar. De 30-dagen postoperatieve mortaliteit was 1.1%. Wondinfectie werd vastgesteld bij vijf patiënten (6.5%).

In tegenstelling tot de huidige literatuur ging deze drie-lagige techniek zonder mesh voor herstel van primaire en recidiverende littekenbreuk met uitgebreide adhesiolysis gepaard met een recidief percentage, dat vergelijkbaar is met de technieken waarbij een mesh wordt gebruikt. Deze nieuwe techniek had een aanvaarbaar complicatierisico.

Hoofdstuk zes is een artikel over de isokinetische kracht van de flexorspieren van de romp na chirurgisch herstel van een littekenbreuk. Correctie van littekenbreuken kan worden bereikt door een open of laparoscopische techniek. De Biodex® dynamometer meet spierkracht tijdens isokinetische beweging. De eerste doelstelling van dit onderzoek was het vergelijken van de kracht van de rompflexoren tussen patiënten, die een littekenbreukcorrectie ondergingen

en een controlegroep. De tweede doelstelling van dit onderzoek was om de flexie van de romp te vergelijken tussen twee soorten operatietechnieken: open anatomisch herstel van de buikwand versus overbruggen van het defect in de buikwand met een kunststof mesh bij laparoscopie ("bridging").

De flexie van de romp bij 30 patiënten, geopereerd voor littekenbreuken met een van deze technieken en van 12 gezonde proefpersonen, werd bestudeerd met de Biodex® isokinetische dynamometer.

Het gemiddelde percentage torque per gewicht (Nm) voor flexie van de romp was significant hoger in de controlegroep vergeleken met de groep patiënten na littekenbreukcorrectie. Een significant hogere torque / gewicht (coëfficiënt 24.45 [95% bti -. 05; 48.94], p =0. 05) werd gevonden in patiënten met anatomisch herstel zonder mesh ten opzichte van de laparoscopische techniek met mesh na correctie voor geslacht (meervoudige regressie).

De isokinetische kracht van de flexorspieren van de romp was verminderd na de littekenbreukoperatie. Er waren aanwijzingen dat open anatomisch herstel (drie-lagige techniek met approximeren van rectus abdominis spieren), tot een hogere isokinetische kracht van de flexorspieren van de romp dan bij de laparoscopische techniek leidde.

In **hoofdstuk zeven** wordt een onderzoek beschreven, dat laparoscopische en open littekenbreukcorrectie vergelijkt betreffende de kracht van de buikspieren en de dikte van de musculus transversus abdominis. Het debat over de voordelen van de laparoscopische versus de open littekenbreukcorrectie wordt nog steeds gevoerd. De primaire uitkomsten van reeds gepubliceerde onderzoeken zijn voornamelijk recidief, pijn en kwaliteit van leven. Data betreffende postoperatieve buikwand functie ontbreken nog steeds. In deze case-control trial uit één instituut werden de spierkracht en de dikte van de musculus transversus abdominis geanalyseerd.

Vijfendertig patiënten, die een open of laparoscopische littekenbreukcorrectie ondergingen, werden in dit onderzoek geïncludeerd. De rectusspieren werden in sommige open procedures geapproximeerd, maar nooit in geval van laparoscopische correctie. Twaalf gezonde personen zonder buikoperatie in de anamnese functioneerden als controlegroep. Flexie van de romp van alle geopereerde patiënten en twaalf gezonde proefpersonen werd onderzocht met de Biodex® isokinetische dynamometer en de conventionele buikspiertrainers voor de rectus en schuine buikspieren. Alle patiënten werden op de polikliniek op recidief littekenbreuk onderzocht. Dit onderzoek omvatte tevens een ultrageluid onderzoek van de buikwand om de dikte van de musculus transversus abdominis te bepalen.

Het gemiddelde percentage torque per gewicht (Nm) voor flexie van de romp, gemeten met de Biodex®, was significant hoger in de controle groep vergeleken met de gecombineerde groep patiënten na de twee typen littekenbreukcorrecties. Een trend voor hogere torque per gewicht voor romp flexie gemeten met de Biodex® werd gevonden voor de open groep patiënten vergeleken met de laparoscopische techniek na correctie voor geslacht (meervoudige regressie). De spiersterkte gemeten met de conventionele buikspiertrainers lieten geen

verschil zien. Het verschil tussen rust en contractie van de musculus transversus abdominis was significant hoger in de open correctie groep.

Concluderend: de isokinetische kracht van de flexorspieren van de romp was afgenomen na operatie voor littekenbreuk. Er waren aanwijzingen, dat open correctie met approximeren van de rectus abdominis spieren in de mediaanlijn resulteerde in grotere spierkracht van de rectus spieren en in dikkere transversus abdominis spieren dan bij de laparoscopische techniek.

Het doel van de observationele studie in **hoofdstuk acht** was om postoperatieve en preoperatieve dimensies van de kwaliteit van leven te onderzoeken na een drie-lagige techniek voor littekenbreuk. Na primair sluiten van een littekenbreuk (gemiddelde follow-up: 4.6 jaar) vulden 72 patiënten (32 vrouwen, 40 mannen, gemiddelde leeftijd 63.6 jaar) de SF-36 Health Survey Questionnaire in om hun huidige postoperatieve, evenals hun preoperatieve kwaliteit van leven te onderzoeken. Alle domeinen van de SF-36 verbeterden aanzienlijk na de operatie. Ten opzichte van de normpopulatie met vergelijkbare leeftijd, werd de preoperatieve kwaliteit van leven negatief beoordeeld voor zeven domeinen, terwijl de postoperatieve kwaliteit van leven slechts voor twee domeinen negatief werd beoordeeld.

Concluderend: in deze studie beoordeelden patiënten na een littekenbreukoperatie hun lichamelijke en geestelijke gezondheid preoperatief als slecht. Na de operatie verbeterde de kwaliteit van leven van de patiënt, maar deze was echter niet volledig genormaliseerd. Toekomstig prospectief onderzoek zal nuttig zijn om de kwaliteit van leven te onderzoeken vóór en na herstel van een littekenbreuk.

Hoofdstuk negen is een case-report betreffende een acute traumatische buikwandbreuk. Ofschoon stompe buiktraumata frequent voorkomen, zijn acute traumatische buikwand breuken zeldzaam. We beschrijven een grote acute traumatische buikwandbreuk met bijkomende intra-abdominale letsels, die werden veroorzaakt door hoog energetisch trauma. De diagnose werd bij klinisch onderzoek gemist, maar werd vervolgens vastgesteld door middel van CT. Het herstel bestond uit een anatomische reconstructie van de buikwandlagen met versterking door middel van een intraperitoneale composite mesh. De patiënt herstelde goed en de resultaten van een postoperatieve CT werden getoond.

Dankwoord

Dit proefschrift kwam tot stand dankzij de steun en inzet van heel veel mensen. Op deze manier wil ik allen die mij, bewust of onbewust, de afgelopen jaren hebben bijgestaan hartelijk bedanken.

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mesh?! Toch kon jij het verantwoorden, want we hadden dezelfde visie. Herniachirurgie is geen algemene chirurgie maar een superspecialisatie. De behandeling van een littekenbreuk door een toegewijd chirurg rechtvaardigt het achterwegen laten van mesh. De samenwerking was fantastisch. Jouw vertrouwen en enthousiasme ook, ik heb dit zeer gewaardeerd.

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PhD Portfolio

Summary of PhD training and teaching

Name PhD student: D. den Hartog	PhD period: 2006-2010
Erasmus MC Department: Surgery	Promotor(s): Prof.dr. J.F. Lange
Research School: Erasmus MC	Supervisor: Dr. W.E. Tuinebreijer

1. PhD training

	Year	Workload (ECTS)
General courses		
- The Cochrane Collaboration, Developing a Cochrane Systematic Review	2006	1
- Teach-the-teacher Course	2006	1
- Generic Instructor Course	2007	1
Specific courses (e.g. Research school, Medical Training)		
- Cursus Basisvaardigheden Laparoscopische Chirurgie	2001	0.5
- International workshop incisional hernia	2002	0.5
- Gevorderdencursus Gastro-Intestinale Chirurgie	2004	0.5
- Open en laparoscopische breukchirurgie	2005	0.5
Presentations		
- International Congress of the European Hernia Society	2002	2
- Wetenschapsdag Heelkunde Regio VU	2003	2
(Inter)national conferences		
- International Congress of the European Hernia Society	2002	0.4
- International Congress of the European Hernia Society	2005	1
- Rotterdam Interactive Congress on Hernia	2008	0.3
- Rotterdam Interactive Congress on Hernia	2009	0.3

2. Teaching

	Year	Workload (ECTS)
Supervising practicals and excursions, Tutoring		
- International exchange medical students China	2006-2010	4
- Training/courses China	2006-2010	9
Supervising Master's theses		
- PhD student (Surgery)	2008-2010	5
- PhD student (Anatomy and Neuroscience)	2009-2010	2

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4. De Haan J, Schep NWL, Tuinebreijer WE, **den Hartog D**. Complex and unstable elbow dislocations: a review and quantitative analysis of individual patient data. Open Orthop J 2010; 4:80-6.

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