Incisional Hernia

Etiology, Prevention, Treatment

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Aan mijn vader en moeder

CONTENTS

1 General introduction

J.W.A. Burger

An abdominal wall hernia is defined as an intermittent or continuous protrusion of abdominal organs through a defect in the abdominal wall. In case of an incisional hernia an abdominal wall defect develops in the scar of a wound in the abdominal wall, which was inflicted during previous surgery.

ABDOMINAL CAVITY AND ABDOMINAL WALL

The abdominal wall contains the abdominal cavity; a space that holds the abdominal organs. The dorsal, lateral and most of the ventral abdominal wall is formed by the external oblique, the internal oblique and transverse abdominis muscles. The external oblique muscle originates from the 5th to 12th ribs and has a medio-caudal direction. The internal oblique muscle originates from the iliac crest and follows a medio-proximal direction. The transverse abdominis muscle originates from the lower six ribs, the lumbodorsal fascia and the iliac crest. Its fibers are directed horizontally. The aponeuroses of these three muscles form the rectus sheaths, which enclose the fourth abdominal wall muscle, the rectus abdominis. The rectus abdominis inserts on the ribcage superiorly and on the pubic bone inferiorly. Its fibers have a vertical direction and are interrupted by three or four tendinous intersections. The sheaths of the rectus abdominis muscle are continuous with those of the contralateral rectus abdominis muscle. In between both muscles they join to form the relatively avascular linea alba.

Inside the abdominal cavity a continuous positive pressure of 2-20 mm Hg is maintained (lying-standing). This pressure can increase to values as high as 150 mm Hg during coughing and vomiting[1]. The abdominal wall counters this pressure, resulting in a continuous strain on the abdominal wall tissues. Moreover, the abdominal wall enables the body to elevate the abdominal cavity pressure at will, for example during defecation, micturition and respiration.

INCISIONAL HERNIA DEVELOPMENT

During a laparotomy, the abdominal wall is incised to gain access to the abdominal cavity and its contents. At the end of the operation, the abdominal wall is closed by suturing the edges of the wound together. The skin is subsequently closed over it. When a defect develops in the abdominal wall scar, abdominal cavity contents may protrude through this defect, pushed outwards by the positive intra-abdominal pressure. Elevated intra-abdominal pressure, which occurs during defecation, vomiting, coughing, etc., may facilitate this event.

The defect in the abdominal wall most likely develops because of an early partial separation of the abdominal wound edges, which makes collagen bridging during wound healing com-

plicated[2]. This separation may be caused by one or a combination of factors that will be discussed later. When a major defect in the abdominal wall develops within days after surgery, the skin may not have had the opportunity to heal sufficiently, and abdominal organs may protrude through an open wound. This situation is called "burst abdomen" or "platzbauch" and requires emergency surgery. However, the skin usually remains intact, probably because of the limited size of an initial defect. Often, this defect goes unnoticed at first and becomes apparent later, because of a gradual increase in size. This situation is called incisional hernia.

RISK-FACTORS FOR INCISIONAL HERNIA DEVELOPMENT

In general, three groups of factors causing or facilitating incisional hernia development can be identified:

1. CONDITIONS ASSOCIATED WITH IMPAIRED WOUND HEALING.

Conditions that cause impaired wound healing are often present before the operation and may not be amenable to intervention. High age is associated with atrophy of the abdominal wall and changes in connective tissue. Inherent connective tissue disorders may result in a deterioration of abdominal wall connective tissue and the tensile strength of scar tissue may be decreased. Diabetics are prone to wound infection, which impairs wound healing. Moreover, atherosclerosis in diabetics may impair wound healing, as may obesity, which is often the cause of diabetes development. Corticosteroids have a deleterious effect on wound healing and are used by large groups of patients, especially those with pulmonary disease. Malnutrition, radiotherapy, smoking and cancer are known to cause impaired wound healing. Incisions through previous scars exhibit slow wound healing. Finally, tissue breakdown and necrosis caused by wound infection severely impede wound healing. Of the abovementioned factors, age[3-6], diabetes[7] , smoking[6], multiple laparotomies[6] and wound infection[3-5,8] were identified as significant incisional hernia risk-factors.

2. CONDITIONS IN WHICH THE ABDOMINAL CAVITY PRESSURE IS RAISED.

Several conditions cause increased intra-abdominal pressure, such as chronic pulmonary disease with cough, obesity, ascites, prostatism, constipation, pregnancy and ileus. During raised intra-abdominal pressure the strain put on the abdominal wall scar is increased, which could lead to wound failure and subsequent hernia development. A significant increase in incisional hernia incidence was reported in patients with pulmonary disease[9], obesity[3-5,10] and ileus[3].

3. FACTORS ASSOCIATED WITH SURGICAL TECHNIQUE AND PERIOPERATIVE CARE.

Surgical factors play an important role in hernia development. Some types of incision, such as the lateral paramedian and transverse incisions have proven to cause less incisional hernia than, for example, the midline incision. This is caused by several factors. In the first place, the anatomical structures that are cut by the incision. Richly vascularized structures heal better than avascular structures, while division of major arteries may result in impaired wound healing. Another important factor is the pulling force of the abdominal muscles, which is mainly transverse. This means that the wound edges in vertical incisions are likely to be separated by this force, while transverse wound edges are approximated. Suture technique is also an important factor. The length of the suture used should exceed the length of the wound by at least 4 times (suture length to wound length ratio 4:1)[4,11,12]. The length of the stitch, or tissue bite, should at least be one centimeter, but not bigger than 5 centimeter. The suture should include aponeurotic tissues, may include muscle, but not peritoneum or subcutaneous tissue[2]. Sutures may be either interrupted or continuous. It is important to realize that the tensile strength of the wound increases to approximately 50% at 4 weeks after operation. After 6-12 months, the wound reaches 80% of its original strength. Suture materials should remain their tensile strength for at least 6 weeks to allow the wound to regain sufficient tensile strength[2]. Rapidly absorbable suture materials, such as polyglyconate (Vicryl), should not be used, while slowly absorbable materials such as polydioxanone (PDS) perform equally well as non-absorbable materials, such as nylon and polypropylene[13-15]. Multifilament sutures result in an increased incidence of wound infection and should therefore not be used. In addition to type of incision and suture technique, prevention of wound infection by aseptic techniques will prevent wound infection, as will prophylactic antibiotics. Atraumatic surgical technique, meticulous hemostasis, removal of necrotic and breakdown tissues may further lower wound infection incidence[2].

CLINICAL PICTURE

Patients who have developed an incisional hernia usually present with a swelling in the laparotomy scar. This swelling may cause discomfort and pain. Quite often, pain and discomfort are associated with specific activities or movements, which the patient now tries to avoid. Many patients cannot accept the aspect of the hernia that is almost always considered disfiguring. Large hernias tend to cause more problems than smaller ones, while very large hernias may cause disability, skin ulceration and respiratory problems. In some patients, abdominal contents incarcerate in the abdominal wall defect. This happens to approximately 6-15% of incisional hernia patients. Especially patients with large hernias that protrude through small abdominal wall defects are thought to be at risk. In 2% of patients, incarceration leads to the

cutting off of the blood supply to the hernia contents[16,17]. Strangulation and necrosis follow. In these critical situations, emergency surgery is needed.

DIAGNOSIS

During physical examination a palpable or visible bulge is found in the vicinity of a laparotomy scar. A fascial brim is often, but not always, palpable. When the abdominal pressure rises, for example when the patient coughs or pushes, the bulge will typically grow. Palpation is rarely painful at first. Additional diagnostics are not necessary when the diagnosis is certain after physical examination. When the nature of a bulge is unclear, ultrasound is an often-used diagnostic tool. When ultrasound is inconclusive, CT-scan and MRI offer superior, but more expensive diagnostic imaging.

TREATMENT

Traditional incisional hernia repair is performed by primary closure of the abdominal wall defect. The wound edges are approximated and sutured. Overlap techniques, such as the Mayo repair, have also been in widespread use. Several abdominoplasty techniques have been developed to close large abdominal wall defects. The Ramirez component separation technique is currently the most popular. Results of primary closure are poor. Simple approximation and the Mayo repair result in recurrence rates of 25-54%[18-21]. After use of the component separation technique recurrence rates of 32% were reported[22]. Better results were reported since the use of prosthetic meshes was introduced. This was confirmed by a randomized controlled trial by Luijendijk et al[19]. In mesh repair, a prosthetic mesh is used to bridge the defect and is fixed to the abdominal wall. This method results in decreased tension on the wound and reinforcement of the abdominal wall. Despite this significant improvement, recurrence rates ranging from 4 to 34% were reported[19,21,23,24].

Apart from recurrence, mesh implantation is associated with several other complications. Mesh placement in direct contact with the abdominal viscera cannot always be avoided. Moreover, direct contact between mesh and abdominal viscera is inherent to laparoscopic hernia repair, which gained popularity in recent years. When the abdominal viscera come into contact with the prosthetic mesh, a foreign body reaction ensues, causing adhesion formation. Adhesion formation may cause pain[25,26], bowel obstruction[27-30] and infertility[31,32]. Inflammation and bowel erosion may also cause enterocutaneous fistula, a feared and life-threatening condition. Leber et al reported an incidence of 3.5%[24]. Many surgeons feel that the severity of this complication is such, that the prevention of one mesh-associated

enterocutaneous fistula equals the occurrence of many suture-repair associated recurrences. Since the introduction of polypropylene mesh by Usher in 1963[33], a multitude of studies was undertaken to investigate whether other meshes resulted in less adhesion formation and erosion, while preserving adequate tissue incorporation and wound tensile strength. Some materials withstood the test of time, such as e-PTFE. In recent years, composite meshes were developed, in which manufacturers tried to combine the non-erosive and anti-inflammatory properties of a particular material with the favourable incorporation and tensile strength properties of polyester and polypropylene. Combinations of polypropylene with e-PTFE and polypropylene with cellulose-hyaluronate are examples of such attempts.

OUTLINE OF THE PROBLEM

Incisional hernia is a problem of magnitude. For the individual patient incisional hernia is an unexpected and hindering complication, which can influence daily life in such a manner that he or she could be considered disabled. Renewed admissions and operations have a major impact on the patient. When subsequent hernia repair does not solve the problem, but results in recurrence or complications, a patient's quality of life may be seriously affected.

Incisional hernia is a problem for health care as well. In the Netherlands, approximately 100,000 laparotomies are performed each year. Considering that 9-19%[13,34-36] of these patients will develop an incisional hernia, 9,000 – 19,000 new incisional hernias can be expected. In the United States approximately 5,000,000 laparotomies are performed annually, resulting in 450,000 to 950,000 new incisional hernias. In approximately 4,000 patients in the Netherlands and 200,000 in the U.S. the complaints will reach such a severity that hernia repair is needed[37-39]. This means that 4% of all patients undergoing a laparotomy will have to undergo a subsequent hernia repair. Following hernia repair, many patients will suffer a recurrence that may require one or more subsequent hernia repairs. In the current socioeconomic climate with tight health care budgets and shortages in personnel and capacity, these are large numbers.

Finally, incisional hernia is a socioeconomic problem. It can cause a patient's non-attendance at work. Some patients may no longer be able to comply with their job's demands, while others need adjusted labour. The economic consequences are impossible to calculate, but one cannot conclude otherwise than that these must be high.

AIM OF THE THESIS

Extensive research on incisional hernia has been done, resulting in increasing knowledge on how to prevent and treat incisional hernia. Many questions remain. With regard to incisional

hernia development, experimental studies were undertaken in search of an underlying connective tissue disorder[40,41]. In clinical studies, incisional hernia was associated with abdominal aortic aneurysm[42-45]. Whether different types of hernia are related and whether they may be attributed to a common connective tissue disorder is not known. The question we wanted to answer in the current thesis is "does a connective tissue disorder play a role in incisional hernia and inguinal hernia development and are these two diseases related?" Moreover, we searched for a link between incisional and inguinal hernia and other diseases, such as aortic aneurysm, hiatus hernia, epigastric hernia and umbilical hernia, in which aberrant connective tissue metabolism may play a role.

Connective tissue disorders are a possible cause of incisional hernia, while the surgical factor is a certain one. How important these two factors are in proportion to each other is unknown. Because the tensile strength of the wound depends on the sutures at first and on the tensile strength of scar tissue later, it has been suggested that an early development of incisional hernia indicates perioperative factors as its main cause[46-49], while a late development implies impaired wound healing due to patient related factors, including connective tissue disorders[50,51]. The logical next step is to determine when an incisional hernia develops. There are two ways to answer this question: by clinical diagnosis, or by radiological detection. Strikingly, these two methods yield contrary results. The clinical diagnosis incisional hernia is often made years after surgery, as was reported by a number of authors [35,50-53]. Only one study looked at the time point at which incisional hernia can be identified radiologically. Playforth and Pollock reported that incisional hernia develops within one month of surgery[47,48]. Although the methods of the latter study appear to be superior to those of the other studies, to this day, it remains the only study to report an early development of incisional hernia. In a retrospective study, using CT-scans of patients that did and patients that did not develop incisional hernia, we investigated whether we could confirm the results of Playforth and Pollock.

With regard to incisional hernia prevention, many authors have reported on type of incision and associated incisional hernia rates. Some types of incision are associated with much lower incisional hernia rates than others. However, these incisions have not become routine. In a systematic review, we studied the types of incision that are at the surgeon's disposal and the type of surgery for which they may be suitable. We established the associated incisional hernia rates, but we also looked at postoperative pain, wound infection and wound dehiscence. In a second study we applied these data to operation data that were obtained from Prismant, the Dutch National Medical Registration[38]. Our impression was that the choice of incision amongst Dutch surgeons was fairly uniform. With this in mind, we estimated what a change of practice with regard to choice of incision may do to the number of incisional hernias in the Netherlands.

With regard to incisional hernia repair, retrospective studies from the past and the randomized controlled trial by Luijendijk et al proved mesh repair to be superior to suture repair[19]. However, data from Germany[54], the United States[55] en the Netherlands[38] show that a great number of surgeons still refrains from using a mesh, despite clinical evidence. Use of a mesh is generally accepted for large incisional hernias, in which use of a mesh is often unavoidable. However, many surgeons still regard suture repair as a good treatment for small incisional hernias. Underestimation of their own recurrence rates is likely to play an important role in this misconception[20]. Moreover, some authorities still advocate suture repair for incisional hernias with a diameter smaller than 5 cm[56] or 3 cm[57]. In the only randomized controlled trial available, a three-year cumulative recurrence of incisional hernia of 23% after mesh repair and 46% after suture repair was reported. Luijendijk also differentiated between small (<10cm^2) and large (>10cm^2) incisional hernias. In this study a small hernia could therefore be a defect of 3.15 x 3.15 cm, which would generally be considered small. The recurrence rate after suture repair of such a defect, or smaller, was 44%, while the recurrence rate after mesh repair was 6%[19]. Another reason why surgeons may refrain from the use of a prosthetic mesh is the occurrence of mesh related complications. To provide additional proof that the answer to the question "how should we treat incisional hernia" is "by always using a mesh" we obtained ten-year follow-up of the previously mentioned randomized controlled trial. In addition to recurrence rates, we studied complications, pain, patient satisfaction and the number of reoperations that recurrences required.

With regard to mesh repair and the complications that are associated with it, many attempts were made to develop new and improved mesh materials, as was described earlier. However, the perfect mesh has not yet been found. The main problem is that incorporation and tensile strength benefit from macroporous meshes that elicit a pronounced foreign body reaction. Adhesion prevention on the other hand relies on non-erosive, anti-inflammatory properties. Mesh manufacturers continue to develop new mesh materials. Recently, four new meshes were introduced, three of which were specifically designed to decrease adhesion formation. Their value was however not yet established. In an experimental study, in which we evaluated adhesion formation, mesh infection, mesh incorporation, foreign body reaction and wound tensile strength, we studied whether these new meshes are superior to meshes currently available.

OUTLINE OF THE THESIS

Chapter two presents an anatomical study of the abdominal wall.
Chapter three is a retrospective study, in which we searched for a relationship between incisional and inguinal hernia patients, thus establishing whether a connective tissue disorder may exist in this specific hernia patient population.
Chapter four is retrospective clinical and radiological study of patients who underwent CT-scans during the first month after abdominal surgery; we tried to establish whether incisional hernia develops early or late.
Chapter five is a review of surgical incisions and their associated incisional hernia and complication rates.
Chapter six is a review of incisional hernia prevention strategies.
Chapter seven is an analysis of current surgical practice in the Netherlands with regard to type of incision and hernia repair and the possible beneficial effects of a change of practice on incisional hernia incidence.
Chapter eight presents the long-term follow-up of a randomized controlled trial of suture vs. mesh repair of incisional hernia. Recurrence, complications, pain and patient satisfaction were studied.
Chapter nine presents the results of an experimental study that was performed to establish the value of new prosthetic meshes in the prevention of mesh associated complications after mesh repair of incisional hernia.
Chapter ten is the general discussion.

REFERENCES

1. Klinge U, Prescher A, Klosterhalfen B, et al. [Development and pathophysiology of abdominal wall defects]. Chirurg 1997; 68(4):293-303.
2. Israelsson LA. Wound failure and incisional hernia: mechanism and prevention. In: Fitzgibbons, R.J., Jr, Greenburg, A.G., eds. Nyhus and Condon's hernia. Philadelphia: Lippincott Williams & Wilkins; 2002; 3-8.
3. Bucknall TE, Cox PJ, Ellis H. Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. Br Med J (Clin Res Ed) 1982; 284(6320):931-3.
4. Israelsson LA, Jonsson T. Incisional hernia after midline laparotomy: a prospective study. Eur J Surg 1996; 162(2):125-9.
5. Wissing J, van Vroonhoven TJ, Schattenkerk ME, et al. Fascia closure after midline laparotomy: results of a randomized trial. Br J Surg 1987; 74(8):738-41.
6. Sorensen LT, Hemmingsen UB, Kirkeby LT, et al. Smoking is a risk factor for incisional hernia. Arch Surg 2005; 140(2):119-23.
7. Sugerman HJ, Kellum JM, Jr., Reines HD, et al. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. Am J Surg 1996; 171(1):80-4.
8. Gislason H, Gronbech JE, Soreide O. Burst abdomen and incisional hernia after major gastrointestinal operations--comparison of three closure techniques. Eur J Surg 1995; 161(5):349-54.
9. Guillou PJ, Hall TJ, Donaldson DR, et al. Vertical abdominal incisions--a choice? Br J Surg 1980; 67(6):395-9.
10. Regnard JF, Hay JM, Rea S, et al. Ventral incisional hernias: incidence, date of recurrence, localization and risk factors. Ital J Surg Sci 1988; 18(3):259-65.
11. Israelsson LA, Jonsson T. Suture length to wound length ratio and healing of midline laparotomy incisions. Br J Surg 1993; 80(10):1284-6.
12. Jenkins TP. The burst abdominal wound: a mechanical approach. Br J Surg 1976; 63(11):873-6.
13. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
14. Rucinski J, Margolis M, Panagopoulos G, et al. Closure of the abdominal midline fascia: meta-analysis delineates the optimal technique. Am Surg 2001; 67(5):421-6.
15. van 't Riet M, Steyerberg EW, Nellensteyn J, et al. Meta-analysis of techniques for closure of midline abdominal incisions. Br J Surg 2002; 89(11):1350-6.
16. Manninen MJ, Lavonius M, Perhoniemi VJ. Results of incisional hernia repair. A retrospective study of 172 unselected hernioplasties. Eur J Surg 1991; 157(1):29-31.
17. Read RC, Yoder G. Recent trends in the management of incisional herniation. Arch Surg 1989; 124(4):485-8.
18. Liakakos T, Karanikas I, Panagiotidis H, et al. Use of Marlex mesh in the repair of recurrent incisional hernia. Br J Surg 1994; 81(2):248-9.
19. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
20. Paul A, Korenkov M, Peters S, et al. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. Eur J Surg 1998; 164(5):361-7.
21. Schumpelick V, Conze J, Klinge U. [Preperitoneal mesh-plasty in incisional hernia repair. A comparative retrospective study of 272 operated incisional hernias]. Chirurg 1996; 67(10):1028-35.
22. de Vries Reilingh TS, van Goor H, Rosman C, et al. "Components separation technique" for the repair of large abdominal wall hernias. J Am Coll Surg 2003; 196(1):32-7.
23. Gillion JF, Begin GF, Marecos C, et al. Expanded polytetrafluoroethylene patches used in the intraperitoneal or extraperitoneal position for repair of incisional hernias of the anterolateral abdominal wall. Am J Surg 1997; 174(1):16-9.

24. Leber GE, Garb JL, Alexander AI, et al. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998; 133(4):378-82.
25. Law NH, Ellis H. Adhesion formation and peritoneal healing on prosthetic materials. Clinical Materials 1988; 3:95-101.
26. Luijendijk RW, de Lange DC, Wauters CC, et al. Foreign material in postoperative adhesions. Ann Surg 1996; 223(3):242-8.
27. Ellis H. The clinical significance of adhesions: focus on intestinal obstruction. Eur J Surg Suppl 1997(577):5-9.
28. Menzies D. Postoperative adhesions: their treatment and relevance in clinical practice. Ann R Coll Surg Engl 1993; 75(3):147-53.
29. Menzies D, Ellis H. Intestinal obstruction from adhesions--how big is the problem? Ann R Coll Surg Engl 1990; 72(1):60-3.
30. Monk BJ, Berman ML, Montz FJ. Adhesions after extensive gynecologic surgery: clinical significance, etiology, and prevention. Am J Obstet Gynecol 1994; 170(5 Pt 1):1396-403.
31. diZerega GS. Biochemical events in peritoneal tissue repair. Eur J Surg Suppl 1997(577):10-6.
32. Drollette CM, Badawy SZ. Pathophysiology of pelvic adhesions. Modern trends in preventing infertility. J Reprod Med 1992; 37(2):107-21; discussion 121-2.
33. Usher FC. Hernia Repair with Knitted Polypropylene Mesh. Surg Gynecol Obstet 1963; 117:239-40.
34. Hoer J, Lawong G, Klinge U, et al. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg 2002; 73(5):474-80.
35. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
36. Schumpelick V, Klinge U, Welty G, et al. [Meshes within the abdominal wall]. Chirurg 1999; 70(8):876-87.
37. National Center for Health Statistics. Combined Surgery Data (NHDS and NSAS) Data Highlights. http://www.cdc.gov/nchs/about/major/hdasd/combtab.htm. 1996.
38. Prismant. Utrecht, the Netherlands: National Medical Registration; 2002.
39. Franz MG, Kuhn MA, Nguyen K, et al. Transforming growth factor beta(2) lowers the incidence of incisional hernias. J Surg Res 2001; 97(2):109-16.
40. Klinge U, Si ZY, Zheng H, et al. Abnormal collagen I to III distribution in the skin of patients with incisional hernia. Eur Surg Res 2000; 32(1):43-8.
41. Klinge U, Si ZY, Zheng H, et al. Collagen I/III and matrix metalloproteinases (MMP) 1 and 13 in the fascia of patients with incisional hernias. J Invest Surg 2001; 14(1):47-54.
42. Adye B, Luna G. Incidence of abdominal wall hernia in aortic surgery. Am J Surg 1998; 175(5):400-2.
43. Hall KA, Peters B, Smyth SH, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. Am J Surg 1995; 170(6):572-5; discussion 575-6.
44. Holland AJ, Castleden WM, Norman PE, et al. Incisional hernias are more common in aneurysmal arterial disease. Eur J Vasc Endovasc Surg 1996; 12(2):196-200.
45. Raffetto JD, Cheung Y, Fisher JB, et al. Incision and abdominal wall hernias in patients with aneurysm or occlusive aortic disease. J Vasc Surg 2003; 37(6):1150-4.
46. Ausobsky JR, Evans M, Pollock AV. Does mass closure of midline laparotomies stand the test of time? A random control clinical trial. Ann R Coll Surg Engl 1985; 67(3):159-61.
47. Playforth MJ, Sauven PD, Evans M, et al. The prediction of incisional hernias by radio-opaque markers. Ann R Coll Surg Engl 1986; 68(2):82-4.
48. Pollock AV, Evans M. Early prediction of late incisional hernias. Br J Surg 1989; 76(9):953-4.
49. Wantz GE. Incisional hernia: the problem and the cure. J Am Coll Surg 1999; 188(4):429-47.
50. Ellis H, Gajraj H, George CD. Incisional hernias: when do they occur? Br J Surg 1983; 70(5):290-1.

51. Franchi M, Ghezzi F, Buttarelli M, et al. Incisional hernia in gynecologic oncology patients: a 10-year study. Obstet Gynecol 2001; 97(5 Pt 1):696-700.
52. Harding KG, Mudge M, Leinster SJ, et al. Late development of incisional hernia: an unrecognised problem. Br Med J (Clin Res Ed) 1983; 286(6364):519-20.
53. Lewis RT, Wiegand FM. Natural history of vertical abdominal parietal closure: Prolene versus Dexon. Can J Surg 1989; 32(3):196-200.
54. Paul A, Lefering R, Kohler L, et al. [Current practice of incisional hernia reconstruction in Germany] Gegenwartige Praxis der Narbenhernienrekonstruktion in der Bundesrepublik Deutschland. Zentralbl Chir 1997; 122(10):859-61.
55. Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. Ann Surg 2003; 237(1):129-35.
56. Korenkov M, Paul A, Sauerland S, et al. Classification and surgical treatment of incisional hernia. Results of an experts' meeting. Langenbecks Arch Surg 2001; 386(1):65-73.
57. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. Lancet 2003; 362(9395):1561-71.

2 | Anatomy of the Anterior Abdominal Wall

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This issue of Operative Techniques in General Surgery deals with selected abdominal wall hernias other than those of the groin. The purpose of this chapter is to set the stage for the operative descriptions that follow. To repair the hernias that will be discussed, a requisite knowledge of the anatomy is essential. Therefore we will illustrate the salient anatomy as it specifically affects surgical decision making in the repair of abdominal wall hernias.

The abdomen represents the portion of the trunk between the thorax and pelvis. For the purpose of the hernia repairs to be described in this issue, only the anterior abdominal wall is of interest. The abdominal wall structure will be described from the most superficial layer to the peritoneum.

SUPERFICIAL FASCIA, VESSELS, AND NERVES

The abdominal wall consists of skin, superficial fascia, fat, muscles, transversalis fascia, and the parietal peritoneum. The panniculus adiposus consists of the fat deposits in the superficial fascial layer often referred to as Camper's fascia. Scarpa's fascia is the membranous deeper layer to this, which contains more fibrous tissue. The fibrous layer is formed by compacted fibrous strata that are in continuity with the fatty layer. This layer has no intrinsic strength for hernia repair but is valuable since it provides another layer of protection for the underlying

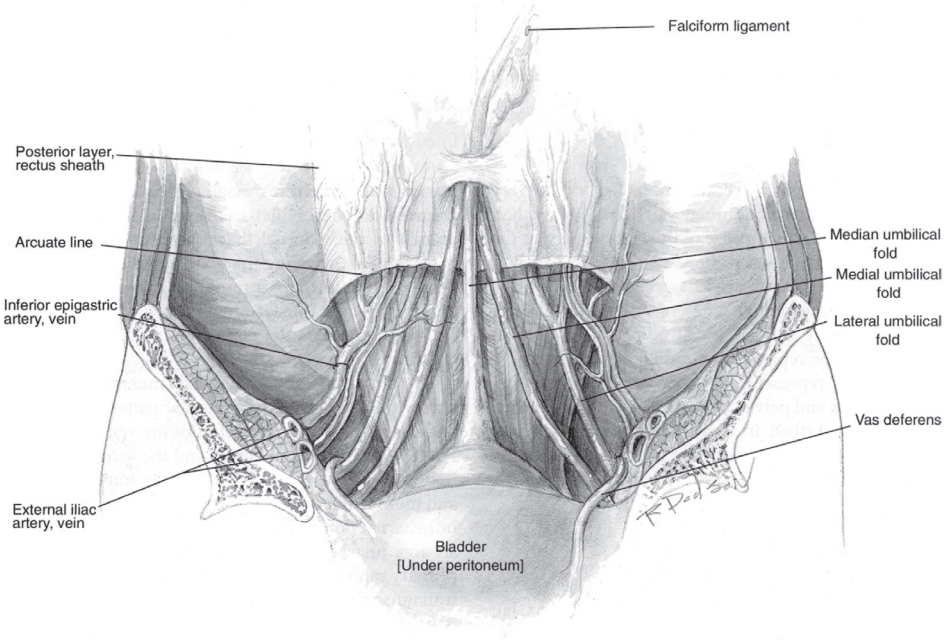

FIGURE 1 (A). Blood supply – anterior abdominal wall.

hernia repair, especially when prosthesis is used. This membranous deep fascia merges with the deep thigh fascia and superficial perineal fascia to contribute to the fascia lata and Colles' fascia, respectively. The blood supply to the superficial layers is derived from branches of the femoral artery, namely the superficial epigastric arteries. Venous drainage into the femoral veins is facilitated via the saphenous hiatus in the thigh.

Three major arterial branches supply blood to either side of the anterior abdominal wall, which includes two branches of the external iliac artery and a branch of the internal thoracic artery. The inferior epigastric artery travels within the transversalis fascia until it reaches the arcuate line where it pierces the rectus sheath. The second branch of the external iliac, the deep circumflex iliac, runs parallel to the inguinal ligament between the transversus abdominis and internal oblique muscles. The superior epigastric, the terminal branch of the internal thoracic artery, enters the rectus sheath superiorly (Fig 1A and B).

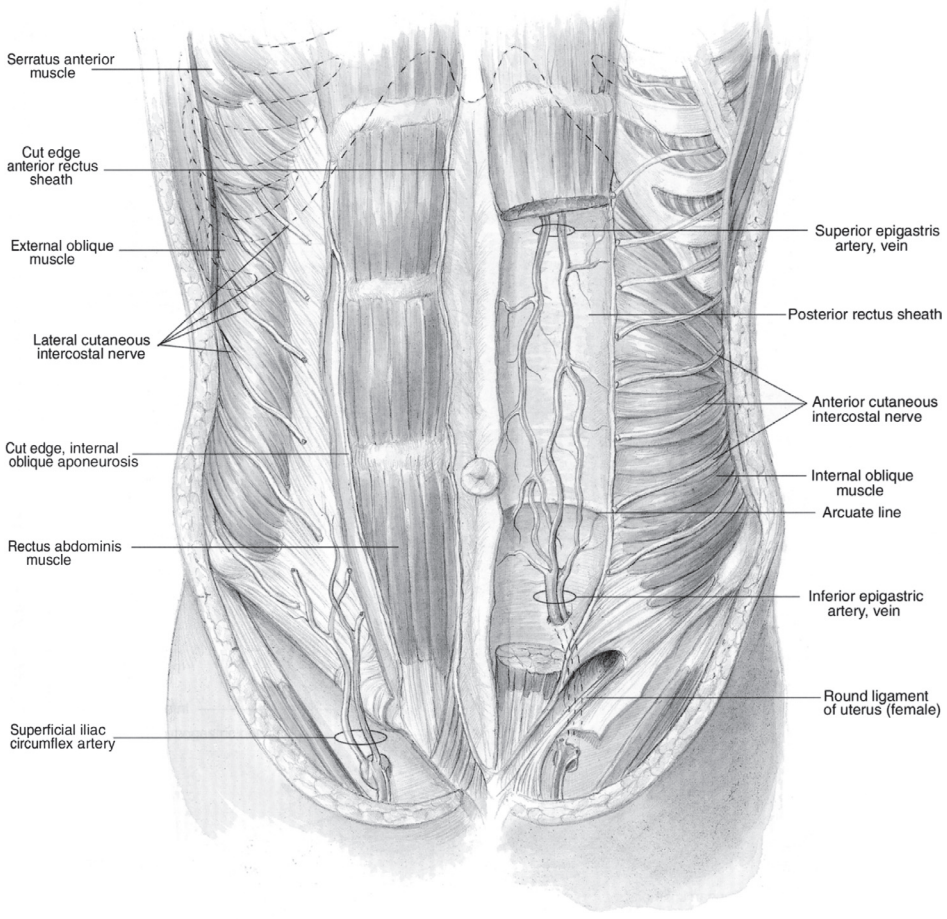

FIGURE 1 (B). Blood supply - anterior abdominal wall.

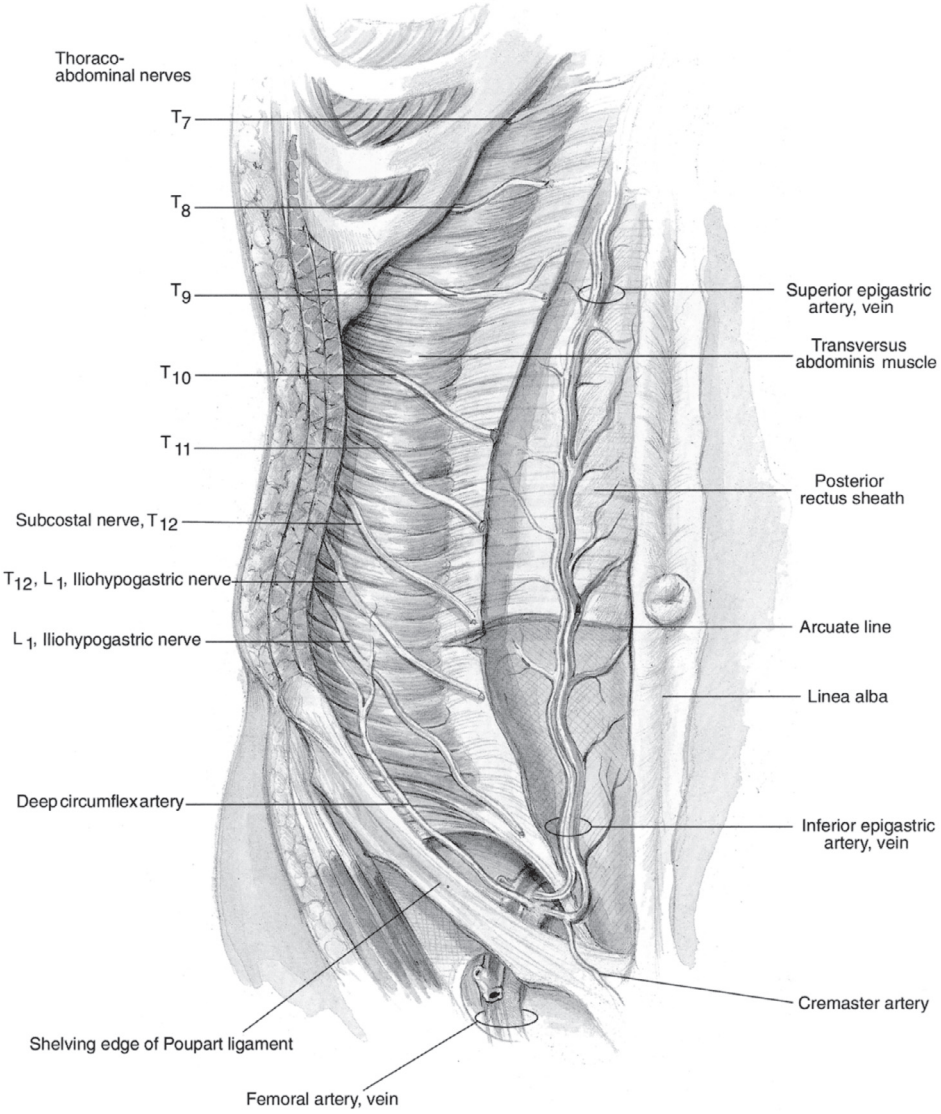

FIGURE 2. Nerve supply – anterior abdominal wall.

The cutaneous abdominal wall innervation is consistent with a segmental dermatomal pattern. The anterior and lateral cutaneous branches of the ventral rami of the 7th to 12th intercostal nerves and the ventral rami of the first and second lumbar nerves have important sensory and motor functions. T7 passes to the area just below the infrasternal notch, T10 towards the umbilicus, and T12 to an area just above the umbilicus (Fig 2). The anterior primary rami of this nerve group innervate the abdominal wall musculature as well as intercostal muscles. There is poor communication between nerves as they run towards the midline. This results in the ability to use transverse incisions through the rectus to gain access to abdominal con-

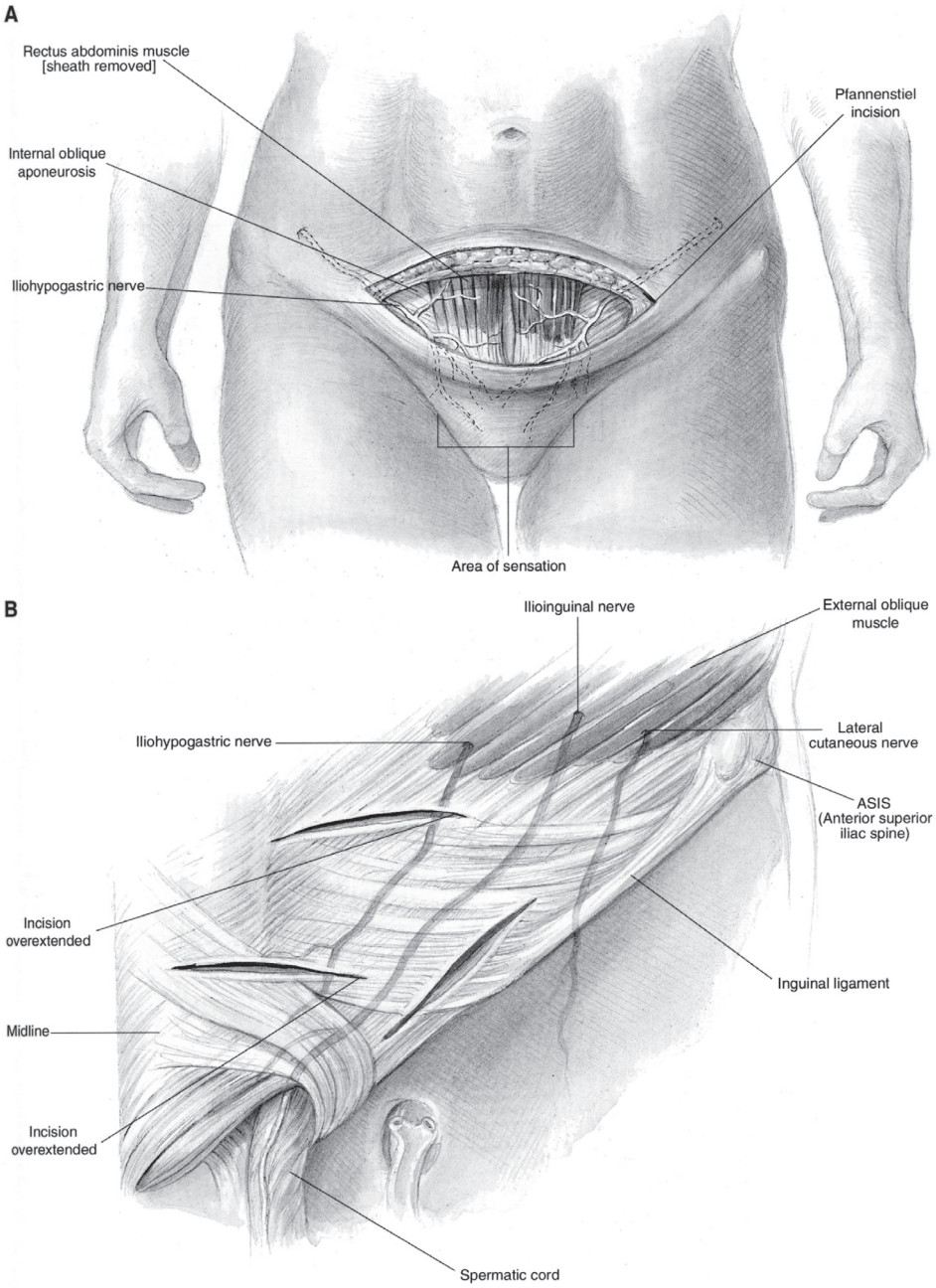

FIGURE 3 (A&B). Nerve supply in relation to various incisions.

tents. (Fig 3A &B). By reflecting the superficial fascia the ilioinguinal (L1) and iliohypogastric (T12, L1) nerves can be noted. The iliohypogastric nerve innervates the skin just above the pubis after traversing the external oblique.

The superficial anatomy is essential to the laparoscopic surgeon as well. Laparoscopic hernia repair is quickly becoming a well performed procedure with decreasing morbidity if performed by those who are suitably trained. Laparoscopic ventral hernia repair with a self-expanding mesh is described later.

ANTERIOR MUSCULATURE AND LIGAMENTS

Much of the strength of the abdominal wall is inherent in four paired muscles and their respective aponeuroses. These aponeuroses in fact represent sheet-like tendons for the insertion of the lateral muscles and also form the sheath of the rectus abdominis.

From most superficial to deep, the external oblique is the first layer of the lateral muscles (Figs 4-6). The largest of the three, the external oblique arises from the lower eight ribs posteriorly to interdigitate with both the serratus and latissimus muscles. The direction of the fibers is approximately horizontal in the uppermost portion only to become oblique in the lowest portions as they fold upon themselves to form the inguinal ligament. The inguinal ligament helps to define the myopectineal orifice, which is the area contained deep to the inguinal ligament. After contributing to the anterior portion of the rectus abdominis sheath, the remaining fibers insert onto the linea alba which is the dense white line formed by the medial termination of all the aponeuroses.

The external and internal oblique muscles both have functions in the support of abdominal viscera as well as assisting in flexion and rotation of the trunk (Figs 4-6). The internal oblique arises from the anterior two-thirds of the iliac crest and lateral half of the inguinal ligament to run essentially at right angles to those of the external oblique. The fibers take the shape of the iliac crest in that they fan out to insert on the 10^{th} and 12^{th} ribs inferiorly. Spigelian hernias in adults are considered to be acquired through areas of separation of the internal oblique and transversus fibers. These fibers arch over the spermatic cord (or round ligament) and the most inferior of these join with similar aponeurotic fibers of the transversus abdominus to form the conjoint tendon. The umbilicus marks an important level in the division of the internal oblique aponeurosis. Above this level, the aponeurosis of the internal oblique splits to envelop the rectus abdominis and subsequently rejoins at the linea alba. The contribution to the linea alba inferior to the umbilicus is somewhat more direct. Here, the aponeurosis remains intact and runs anterior to the rectus to finally contribute to the linea alba. The entire rectus sheath can now be illustrated with the inclusion of the aponeurosis of the transversus abdominis muscle.

As described by Flament, these lateral muscles are important in the formation of midline incisional hernias. In addition to infection of underlying wounds, his group found that incisional hernias were in large part due to disinsertion of these lateral muscles in the midline thus resulting in retraction and subsequent atrophy. His recommendations for repair are outlined in later articles.

The final contribution to the rectus sheath arises from the innermost of the three lateral abdominal muscles, the transversus abdominis (Figs 4-6). This muscle arises from the 7th to 12th costal cartilages, iliac crest, and the lateral third of the inguinal ligament. The muscle bundles of this group run essentially horizontally except the lower most medial fibers which run a more inferomedial course to their insertion on the pubic crest and pecten pubis. The umbilicus is an important landmark in the division of the transversus abdominis muscle fibers. Above the umbilicus the transversus abdominis aponeurosis joins that of the internal oblique aponeurosis to form a portion of the posterior rectus sheath as mentioned previously. Below

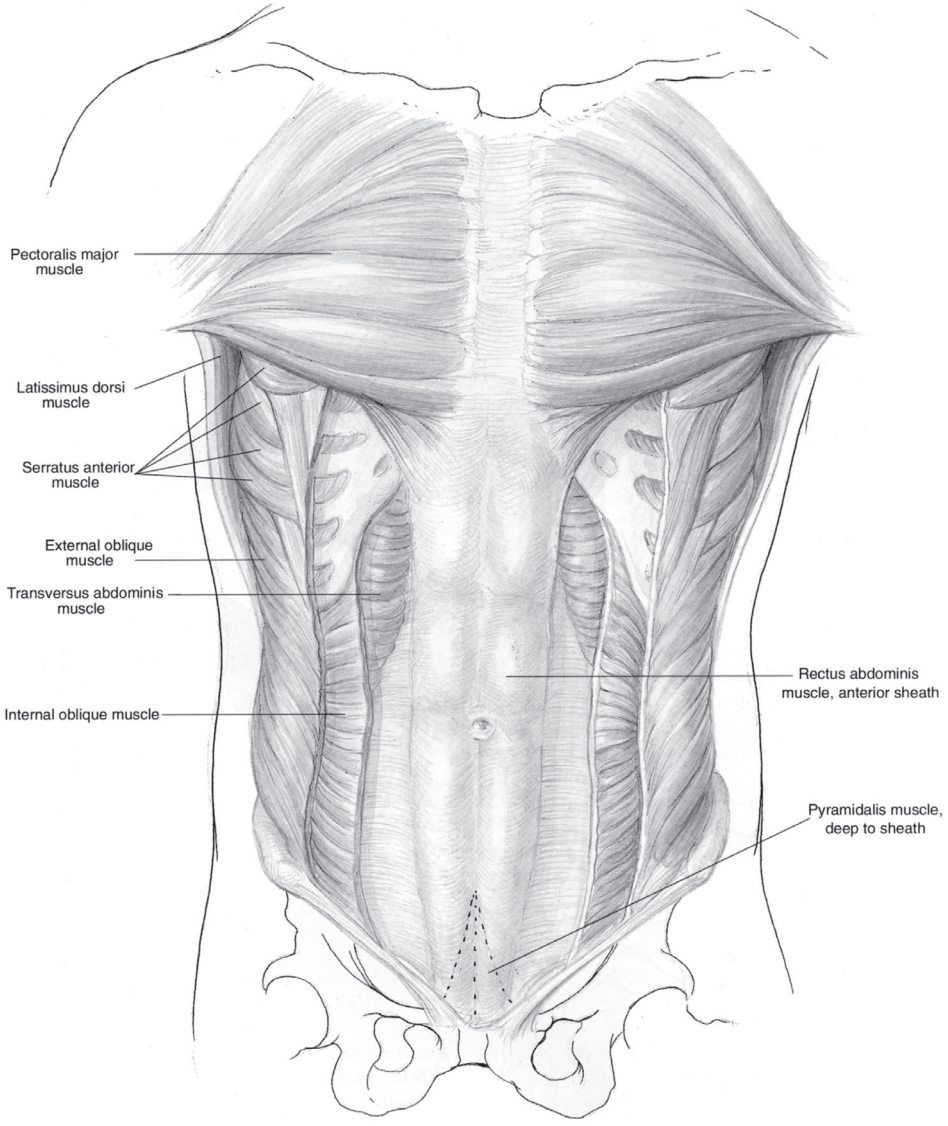

FIGURE 4. Musculature – anterior abdominal wall.

the umbilicus, the transversus aponeurosis only contributes to the anterior rectus sheath. The arcuate line (of Douglas) is the site at which termination of these contributing fibers onto the posterior aspect of the rectus abdominis muscle occurs.

The principal vertical muscle of the anterior abdominal wall consists of a pair of muscles separated by the linea alba. The rectus abdominis muscle originates from the 5th through 7th costal cartilages to insert on the symphysis pubis and crest. Superiorly, the rectus is wide, broad, and thin becoming narrow and thick inferiorly. The rectus muscle and sheath form the linea semilunaris laterally. Segmentation of each rectus muscle occurs by tendinous intersections, which represent attachment of the rectus muscle with the anterior layer of the rectus

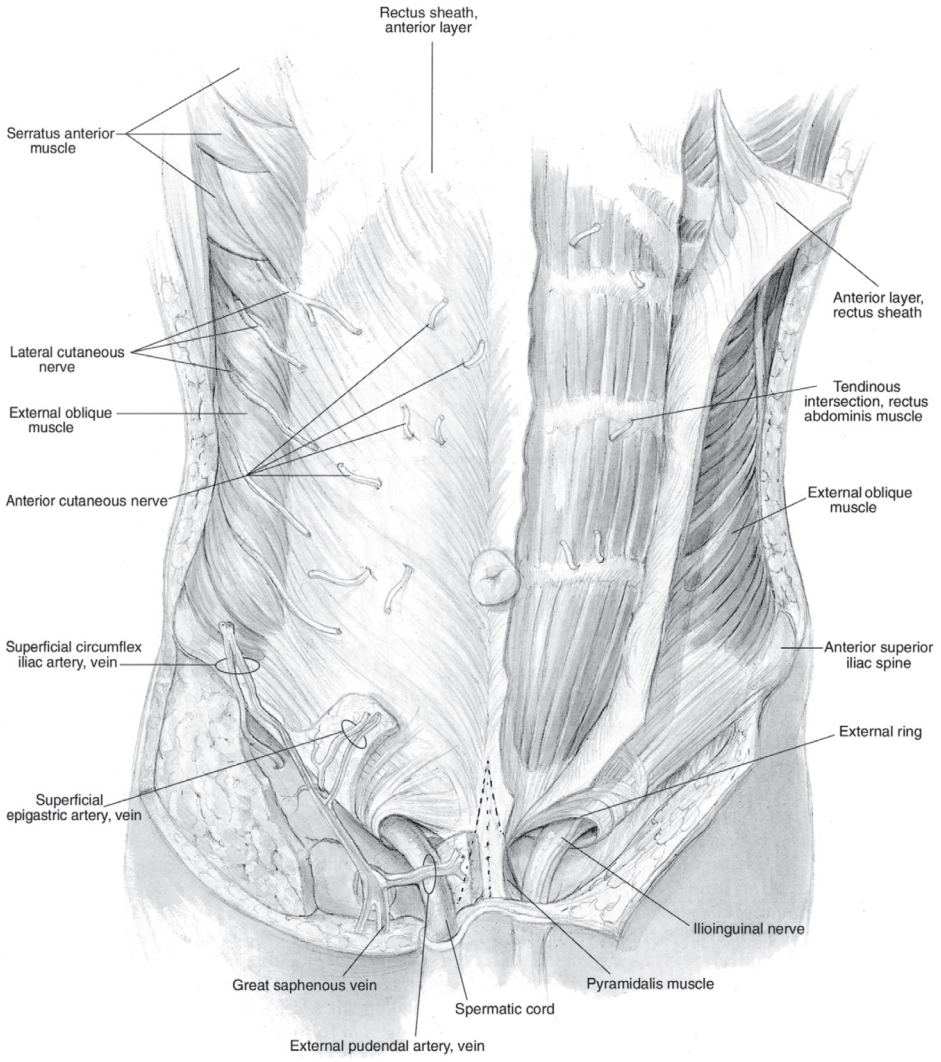

FIGURE 5. Musculature – anterior abdominal wall.

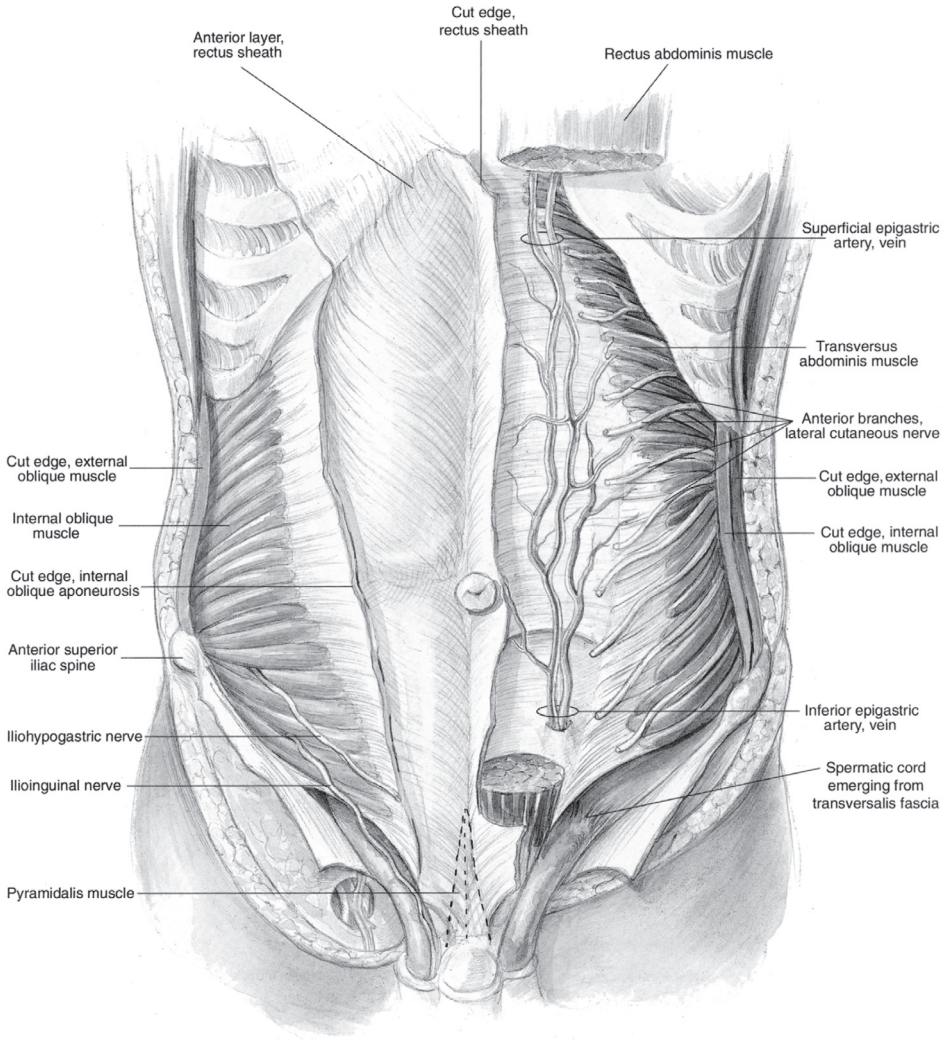

FIGURE 6. Musculature – anterior abdominal wall.

sheath. In 80% of people there is a small triangular muscle, called the pyramidalis, located anterior to the inferior part of the rectus. It assists in tensing the linea alba (Fig 5). The superior and inferior epigastric arteries are the principal blood supply to the rectus. Laterally, the 7th through the 12th intercostal nerves provide innervation.

The rectus abdominis is therefore invested within a sheath derived from the combined aponeuroses and fasciae of the external oblique, internal oblique and transversus abdominis (Fig 6).

Further delineation of the rectus sheath is important in the understanding of anterior abdominal wall anatomy (Fig 7). The rectus sheath has contributions from all the mentioned

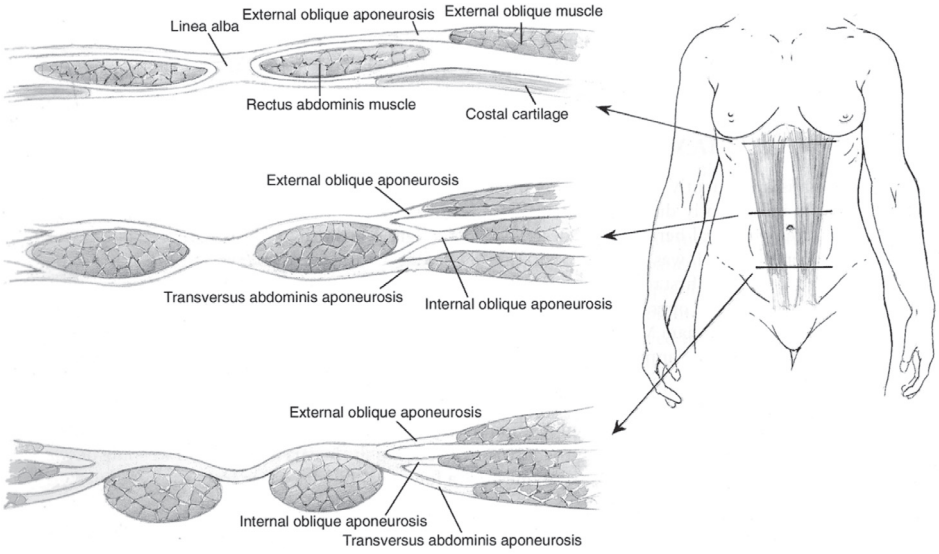

FIGURE 7. The rectus sheath at various levels.

aponeuroses only when inferior to the umbilicus. The anterior sheath superior to the umbilicus is composed only of aponeuroses from the external and internal abdominal muscles; the transversalis aponeurosis has no contribution to the formation of the anterior sheath at this level. In effect, the internal oblique aponeurosis splits allowing one layer to pass anterior and one posterior to the rectus muscle. The anterior layer will then join with the external oblique aponeurosis to form the anterior wall of the rectus sheath. The anterior sheath can be truly considered a composite of all three aponeurotic layers only at a variable level below the umbilicus. The posterior sheath is similarly described in relation to the umbilicus. Superior to the umbilicus the posterior sheath consists of contributions from both the aponeuroses of the internal oblique and the transversus abdominis aponeuroses. Inferior to the umbilicus, the external abdominal aponeurosis has no contribution to the formation of the posterior rectus sheath.

Bleichrodt's group has taken advantage of these aponeurotic layers to modify the "components separation" technique described in this text. They use this technique to close abdominal defects by finely choosing muscle layers and their investing aponeurosis while simultaneously creating a smaller wound surface.

The arcuate line is defined by the most inferior extension of the posterior sheath forming a crescent shaped border. In the midline, fibers of the anterior and posterior sheaths interlace forming the linea alba. It is now recognized that mechanical forces acting here contribute to the formation of epigastric hernias. As the following chapters will describe, these may be successfully repaired laparoscopically as well as by using conventional open techniques. Laparoscopic mesh repair has also been employed by many groups and one such technique is outlined in this text.

3 | Evidence of a Clinical Relationship between Incisional and Inguinal Hernia

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Submitted

ABSTRACT

OBJECTIVES

It has been suggested that a metabolic connective tissue disorder is the common cause of incisional and inguinal hernia. However, a clinical relationship between incisional and inguinal hernia has not been established. The objective of the current study was to establish such a relationship. We hypothesize that the prevalence of several disorders, which are likely to be related to incisional and inguinal hernia is higher in patients with both incisional and inguinal hernia than in patients with only one of both types of hernia.

METHODS

In a retrospective study, patients (1983-2001) with an incisional or inguinal hernia were identified. The prevalence of umbilical hernia, hiatus hernia, epigastric hernia, burst abdomen and aortic aneurysm was compared in patients with incisional hernia, patients with inguinal hernia and patients with both incisional and inguinal hernia.

RESULTS

Patients with incisional and inguinal hernia had a significantly higher prevalence of hiatus hernia, umbilical hernia, burst abdomen and aortic aneurysm than patients with only incisional or inguinal hernia ($p<0.05$). The prevalence of aortic aneurysm was 38% in patients with incisional and inguinal hernia, compared to 10% in patients with incisional hernia ($p<0.0001$) and 5% in patients with inguinal hernia ($p<0.0001$).

CONCLUSIONS

This study provides evidence that incisional and inguinal hernia are related. Patients diagnosed with both types of hernia are at risk for aortic aneurysm. The probability of identifying an underlying metabolic disorder is high in patients with incisional hernia, inguinal hernia and abdominal aortic aneurysm.

INTRODUCTION

Incisional hernia is a frequent complication of abdominal surgery. The reported incidence of incisional hernia following abdominal surgery ranges from 2-20%[1-6]. In the United States alone, approximately 200,000 incisional hernia repairs are performed annually[7,8]. The disappointing results of incisional hernia repair add further to the magnitude of the problem[9]. The cause of this frequent, sometimes serious complication of abdominal surgery has, however, yet to be determined. It may be caused by flawed operative techniques, by postoperative complications such as wound infection, by increased abdominal wall tension or by a metabolic connective tissue disorder[10,11].

Inguinal hernia is an even more common disorder with a life-time incidence of approximately 5%[12]. Data from 1996 show that more than 600,000 inguinal hernia repairs were performed in the United States per year[7]. In addition to a patent processus vaginalis, increased abdominal wall tension and cigarette smoking[12], inguinal hernia too has been associated with a metabolic connective tissue disorder[13-18]. A strong indication that a connective tissue disorder may play a role in both incisional and inguinal hernia is the high incidence of abdominal wall hernias in patients with abdominal aneurysmatic disease. Several authors reported increased incisional hernia rates after surgery for abdominal aneurysmatic disease compared to aorto-iliac occlusive disease[19-23]. A relationship between inguinal hernia and abdominal aneurysmatic disease was reported as well[19,21,24-26]. With regard to incisional hernia, it is conceivable that the type of operation required for abdominal aortic surgery leads to a high incidence of incisional hernia. Israelsson et al compared aortic aneurysm patients with patients undergoing otherwise major abdominal surgery and found that when closure technique and length of incision were accounted for, no increased incidence of incisional hernia was present[27].

In conclusion, many factors influence incisional and inguinal hernia development. Whether a metabolic connective tissue disorders plays a part, and if it does, how important that part is, remains unclear. Our objective was to establish whether a clinical relationship between incisional hernia and inguinal hernia exists. This relationship was not reported previously. To answer this question, patients with a history of inguinal hernia and incisional hernia at the Erasmus University Medical Center were identified. In these patients, the prevalence of several disorders that are likely to be related to inguinal and incisional hernia was established. The prevalence of these disorders was subsequently compared to the prevalence in patients with both inguinal and incisional hernia in their medical history. In addition, characteristics of patients with both inguinal and incisional hernia were studied in detail.

METHODS

To identify inguinal hernia and incisional hernia patients, a computerized search in the database of the Erasmus University Medical Center was performed. All correspondence, operation records, radiology records, clinical and outpatient diagnostic codes (1983-2001) were searched for inguinal hernia and incisional hernia. Individual patients with incisional hernia or inguinal hernia were identified. Subsequently, the records of these patients were searched for hiatus hernia, umbilical hernia, epigastric hernia, burst abdomen and abdominal aneurysmatic disease. After identification of a disorder in a patient by computerized search, the presence of the disorder was verified by chart review. The prevalence of individual disorders was compared between patients with incisional hernia, patients with inguinal hernia and patients with both incisional and inguinal hernia. To compare the prevalence of abdominal aortic aneurysm, patients were subdivided in gender and age groups. Furthermore, the prevalence of abdominal aneurysmatic disease in patients with incisional hernia, patients with inguinal hernia and patients with both incisional and inguinal hernia was compared to a reference group of 2217 men and 3066 women, who underwent ultrasonography of the abdominal aorta during screening, which was performed on account of the Rotterdam Elderly Study[28,29]. Characteristics of patients with both types of ventral abdominal wall hernias (inguinal and incisional) were gathered by chart review. Fisher's exact test and the Mann-Whitney U test were used to statistically analyze data (SPSS®, Chicago, Illinois, USA).

RESULTS

The computerized search in the 1983-2001 database of the Erasmus University Medical Center identified 1334 patients with incisional hernia and 3056 patients with inguinal hernia. One hundred and twenty-one patients had both inguinal hernia and incisional hernia in their history. Patients with both inguinal and incisional hernia were older (median 65) than patients with only incisional hernia (median 60) or inguinal hernia (median 58). Men constituted 82%

TABLE 1. Median age (range) and sex of patients at time of diagnosis

	Incisional + Inguinal Hernia N=121	Incisional Hernia N=1334	P-value	Inguinal Hernia N=3056	P-value
Age	65 (20-87)	60 (19-91)	0.0003*	58 (18-94)	<0.0001*
Male	82% (99)	53% (707)	<0.0001†	88% (2689)	0.587†

* Compared to age in incisional + inguinal hernia patients (Mann-Whitney U test)
† Compared to incisional + inguinal hernia patients' gender (Fisher's Exact test)

TABLE 2. Prevalence of hernia related disorders in patients with incisional + inguinal hernia, patients with incisional hernia and patients with inguinal hernia

	Incisional + Inguinal Hernia N=121	**Incisional Hernia N=1334**	**P-value***	**Inguinal Hernia N=3056**	**P-value***
Hiatus Hernia	7.4% (9)	3.0% (40)	0.0165	1.7% (52)	<0.0001
Umbilical Hernia	9.1% (11)	2.7% (36)	0.0011	2.3% (70)	<0.0001
Epigastric Hernia	3.3% (4)	1.5% (20)	0.1324	0.7% (21)	0.0075
Burst Abdomen	9.9% (12)	5.1% (68)	0.0354	0.8% (244)	<0.0001
Abdominal Aneurysm	38% (46)	9.8% (131)	<0.0001	5.1% (156)	<0.0001

*Prevalence compared to prevalence in incisional + inguinal hernia patients (Fisher's Exact test)

of the group, which was comparable to the distribution of sex in the inguinal hernia group. Incisional hernia was more equally distributed among the sexes (Table 1).

In patients who had had both incisional and inguinal hernia, a significantly higher prevalence of hiatus hernia, umbilical hernia, epigastric hernia, burst abdomen and abdominal aneurysm was found than in patients with only incisional or inguinal hernia (exception: epigastric hernia in incisional hernia patients) (Table 2).

For the prevalence of abdominal aneurysm, patients were subdivided in gender and age groups. The prevalence of abdominal aneurysm was increased in male patients with both incisional and inguinal hernia. In male patients over 75 years old, significance was lost (Table 3). The prevalence of abdominal aneurysm was higher in female patients with both incisional and inguinal hernia. Subdivision into age groups led to loss of significance in all but one category (Table 4).

TABLE 3. Prevalence of abdominal aneurysm in male patients in separate age groups

	Incisional + Inguinal Hernia (n=99)	**Incisional Hernia (n=708)**	**P-value***	**Inguinal Hernia (n=2692)**	**P-value***
All ages	43% (43/99)	16% (110/708)	<0.0001	6% (153/2692)	<0.0001
≤64	39% (17/44)	7% (29/407)	<0.0001	2% (28/1619)	<0.0001
65-74	49% (19/39)	26% (56/213)	0.0073	10% (69/690)	<0.0001
≥75	44% (7/16)	28% (25/88)	0.2469	14.6% (56/383)	0.0063

*Prevalence compared to prevalence in incisional + inguinal hernia patients (Fisher's Exact test)

TABLE 4. Prevalence of abdominal aneurysm in female patients in separate age groups

	Incisional + Inguinal Hernia (n=22)	**Incisional Hernia (n=626)**	**P-value***	**Inguinal Hernia (n=364)**	**P-value***
All ages	14% (3/22)	3% (21/626)	0.0433	1% (4/364)	<0.0001
≤64	7% (1/15)	1% (4/409)	0.1655	0.4% (1/252)	0.1094
65-74	0% (0/2)	6% (11/171)	1.000	3.4% (2/58)	1.000
≥75	40% (2/5)	8% (6/74)	0.0774	2% (1/53)	0.0175

*Prevalence compared to prevalence in incisional + inguinal hernia patients (Fisher's Exact test)

Patients with both inguinal and incisional hernia were 63 years of age on average when both the inguinal and the incisional hernia were diagnosed. Patients were often obese and almost 55% were active smokers. Almost 30% suffered of chronic obstructive pulmonary disease. More than 36% of patients suffered one or more incisional hernia recurrence and 33% one or more inguinal hernia recurrence. Twenty-eight percent had a bilateral inguinal hernia (Table 5).

TABLE 5. Patients with incisional hernia and inguinal hernia (n=121)

Average age at diagnosis	63
Male	82% (99)
Female	18% (22)
BMI	25.3
Smoking	55% (66)
Chronic Obstructive Pulmonary Disease	29% (35)
Aortic aneurysm	38% (46)
Incisional hernia recurrence	36% (44)
Inguinal hernia recurrence	33% (40)
Bilateral inguinal hernia	28% (34)

The prevalence of aortic aneurysm in the general population is lower than in patients with both inguinal and incisional hernia. Patients with inguinal hernia, incisional hernia and aortic aneurysm were 63 years old on average when their incisional and inguinal hernias were diagnosed. In the corresponding age group in the screening study, the prevalence of aortic

TABLE 6*. Aortic aneurysm prevalence: Rotterdam Elderly Study[27,28]

Age	Male	Female
55-59	0.9%	0.2%
60-64	3.1%	0.4%
65-69	3.8%	0.2%
70-74	4.4%	1.1%
75-79	8.3%	1.1%
>79	10.3%	2.1%

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aneurysm was 3.1% for men and 0.4% for women. The highest prevalence of aortic aneurysm was found in men over 79 years of age: 10.3% (Table 6).

DISCUSSION

Our results have established a clinical relationship between incisional and inguinal hernia. This relationship is evidenced by the fact that patients with both inguinal and incisional hernia in their history had a significantly higher prevalence of umbilical hernia, hiatus hernia, epigastric hernia, burst abdomen and abdominal aneurysmatic disease, compared to patients with only one of both hernias in their history. In addition, we found a strikingly high prevalence of aortic aneurysm in patients with both inguinal and incisional hernia.

Patients that had both an inguinal and an incisional hernia in their history had a significantly higher prevalence of almost all studied disorders. Therefore, these disorders seem to be related. Although the prevalence of almost all studied disorders was increased in patients with both incisional and inguinal hernia, the fact that 38% of patients had a history of abdominal aneurysmatic disease provides stronger, almost indisputable proof of a relationship between incisional hernia, inguinal hernia and abdominal aneurysmatic disease. The much lower prevalence of abdominal aneurysmatic disease in the general population, as established in the Rotterdam Elderly Study[28,29], supports this assumption. We hypothesize that the best place to search for a common metabolic disorder causing connective tissue degeneration is the patient group with incisional hernia, inguinal hernia and aortic aneurysm. In addition to introducing this new patient group as a high potential research subject, our results have clinical implications. Almost half of the incisional hernias in aortic aneurysm patients developed in the scar of an aortic aneurysm operation. However, the other half did not. These incisional hernias were caused by previous surgery. In 19% of patients that presented with a

history of inguinal and incisional hernia, aortic aneurysm was not diagnosed yet, but would be in the near future (median 3 years).

Previously, aortic aneurysm has been associated with inguinal hernia[21,22,24-26] and incisional hernia[20-22,30]. The connection between hernia and aortic aneurysm was often thought to be a metabolic connective tissue disorder. Abnormal connective tissue may cause a deterioration of the abdominal wall integrity, resulting in primary hernias, such as inguinal hernia. A similar mechanism may cause degeneration of the vascular wall of the abdominal aorta in aneurysm development. Possibly, a connective tissue disorder results in insufficient wound healing as well, causing incisional hernia. It is conceivable that such a connective tissue disorder would present itself in other forms. In 2000, Wilmink added several expressions of tissue-laxity to the list of such disorders[31]. Our study suggests that umbilical hernia, epigastric hernia, hiatus hernia and burst abdomen should be added as well.

The nature of the alleged connective disorder has been the subject of speculation and study[32]. A decrease of the collagen I/III ratio in tissues of incisional hernia[10,11], inguinal hernia[13-15] and aortic aneurysm patients has been established[33-37]. Mature type I collagen forms thick collagen fibrils, resulting in superior mechanical strength compared to thinner type III collagen fibrils[16]. MMPs are the principal enzymes degrading collagen types I, II and III and participate in the formation and removal of granulation tissue and resolution of scar tissue[16]. An increase in matrix metalloproteinase (MMP) expression has been reported in hernia patients[16,38,39]. Furthermore, MMPs may play a role in the development of abdominal aortic aneurysm[40,41] and wound healing[42-44]. Still, the precise nature of the metabolic imbalance remains unclear. Smoking may be the common denominator. In 1981, Cannon et al found that smokers with inguinal hernia had significantly higher blood levels of elastin-degrading activity, as well as a significantly lower serum α1-anti-trypsine capacity[45]. The authors hypothesized that smoking induced a systemic imbalance in levels of protease and antiprotease, which altered the connective tissue of the groin. A similar imbalance was found in smokers with abdominal aortic aneurysm[24,46]. Moreover, smoking is associated with activation of neutrophils and macrophages and the release of oxidants damaging antiprotease defense, leading to increased collagenolysis and inhibited repair[47]. Jorgensen et al reported decreased collagen deposition in smokers compared to non-smoking counterparts[48]. Nevertheless, there is little clinical evidence linking smoking and hernia development. In our study, the high number of active smokers in the group of patients with incisional hernia and inguinal hernia (55%, compared to 17-24% in the general population > 55 yrs[49]) supports a role for smoking in hernia and aneurysm development. It does not, however, prove it.

There are limitations to our study. Although our methods allowed us to retrieve large patient groups and a significant group of patients with both inguinal and incisional hernia, the het-

erogeneity of the groups made it impossible to construct a representative control group. This makes our results vulnerable to bias. We studied gender and age related diseases, hernia and aortic aneurysm, making age and gender biases the most obvious. To enhance our results, we analyzed the prevalence of aortic aneurysm in separate gender and age groups. Although increasing age was often associated with an increasing prevalence of the studied disorders, especially in the groups with only incisional or inguinal hernia, the prevalence of the studied disorders usually remained much higher in patients with both incisional and inguinal hernia. However, as groups got smaller, significance was sometimes lost. To clarify our results further, we resorted to comparing part of the results to the results of a screening study. This comparison strengthened our conclusions: the prevalence of abdominal aortic aneurysm in adults of the same age as our patient group with both inguinal and incisional hernia was 3.1% for men and 0.4% in women. Furthermore, the highest prevalence of aortic aneurysm found in the screening study was only 10.3%, in men over 79 years of age[29].

In conclusion, this study provides evidence of a relationship between inguinal and incisional hernia. We know of no other study reporting this relationship. We hypothesize that hiatus hernia, umbilical hernia, epigastric hernia and burst abdomen share a common etiology with inguinal and incisional hernia. Additional evidence that abdominal wall hernia and aortic aneurysm are related is reported. To identify the key factors that play a role in an alleged metabolic connective tissue disorder, patients with a history of inguinal hernia, incisional hernia and aortic aneurysm form high potential research subjects. Finally, physicians should be aware that patients with a history of both inguinal and incisional hernia are at risk for aortic aneurysm development.

REFERENCES

1. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
2. Eisner L, Harder F. [Incisional hernias]. Chirurg 1997; 68(4):304-9.
3. Klinge U, Prescher A, Klosterhalfen B, et al. [Development and pathophysiology of abdominal wall defects]. Chirurg 1997; 68(4):293-303.
4. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
5. Santora TA, Roslyn JJ. Incisional hernia. Surg Clin North Am 1993; 73(3):557-70.
6. Schumpelick V, Klinge U, Welty G, et al. [Meshes within the abdominal wall]. Chirurg 1999; 70(8):876-87.
7. National Center for Health Statistics. Combined Surgery Data (NHDS and NSAS) Data Highlights. http://www.cdc.gov/nchs/about/major/hdasd/combtab.htm. 1996.
8. Franz MG, Kuhn MA, Nguyen K, et al. Transforming growth factor beta(2) lowers the incidence of incisional hernias. J Surg Res 2001; 97(2):109-16.
9. Burger JWA, Luijendijk RW, Hop WCJ, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004; 240(4):578-585.
10. Klinge U, Si ZY, Zheng H, et al. Abnormal collagen I to III distribution in the skin of patients with incisional hernia. Eur Surg Res 2000; 32(1):43-8.
11. Klinge U, Si ZY, Zheng H, et al. Collagen I/III and matrix metalloproteinases (MMP) 1 and 13 in the fascia of patients with incisional hernias. J Invest Surg 2001; 14(1):47-54.
12. Abrahamson J. Etiology and pathophysiology of primary and recurrent groin hernia formation. Surg Clin North Am 1998; 78(6):953-72, vi.
13. Klinge U, Zheng H, Si Z, et al. Expression of the extracellular matrix proteins collagen I, collagen III and fibronectin and matrix metalloproteinase-1 and -13 in the skin of patients with inguinal hernia. Eur Surg Res 1999; 31(6):480-90.
14. Klinge U, Zheng H, Si ZY, et al. Synthesis of type I and III collagen, expression of fibronectin and matrix metalloproteinases-1 and -13 in hernial sac of patients with inguinal hernia. Int J Surg Investig 1999; 1(3):219-27.
15. Friedman DW, Boyd CD, Norton P, et al. Increases in type III collagen gene expression and protein synthesis in patients with inguinal hernias. Ann Surg 1993; 218(6):754-60.
16. Zheng H, Si Z, Kasperk R, et al. Recurrent inguinal hernia: disease of the collagen matrix? World J Surg 2002; 26(4):401-8.
17. Jorgensen LN, Gottrup F. The role of collagen in hernia genesis. In: Bendavid R, Abrahamson J, Arregui ME, Flament JB, Philips EH, eds. Abdominal wall hernias. Principles and management. New York: Springer Verlag; 2001:150-155.
18. Uden A, Lindhagen T. Inguinal hernia in patients with congenital dislocation of the hip. A sign of general connective tissue disorder. Acta Orthop Scand 1988; 59(6):667-8.
19. Papadimitriou D, Pitoulias G, Papaziogas B, et al. Incidence of abdominal wall hernias in patients undergoing aortic surgery for aneurysm or occlusive disease. Vasa 2002; 31(2):111-4.
20. Holland AJ, Castleden WM, Norman PE, et al. Incisional hernias are more common in aneurysmal arterial disease. Eur J Vasc Endovasc Surg 1996; 12(2):196-200.
21. Adye B, Luna G. Incidence of abdominal wall hernia in aortic surgery. Am J Surg 1998; 175(5):400-2.
22. Hall KA, Peters B, Smyth SH, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. Am J Surg 1995; 170(6):572-5; discussion 575-6.
23. Raffetto JD, Cheung Y, Fisher JB, et al. Incision and abdominal wall hernias in patients with aneurysm or occlusive aortic disease. J Vasc Surg 2003; 37(6):1150-4.

24. Cannon DJ, Casteel L, Read RC. Abdominal aortic aneurysm, Leriche's syndrome, inguinal herniation, and smoking. Arch Surg 1984; 119(4):387-9.
25. Pleumeekers HJ, De Gruijl A, Hofman A, et al. Prevalence of aortic aneurysm in men with a history of inguinal hernia repair. Br J Surg 1999; 86(9):1155-8.
26. Lehnert B, Wadouh F. High coincidence of inguinal hernias and abdominal aortic aneurysms. Ann Vasc Surg 1992; 6(2):134-7.
27. Israelsson LA. Incisional hernias in patients with aortic aneurysmal disease: the importance of suture technique. Eur J Vasc Endovasc Surg 1999; 17(2):133-5.
28. Pleumeekers HJ. Clinical epidemiology of aneurysms of the abdominal aorta; Thesis. Rotterdam, ISBN 90-74494-05-06; 1995:79.
29. Pleumeekers HJ, Hoes AW, van der Does E, et al. Aneurysms of the abdominal aorta in older adults. The Rotterdam Study. Am J Epidemiol 1995; 142(12):1291-9.
30. Stevick CA, Long JB, Jamasbi B, et al. Ventral hernia following abdominal aortic reconstruction. Am Surg 1988; 54(5):287-9.
31. Wilmink AB, Quick CR, Hubbard CS, et al. The association between connective tissue laxity and the risk of an abdominal aortic aneurysm. Eur J Vasc Endovasc Surg 2000; 20(3):290-5.
32. Sorenson LT, Jorgenson, L.N., Gottrup, F. Biochemical aspects of abdominal wall hernia formation and recurrence. In: Nyhus and Condon's hernia, Fitzgibbons, R.J., Jr, Greenburg, A.G. (eds), Lippincott Williams & Wilkins, Philadelphia 2002:9-16.
33. Dobrin PB, Baker WH, Gley WC. Elastolytic and collagenolytic studies of arteries. Implications for the mechanical properties of aneurysms. Arch Surg 1984; 119(4):405-9.
34. Nakamura M, Tachieda R, Niinuma H, et al. Circulating biochemical marker levels of collagen metabolism are abnormal in patients with abdominal aortic aneurysm. Angiology 2000; 51(5):385-92.
35. Bode MK, Soini Y, Melkko J, et al. Increased amount of type III pN-collagen in human abdominal aortic aneurysms: evidence for impaired type III collagen fibrillogenesis. J Vasc Surg 2000; 32(6):1201-7.
36. Satta J, Juvonen T, Haukipuro K, et al. Increased turnover of collagen in abdominal aortic aneurysms, demonstrated by measuring the concentration of the aminoterminal propeptide of type III procollagen in peripheral and aortal blood samples. J Vasc Surg 1995; 22(2):155-60.
37. Treska V, Topolcan O. Plasma and tissue levels of collagen types I and III markers in patients with abdominal aortic aneurysms. Int Angiol 2000; 19(1):64-8.
38. Bellon JM, Bujan J, Honduvilla NG, et al. Study of biochemical substrate and role of metalloproteinases in fascia transversalis from hernial processes. Eur J Clin Invest 1997; 27(6):510-6.
39. Bellon JM, Bajo A, Ga-Honduvilla N, et al. Fibroblasts from the transversalis fascia of young patients with direct inguinal hernias show constitutive MMP-2 overexpression. Ann Surg 2001; 233(2):287-91.
40. Tamarina NA, McMillan WD, Shively VP, et al. Expression of matrix metalloproteinases and their inhibitors in aneurysms and normal aorta. Surgery 1997; 122(2):264-71; discussion 271-2.
41. McMillan WD, Pearce WH. Increased plasma levels of metalloproteinase-9 are associated with abdominal aortic aneurysms. J Vasc Surg 1999; 29(1):122-7; discussion 127-9.
42. Agren MS, Jorgensen LN, Andersen M, et al. Matrix metalloproteinase 9 level predicts optimal collagen deposition during early wound repair in humans. Br J Surg 1998; 85(1):68-71.
43. Savage FJ, Lacombe DL, Hembry RM, et al. Effect of colonic obstruction on the distribution of matrix metalloproteinases during anastomotic healing. Br J Surg 1998; 85(1):72-5.
44. Tarlton JF, Vickery CJ, Leaper DJ, et al. Postsurgical wound progression monitored by temporal changes in the expression of matrix metalloproteinase-9. Br J Dermatol 1997; 137(4):506-16.
45. Cannon DJ, Read RC. Metastatic emphysema: a mechanism for acquiring inguinal herniation. Ann Surg 1981; 194(3):270-278.

46. Cannon DJ, Read RC. Blood elastolytic activity in patients with aortic aneurysm. Ann Thorac Surg 1982; 34(1):10-15.
47. Read RC. Why do human beings develop groin hernias. In: Fitzgibbons, R.J., Jr, Greenburg, A.G., eds. Nyhus and Condon's hernia. Philadelphia: Lippincott Williams & Wilkins; 2002; 3-8.
48. Jorgensen LN, Kallehave F, Christensen E, et al. Less collagen production in smokers. Surgery 1998; 123(4):450-5.
49. Meijer WT, Grobbee DE, Hunink MG, et al. Determinants of peripheral arterial disease in the elderly: the Rotterdam study. Arch Intern Med 2000; 160(19):2934-8.

4 | Incisional Hernia: Early Complication of Abdominal Surgery

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ABSTRACT

OBJECTIVE

It has been suggested that early development of incisional hernia is caused by perioperative factors, such as surgical technique and wound infection. Late development may imply other factors, such as connective tissue disorders. Our objective was to establish whether incisional hernia develops early after abdominal surgery, *i.e.* during the first postoperative month.

METHODS

Patients who underwent a midline laparotomy between 1995 and 2001 and had a CT-scan of the abdomen within the first postoperative month were identified retrospectively. The distance between both rectus abdominis muscles was measured on these CT-scans, after which several parameters were calculated to predict incisional hernia development. Incisional hernia development was established clinically through chart review, or, if chart review was inconclusive, by an outpatient clinic visit.

RESULTS

The average and maximum distances between the left and right rectus abdominis muscles were significantly larger in patients with subsequent incisional hernia development than in patients without incisional hernia ($p<0.0001$). Ninety-two percent (23/25) of incisional hernia patients had a maximum distance of more than 25 mm, compared to only 18% (5/28) of patients without incisional hernia ($p<0.0001$).

CONCLUSION

Incisional hernia occurrence can be predicted by measuring the distance between the rectus abdominis muscles on a postoperative CT-scan. Although incisional hernia develops within weeks of surgery, clinical manifestation may take years. Our results indicate perioperative factors as the main cause of incisional hernia. Therefore, incisional hernia prevention should focus on perioperative factors.

INTRODUCTION

Incisional hernia is a frequent and serious complication of abdominal surgery, with an incidence of 2-20%[1-8]. Remarkably, the etiology of this common disorder is not well understood. Several risk factors have been identified, of which type of incision, suture technique, wound infection, obesity, abdominal aneurysm, gender and age are the most frequently reported[2,5,6,8-17].

It has been suggested that early development of incisional hernia implies an important role for perioperative factors, such as wound infection and suture technique[18-21]. Late development would imply other, largely unknown, mechanisms, such as connective tissue disorders[13,22]. Several clinical studies reported that incisional hernias occur up to 10 years after surgery[1,13,22-24]. These studies gave reason to believe that a well-healed abdominal wound can weaken over the course of years and then give rise to incisional hernia. Such etiology makes a major role for perioperative factors unlikely, which was confirmed in studies by Ellis and Franchi[13,22]. This however is in strong contradiction with the results of Pollock et al[19,20]. By applying vascular clips to the wound edges of the abdominal wall and by subsequent radiography, Pollock showed that separation of the wound edges predisposes to incisional hernia and that this separation was present in almost all incisional hernia patients within one month of surgery. Pollock concluded that the development of incisional hernias could be traced back to events taking place during the first postoperative month [19,20]. To date, this study is the only one to prove that incisional hernias develop shortly after surgery.

Profound knowledge of the etiology of incisional hernia is needed to point out which strategy should be followed to prevent incisional hernia. If late development implies that incisional hernia is a systemic disease, inherent to surgery in the elderly and diabetics, or caused by an unidentified connective tissue disorder, then there may be little the surgeon can do to prevent it. If incisional hernia on the other hand develops during the first postoperative month, perioperative factors are likely to play an important role. Perioperative factors, such as type of incision, suture technique and wound infection may be influenced by training or surgical treatment protocols.

The purpose of the current study was to answer the following question: do incisional hernias develop early, *i.e.* within one month of surgery? In a retrospective study, we identified patients who underwent abdominal surgery through a midline incision and had a CT-scan of the abdomen during the first postoperative month. By measuring the distance between both rectus abdominis muscles on these CT-scans, we investigated whether it is possible to predict the occurrence of incisional hernia within one month of surgery.

MATERIALS AND METHODS

A computerized search was carried out in the databases of the Erasmus University Medical Center and the Leiden University Medical Center. In the database of the Erasmus University Medical Center, all patients who underwent a midline laparotomy between 1995 and 2001 were identified. In the database of the Leiden University Medical Center, patients who were diagnosed with an incisional hernia in a midline incision between 1995 and 2001 were identified. This difference in patient retrieval methods was caused by structural differences between both databases. Subsequently, patients who underwent an abdominal CT-scan during the first month after the midline laparotomy were selected. The reasons for making the CT-scan and the findings on the CT-scan were recorded. Patient characteristics and post-operative follow-up were obtained through chart review. Incisional hernia was defined as a palpable defect in the abdominal wall diagnosed by physical examination. When physical examination was inconclusive, the diagnosis was made by ultrasound. When chart review was inconclusive with regard to the occurrence of incisional hernia or when chart review resulted in insufficient follow-up (<1 year), patients were contacted and asked to visit the outpatient clinic. Patients who had died or had a re-operation within 6 months of surgery were excluded, as well as patients who underwent open-abdomen treatment and patients without sufficient follow-up.

The above-mentioned procedure resulted in the formation of two groups: 1) patients with a midline incision (1995–2001), a CT-scan of the complete abdominal wall (sternum-pubis) and with incisional hernia, and 2) patients with a midline laparotomy, a CT-scan of the complete abdominal wall, but without incisional hernia.

On all CT-scans, two independent, blinded observers measured the distance between the left and right rectus abdominis muscles (R.A.M.) from sternum to pubis. All measurements were performed with a caliper on hardcopies of the CT-scans. After completion of these measurements, a virtual reconstruction of the rectus abdominis muscles (R.A.M.) was made. Three parameters were recorded: the maximum distance between the rectus abdominis muscles (R.A.M.), the average distance between the R.A.M. (full length: sternum to pubis) and the average distance between the R.A.M. at the level at which the midline incision had been placed. In addition, the maximum distance between the R.A.M. was compared to the average distance between the R.A.M. (full length: sternum to pubis) and to the distance between the R.A.M. at the level of the midline incision. By interpretation of these five parameters, the observers tried to predict the occurrence of incisional hernia.

Statistical analysis was performed using the Mann-Whitney U test for independent samples and Fisher's exact test for all measurements (SPSS®, Chicago, Illinois, USA). The inter-observer agreement was evaluated by calculating the intra class correlation.

RESULTS

Sixty-four patients underwent a CT-scan of the complete abdomen within one month of a midline laparotomy. In all these patients, the abdominal wall had been closed with a running polydioxanone suture. During follow-up, 25 patients were diagnosed with incisional hernia and 39 patients were not. From 11 of these 39 patients adequate follow-up could not be obtained. This was due to death shortly after surgery (n=5), unwillingness to cooperate with the study (n=2) and inability to retrieve the patient's whereabouts (n=4). With CT-scans of these 11 patients excluded, CT-scans of 25 patients with incisional hernia and 28 patients without incisional hernia were available at baseline. Table 1 presents patient characteristics of both groups. There were significantly more wound infections in the incisional hernia group than

TABLE 1. Patient characteristics

	Incisional Hernia N=25	**No Incisional Hernia N=28**	**P-value**
Age[a]	59	60	0.377[b]
Gender (M:F)	1.5:1	1.3:1	0.534[c]
Type of Surgery			
Oesophagus / Stomach	3 (12%)	4 (14%)	1.000[c]
Hepatobiliary	6 (24%)	6 (21%)	1.000[c]
Colorectal	7 (28%)	10 (36%)	0.572[c]
Vascular	5 (20%)	6 (21%)	1.000[c]
Exploratory	4 (16%)	2 (7%)	0.404[c]
Postoperative Complications			
Wound infection	11 (44%)	4 (14%)	0.031[c]
Pneumonia	4 (16%)	2 (7%)	0.404[c]
Abdominal distension	4 (16%)	2 (7%)	0.404[c]
Abdominal abscess	7 (28%)	10 (36%)	0.572[c]
BMI[a]	26 (18-35)	25 (16-32)	0.243[b]
Interval Surgery - CT-scan[a]	15 days (4-31)	18 days (6-31)	0.481[b]
Diagnosis Incisional Hernia[a]	12 months (3-88)	X	
Follow-up[a]	X	24 months (6-100)	

[a]Values are median (range). [b]Mann-Whitney U Test. [c]Fisher's Exact Test.

in the group without incisional hernia. The reason for obtaining a CT-scan was exclusion of an abscess in 68% (17/25) of incisional hernia patients and 46% (13/28) of patients without incisional hernia (P=0.166). Abdominal abscess was present in 28% (7/25) of incisional hernia patients and 36% (10/28) of patients without incisional hernia (p=0.572). The CT-scan did not reveal pathology in 64% (16/25) of incisional hernia patients and 42% (12/28) of patients without incisional hernia (P=0.171). Sixty percent (15/25) of incisional hernias was diagnosed more than 1 year after abdominal surgery, while 16% (4/25) was diagnosed more than 3 years after surgery.

Table 2 presents the results of the measurements. The mean of measurements by both observers was calculated and compared for patients with and without incisional hernia. Inter-observer agreement was tested by calculating the intra class correlation. Agreement was higher than 0.95 in all cases. The average distance between both rectus abdominis muscles (R.A.M.), measured from sternum to pubis, was significantly larger in patients with incisional hernia than in patients without incisional hernia. The same applies to the average distance measured at the level of the midline incision and to the maximum distance between the R.A.M. To correct for the physiological distance between the R.A.M., caused by interposition of the linea alba, the maximum distance was compared to the average distance between the R.A.M. This was done for the entire length of the R.A.M. and for the R.A.M. at the level of the midline incision. In both cases, the relative increase from average to maximum distance was significantly larger in incisional hernia patients than in patients without incisional hernia.

Subsequently, we determined whether we could predict which patients would develop incisional hernia and which patients would not, based on the five parameters mentioned above. The distribution of measurements in patients with and without incisional hernia showed that

TABLE 2. Results of measurements of rectus abdominis muscles (R.A.M.) on CT-scans

	Average Sternum-Pubis[a]	**Average Incision[b]**	**Maximum Distance[c]**	**Maximum-Average Total[d]**	**Maximum-Average Incision[e]**
No Incisional Hernia[f]	0.9 cm (0.8, 1.1)	1.1 cm (0.9, 1.3)	2.1 cm (1.8, 2.5)	1.2 cm (0.9, 1.4)	1.0 cm (0.8, 1.3)
Incisional Hernia[f]	1.5 cm (1.2, 1.9)	1.7 cm (1.3, 2.0)	3.8 cm (3.3, 4.4)	2.3 cm (1.9, 2.6)	2.1 cm (1.8, 2.4)
P-value[g]	<0.001	<0.001	<0.0001	<0.0001	<0.0001

[a]Average distance rectus abdominis muscles (R.A.M) from sternum to pubis. [b]Average distance R.A.M. along the length of midline incision. [c]Maximum distance R.A.M. [d]Maximum - average distance R.A.M. from sternum to pubis. [e]Maximum - average distance R.A.M. along the length of midline incision. [f]Values are mean (95% confidence interval).[g]Mann Whitney U Test.

TABLE 3. Predicting incisional hernia with measurements on rectus abdominis muscles (R.A.M.)

		Incisional Hernia	No Incisional Hernia	P-value[a]
Maximum distance R.A.M.	>25 mm	23	5	<0.0001
	<25 mm	2	23	
Maximum – average distance R.A.M. from sternum to pubis	>15 mm	21	5	<0.0001
	<15 mm	4	23	
Maximum – average distance R.A.M. at the level of the incision	>15 mm	20	5	<0.0001
	<15 mm	5	23	

[a]Fisher's Exact Test

of the five parameters available, the average distance between both R.A.M. (sternum-pubis) and the average distance at the level of the incision were the most indistinctive (data not shown). Table 3 presents the prognostic value of the other three parameters. Of the five parameters tested, the maximum distance between the R.A.M. was the most distinctive: When a cut-off point of 25 mm was applied, 23 of 25 incisional hernia patients and 23 of 28 patients without incisional hernia could be correctly identified.

DISCUSSION

The current study shows that incisional hernia develops during the first postoperative month. This is evidenced by the fact that we could predict incisional hernia by measurements performed on CT-scans made within one month of surgery. While we could correctly predict almost all incisional hernias, the clinical diagnosis incisional hernia was made much later in all patients. In addition to the finding that incisional hernia could be predicted on the basis of a first postoperative month observation, we found that these observations could sometimes be made within mere days after surgery.

In our study, five parameters were used to predict incisional hernia occurrence. Of these five parameters, the maximum distance between the rectus abdominis muscles proved to be the most distinctive. The cut-off points applied in this study were more than 25 mm maximum distance and more than 15 mm relative increase in distance between the rectus abdominis muscles. These cut-off points have implications in midline incision patients only. A study by Rath et al demonstrated that in normal individuals the width of the linea alba at the umbilicus already averages 20 mm[25]. Maximum distances of more than 25 mm between the rectus abdominis muscles at the umbilical level may therefore be commonly encountered. The al-

tered anatomy in midline laparotomy patients is probably caused by the pulling together of the rectus abdominis muscles during the suturing process, making separation of more than 25 mm rare in patients that are not developing incisional hernia.

Ideally, a study on midline incision wound healing would measure the separation of the wound edges directly. However, to make out the fascial wound edges on a CT-scan often proved impossible. This was probably due to the limited resolution of computed tomography in soft tissue, especially when tissue damage and inflammation were present. We therefore chose to measure the rectus abdominis muscle-edges, which were usually clearly visible. Pollock et al described that patients with incisional hernia had a separation of the fascia edges of more than 12 mm[19,20]. Our data suggest a slightly larger cut-off point (>15 mm), but this difference may well be insignificant and caused by different methodology.

The fact that incisional hernias could be predicted by measuring the edges of the rectus abdominis muscles implies that in patients developing incisional hernia, the rectus abdominis muscles are yielding. Given the mainly transverse pulling forces of the lateral abdominal muscles, this is perfectly conceivable, provided a defect is present. We therefore conclude that the increased distance between the rectus abdominis muscles is caused by the development of a defect between the medial edges of both muscles, *i.e.* in the linea alba. The most plausible explanation for the development of such a defect within weeks of surgery is the tearing of sutures through abdominal wall tissue, much similar to the etiology of burst abdomen. Whether this is caused by flawed suture technique, insufficient abdominal wall tissue due to infection or by increased intra-abdominal pressure cannot be concluded from our study.

Our results show that incisional hernias are often discovered many years after surgery. In retrospective, these late incisional hernias were visible on CT-scans made during the first postoperative month. Although evidence for both early and late origination of incisional hernia may seem contradictory, it need not be. Recently Rodriguez et al reported that many incisional hernias diagnosed on a CT-scan, had in fact not been diagnosed clinically[26]. Although incisional hernias may in some cases become clinically manifest years after surgery, the process started within the first postoperative month. These defects may remain small and asymptomatic for years, gaining size later, allowing for protrusion of abdominal content and visible bulging and complaints. Increasing weight, deterioration of physical status and increasing age may play a role in these late clinical manifestations of a long time present disorder.

Now that we have found that CT-scan can positively identify developing incisional hernias within one month of surgery, the question arises whether this information could be beneficial to the individual patient. We argue that the early development of incisional hernia implicates perioperative factors such as suture technique and wound infection as the main

cause of incisional hernia development. Correct suture technique, using non-absorbable or slowly absorbable suture materials and ensuring a 4:1 suture length to wound length ratio decreases hernia incidence. Adequate wound care may lower wound infection rates or lower wound infection severity. Another important question is whether high-risk patients should undergo CT-scan to diagnose a developing incisional hernia and whether these patients should undergo preventive hernia repair. Searching for occult incisional hernias and subsequent repair would be highly controversial, because it is unclear whether the patient would benefit from such an approach. It is therefore doubtful whether costs and irradiation could be answered for. Moreover, careful examination in an outpatient department setting should enable the physician to detect an incisional hernia at an early stage, well before problems due to incisional hernia size arise.

There are limitations to the current study. We selected patients with a midline incision, a CT-scan of the complete abdomen within a month of surgery, without additional surgery and with obtainable follow-up. These patients proved to be rare. However, the fact that our results are in complete accordance with the only other study performed on the subject[19], strengthens our results. The small number of patients does however limit our capability to confirm or denounce risk-factors such as abscess and increased intra-abdominal pressure as a risk-factor for incisional hernia development. A second limitation is that our patients may not represent a normal patient population. Patients with an uncomplicated postoperative course left the hospital without CT-scan, whereas the current group of patients underwent CT-scan for a number of reasons, of which several are risk-factors for incisional hernia development. We feel this does not weaken our conclusions, because the aim of the study was to determine the time-point at which incisional hernia develops, not the risk-factors that cause incisional hernia. It is a unique selection, but it is the patient group we are looking for, *i.e.* patients who develop incisional hernia. To rule out the possibility that our conclusions are valid only for this complicated patient group, a prospective study would be needed. However, such a study would meet resistance in ethical committees, since benefits for the individual patient are lacking.

We conclude that incisional hernia can be predicted by measuring the distance between both rectus abdominis muscles on a CT-scan. In general, a distance of more than 25 mm between the medial edges of the rectus abdominis muscles implies incisional hernia development. Although incisional hernia results from a process that starts within weeks of surgery, clinical manifestation may take years. Our results indicate perioperative factors, such as suture technique and wound infection, as the main cause of incisional hernia.

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REFERENCES

1. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
2. Santora TA, Roslyn JJ. Incisional hernia. Surg Clin North Am 1993; 73(3):557-70.
3. Eisner L, Harder F. [Incisional hernias]. Chirurg 1997; 68(4):304-9.
4. Klinge U, Prescher A, Klosterhalfen B, et al. [Development and pathophysiology of abdominal wall defects]. Chirurg 1997; 68(4):293-303.
5. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
6. Hoer J, Lawong G, Klinge U, et al. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg 2002; 73(5): 474-80.
7. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. Lancet 2003; 362(9395):1561-71.
8. Wissing J, van Vroonhoven TJ, Schattenkerk ME, et al. Fascia closure after midline laparotomy: results of a randomized trial. Br J Surg 1987; 74(8):738-41.
9. Bucknall TE, Cox PJ, Ellis H. Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. Br Med J (Clin Res Ed) 1982; 284(6320):931-3.
10. Grantcharov TP, Rosenberg J. Vertical compared with transverse incisions in abdominal surgery. Eur J Surg 2001; 167(4):260-7.
11. Burger JW, van 't Riet M, Jeekel J. Abdominal incisions: techniques and postoperative complications. Scand J Surg 2002; 91(4):315-21.
12. Israelsson LA, Jonsson T. Suture length to wound length ratio and healing of midline laparotomy incisions. Br J Surg 1993; 80(10):1284-6.
13. Franchi M, Ghezzi F, Buttarelli M, et al. Incisional hernia in gynecologic oncology patients: a 10-year study. Obstet Gynecol 2001; 97(5 Pt 1):696-700.
14. Regnard JF, Hay JM, Rea S, et al. Ventral incisional hernias: incidence, date of recurrence, localization and risk factors. Ital J Surg Sci 1988; 18(3):259-65.
15. Adye B, Luna G. Incidence of abdominal wall hernia in aortic surgery. Am J Surg 1998; 175(5): 400-2.
16. Hall KA, Peters B, Smyth SH, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. Am J Surg 1995; 170(6):572-5; discussion 575-6.
17. Raffetto JD, Cheung Y, Fisher JB, et al. Incision and abdominal wall hernias in patients with aneurysm or occlusive aortic disease. J Vasc Surg 2003; 37(6):1150-4.
18. Wantz GE. Incisional hernia: the problem and the cure. J Am Coll Surg 1999; 188(4):429-47.
19. Pollock AV, Evans M. Early prediction of late incisional hernias. Br J Surg 1989; 76(9):953-4.
20. Playforth MJ, Sauven PD, Evans M, et al. The prediction of incisional hernias by radio-opaque markers. Ann R Coll Surg Engl 1986; 68(2):82-4.
21. Ausobsky JR, Evans M, Pollock AV. Does mass closure of midline laparotomies stand the test of time? A random control clinical trial. Ann R Coll Surg Engl 1985; 67(3):159-61.
22. Ellis H, Gajraj H, George CD. Incisional hernias: when do they occur? Br J Surg 1983; 70(5):290-1.
23. Harding KG, Mudge M, Leinster SJ, et al. Late development of incisional hernia: an unrecognised problem. Br Med J (Clin Res Ed) 1983; 286(6364):519-20.
24. Lewis RT, Wiegand FM. Natural history of vertical abdominal parietal closure: Prolene versus Dexon. Can J Surg 1989; 32(3):196-200.
25. Rath AM, Attali P, Dumas JL, et al. The abdominal linea alba: an anatomo-radiologic and biomechanical study. Surg Radiol Anat 1996; 18(4):281-8.
26. Rodriguez HE, Matsumura JS, Morasch MD, et al. Abdominal wall hernias after open abdominal aortic aneurysm repair: prospective radiographic detection and clinical implications. Vasc Endovascular Surg 2004; 38(3):237-240.

5 | Abdominal Incisions: Techniques and Postoperative Complications

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ABSTRACT

BACKGROUND AND AIMS

The choice of incision for laparotomy depends on the area that needs to be exposed, the elective or emergency nature of the operation and personal preference. Type of incision may however have its influence on the occurrence of postoperative wound complications. Techniques and features of various incisions are discussed, as well as the incidence of their postoperative complications.

METHOD

A Medline search was conducted identifying prospective randomized trials, as well as retrospective studies with sufficient follow-up, comparing midline, paramedian, transverse and oblique incisions.

RESULTS

Significant differences in wound infection and wound dehiscence rates were not reported. Transverse, oblique and paramedian incisions caused significantly less incisional hernias than midline incisions. However, trials comparing transverse and midline incisions for larger laparotomies did not show significant differences. All four trials comparing lateral paramedian with midline incisions reported incisional hernia rates of 0% after the lateral paramedian incision. Differences with the midline incision were significant.

CONCLUSION

Transverse or oblique incisions should be preferred for small unilateral operations. The paramedian incision should be used for major elective laparotomies. The use of the midline incision should be restricted to operations in which unlimited access to the abdominal cavity is useful or necessary.

INTRODUCTION

The choice of incision is mainly dependent on the area that needs to be exposed, the elective or emergency nature of the operation and the surgeon's personal preference. However, type of incision may have a profound influence on the occurrence of postoperative wound complications. Considering the number of laparotomies performed (*e.g.* 4,000,000 in the USA annually[1]), consequences of the use of a specific type of incision may be substantial.

In the following review the techniques and features of vertical, transverse and oblique abdominal incisions will be discussed, as well as clinical trials and retrospective analysis evaluating these incisions in relation to the severity of postoperative pain and complications like wound infection, wound dehiscence and incisional hernia.

ANATOMY OF THE VENTRAL ABDOMINAL WALL (Figure 1)

The external oblique muscle originates from the 5th to 12th ribs and has a medio-caudal direction. The internal oblique muscle originates from the iliac crest and follows a medio-proximal direction. The direction of the fibers of both muscles rarely deviates more than 30^0 from the horizontal[2]. The transversus abdominis muscle originates from the lower six ribs, the lumbodorsal fascia and the iliac crest. Its fibers are directed horizontally. The aponeuroses of these three muscles form the sturdy rectus sheaths, which enclose the fourth abdominal wall muscle, the rectus abdominis, which inserts on the 5th, 6th and 7th ribs superiorly and on the pubic bone inferiorly. Its fibers have a vertical direction and are interrupted by three or four tendinous intersections. The sheaths of the rectus abdominis muscle are continuous with those of its contralateral counterpart. In between both muscles the rectus sheaths join to form the relatively avascular linea alba. The fiber direction within the linea alba is equal to that of the aponeuroses of the oblique and transverse muscles: medio-proximal, medio-caudal and horizontal. The width of the linea alba is approximately 15-20 mm above the umbilicus, 20-25 mm at the level of the umbilicus and 0-5 mm below the umbilicus[3].

Blood supply to the abdominal wall is taken care of by two systems. Firstly, the inferior and superior epigastric arteries form a longitudinal anastomosis, which is called the deep epigastric arcade. The arcade is situated between the rectus abdominis muscle and its posterior sheath and supplies the muscle by perforating vessels. Some of these perforating vessels send small branches across the midline to take care of blood supply to the linea alba. Secondly, blood supply to the oblique and transverse muscles is taken care of by transverse segmental arteries that arise from the aorta and are situated between the internal oblique and transverse muscles. These segmental arteries follow a slightly downward transverse direction.

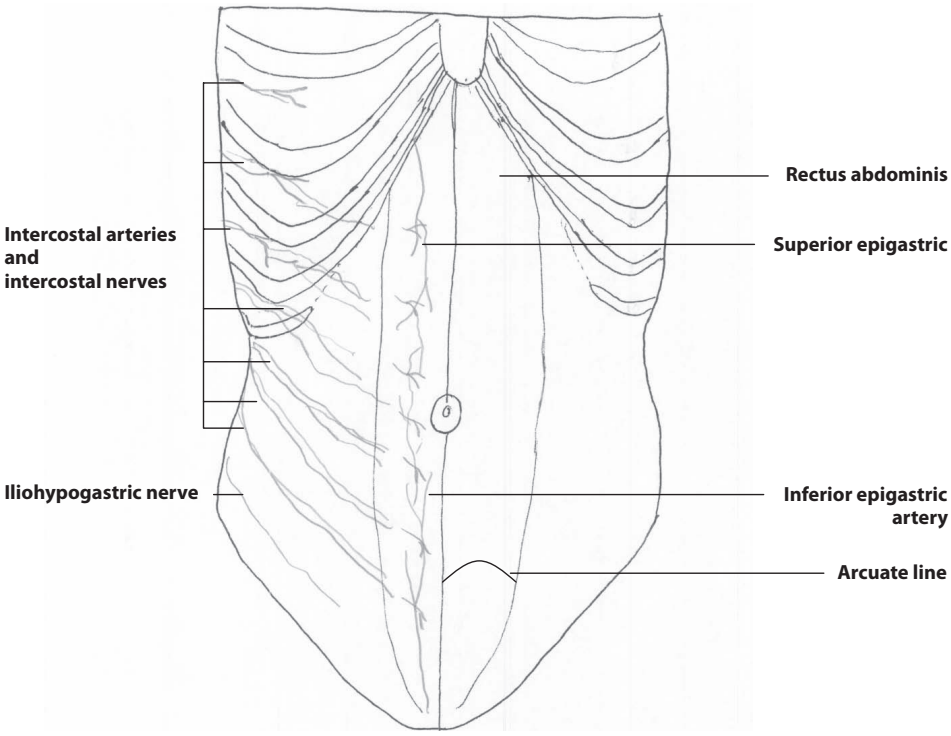

FIGURE 1. Anatomy of the abdominal wall: vascularisation and innervation

The innervation of the abdominal wall consists of ventral branches of the 5th to 12th thoracic nerves and the iliohypogastric and ilioinguinal nerves. These nerves are directed transversely with a course comparable to the course of the segmental arteries.[2,4,5]

INCISIONS (Figure 2)

MIDLINE INCISION

The *midline incision* implies a vertical incision through skin, subcutaneous fat, linea alba, and peritoneum. Most of the fibers, crossing the linea alba in a medio-caudal and medio-proximal direction, are cut transversely. The incision is easy to perform and results in minimal blood loss, because of the avascular nature of the linea alba. The incision can be made quickly, taking 7 minutes on average[6-9]. Moreover, exposure of the abdomen is excellent. Extensions, when required, can easily be made superiorly or inferiorly, providing access to the whole abdominal cavity, including the retroperitoneum. All these qualities make the midline approach especially suitable for emergency and exploratory surgery.

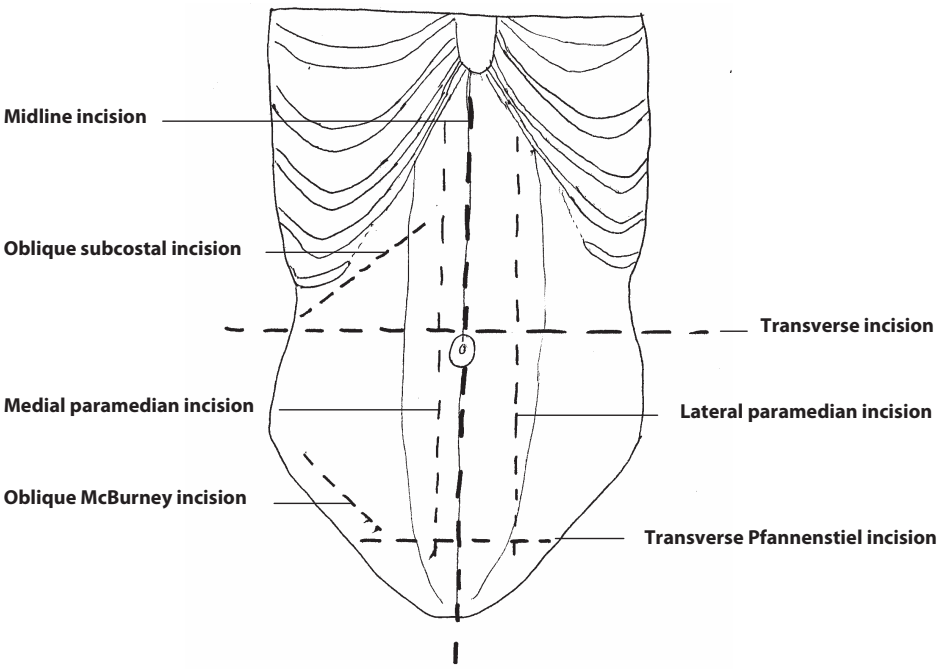

FIGURE 2. Incisions

PARAMEDIAN INCISION

An alternative for the standard midline incision is the *paramedian incision*. This technique stays clear of the relatively avascular linea alba, possibly avoiding impaired wound healing. Two variants are known: the *conventional "medial" paramedian incision*, in which the rectus sheath and rectus muscles are transected close to the linea alba, and the so-called *lateral paramedian* technique. In the latter, a longitudinal incision near the lateral border of the rectus sheath is made. The rectus muscle is freed from the anterior sheath and is then retracted laterally. This lateral retraction prevents dissection of the deep epigastric arcade. Finally, the posterior rectus sheath (above the arcuate line) and the peritoneum are opened in the same plane as the anterior rectus sheath. This technique is more complex than the midline incision, resulting in increased opening time (average 13 minutes[6,10]) and blood loss. Exposure of the abdomen is better on the side of the incision than on the contralateral side. The possibilities for extending the incision superiorly are limited by the costal margin.

TRANSVERSE INCISIONS

A *supraumbilical transverse* incision offers excellent exposure of the upper abdomen. However, in case the operation area needs to be enlarged, extending the original incision is more difficult than when the midline incision was used and extensions do not always offer the desired view. When a full-length transverse incision is made, the oblique and transverse muscles, as well as the rectus abdominis muscle and linea alba are cut in a horizontal plane. The fibers of

the oblique muscles are partly split and partly cut, while the transverse muscle is split along the direction of its fibers. The rectus muscle fibers are cut perpendicular to their direction. The deep epigastric arcade is divided, but as it is supplied from above and below this should not pose a problem. Damage to the segmental arteries and nerves is minor[4]. The incision is accompanied by more blood loss than the midline incision[11] and is more time-consuming (average 13 minutes[7,9]). Smaller transverse incisions can remain unilateral, take less time to perform and leave the deep epigastric arcade unharmed.

An infraumbilical transverse incision in the lower abdomen is the *Pfannenstiel incision*[12], often used for gynecological and obstetric procedures. The skin is incised transversely, often with a convexity downward to avoid dissection of blood vessels and nerves. The abdominal wall muscles are often cut in the same plane as the skin incision, but some surgeons open the abdominal cavity in a vertical direction, thus combining a transverse with a vertical technique.

OBLIQUE INCISIONS

The *subcostal or Kocher incision* is an oblique incision that follows the profile of the costal margin and is directed in a medio-proximal direction. It provides good exposure for biliary and bariatric surgery and can be extended bilaterally if needed. Many segmental blood vessels and nerves are dissected, as well as the fibers of the external oblique, the transverse and the rectus abdominis muscles[5]. The direction of the *gridiron or McBurney* incision is medio-caudal. It follows the direction of the fibers of the external oblique muscle, segmental blood vessels and nerves, damaging as little as possible. Notably, this incision splits all three

TABLE 1. Postoperative pain

	Study design	No of patients	Types of incision	Method	Reduced postoperative pain after
Lacy[9]	randomized	50	Midline vs. transverse	Morphine/24h	NS
Armstrong[13]	randomized	60	Midline vs. transverse	Total pethidine	Transverse*
Lip[7]	randomized	149	Midline vs. transverse	Pain scale	Transverse*
Greenall[11]	randomized	557	Midline vs. transverse	Pain scale	NS
Garcia[15]	randomized	129	Midline vs. oblique	Meperidine/24h	Oblique*
Ali[33]	randomized	19	Midline vs. oblique	Meperidine first 3days	NS
Halasz[14]	randomized	100	Paramedian vs. oblique	Total meperidine	Oblique*
Donati[34]	retrospective	123	Midline vs. transverse	Time with PCA	NS

*$p < 0.05$

muscular layers parallel to the direction of their fibers. Time to perform the incision and blood loss are comparable to those of transverse incisions.

POSTOPERATIVE COMPLICATIONS

POSTOPERATIVE PAIN (TABLE 1)

Randomized trials by Armstrong et al and Lip et al showed a significant reduction in postoperative pain in patients that received a transverse incision compared to patients who received a midline incision ($p<0.001$)[7,13]. Halasz reported a significant reduction in the use of postoperative analgesia after oblique incisions, compared to paramedian incisions ($p<0.001$)[14]. Garcia-Valdecasas reported less use of analgesics after oblique than after midline incisions ($p<0.001$)[15].

WOUND INFECTION (TABLE 2)

Wound infection is probably an important risk factor for the development of incisional hernia and wound dehiscence[16-18]. Ten randomized clinical trials and four retrospective studies ad-

TABLE 2. Wound infection rates (%)

	Study design	No of pts	Midline (%)	Lat para (%)	Med para (%)	Transverse (%)	Oblique (%)
Guillou[6]	randomized	116	12	23	11		
Cox[25]	randomized	431	8	6			
Kendall[8]	randomized	241	11	7			
Stone[35]	randomized	551	3			1	
Lip[7]	randomized	149	8			2	
Lewis[36]	randomized	100	6				2
Garcia[15]	randomized	129	3				0
Greenall[11]	randomized	557	24			28	see transv.
Brennan[26]	randomized	351		8	7		
Halasz[14]	randomized	100		14			12
Israelsson[16]	prospective	861	9				
Blomstedt[24]	retrospective	279	14	13			15
Douzdjan[37]	retrospective	56	34			20	
Thompson[23]	retrospective	1363	6			3	
Donaldson[10]	retrospective	850		15			

dressed the matter of wound infection and incision technique. None of these trials reported a significant difference in wound infection rates after the use of different types of incision.

WOUND DEHISCENCE (TABLE 3)

None of nine randomized trials was able to show a significant difference in wound dehiscence rates after different types of abdominal incisions. Only Waldhausen et al reported a 1.7% wound dehiscence rate after midline and a 0.25% rate after transverse incisions in a retrospective study in a pediatric setting ($p<0.001$)[19]. When reviewing all data, the transverse incision seems to cause less wound dehiscence than the midline and paramedian incisions, but numbers are too small to speak of an actual trend.

TABLE 3. Wound dehiscence rates (%)

	Study design	No of pts	Midline (%)	Lat para (%)	Med para (%)	Transverse (%)	Oblique (%)
Guillou[6]	randomized	116	0	0	1		
Cox[25]	randomized	431	0	1			
Kendall[8]	randomized	241	0	0			
Stone[35]	randomized	551	4			2	
Greenall[11]	randomized	557	0.3			0	
Garcia[15]	randomized	129	2				0
Ellis[27]	randomized	79	0	2			
Ellis[27]	randomized	96		2		0	
Brennan[26]	randomized	351		0	0		
Israelsson[16]	prospective	861	0.6				
Donaldson[10]	retrospective	850		0			
Thompson[23]	retrospective	1363	2.5			0.5	
Waldhausen[19]	retrospective	2785	1.7*			0.25*	

* $p < 0.05$

INCISIONAL HERNIA (TABLE 4)

Incisional hernias occur in 2-19% of patients after various abdominal incisions[5,17,18,20,21]. Two randomized trials compared midline with transverse incisions. Of these, Greenall et al found no statistical difference[11] , while Lip et al reported an incisional hernia rate of 14% for midline incisions and 1% for transverse incisions ($p<0.05$)[7]. Two of three retrospective studies showed the same trend but failed to reach significant values[22,23].

A comparison of midline with oblique incisions was performed in two studies. The randomized trial by Garcia-Valdecasas et al did not show a significant difference[15]. A retrospec-

TABLE 4. Incisional hernia rates (%)

	Study design	No of pts	FU (months)	Midline (%)	Lat para (%)	Med para (%)	Transverse (%)	Oblique (%)
Guillou[6]	randomized	116	12	7*	0*	15*		
Ellis[27]	randomized	79	12	23		18		
Ellis[27]	randomized	96	12			17	14	
Cox[25]	randomized	431	12	10*	0*			
Kendall[8]	randomized	241	12	7*	0*			
Lip[7]	randomized	149	>12	14*			1*	
Garcia[15]	randomized	129	4	3				0
Brennan[26]	randomized	119	12		0*	4*		
Greenall[11]	randomized	557	6	8			6	
Israelsson[16]	prospective	861	12	12				
Thompson[23]	retrospective	1363	18	3			1	
Johnson[30]	retrospective	233	12	5			7	
Lord[22]	retrospective	329	12	17			13	
Blomstedt[24]	retrospective	279	n.r.	14*		9		4*
Donaldson[10]	retrospective	850	12		0.3			
Luijendijk[38]	retrospective	272	60				0	

* $p < 0.05$

tive study by Blomstedt et al reported a 14% hernia rate after midline and a 4% hernia rate after oblique incisions ($p<0.01$)[24].

Three prospective randomized clinical trials compared lateral paramedian with midline incisions and found no incisional hernias after the lateral paramedian incision. The difference with the midline incision was significant in all three studies[6,8,25]. A similar low incisional hernia rate after the lateral paramedian incision was reported by Donaldson et al in a large retrospective series[10]. One randomized and one retrospective study did not report significant differences, but in both cases the conventional "medial" paramedian, rather than the lateral paramedian technique was used. The latter technique has proven superior in two randomized trials[6,26].

The paramedian incision was compared with the transverse incision in one randomized trial[27] and with the oblique incision in one retrospective study [24]. Neither study reported a statistical difference, but again the conventional "medial" paramedian, in stead of the lateral paramedian incision, was used.

DISCUSSION

The midline incision is generally preferred by surgeons because of its ease, speed and excellent exposure. However, as was shown in the current review, the midline incision is associated with increased postoperative pain compared to transverse or oblique incisions. Furthermore, higher incisional hernia rates were found after the use of the midline incision than after lateral paramedian, oblique or transverse incisions.

After laparotomy, the incisional hernia incidence lies between 2% and 19%[5,17,18,20,21]. In the Netherlands, a country with 16 million inhabitants, about 125,000 laparotomies are carried out per year, which would mean that every year approximately 12,500 patients will suffer a new incisional hernia. This has both individual and social repercussions. Patients may suffer pain, discomfort and, in the worst case, an incarceration, which is a potentially lethal situation that requires emergency surgery. Furthermore, the loss of productivity, the impact on hospital capacity and financial resources is considerable. The results of hernia repair are disappointing, with recurrence rates up to 43% after suture repair and up to 24% after mesh repair[28]. Therefore, prevention of incisional hernia is warranted.

There are possible explanations for the high incisional hernia rate after midline laparotomy. Firstly, contraction of abdominal wall muscles retracts wound edges laterally. Secondly, the avascular nature of the midline incision may impair wound healing. Thirdly, the fibers of the linea alba, which are continuous with abdominal wall muscle aponeuroses, cross the midline mostly in transverse or oblique directions. Therefore, a vertical incision cuts most of them perpendicularly.

The transverse incision gained popularity from the beginning of this century. It was advocated by, amongst others, Maylard, Pfannenstiel, Rees and Thompson[2,12,23,29]. They attributed a reduction of postoperative wound complications to the more sound anatomical and physiological properties of the incision, compared to vertical incisions. When a transverse incision is used, Langer's lines of cleavage are followed, as well as the direction of most oblique and transverse muscle fibers, nerves and segmental blood vessels. Therefore, dissection of segmental blood vessels and nerves is limited. The latter may explain the reduction of postoperative pain[2,23]. Further, contraction of the abdominal wall muscles (coughing, vomiting, erecting) does not increase tension on the wound as these forces parallel the transverse operation wound. In addition, unlike the midline incision wound, the transverse incision wound is situated in richly vascularized muscular tissue, which may benefit wound healing.

Results of trials comparing midline incision with transverse incision should however be interpreted with care. In those randomized trials finding significant differences between transverse and midline incisions, the transverse incision was always unilateral. No significant differences

were found between bilateral transverse incisions and midline incision[11,22,30]. Therefore, transverse incisions only seem to have advantages over midline incisions if the operation area is limited to one quadrant of the abdomen. If full exposure of the abdominal cavity is needed, advantages of the transverse incision over the midline incision have not been proven, while exposure of the transverse incision is often less than after a midline incision.

Regarding oblique incisions, only open cholecystectomies were included in the reviewed studies. As the incision has a medio-proximal direction, it tends to cut most nerves, segmental blood vessels and muscle fibers perpendicularly. The partial denervation of the abdominal wall ensues with permanent muscle weakness and numbness[31]. Despite extensive nerve dissection, postoperative pain after oblique incision was less than after midline incision. The incisional hernia rate might be lower than that of the midline incision, although this has not been proven in a randomized clinical trial.

The paramedian incision combines some of the advantages of the midline incision, such as exposure and the possibility of extending the operation, with a richly vascularized wound bed. When the rectus muscle is retracted laterally, the risk of serious blood vessel dissection is minimal[4] and the rectus muscle remains largely intact. On the other hand, the technique is more complex, leading to increased operation time[6,25] and probably to increased blood loss. Undoubtedly, the most noteworthy characteristic of the paramedian incision is the significant reduction of incisional hernia incidence to approximately 0-1%. Apart from the rich vascularisation of the wound bed, splintage of the wound by the rectus muscle and the so-called shutter mechanism this provides might be another explanation for the low hernia rate after the lateral paramedian incision[32]. The rectus muscle remains intact and is located medially to the wound, enabling abdominal wall muscle contraction to bring the wound edges together in stead of separating them. This hypothesis could explain the less favorable results of the conventional "medial" paramedian incision.

CONCLUSION

Although the midline incision is easy and fast, there should be caution with its use, because of the high incidence of incisional hernia. A significant reduction of incisional hernia can be accomplished by the use of a unilateral transverse incision, or by the use of the lateral paramedian incision. Although these incisions take more time to perform, the unilateral transverse incision should be the preferred incision for small unilateral operations, while the lateral paramedian incision should be used for most major elective laparotomies. The use of midline incision should be limited to emergency surgery and exploratory surgery in which unlimited access to the entire abdominal cavity is necessary or useful.

REFERENCES

1. National Hospital Discharge Survey, Series 13, No. 122. National Center for Health Statistics. Detailed diagnoses and procedures. 1995.
2. Rees VL, Coller FA. Anatomic and clinical study of the transverse abdominal incision. Archives of surgery 1943; 47:136-146.
3. Axer H, Keyserlingk DG, Prescher A. Collagen fibers in linea alba and rectus sheaths. I. General scheme and morphological aspects. J Surg Res 2001; 96(1):127-34.
4. Nahai F, Brown RG, Vasconez LO. Blood supply to the abdominal wall as related to planning abdominal incisions. Am Surg 1976; 42(9):691-5.
5. Klinge U, Prescher A, Klosterhalfen B, et al. [Development and pathophysiology of abdominal wall defects]. Chirurg 1997; 68(4):293-303.
6. Guillou PJ, Hall TJ, Donaldson DR, et al. Vertical abdominal incisions--a choice? Br J Surg 1980; 67(6):395-9.
7. Lip H. De dwarse en vertikale incisie van de bovenbuik bij galblaasoperaties. Thesis 1981.
8. Kendall SW, Brennan TG, Guillou PJ. Suture length to wound length ratio and the integrity of midline and lateral paramedian incisions. Br J Surg 1991; 78(6):705-7.
9. Lacy PD, Burke PE, O'Regan M, et al. The comparison of type of incision for transperitoneal abdominal aortic surgery based on postoperative respiratory complications and morbidity. Eur J Vasc Surg 1994; 8(1):52-5.
10. Donaldson DR, Hegarty JH, Brennan TG, et al. The lateral paramedian incision--experience with 850 cases. Br J Surg 1982; 69(10):630-2.
11. Greenall MJ, Evans M, Pollock AV. Midline or transverse laparotomy? A random controlled clinical trial. Part I: Influence on healing. Br J Surg 1980; 67(3):188-90.
12. Pfannenstiel J. Über die Vorteile des suprasymphysären Fascienquerschnitts für die gynäkologischen Koeliotomien. Sammlung Klinischer Vorträge N.F. no. 268, Gynäkologie 1900; 97:1735-1756.
13. Armstrong PJ, Burgess RW. Choice of incision and pain following gallbladder surgery. Br J Surg 1990; 77(7):746-8.
14. Halasz NA, Calif T. Vertical vs horizontal laparotomies. Arch Surg 1964; 88:911-914.
15. Garcia-Valdecasas JC, Almenara R, Cabrer C, et al. Subcostal incision versus midline laparotomy in gallstone surgery: a prospective and randomized trial. Br J Surg 1988; 75(5):473-5.
16. Israelsson LA, Jonsson T. Incisional hernia after midline laparotomy: a prospective study. Eur J Surg 1996; 162(2):125-9.
17. Santora TA, Roslyn JJ. Incisional hernia. Surg Clin North Am 1993; 73(3):557-70.
18. Eisner L, Harder F. [Incisional hernias]. Chirurg 1997; 68(4):304-9.
19. Waldhausen JH, Davies L. Pediatric postoperative abdominal wound dehiscence: transverse versus vertical incisions. J Am Coll Surg 2000; 190(6):688-91.
20. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
21. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
22. Lord RS, Crozier JA, Snell J, et al. Transverse abdominal incisions compared with midline incisions for elective infrarenal aortic reconstruction: predisposition to incisional hernia in patients with increased intraoperative blood loss. J Vasc Surg 1994; 20(1):27-33.
23. Thompson JB, MacLean KF, Coller FA. Role of the transverse abdominal incision and early ambulation in the reduction of postoperative complications. Archives of surgery 1949; 59:1267-1277.
24. Blomstedt B, Welin-Berger T. Incisional hernias. A comparison between midline, oblique and transrectal incisions. Acta Chir Scand 1972; 138(3):275-8.

25. Cox PJ, Ausobsky JR, Ellis H, et al. Towards no incisional hernias: lateral paramedian versus midline incisions. J R Soc Med 1986; 79(12):711-2.
26. Brennan TG, Jones NA, Guillou PJ. Lateral paramedian incision. Br J Surg 1987; 74(8):736-7.
27. Ellis H, Coleridge-Smith PD, Joyce AD. Abdominal incisions--vertical or transverse? Postgrad Med J 1984; 60(704):407-10.
28. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
29. Maylard AE. British Medical Journal 1907; 2:895.
30. Johnson B, Sharp R, Thursby P. Incisional hernias: incidence following abdominal aortic aneurysm repair. J Cardiovasc Surg (Torino) 1995; 36(5):487-90.
31. Cahalane MJ, Shapiro ME, Silen W. Abdominal incision: decision or indecision? Lancet 1989; 1(8630):146-8.
32. Donaldson DR, Hall TJ, Zoltowski JA, et al. Does the type of suture material contribute to the strength of the lateral paramedian incision? Br J Surg 1982; 69(3):163-5.
33. Ali J, Khan TA. The comparative effects of muscle transection and median upper abdominal incisions on postoperative pulmonary function. Surg Gynecol Obstet 1979; 148(6):863-6.
34. Donati D, Brown SR, Eu KW, et al. Comparison between midline incision and limited right skin crease incision for right-sided colonic cancers. Tech Coloproctol 2002; 6(1):1-4.
35. Stone HH, Hoefling SJ, Strom PR, et al. Abdominal incisions: transverse vs vertical placement and continuous vs interrupted closure. South Med J 1983; 76(9):1106-8.
36. Lewis RT, Allan CM, Goodall RG, et al. The conduct of cholecystectomy: incision, drainage, bacteriology and postoperative complications. Can J Surg 1982; 25(3):304-7.
37. Douzdjian V, Gugliuzza KK. The impact of midline versus transverse incisions on wound complications and outcome in simultaneous pancreas-kidney transplants: a retrospective analysis. Transpl Int 1996; 9(1):62-7.
38. Luijendijk RW, Jeekel J, Storm RK, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg 1997; 225(4):365-9.

6 | Incisional Hernia Prevention

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INTRODUCTION

Incisional hernia is the most common complication of the laparotomy with an incidence of 2-20%[1-6]. In 2001, approximately 150,000 abdominal procedures (laparotomy and laparoscopy) were carried out in the Netherlands (16 million inhabitants). Considering hernia rates from the literature, a number of 12,500 new incisional hernias should be expected annually. These numbers have a high negative impact on cost-effectiveness of surgery and result in an unacceptably high frequency of co-morbidity. In addition, they have a significant impact on hospital capacity. To investigate to what extent the occurrence of incisional hernias is avoidable, we studied risk factors for incisional hernia and how the negative influence of these risk factors may be reduced or eliminated.

RISK FACTORS FOR INCISIONAL HERNIA

Incisional hernia incidence is influenced by several factors. Firstly, type of incision, method of closure, materials used and hernia repair procedure play an important role. In addition, many patient and disease related risk factors have been identified, of which wound infection is probably the most important. In this study, only the influence of technical factors was considered, as it may be reduced by application of alternative techniques.

INFLUENCE OF TYPE OF INCISION (TABLE 1)

In 2001 Grantcharov and Rosenberg conducted a meta-analysis comparing transverse (oblique and transverse) with vertical (midline) incisions[7]. Their conclusions were in favor of the transverse incision. However, for unknown reasons, many studies were not included in the analysis. When all trials comparing midline, paramedian, transverse and oblique incisions are reviewed, the difficulty of comparison becomes clear. In many cases only specific operations, such as cholecystectomy, are studied. Results from such studies are often unrightfully projected to the entire range of operations. Therefore, the conclusion that small transverse incisions cause less incisional hernias than midline incisions is justified (5%)[8-12]. This does however not apply to large bilateral incisions[13-16]. In that case, hernia rates comparable to that of the midline incision (10%) can be expected.

The lateral paramedian resulted in significantly reduced hernia rates compared to the midline incision in three randomized-controlled trials. Hernia rates of 0-1% were reported[17-20]. The Pfannenstiel incision results in hernia rates of 0-1%[21-24], but was not compared to standard incisions in randomized controlled trials. The flank incision, commonly used by urologists, has not been compared with other techniques in randomized-controlled trials either. Hernia rates of 0.4-17% are reported[25-32].

TABLE 1. Techniques, area of application and incisional hernia incidence

Techniques/Incisions	Application	Hernia rates (%)
Laparoscopy	Cholecystectomy, splenectomy, appendectomy, fundoplication, endocrine	1
Lateral paramedian	Major elective surgery	1
Pfannenstiel	Lower colon and rectum surgery, pelvic surgery	1
Unilateral transverse / oblique	Small biliary surgery, bariatric surgery, small gastrointestinal surgery	5
Flank	Kidney	8
Bilateral transverse / oblique	Biliary tract, liver, pancreatic, gastrointestinal	>10
Midline	All minor and major laparotomies	>12

To close, the rising of laparoscopy is a development, which could significantly reduce incisional hernia rates. Most authors presume an incisional hernia rate of 0.2-1.8%[33].

We conclude that the lateral paramedian incision, the unilateral transverse incision, the Pfannenstiel incision and laparoscopic surgery result in reduced incisional hernia rates compared to midline, bilateral and flank incisions. If possible, these techniques should be applied to avoid incisional hernia; the most frequent complication of abdominal surgery. Transverse and oblique incisions are suitable for small unilateral operations, such as open cholecystectomy, bariatric surgery[34] and small bowel resections[35,36]. The lateral paramedian incision can be used for most major elective surgery, including exploratory operations[17-20]. The Pfannenstiel incision can be used for surgery of the lower colon and rectum[37] and pelvic surgery. Laparoscopy has taken possession of several specific elective operations, such as cholecystectomy, splenectomy, endocrine surgery and fundoplication. Hernia rates following these laparoscopic procedures are low.

The midline incision should be reserved for emergency laparotomies and for elective and exploratory surgery in which full exposure of the abdomen is needed[38].

INFLUENCE OF SUTURE TECHNIQUE AND MATERIAL

Recently, three meta-analyses on the subject of abdominal closure were published[1,39,40], of which the second, published in 2000 by Hodgson et al[1], is undoubtedly the most thorough. Her conclusions were clear-cut:

1. Hernia rates are lower when non-absorbable materials are used.
2. Hernia rates are lower when a continuous technique is used.
3. There is no difference in hernia rates after use of polydioxanone (PDS) or polypropylene.

In addition, Weiland et al compared layered with mass closure of the abdominal wall, concluding in favor of the latter[40].

In conclusion, we state that closure of the abdominal wall should be performed by mass closure, a continuous suture technique and by using a non-absorbable (e.g. polypropylene) or slow-absorbable (polydioxanone) suture material.

INFLUENCE OF SUTURE LENGTH – WOUND LENGTH RATIO

The suture length – wound length ratio can be calculated by dividing the length of the used suture thread by the length of the wound. What this number indicates is a rough measure of tissue bite size and the interval between stitches. We are aware of only two comparative clinical studies on SLWL ratio. The most important is by Israelsson et al[41]. In a prospective study, hernia rates decreased from 23.7% when the SLWL was < 4 to a hernia rate of 9% when it was ≥ 4. These results apply to midline incisions. Kendall et al proved that the inherent strength of the lateral paramedian incision was independent of SLWL ratio[19].

INFLUENCE OF HERNIA REPAIR

In hernia repair, there are four choices to be made:

1. Suture or mesh repair
2. Type of mesh
3. Mesh position
4. Open or laparoscopic procedure

Considering suture and mesh repair of incisional hernias, two randomized-controlled trials exist. Luijendijk et al reported a significant reduction in hernia recurrence rates after mesh repair, irrespective of the size of the hernia[42]. Similar findings were reported by a Arroyo et al, who compared suture and mesh repair for umbilical hernia[43]. A randomized-controlled trial by Korenkov et al could not confirm these findings. However, suture repair was only performed when hernias were primary and small and meshes were placed in an onlay position[44].

Regarding type of mesh, non-absorbable meshes or meshes with a non-absorbable component are mandatory. Absorbable meshes do not prevent hernia occurrence or recurrence[45,46].

Hernia recurrence rates are lower when meshes are placed in a sublay position (on the posterior rectus sheath in an open procedure and intraperitoneally in a laparoscopic procedure), rather than in an onlay or inlay position[6].

One randomized-controlled trial comparing open with laparoscopic repair exists, not reporting significant differences between the two[47]. A larger randomized-controlled trial comparing open with laparoscopic incisional hernia is underway in the Erasmus Medical Center and affiliated hospitals. Presently, 70 patients are included.

In conclusion, non-absorbable meshes should be placed in a sublay position, either by an open or a laparoscopic procedure. Recurrence rates of approximately 13% (1-24%) can be achieved[6,42-44,47,48].

DISCUSSION

The influence of surgical technique has a high impact on incisional hernia rates. The goal of this study was to evaluate benefits of altering standard procedures. Recent meta-analyses show that laparotomies should be closed using a non- or slow-absorbable suture and a continuous mass technique. At present, continuous mass closure with a polydioxanone loop is the customary abdominal closure technique in the Netherlands.

Optimization of the SLWL ratio may significantly reduce hernia rates, especially when a midline incision is used[19,41]. The midline incision may never become obsolete, because of its ease, speed and exposure. Therefore, achieving a SLWL ratio of ≥ 4 is essential when use of the midline incision is unavoidable. It is however impossible to calculate gains of improving the SLWL ratio, due to a lack of data. However, our impression is that midline incisions are usually closed with a SLWL ratio of 3-3.5. Therefore, general understanding of the importance of the SLWL ratio could lower incisional hernia rates significantly.

Regarding incisional hernia repair, improvements can be made. Although it was proven in a randomized-controlled trial that mesh repair of incisional hernias significantly reduces recurrence[42], at least 32% of hernia repairs are still performed by suture repair. Application of mesh repair for all incisional hernias could reduce hernia recurrence by 25%.

A significant decline of incisional hernia incidence can be achieved by the use of alternative incisions. The midline incision has an estimated hernia rate of 12%. However, hernia rates after midline incision can occasionally be higher, for example if a SLWL ratio of <4 is used (24%[41]), when it is performed for abdominal aneurysm surgery (20%[13,14,49-52]) or in emergency situations (18%[53]).

The transverse incision has an inherent hernia rate of approximately 5% when it is unilateral[8-12] and of 10% when it is bilateral[13-16]. Therefore, application of small transverse incisions when possible, in stead of using a midline incision, might induce a significant reduction in hernia incidence.

The infraumbilical transverse Pfannenstiel incision has a hernia rate of approximately 1% and is especially suitable for surgery in the lower abdomen. It has been successfully used for colorectal surgery[37] and has since long been the main incision in gynecological and obstetrical procedures. An alternative incision that provides good access to the upper abdomen as well is the lateral paramedian incision. When performed correctly[17,54], incisional hernia rates are as low as 0-1%. Application of the lateral paramedian and Pfannenstiel incision for vas-

cular surgery, colorectal surgery and elective exploratory procedures could bring about an enormous decrease of incisional hernias.

Laparoscopy results in incisional hernia rates of approximately 1%. In areas where laparoscopic surgery has been generally accepted as equal or superior to open techniques, many laparotomies are still performed, resulting in unnecessary incisional hernias. Further application of laparoscopic surgery can induce a reduction in incisional hernia rates, which may be well worth the effort.

CONCLUSION

Optimization of surgical techniques offers promising perspectives. A significant reduction of incisional hernia occurrence is anticipated.

REFERENCES

1. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
2. Santora TA, Roslyn JJ. Incisional hernia. Surg Clin North Am 1993; 73(3):557-70.
3. Eisner L, Harder F. [Incisional hernias]. Chirurg 1997; 68(4):304-9.
4. Klinge U, Prescher A, Klosterhalfen B, et al. [Development and pathophysiology of abdominal wall defects]. Chirurg 1997; 68(4):293-303.
5. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
6. Schumpelick V, Klinge U, Welty G, et al. [Meshes within the abdominal wall]. Chirurg 1999; 70(8):876-87.
7. Grantcharov TP, Rosenberg J. Vertical compared with transverse incisions in abdominal surgery. Eur J Surg 2001; 167(4):260-7.
8. Blomstedt B, Welin-Berger T. Incisional hernias. A comparison between midline, oblique and transrectal incisions. Acta Chir Scand 1972; 138(3):275-8.
9. Garcia-Valdecasas JC, Almenara R, Cabrer C, et al. Subcostal incision versus midline laparotomy in gallstone surgery: a prospective and randomized trial. Br J Surg 1988; 75(5):473-5.
10. Lip H. De dwarse en vertikale incisie van de bovenbuik bij galblaasoperaties. Thesis 1981.
11. Sanz-Lopez R, Martinez-Ramos C, Nunez-Pena JR, et al. Incisional hernias after laparoscopic vs open cholecystectomy. Surg Endosc 1999; 13(9):922-4.
12. Ros E, Zambon D. Postcholecystectomy symptoms. A prospective study of gall stone patients before and two years after surgery. Gut 1987; 28(11):1500-4.
13. Lord RS, Crozier JA, Snell J, et al. Transverse abdominal incisions compared with midline incisions for elective infrarenal aortic reconstruction: predisposition to incisional hernia in patients with increased intraoperative blood loss. J Vasc Surg 1994; 20(1):27-33.
14. Johnson B, Sharp R, Thursby P. Incisional hernias: incidence following abdominal aortic aneurysm repair. J Cardiovasc Surg (Torino) 1995; 36(5):487-90.
15. Ellis H, Coleridge-Smith PD, Joyce AD. Abdominal incisions--vertical or transverse? Postgrad Med J 1984; 60(704):407-10.
16. Greenall MJ, Evans M, Pollock AV. Midline or transverse laparotomy? A random controlled clinical trial. Part I: Influence on healing. Br J Surg 1980; 67(3):188-90.
17. Guillou PJ, Hall TJ, Donaldson DR, et al. Vertical abdominal incisions--a choice? Br J Surg 1980; 67(6):395-9.
18. Cox PJ, Ausobsky JR, Ellis H, et al. Towards no incisional hernias: lateral paramedian versus midline incisions. J R Soc Med 1986; 79(12):711-2.
19. Kendall SW, Brennan TG, Guillou PJ. Suture length to wound length ratio and the integrity of midline and lateral paramedian incisions. Br J Surg 1991; 78(6):705-7.
20. Donaldson DR, Hegarty JH, Brennan TG, et al. The lateral paramedian incision--experience with 850 cases. Br J Surg 1982; 69(10):630-2.
21. Pfannenstiel J. Über die Vorteile des suprasymphysären Fascienquerschnitts für die gynäkologischen Koeliotomien. Sammlung Klinischer Vorträge N.F. no. 268, Gynäkologie 1900; 97:1735-1756.
22. Biswas K. Why not Pfannenstiel's incision. Obstet Gynecol 1973; 41:303-307.
23. Pietrantoni M, Parsons MT, O'Brien WF, et al. Peritoneal closure or non-closure at cesarean. Obstet Gynecol 1991; 77(2):293-6.
24. Griffiths DA. A reappraisal of the Pfannenstiel incision. Br J Urol 1976; 48(6):469-74.
25. Aubert J, Koumare K, Dufrenot A. [Anatomical study of the twelfth intercostal nerve and oblique lumbotomies (author's transl)]. J Urol (Paris) 1981; 87(5):283-9.

26. Bayazit Y, Aridogan IA, Tansug Z, et al. Morbidity of flank incision in 100 renal donors. Int Urol Nephrol 2001; 32(4):709-11.
27. Hemal AK, Gupta NP, Wadhwa SN, et al. Retroperitoneoscopic nephrectomy and nephroureterectomy for benign nonfunctioning kidneys: a single-center experience. Urology 2001; 57(4):644-9.
28. Hawasli A, Boutt A, Cousins G, et al. Laparoscopic versus conventional live donor nephrectomy: experience in a community transplant program. Am Surg 2001; 67(4):342-5.
29. Yasumura T, Nakai I, Oka T, et al. Experience with 247 living related donor nephrectomy cases at a single institution in Japan. Jpn J Surg 1988; 18(3):252-8.
30. Dunn JF, Nylander WA, Jr., Richie RE, et al. Living related kidney donors. A 14-year experience. Ann Surg 1986; 203(6):637-43.
31. Humar A, Ramcharan T, Denny R, et al. Are wound complications after a kidney transplant more common with modern immunosuppression? Transplantation 2001; 72(12):1920-3.
32. Elashry OM, Giusti G, Nadler RB, et al. Incisional hernia after laparoscopic nephrectomy with intact specimen removal: caveat emptor. J Urol 1997; 158(2):363-9.
33. Holzinger F, Klaiber C. [Trocar site hernias. A rare but potentially dangerous complication of laparoscopic surgery]. Chirurg 2002; 73(9):899-904.
34. Jones KB, Jr. The left subcostal incision revisited. Obes Surg 1998; 8(2):225-8.
35. Donati D, Brown SR, Eu KW, et al. Comparison between midline incision and limited right skin crease incision for right-sided colonic cancers. Tech Coloproctol 2002; 6(1):1-4.
36. Stipa F, Barreca M, Lucandri G, et al. [Transverse minilaparotomy as an access route in right colon disease: a valid alternative to midline laparotomy]. Chir Ital 2000; 52(1):91-6.
37. Lechaux JP, Gerbaux B, Lambert MP, et al. [The Pfannenstiel incision in colorectal surgery]. Chirurgie 1997; 122(7):418-23.
38. Burger J, van 't Riet M, Jeekel J. Abdominal incisions: techniques and postoperative complications. Scandinavian Journal of Surgery 2002; accepted.
39. Rucinski J, Margolis M, Panagopoulos G, et al. Closure of the abdominal midline fascia: meta-analysis delineates the optimal technique. Am Surg 2001; 67(5):421-6.
40. Weiland DE, Bay RC, Del Sordi S. Choosing the best abdominal closure by meta-analysis. Am J Surg 1998; 176(6):666-70.
41. Israelsson LA, Jonsson T. Suture length to wound length ratio and healing of midline laparotomy incisions. Br J Surg 1993; 80(10):1284-6.
42. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
43. Arroyo A, Garcia P, Perez F, et al. Randomized clinical trial comparing suture and mesh repair of umbilical hernia in adults. Br J Surg 2001; 88(10):1321-3.
44. Korenkov M, Sauerland S, Arndt M, et al. Randomized clinical trial of suture repair, polypropylene mesh or autodermal hernioplasty for incisional hernia. Br J Surg 2002; 89(1):50-6.
45. Pans A, Desaive C. Use of an absorbable polyglactin mesh for the prevention of incisional hernias. Acta Chir Belg 1995; 95(6):265-8.
46. Pans A, Elen P, Dewe W, et al. Long-term results of polyglactin mesh for the prevention of incisional hernias in obese patients. World J Surg 1998; 22(5):479-82; discussion 482-3.
47. Carbajo MA, Martin del Olmo JC, Blanco JI, et al. Laparoscopic treatment vs open surgery in the solution of major incisional and abdominal wall hernias with mesh. Surg Endosc 1999; 13(3):250-2.
48. Cassar K, Munro A. Surgical treatment of incisional hernia. Br J Surg 2002; 89(5):534-45.
49. Augestad KM, Wilsgaard T, Solberg S. [Incisional hernia after surgery for abdominal aortic aneurysm]. Tidsskr Nor Laegeforen 2002; 122(1):22-4.
50. Holland AJ, Castleden WM, Norman PE, et al. Incisional hernias are more common in aneurysmal arterial disease. Eur J Vasc Endovasc Surg 1996; 12(2):196-200.

51. Papadimitriou D, Pitoulias G, Papaziogas B, et al. Incidence of abdominal wall hernias in patients undergoing aortic surgery for aneurysm or occlusive disease. Vasa 2002; 31(2):111-4.
52. Stevick CA, Long JB, Jamasbi B, et al. Ventral hernia following abdominal aortic reconstruction. Am Surg 1988; 54(5):287-9.
53. Mingoli A, Puggioni A, Sgarzini G, et al. Incidence of incisional hernia following emergency abdominal surgery. Ital J Gastroenterol Hepatol 1999; 31(6):449-53.
54. Brennan TG, Jones NA, Guillou PJ. Lateral paramedian incision. Br J Surg 1987; 74(8):736-7.

7 Possible Gains of Optimizing Surgical Techniques in Preventing Incisional Hernia

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INTRODUCTION

Incisional hernia is the most common long-term complication of abdominal surgery with an incidence of 9-19%[1-4]. In 2001, general surgeons, gynecologists and urologists in the Netherlands (16 million inhabitants) carried out 155,000 abdominal procedures (106,000 laparotomies, 49,000 laparoscopies)[5]. Taking figures from the medical literature into consideration, a number of 10,000 – 21,000 incisional hernias can be expected annually. Hernia repair was performed 3,827 times in 2001. The number of hospitalization days related to hernia repair was 21,437. These numbers have a high negative impact on cost-effectiveness of surgery and result in unacceptable co-morbidity. In addition, they have a significant impact on hospital capacity.

Incisional hernia is caused by several factors. Firstly surgical factors, such as type of incision, suture technique, suture material and type of hernia repair play an important role. In addition, many patient and disease related risk factors have been identified, such as diabetes and wound infection. Of all factors associated with incisional hernia development, the surgical factor is the one that may be amenable to improvement. The aim of the current study was to review surgical factors associated with incisional hernia development and to establish what the possible beneficial effects of a change of surgical practice on incisional hernia development might be.

SURGICAL FACTORS ASSOCIATED WITH INCISIONAL HERNIA DEVELOPMENT

TYPE OF INCISION

Hernia rates after the midline incision are approximately 12%[6-14]. The incidence of incisional hernia in midline incisions for abdominal aortic aneurysm is even higher: 25%[15-20]. Several randomized controlled trials were performed comparing the midline incision with transverse and lateral paramedian incisions. The incidence of incisional hernia after small unilateral transverse incisions is less than that after midline incisions: 5%[6,13,21-23]. Although a recent randomized trial showed a decrease in incisional hernia incidence after the transverse incision for abdominal aneurysm[20], several other studies did not report a difference in incisional hernia incidence between midline and bilateral transverse incisions (10% after bilateral transverse)[8,11,14,24]. The lateral paramedian incision resulted in reduced hernia rates compared to the midline incision in three randomized controlled trials[7,9,12]. Incisional hernia incidences of less than 1% were reported. The Pfannenstiel incision results in hernia rates of approximately 1%[25-27], but it was not compared to standard incisions in randomized controlled trials. The flank incision was not compared to other techniques in randomized-controlled trials either. Hernia rates around 4% are expected[28,29]. The growing popularity of laparoscopy is a development

TABLE 1. Incisional hernia rates after different types of incision

Techniques	Application	Hernia rates
Laparoscopy	Cholecystectomy, splenectomy, appendectomy, fundoplication, endocrine	2%
Lateral paramedian	Major elective surgery	1%
Pfannenstiel	Lower colon and rectum surgery	1%
Unilateral transverse / oblique	Biliary surgery, bariatric surgery, gastrointestinal surgery	5%
Flank	Kidney	4%
Bilateral transverse / oblique	Biliary tract, liver, pancreatic, gastrointestinal	>10%
Midline	All minor and major laparotomies	>12%

that may significantly reduce incisional hernia incidence. Initial reports led to believe that the incidence of incisional hernia after laparoscopy was negligable[30,31]. Later studies however reported an incisional hernia rate of approximately 2%[32-34]. Recently, laparoscopic colectomy became increasingly popular. However, the need for a small laparotomy to retrieve the resected segment appears to take away the benefit of a low incisional hernia incidence[35].

We conclude that the lateral paramedian incision, the unilateral transverse incision, the Pfannenstiel incision and laparoscopy result in reduced incisional hernia rates compared to midline, bilateral transverse and flank incisions. The former techniques should be applied when possible. Transverse and oblique incisions are suitable for unilateral operations, such as open cholecystectomy, bariatric surgery[36] and right colon disease[37,38]. The lateral paramedian incision and the bilateral transverse incision can be used for all major elective surgery, including vascular surgery, colorectal surgery and diagnostic laparotomies[7,24,39]. The Pfannenstiel incision can be used for left colorectal surgery[40]. Use of the midline incision should be restricted to emergency surgery, intra-abdominal hemorrhage and perforation in particular, and for diagnostic laparotomies in which maximum exposure of the abdomen is essential[41].

INFLUENCE OF SUTURE TECHNIQUE AND MATERIAL

In recent years, four meta-analyses of suture technique and material were performed[1,42-44]. The conclusions were mostly uniform. To prevent incisional hernia development, closure of the abdominal wall should be performed by using a non-absorbable (nylon or polypropylene) or slow-absorbable (polydioxanone) suture material, and a continuous mass closure technique. With regard to tissue bite size and the interval between stitches, the so-called suture length – wound length (SLWL) ratio is of importance. This ratio can be calculated by dividing the length of the used suture by the length of the wound. Israelsson et al reported that incisional

hernia rates decreased from 23.7% when the SLWL was < 4 to a hernia rate of 9% when it was ≥ 4[45]. Therefore, the length of the suture should always be four times as long as the length of the wound. Israelsson's results apply to midline incisions. Kendall et al reported that the inherent strength of the lateral paramedian incision was independent of the SLWL ratio[12].

INFLUENCE OF HERNIA REPAIR

With regard to suture or mesh repair of incisional hernia, one randomized-controlled trial is available. Luijendijk et al reported a significant reduction in hernia recurrence rates after mesh repair[46]. In 2004, follow-up of this trial was updated. The 10-yr cumulative recurrence of incisional hernia was 32% after mesh repair and 63% after suture repair. For small incisional hernias these percentages were 17% and 67% respectively[47]. Regarding the type of mesh, non-absorbable meshes or meshes with a non-absorbable component are mandatory[48]. The mesh should be placed in a sublay position, rather than an onlay or inlay position. This means that the mesh is placed under the rectus abdominis muscle and on the posterior rectus sheath or peritoneum in an open procedure and intraperitoneally in a laparoscopic procedure[3]. Overlap between mesh and abdominal wall should be ample (5 cm). With regard to laparoscopic vs. open incisional hernia repair, one randomized-controlled trial comparing open with laparoscopic repair is currently available, not reporting a significant difference between the two[49].

We conclude that in incisional hernia repair non-absorbable meshes should be placed in a sublay position, either by an open or laparoscopic procedure. Long-term recurrence rates are estimated at 25%[3,50-52]. After suture repair, hernia rates of approximately 50% may be expected[47,53-56].

APPLICATION OF ALTERNATIVE TECHNIQUES IN THE NETHERLANDS

With regard to suture technique and suture material, continuous mass closure with polydioxanone is already customary in the Netherlands. In general, the suture length - wound length ratio is not recorded at a local level, not to mention nationwide. Therefore, possible beneficial effects of improving the SLWL ratio cannot be estimated. It was, however, possible to project the influence of a change of practice with regard to choice of incision and type of incisional hernia repair on the situation in the Netherlands.

METHODS

From the database of the Dutch Medical Registration[5], general surgical abdominal procedures were identified (including vascular, colorectal, trauma, gastrointestinal, oncologic, bili-

ary and endocrine surgery). Diagnostic laparoscopies were excluded, as were relaparotomies and stoma reversal. For each specific procedure the number of cases was established. Subsequently, the type of incision was established. For some procedures, the type of incision could be retrieved from the database (*e.g.* appendectomy, cholecystectomy and gastric surgery). However, for many other procedures, the type of incision used was not recorded. For most procedures a specific type of incision is used routinely. For some procedures, however, more than one type of incision is commonly used. In that case, the type of incision with the most favorable incisional hernia rate was used for further analysis and comparison.

Incisional hernia rates for specific incisions and procedures were applied to the number of cases for each specific procedure. Secondly, we verified whether an alternative incision was available for that specific procedure. If so, the expected incisional hernia rate following the alternative incision was calculated. In some procedures quick access is mandatory. For these procedures, the lateral paramedian and transverse incisions were not considered alternatives. Ruptured abdominal aneurysm and gastric perforation and hemorrhage were defined as such procedures. With regard to incisional hernia repair, the expected number of recurrences after suture and mesh repair of incisional hernia were calculated. Subsequently, we calculated the expected number of recurrences assuming all repairs would have been mesh repairs.

RESULTS

Table 2 presents the results. The number of incisional hernias after use of standard techniques is expected to be 5,951. When alternative incisions are applied, this number could decrease to 2,147, which means a 64% reduction of incisional hernia incidence. The largest reductions in incisional hernia incidence can be achieved by replacing the midline incision for intra-abdominal vascular surgery (12% reduction) and colorectal and intestinal surgery (31%).

DISCUSSION

Our results demonstrate that a significant reduction in incisional hernia incidence may be achieved by altering standard surgical procedures. Changing the type of incision would bring about the largest reduction of incisional hernia incidence. Implementation of mesh repair for all incisional hernias will add to the effect. Good surgical technique, *i.e.* ensuring a SLWL ratio of >4, may cause a significant reduction as well, although it is not possible to calculate the effect.

TABLE 2. Expected incisional hernia rates after standard and alternative incisions

Group	N	Standard incision	HR	Alternative	HR
Adrenalectomy	170	Trocar (2%)	3	None	3
Aortoiliac occlusive disease and other intra-abdominal vascular	1923	Midline (12%)	230	Lateral paramedian (1%)	20
Elective aortic aneurysm	2086	Midline (25%)	521	Lateral paramedian (1%)	21
Acute aortic aneurysm	500	Midline (25%)	125	None	125
Splenectomy (laparotomy)	358	Midline (12%)	43	Lateral paramedian (1%), laparoscopy (2%)	4
Splenectomy (laparoscopy)	81	Trocar (2%)	2	None	2
Esophagus and/or gastric resection	1547	Midline (12%)	185	Lateral paramedian (1%)	16
Gastric perforation/hemorrhage	979	Midline (12%)	117	None	117
Other gastric, including bariatric and fundoplication (laparotomy)	1314	Midline (12%)	158	Lateral paramedian (1%), laparoscopy (2%)	13
Other gastric, including bariatric and fundoplication (laparoscopy)	912	Trocar (2%)	19	None	19
Colon	9265	Midline (12%)	1112	Lateral paramedian (1%), transverse (5%)	93
Small intestines	1566	Midline (12%)	188	Lateral paramedian (1%)	16
Stoma	1327	Midline (12%)	159	Lateral paramedian (1%)	13
Intestinal bypass	353	Midline (12%)	42	Lateral paramedian (1%)	4
Other	822	Midline (12%)	99	Lateral paramedian (1%)	8
Appendix (gridiron)	12872	Gridiron (0.4%)	51	None	51
Appendix (midline)	758	Midline (12%)	91	Lateral paramedian (1%)	8
Appendix (laparoscopy)	1517	Trocar (2%)	30	None	30
Rectum (laparotomy)	3573	Midline (12%)	429	Lateral paramedian (1%), Pfannenstiel (1%)	36
Rectum (laparoscopy)	154	Trocar (2%)	3	None	3
Liver	523	Transverse (10%)	52	None	52
Biliary (laparotomy)	3467	Subcostal (5%)	173	None	173
Biliary (laparoscopy)	14540	Trocar (2%)	289	None	289
Pancreas (laparotomy)	435	Transverse/midline (10%)	44	Transverse (10%)	44
Pancreas (laparoscopy)	14	Trocar (2%)	0	None	0
Diagnostic laparotomy	2997	Midline (12%)	360	Lateral paramedian (1%)	30
Adhesiolysis (laparotomy)	768	Midline (12%)	92	Lateral paramedian/laparoscopy (2%)	8
Adhesiolysis (laparoscopy)	352	Trocar (2%)	7	None	7
CAPD (laparotomy)	542	Transverse (<1%)	5	None	5
CAPD (laparoscopy)	146	Trocar (<1%)	1	None	1
Kidney transplantation (laparotomy)	562	Oblique (5%)	28	None	0
Kidney transplantation (laparoscopy)	43	Trocar (2%)	1	None	0
Other intra-abdominal	671	Midline (12%)	81	Lateral paramedian (1%)	7
Incisional Hernia repair (mesh)	2592	Mesh (25%)	648	None	648
Incisional Hernia repair (suture)	1125	Suture (50%)	563	Mesh (25%)	281
Total number	70854		5951		2147

Although our results are entirely based on hypothesis, we consider our conclusions to be valid. All incisional hernia incidences were retrieved from prospective studies or retrospective studies with adequate follow-up. Moreover, the 64% reduction of incisional hernia incidence was achieved by replacing the midline incision and suture repair by the lateral paramedian incision and mesh repair respectively. The superiority of the latter two techniques was proven in prospective randomized controlled trials.

With regard to the feasibility of the proposed alternatives, adequate exposure of the whole abdominal cavity was reported for both the lateral paramedian incision and for the bilateral transverse incision[7,24,39]. Even so, total abolishment of the midline incision may not be possible. Quick access to the abdominal cavity may be necessary, for example in ruptured aneurysm, abdominal trauma or the unstable patient with perforation of a hollow viscus. Because we assumed that the use of alternative incisions was not possible in any acute aneurysm patient or any gastric hemorrhage or perforation patient, we argue that we have compensated amply for this limitation.

There are several possible explanations for the large differences between incisional hernia incidences after different incisions. When the abdominal wall muscles contract, the midline incision's wound edges are retracted laterally, because the muscle fibers have a mostly transverse direction. In addition, the midline incision is situated in the relatively avascular linea alba. The inherent strength of the lateral paramedian incision may be caused by the so-called shutter mechanism, which is caused by splintage of the wound by the rectus muscle. Contraction of the abdominal wall muscles actually approximates the wound edges in stead of separating them[39]. In comparison to the midline incision, the lateral paramedian incision is situated in richly vascularized tissue. The same is true for the transverse incision. Moreover, in transverse or oblique incisions, the direction of the incision follows the direction of most muscle fibers. Therefore, contraction approximates the wound edges.

Use of the midline incision is widespread, because it provides quick access and maximum exposure. However, the high number of incisional hernias is a major drawback. The lateral paramedian incision is laborious, because the rectus sheath has to be incised laterally, after which the rectus abdominis muscle is retracted laterally and the posterior rectus sheath and peritoneum are incised laterally. However, the difference in time required to perform the incision may only be 5 minutes[7,9,12]. Such a small difference in time does not justify the much greater number of incisional hernias after the midline incision. Moreover, Donaldson et al reported the use of the lateral paramedian incision for emergency procedures in a large consecutive series. The transverse incision has since long been advocated as the standard incision for abdominal surgery. It seems however that its popularity is declining. Use of transverse incisions may still result in a decreased incisional hernia incidence[57].

With regard to incisional hernia repair, the reduced recurrence rate after mesh repair may either be caused by augmentation of the abdominal wall, or by tension-free bridging of the defect. Surprisingly, many surgeons still perform suture repair. The reason behind this illogical practice is unknown. Possibly, surgeons still think that small incisional hernias can effectively be treated with suture repair, although it was proven that this is not the case[47]. In other cases, surgeons may feel that mesh placement is contraindicated. In these cases, surgeons should perhaps consider refraining from incisional hernia repair altogether.

In conclusion, we state that surgeons should reconsider the incisions they are currently using for abdominal surgery. Although alternative incisions are more laborious, a minimum of extra effort will result in a significant decrease in incisional hernia incidence. A switch to mesh repair may further decrease the number of incisional hernias.

REFERENCES

1. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
2. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
3. Schumpelick V, Klinge U, Welty G, et al. [Meshes within the abdominal wall]. Chirurg 1999; 70(8):876-87.
4. Hoer J, Lawong G, Klinge U, et al. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg 2002; 73(5): 474-80.
5. Prismant. Nationwide Medical Registration; Annual Report. 2001.
6. Blomstedt B, Welin-Berger T. Incisional hernias. A comparison between midline, oblique and transrectal incisions. Acta Chir Scand 1972; 138(3):275-8.
7. Cox PJ, Ausobsky JR, Ellis H, et al. Towards no incisional hernias: lateral paramedian versus midline incisions. J R Soc Med 1986; 79(12):711-2.
8. Ellis H, Coleridge-Smith PD, Joyce AD. Abdominal incisions--vertical or transverse? Postgrad Med J 1984; 60(704):407-10.
9. Guillou PJ, Hall TJ, Donaldson DR, et al. Vertical abdominal incisions--a choice? Br J Surg 1980; 67(6):395-9.
10. Israelsson LA, Jonsson T. Incisional hernia after midline laparotomy: a prospective study. Eur J Surg 1996; 162(2):125-9.
11. Johnson B, Sharp R, Thursby P. Incisional hernias: incidence following abdominal aortic aneurysm repair. J Cardiovasc Surg (Torino) 1995; 36(5):487-90.
12. Kendall SW, Brennan TG, Guillou PJ. Suture length to wound length ratio and the integrity of midline and lateral paramedian incisions. Br J Surg 1991; 78(6):705-7.
13. Lip H. (Transverse and vertical incisions of the upper abdomen for galbladder surgery). Thesis 1981.
14. Lord RS, Crozier JA, Snell J, et al. Transverse abdominal incisions compared with midline incisions for elective infrarenal aortic reconstruction: predisposition to incisional hernia in patients with increased intraoperative blood loss. J Vasc Surg 1994; 20(1):27-33.
15. Adye B, Luna G. Incidence of abdominal wall hernia in aortic surgery. Am J Surg 1998; 175(5): 400-2.
16. Hall KA, Peters B, Smyth SH, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. Am J Surg 1995; 170(6):572-5; discussion 575-6.
17. Holland AJ, Castleden WM, Norman PE, et al. Incisional hernias are more common in aneurysmal arterial disease. Eur J Vasc Endovasc Surg 1996; 12(2):196-200.
18. Papadimitriou D, Pitoulias G, Papaziogas B, et al. Incidence of abdominal wall hernias in patients undergoing aortic surgery for aneurysm or occlusive disease. Vasa 2002; 31(2):111-4.
19. Raffetto JD, Cheung Y, Fisher JB, et al. Incision and abdominal wall hernias in patients with aneurysm or occlusive aortic disease. J Vasc Surg 2003; 37(6):1150-4.
20. Fassiadis N, Roidl M, Hennig M, et al. Randomized clinical trial of vertical or transverse laparotomy for abdominal aortic aneurysm repair. Br J Surg 2005; 92(10):1208-11.
21. Ros E, Zambon D. Postcholecystectomy symptoms. A prospective study of gall stone patients before and two years after surgery. Gut 1987; 28(11):1500-4.
22. Garcia-Valdecasas JC, Almenara R, Cabrer C, et al. Subcostal incision versus midline laparotomy in gallstone surgery: a prospective and randomized trial. Br J Surg 1988; 75(5):473-5.
23. Sanz-Lopez R, Martinez-Ramos C, Nunez-Pena JR, et al. Incisional hernias after laparoscopic vs open cholecystectomy. Surg Endosc 1999; 13(9):922-4.
24. Greenall MJ, Evans M, Pollock AV. Midline or transverse laparotomy? A random controlled clinical trial. Part I: Influence on healing. Br J Surg 1980; 67(3):188-90.

25. Biswas K. Why not Pfannenstiel's incision. Obstet Gynecol 1973; 41:303-307.
26. Griffiths DA. A reappraisal of the Pfannenstiel incision. Br J Urol 1976; 48(6):469-74.
27. Luijendijk RW, Jeekel J, Storm RK, et al. The low transverse Pfannenstiel incision and the prevalence of incisional hernia and nerve entrapment. Ann Surg 1997; 225(4):365-9.
28. Dunn JF, Nylander WA, Jr., Richie RE, et al. Living related kidney donors. A 14-year experience. Ann Surg 1986; 203(6):637-43.
29. Humar A, Ramcharan T, Denny R, et al. Are wound complications after a kidney transplant more common with modern immunosuppression? Transplantation 2001; 72(12):1920-3.
30. Ahmad SA, Schuricht AL, Azurin DJ, et al. Complications of laparoscopic cholecystectomy: the experience of a university-affiliated teaching hospital. J Laparoendosc Adv Surg Tech A 1997; 7(1):29-35.
31. Larson GM, Vitale GC, Casey J, et al. Multipractice analysis of laparoscopic cholecystectomy in 1,983 patients. Am J Surg 1992; 163(2):221-6.
32. Mayol J, Garcia-Aguilar J, Ortiz-Oshiro E, et al. Risks of the minimal access approach for laparoscopic surgery: multivariate analysis of morbidity related to umbilical trocar insertion. World J Surg 1997; 21(5):529-33.
33. Nassar AH, Ashkar KA, Rashed AA, et al. Laparoscopic cholecystectomy and the umbilicus. Br J Surg 1997; 84(5):630-3.
34. Bowrey DJ, Blom D, Crookes PF, et al. Risk factors and the prevalence of trocar site herniation after laparoscopic fundoplication. Surg Endosc 2001; 15(7):663-6.
35. Winslow ER, Fleshman JW, Birnbaum EH, et al. Wound complications of laparoscopic vs open colectomy. Surg Endosc 2002; 16(10):1420-5.
36. Jones KB, Jr. The left subcostal incision revisited. Obes Surg 1998; 8(2):225-8.
37. Donati D, Brown SR, Eu KW, et al. Comparison between midline incision and limited right skin crease incision for right-sided colonic cancers. Tech Coloproctol 2002; 6(1):1-4.
38. Stipa F, Barreca M, Lucandri G, et al. [Transverse minilaparotomy as an access route in right colon disease: a valid alternative to midline laparotomy]. Chir Ital 2000; 52(1):91-6.
39. Donaldson DR, Hegarty JH, Brennan TG, et al. The lateral paramedian incision--experience with 850 cases. Br J Surg 1982; 69(10):630-2.
40. Lechaux JP, Gerbaux B, Lambert MP, et al. [The Pfannenstiel incision in colorectal surgery]. Chirurgie 1997; 122(7):418-23.
41. Burger J, van 't Riet M, Jeekel J. Abdominal incisions: techniques and postoperative complications. Scandinavian Journal of Surgery 2002; accepted.
42. Rucinski J, Margolis M, Panagopoulos G, et al. Closure of the abdominal midline fascia: meta-analysis delineates the optimal technique. Am Surg 2001; 67(5):421-6.
43. Weiland DE, Bay RC, Del Sordi S. Choosing the best abdominal closure by meta-analysis. Am J Surg 1998; 176(6):666-70.
44. van 't Riet M, Steyerberg EW, Nellensteyn J, et al. Meta-analysis of techniques for closure of midline abdominal incisions. Br J Surg 2002; 89(11):1350-6.
45. Israelsson LA, Jonsson T. Suture length to wound length ratio and healing of midline laparotomy incisions. Br J Surg 1993; 80(10):1284-6.
46. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
47. Burger JW, Luijendijk RW, Hop WC, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004; 240(4):578-83; discussion 583-5.
48. Pans A, Elen P, Dewe W, et al. Long-term results of polyglactin mesh for the prevention of incisional hernias in obese patients. World J Surg 1998; 22(5):479-82; discussion 482-3.
49. Carbajo MA, Martin del Olmo JC, Blanco JI, et al. Laparoscopic treatment vs open surgery in the solution of major incisional and abdominal wall hernias with mesh. Surg Endosc 1999; 13(3):250-2.

50. Leber GE, Garb JL, Alexander AI, et al. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998; 133(4):378-82.
51. Burger JWA, Luijendijk RW, Hop WCJ, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004; 240(4):578-585.
52. Conze J, Kingsnorth AN, Flament JB, et al. Randomized clinical trial comparing lightweight composite mesh with polyester or polypropylene mesh for incisional hernia repair. Br J Surg 2005; 92(12):1488-93.
53. Anthony T, Bergen PC, Kim LT, et al. Factors affecting recurrence following incisional herniorrhaphy. World J Surg 2000; 24(1):95-100;discussion 101.
54. Luijendijk RW, Lemmen MH, Hop WC, et al. Incisional hernia recurrence following "vest-overpants" or vertical Mayo repair of primary hernias of the midline. World J Surg 1997; 21(1):62-5; discussion 66.
55. Manninen MJ, Lavonius M, Perhoniemi VJ. Results of incisional hernia repair. A retrospective study of 172 unselected hernioplasties. Eur J Surg 1991; 157(1):29-31.
56. Paul A, Korenkov M, Peters S, et al. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. Eur J Surg 1998; 164(5):361-7.
57. Grantcharov TP, Rosenberg J. Vertical compared with transverse incisions in abdominal surgery. Eur J Surg 2001; 167(4):260-7.

8 Long-Term Follow-Up of a Randomized Controlled Trial of Suture versus Mesh Repair of Incisional Hernia

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ABSTRACT

OBJECTIVE

The objective of this study was to determine the best treatment for incisional hernia, taking into account recurrence, complications, discomfort, cosmetic result and patient satisfaction.

BACKGROUND

Long-term results of incisional hernia repair are lacking. Retrospective studies and the mid-term results of this study indicate that mesh repair is superior to suture repair. However, many surgeons are still performing suture repair.

METHODS

Between 1992 and 1998 a multicenter trial was performed, in which 181 eligible patients with a primary or first time recurrent midline incisional hernia were randomly assigned to suture or mesh repair. In 2003, follow-up was updated.

RESULTS

Median follow-up was 75 months for suture repair and 81 months for mesh repair patients. The 10-year cumulative rate of recurrence was 63% for suture repair and 32% for mesh repair ($P<0.001$). Abdominal aneurysm ($P=0.01$) and wound infection ($P=0.02$) were identified as independent risk factors for recurrence. In patients with small incisional hernias, the recurrence rates were 67% after suture repair and 17% after mesh repair ($P=0.003$). One hundred and twenty-six patients completed long-term follow-up (median follow-up 98 months). In the mesh repair group, 17% suffered a complication, compared to 8% in the suture repair group ($P=0.17$). Abdominal pain was more frequent in suture repair patients ($P=0.01$), but there was no difference in scar pain, cosmetic result and patient satisfaction.

CONCLUSIONS

Mesh repair results in a lower recurrence rate, less abdominal pain and does not result in more complications than suture repair. Suture repair of incisional hernia should be abandoned.

INTRODUCTION

Incisional hernia remains a frequent complication of abdominal surgery with a reported incidence of 2-20%[1-5]. In the United States, 4 to 5 million laparotomies are performed annually[6], which means that at least 400,000–500,000 incisional hernias can be expected to develop each year. Incisional hernia repair is performed approximately 200,000 times per year[6,7]. In the Netherlands, 100,000 laparotomies and 3,900 incisional hernia repairs are performed annually (data obtained from Prismant[8]). These data imply that in both countries, and probably in general, 4% of patients undergoing a laparotomy will go through additional surgery to repair an incisional hernia. When morbidity is added to the vast numbers and the tremendous costs associated with incisional hernia repair[9], it becomes clear that the efficacy of incisional hernia repair is of major importance. Unfortunately, results of incisional hernia repair are disappointing. Suture repair of incisional hernia results in recurrence rates of 12-54% [10-16], while mesh repair results in recurrence rates of 2-36% [13-15,17-23]. Because most studies only provide short-term follow-up, these recurrence rates may even be underestimated. In addition to the high recurrence rates, incisional hernia repair may give rise to serious complications, such as enterocutaneous fistula and bowel obstruction, causing deterioration rather than improvement of the patient's situation. Furthermore, patients may suffer pain and the cosmetic result of incisional hernia repair may be disappointing.

In 2000, a randomized controlled trial by our group indicated that mesh repair is superior to suture repair, even for small incisional hernias[14]. Unfortunately, there have not been randomized trials of incisional hernia repair since and some authors have even suggested that there may still be a place for suture repair of incisional hernia[15,24,25]. Disconcerting data indicate that surgeons are still performing suture repair, in spite of clinical evidence. In 1997, in Germany, 85% of incisional hernias repairs was still performed without prosthetic mesh[26], while in 1999, in Washington state, 35% of incisional hernias was repaired without mesh[27]. In the Netherlands in 2002, surgeons failed to use a mesh in 40% of incisional hernia repairs[8].

To determine what type of hernia repair should be performed, long-term results of incisional hernia repair are needed. The purpose of this study was to provide these long-term results. Patients who participated in a randomized controlled trial on incisional hernia repair, which included 181 patients between 1992 and 1998, were asked to complete a questionnaire and visit the out-patient clinic.

METHODS

Between March 1992 and February 1998, we randomly assigned 200 adult patients with a primary or first recurrent incisional hernia to suture repair or mesh repair.

Singular small (≤ 6 cm) midline incisional hernias were included. Patient-related factors that were recorded were gender, age, obesity, cough, constipation, prostatism, diabetes mellitus, glucocorticoid therapy, smoking status and abdominal surgical history. Operation related factors that were recorded were surgical technique, size of the defect, presence of haematoma, dehiscence, and wound infection. During suture repair, the edges of the fascia were approximated in the midline with a continuous polypropylene suture (Prolene no. 1, Ethicon, Amersfoort, the Netherlands). In patients assigned to mesh repair, a polypropylene mesh (Prolene, Ethicon or Marlex, Bard Benelux, Nieuwegein, the Netherlands) was tailored to the defect so that at least 2 cm of the mesh overlapped the fascia, and the mesh was sutured to the back of the abdominal wall with a continuous polypropylene suture. Any peritoneal defect was closed or the omentum was sutured between bowels and mesh. When this could not be done, a polyglactin 910 (Vicryl, Ethicon) mesh was fixed in between. The study was approved by the ethics committees of the participating hospitals, and all patients gave informed consent. A more meticulous description of inclusion and exclusion criteria, surgical technique and recorded patient characteristics has been published previously[14].

In 2003, all patients were asked to complete a questionnaire. Patients were asked whether they had suffered a recurrence, scar pain, abdominal pain, mesh infection, incarcerated hernia, small bowel obstruction or enterocutaneous fistula. Patients were also asked whether they had undergone hernia repair since their last visit and patients were asked to score pain in a visual analogue scale. They were asked to rate the cosmetic appearance of their abdomen and to state whether they were ashamed of the appearance of the abdomen. Finally, patients were asked whether they were satisfied with the result of the operation. Patients were invited to visit the out-patient clinic, where a patient history was taken and a physical examination performed. The abdomen was examined for hernia recurrence, which was defined as any fascial defect that was palpable or detected by ultrasound examination and was located within 7 cm of the site of hernia repair. The examination included palpation while the patient was in the supine position with legs extended and raised. Ultrasound examination was performed when physical examination was not conclusive.

STATISTICAL ANALYSIS

Percentages and continuous variables were compared with the use of Fisher's exact test and the Mann–Whitney test, respectively. The cumulative percentages of patients with recurrences over time were calculated and compared with use of Kaplan–Meier curves and log-rank tests. Multivariate analysis of various factors was performed with Cox regression analysis. Through the use of appropriate interaction terms, we investigated whether the effect of treatment depended on the size of the repaired hernia. All statistical tests were two-sided. The primary analysis was performed on an intention-to-treat basis; that is, patients remained in their assigned group even if during the procedure the surgeon judged the patient not to be suitable for the technique assigned.

RESULTS

Among the 200 patients enrolled in the study, 171 had a primary incisional hernia and 29 had a first recurrence of incisional hernia. Nineteen patients were found to be ineligible for the study for reasons described previously[14]. At base line, there were no significant differences between patients in the suture repair and the mesh repair groups (table 1). Ninety-seven patients were assigned to suture repair and 84 to mesh repair. Seven patients assigned to the suture-repair group underwent mesh repair and five patients assigned to the mesh-repair group underwent suture repair.

TABLE 1. Base-Line characteristics of the patients with incisional hernia, according to study group*.

Variable	Suture repair (N=97)	Mesh repair (N=84)
Gender – M:F	1.0:1	1.5:1
Age – yr		
Median	63	57
Range	25-82	23-85
Body-mass index†		
Median	26.0	26.2
Range	20.0-41.5	19.7-41.5
Prostatism (no. of males)	6/47 (13%)	1/49 (1%)
Smoking (%)	27/92 (29%)	32/82 (39%)
Infection (%)	2/92 (2%)	3/82 (4%)
Haematoma (%)	8/96 (8%)	9/83 (11%)
Intraoperative size of hernia – cm^2		
Median	20	24
Range	1-225	1-160
Main reason for laparotomy before repair – no. §		
Gastrointestinal operation	48	38
Gynecologic operation	16	15
Cholecystectomy	9	5
Abdominal aortic aneurysm	6	12
Other	28	30

*For some variables, data were not available for all the patients in the group.
†The body-mass index was calculated as the weight in kilograms divided by the square of the height in meters.
§Some patients had undergone more than one previous laparotomy.

During the 2003 update 126 patients were successfully contacted. Thirty-nine patients had died, 11 patients could not be located and 5 patients refused to cooperate. Causes of death were not related to the repair, but were cardiovascular (12), cerebrovascular (6), malignancy (10), per operative (not incisional hernia repair related) (5), pulmonary (5) and alcohol and drug abuse related (1). Inability to locate patients was due to patients having moved (5) and emigrated (6). Reasons for refusing cooperation were: not wanting to take leave from work (2), lack of interest (1) and unknown (2). One hundred and twenty-six of 142 living patients (89%) were seen at the out-patient clinic. Data of the 55 patients that did not visit the out-patient clinic during the current update were censored to their previous visit. With data of the 2003 update added, the median follow-up of patients without recurrence was 75 months for suture repair and 81 months for mesh repair.

RECURRENCE

In the 2003 study update, 25 new recurrences were found that had not been present during the original study. The 10-year cumulative rate of recurrence was 63% for suture repair and 32% for prosthetic repair (P<0.001) (figure 1). In a univariate analysis, surgery for abdominal aortic aneurysm (P=0.01) and infection (P=0.02) were identified as risk factors for recurrence. Among the preoperative data that were not identified as risk factors for recurrence were age, gender, primary or first recurrent hernia, size of the defect, smoking, prostatism, diabetes,

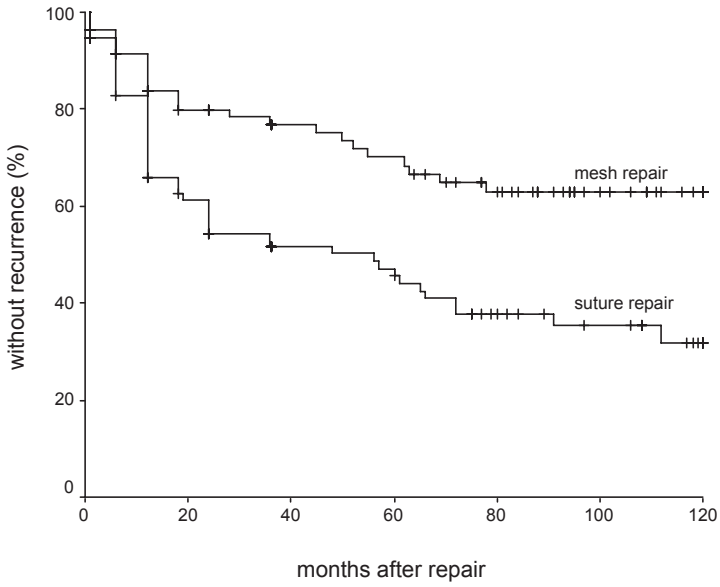

FIGURE 1. Kaplan-Meier curves for recurrence of hernia after repair of a primary or first recurrent incisional hernia, according to whether the patient was assigned to suture repair (97 patients) or mesh repair (84 patients). There were significantly fewer recurrences in patients who were assigned to mesh repair (P<0.001).

TABLE 2. Rate of recurrence after suture or mesh repair of incisional hernia

Type of repair	No. of patients	No. of recurrences	10-yr cumulative rate of recurrence (%)	P value
Suture repair	97	54	63	P<0.001*
Mesh repair	84	27	32	
Total	181	81		

*P value was obtained by stratified log-rank test

obesity and steroid-use. In a subgroup of 50 patients with small incisional hernia (≤10cm^2), the 10-year cumulative rate of recurrence was 67% after suture repair, compared to 17% after mesh repair (P=0.003).

COMPLICATIONS

Long-term follow-up was obtained from 126 patients. In these patients, the median follow-up was 97 months for suture repair and 98 months for mesh repair. Sixty-six patients were in the suture repair group, while 60 patients were in the mesh repair group. In the mesh repair group, 17% (10 patients) suffered a hernia repair related complication, compared to 8% (5 patients) in the suture repair group (P=0.17). Complications in the mesh repair group were: small bowel obstruction (7 patients), fistula from mesh to skin (3 patients), mesh infection (1 patient) and enterocutaneous fistula (2 patients). Complications in the suture repair group were: small bowel obstruction (3 patients), strangulated hernia (1 patient) and burst abdomen (1 patient). Of the 10 patients in the mesh repair group that had a complication that could be related to the hernia repair, 2 had undergone further surgery before the onset of the complication.

SUCCESSIVE INCISIONAL HERNIA REPAIR

In the suture repair group, 23 of 66 patients (35%) went through repair of a recurrence of an incisional hernia repair that was performed in the framework of the trial, while 7 of 60 (12%) of the mesh repair patients underwent a successive hernia repair (P=0.003).

PAIN

Twenty-seven percent of suture repair patients had experienced scar pain during the last month, compared to 20% of mesh repair patients (P=0.53). When asked whether they had experienced scar pain during the past years, 23% of suture repair patients and 20% of mesh repair patients answered affirmatively (P=0.83). In a visual analogue scale (VAS), suture repair patients rated their scar pain during the past month as 1.17, while patients in the mesh repair group rated the pain as 1.12 (P=0.68). Patients in the suture repair group rated their scar pain

during the last years as 1.30 on average, while patients in the mesh repair group rated the pain as 1.12 (P=0.75).

Thirty-six percent of suture repair patients had experienced abdominal pain during the last month, compared to 20% of patients with mesh repair (P=0.05). When asked whether they had experienced abdominal pain in the years after incisional hernia repair, 39% of suture repair patients and 18% of mesh repair patients answered affirmatively (P=0.01). In a visual analogue scale, suture repair patients rated their abdominal pain during the past month as 1.9 on average, while patients in the mesh repair group rated the pain as 1.0 (P=0.04). Patients in the suture repair group rated their abdominal pain in the last years as 2.2 on average, while patients in the mesh repair group rated the abdominal pain during the past years as 1.0 (P=0.009).

COSMETICS

Forty-seven percent of suture repair patients and 52% of mesh repair patients were satisfied with the way their abdomen looked (P=0.86). Patients were asked to score the cosmetic result on a visual analogue scale, in which 0 meant the worst possible result and 10 the best possible result. Both suture repair and mesh repair patients rated the cosmetic appearance as 6.0 (P=0.70). Twenty-four percent of suture repair patients and 20% of mesh repair patients was ashamed of the appearance of their abdomen (P=0.52). Whenever patients answered that their abdomen looked bad, asymmetry of the abdomen was the most frequent objection, which was the same in both groups. Other frequent complaints were a disfiguring scar and bulging, often representing a recurrent hernia.

SATISFACTION

Patients were asked to take into consideration all possible positive and negative effects of the incisional hernia repair and state whether they were satisfied with the procedure or not. In the suture repair group, 64% was satisfied, while in the mesh repair group, 77% was satisfied (P=0.12). When patients were asked why they were dissatisfied, most patients answered that they had suffered a recurrence. Other reasons were scar and abdominal pain and a disappointing cosmetic result.

DISCUSSION

Our study provides evidence that in the long-term mesh repair of incisional hernia is superior to suture repair. Recurrence is more frequent after suture repair, while the incidence of hernia repair related complications, scar pain, cosmetic result and patient satisfaction is comparable for both groups. Two findings in particular are new and important. Firstly, the incidence and

intensity of abdominal pain are lower after mesh repair than after suture repair. Secondly, recurrence of incisional hernia continues to occur up to 10 years after hernia repair.

The current study established that the recurrence rate after suture repair of incisional hernia rises to an unacceptable level 10 years after surgery (63%). Although the results of mesh repair are disappointing as well, its recurrence rate is approximately half of the recurrence rate after suture repair. For small incisional hernias (≤10 cm^2), the difference was even more outspoken. Not only did mesh repair patients suffer fewer recurrences than suture repair patients, they also underwent fewer successive repairs of a recurrence. Remarkably, recurrence continues to occur up to ten years after incisional hernia repair, also after mesh repair. It is therefore likely that recurrence rates are generally underestimated, because most studies are either not prospective or do not include long-term follow-up. Our results show that long-term follow-up is mandatory in any study dealing with recurrence after incisional hernia repair.

Comparison of our data with the results of others is troublesome, because of the lack of randomized controlled trials. In 2001, Korenkov et al published the results of a randomized controlled trial of incisional hernia repair. Korenkov concluded that suture repair of incisional hernia was safe and did not result in higher recurrence rates. However, the trial was discontinued due to the severity of mesh infections. In our study, we encountered only few mesh infections (incidence 3.7%) and the course of these infections was mild. In 2001, Arroyo et al published a randomized controlled trail on umbilical hernia repair. Although umbilical hernia may differ from incisional hernia etiologically, treatment modalities for ventral hernia repair are similar and results may therefore be compared. In line with our results, Arroyo reported that even for small umbilical hernias, mesh repair results in significantly fewer recurrences than suture repair[28].

Mesh repair of incisional hernia has been associated with complications, such as enterocutaneous fistula and small bowel obstruction. In our study, we found no significant difference in the incidence of complications. In a study by Leber et al, the incidence of small bowel obstruction following mesh repair of incisional hernia was 5.4%[29], which compares well to our 11.7%. The incidence of enterocutaneous fistula following mesh repair of incisional hernia is thought to be low[30]. Leber reported a 3.5% incidence of enterocutaneous fistula and a 5.9% incidence of mesh to skin fistulas. In the current study, 5% of patients developed a fistula from mesh to skin (sinus tract), while 3% developed an enterocutaneous fistula. Although numbers were too small to reach significance, we believe that the importance of this finding is determined by the severity of the complication. On the other hand, others have reported the intra-abdominal use of meshes to be safe[31]. Moreover, the occurrence of burst abdomen and strangulated hernia in the suture repair group may equal the enterocutaneous fistulas in complication severity.

Because physical complaints are an important reason for performing incisional hernia repair, any analysis of incisional hernia repair should include discomfort. Others have suggested that up to 50% of patients having undergone mesh repair of an incisional hernia developed complaints, because of a reduced mobility of the abdominal wall[20,32]. Our study does not reveal any difference in scar or superficial pain between mesh and suture repair patients. Moreover, abdominal pain was less frequent (18 vs. 39%) and less intense in patients having undergone mesh repair. We think that discomfort following incisional hernia repair is caused by tension on the abdominal wall and that the relative decrease in pain after mesh repair may be caused by the tension-free technique that is applied in mesh repair, but not in suture repair.

Cosmetics too may play a key role in the patient's wish to have an incisional hernia repaired. Remarkably, in our study, only 47-52% of patients considered the cosmetic result satisfactory. It is important for surgeons to be aware of this general discontent among incisional hernia repair patients. Adequate information preoperatively may result in some patients refraining from incisional hernia repair.

In conclusion, our study is the first and only to provide prospective long-term follow-up of incisional hernia repair. It proves that mesh repair is superior to suture repair for both small and large incisional hernias. Mesh repair results in lower recurrence rates and less discomfort in the long term, while mesh repair is not associated with an increased incidence of complications. We conclude that to reduce the morbidity and the costs associated with incisional hernia repair and to prevent patients from undergoing pointless surgery, suture repair of incisional hernia should be completely abandoned.

REFERENCES

1. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
2. Lewis RT, Wiegand FM. Natural history of vertical abdominal parietal closure: Prolene versus Dexon. Can J Surg 1989; 32(3):196-200.
3. Sugerman HJ, Kellum JM, Jr., Reines HD, et al. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. Am J Surg 1996; 171(1):80-4.
4. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
5. Hoer J, Lawong G, Klinge U, Schumpelick V. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg 2002; 73(5):474-80.
6. National Center for Health Statistics. Combined Surgery Data (NHDS and NSAS) Data Highlights. http://www.cdc.gov/nchs/about/major/hdasd/combtab.htm. 1996.
7. Franz MG, Kuhn MA, Nguyen K, et al. Transforming growth factor beta(2) lowers the incidence of incisional hernias. J Surg Res 2001; 97(2):109-16.
8. Prismant. Utrecht, the Netherlands: National Medical Registration; 2002.
9. DeMaria EJ, Moss JM, Sugerman HJ. Laparoscopic intraperitoneal polytetrafluoroethylene (PTFE) prosthetic patch repair of ventral hernia. Prospective comparison to open prefascial polypropylene mesh repair. Surg Endosc 2000; 14(4):326-9.
10. Read RC, Yoder G. Recent trends in the management of incisional herniation. Arch Surg 1989; 124(4):485-8.
11. Manninen MJ, Lavonius M, Perhoniemi VJ. Results of incisional hernia repair. A retrospective study of 172 unselected hernioplasties. Eur J Surg 1991; 157(1):29-31.
12. Paul A, Korenkov M, Peters S, et al. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. Eur J Surg 1998; 164(5):361-7.
13. Anthony T, Bergen PC, Kim LT, et al. Factors affecting recurrence following incisional herniorrhaphy. World J Surg 2000; 24(1):95-100;discussion 101.
14. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
15. Korenkov M, Sauerland S, Arndt M, et al. Randomized clinical trial of suture repair, polypropylene mesh or autodermal hernioplasty for incisional hernia. Br J Surg 2002; 89(1):50-6.
16. Luijendijk RW, Lemmen MH, Hop WC, Wereldsma JC. Incisional hernia recurrence following "vest-over-pants" or vertical Mayo repair of primary hernias of the midline. World J Surg 1997; 21(1):62-5; discussion 66.
17. van der Linden FT, van Vroonhoven TJ. Long-term results after surgical correction of incisional hernia. Neth J Surg 1988; 40(5):127-9.
18. Liakakos T, Karanikas I, Panagiotidis H, Dendrinos S. Use of Marlex mesh in the repair of recurrent incisional hernia. Br J Surg 1994; 81(2):248-9.
19. Langer I, Herzog U, Schuppisser JP, et al. [Preperitoneal prosthesis implantation in surgical management of recurrent inguinal hernia. Retrospective evaluation of our results 1989-1994]
Die praperitoneale Protheseneinlage zur operativen Versorgung der Rezidivleistenhernie. Retrospektive Beurteilung unserer Resultate von 1989-1994. Chirurg 1996; 67(4):394-402.
20. McLanahan D, King LT, Weems C, et al. Retrorectus prosthetic mesh repair of midline abdominal hernia. Am J Surg 1997; 173(5):445-9.
21. Park A, Birch DW, Lovrics P. Laparoscopic and open incisional hernia repair: a comparison study. Surgery 1998; 124(4):816-21; discussion 821-2.

22. Schumpelick V, Klosterhalfen B, Muller M, Klinge U. [Minimized polypropylene mesh for preperitoneal net plasty (PNP) of incisional hernias] Minimierte Polypropylen-Netze zur praperitonealen Netzplastik (PNP) der Narbenhernie. Eine prospektive randomisierte klinische Studie. Chirurg 1999; 70(4):422-30.
23. Toniato A, Pagetta C, Bernante P, et al. Incisional hernia treatment with progressive pneumoperitoneum and retromuscular prosthetic hernioplasty. Langenbecks Arch Surg 2002; 387(5-6): 246-8.
24. Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. Lancet 2003; 362(9395):1561-71.
25. Korenkov M, Paul A, Sauerland S, et al. Classification and surgical treatment of incisional hernia. Results of an experts' meeting. Langenbecks Arch Surg 2001; 386(1):65-73.
26. Paul A, Lefering R, Kohler L, Eypasch E. [Current practice of incisional hernia reconstruction in Germany] Gegenwartige Praxis der Narbenhernienrekonstruktion in der Bundesrepublik Deutschland. Zentralbl Chir 1997; 122(10):859-61.
27. Flum DR, Horvath K, Koepsell T. Have outcomes of incisional hernia repair improved with time? A population-based analysis. Ann Surg 2003; 237(1):129-35.
28. Arroyo A, Garcia P, Perez F, et al. Randomized clinical trial comparing suture and mesh repair of umbilical hernia in adults. Br J Surg 2001; 88(10):1321-3.
29. Leber GE, Garb JL, Alexander AI, Reed WP. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998; 133(4):378-82.
30. Morris-Stiff GJ, Hughes LE. The outcomes of nonabsorbable mesh placed within the abdominal cavity: literature review and clinical experience. J Am Coll Surg 1998; 186(3):352-67.
31. Vrijland WW, Jeekel J, Steyerberg EW, et al. Intraperitoneal polypropylene mesh repair of incisional hernia is not associated with enterocutaneous fistula. Br J Surg 2000; 87(3):348-52.
32. Welty G, Klinge U, Klosterhalfen B, et al. Functional impairment and complaints following incisional hernia repair with different polypropylene meshes. Hernia 2001; 5(3):142-7.

ORAL DISCUSSION

(123RD MEETING OF THE AMERICAN SURGICAL ASSOCIATION, SAN FRANCISCO, APRIL 2003)

Dr. Theodore N. Pappas (Durham, North Carolina): I think this is an important paper because it deals with a common disease. We are not talking about subspecialty care here; we are talking about something that impacts on almost every abdominal surgeon in the country.

The paper undoubtedly will be criticized—as most multicenter trials are—with respect to whether there was adequate standardization of the operation. There will be talk about the drop-out rate, the large number of patients who died, and the cross-over. But taking those criticisms into account, I think the data is still very compelling, because the differences in recurrence between mesh and suture repair are large, the differences are obvious, and, most importantly, there is a clinically important difference between the 2 groups. I have several questions.

Number one, it looked as though to me your recurrence rates dominate your other outcomes, which are satisfaction, pain, cosmetics. It is undoubtedly true that if a patient has a recurrence, that fact will impact on the other 3 endpoints. So did you do an analysis of the non-recurrent patients to see if in fact there were differences in those 3 endpoints? That might tell you more about satisfaction, pain, and cosmetics and not allow the recurrence to bias those endpoints.

You mention in your manuscript, although you didn't mention it today, that you used Vicryl mesh behind your prosthetic mesh in an effort to protect the bowel and avoid fistulization. Is there compelling data that we should be doing this? Do you have enough patients that you have analyzed that have allowed you to say convincingly that Vicryl mesh does protect from fistulization?

Could you tell us a little bit more about the relationship between size and recurrence? You did some analysis, but is there a linear relationship between size and recurrence? There are many people who believe that the size issue is in fact more important or at least as important as the type of repair.

Finally, do you have any experience with component separation? Component separation is a very commonly used technique, which allows to you avoid mesh but yields a tension-free repair.

Dr. J. W. A. Burger (Rotterdam, the Netherlands): The first question, did we look at patient satisfaction, abdominal pain and scar pain in patients that did not have a recurrence? We did not look at that specifically. We did, however, see that what you just hypothesized is correct. Patient satisfaction and abdominal pain are strongly related to incisional hernia recurrence. I can't tell you how it was in patients that did not suffer a recurrence.

The second question about the use of a Vicryl mesh between the polypropylene mesh and the bowels. We actually did not do that in many patients. We only did it if we could not close

the peritoneum and if that was not possible, if we could not position the omentum between mesh and bowels. At that point in 1991, we thought that Vicryl might prevent adhesion formation. By now we know from experimental studies that this is not the case and therefore, we are not using Vicryl for that purpose any more.

The third question was, do size and recurrence relate? According to our data, they do not; that is, not for suture repair. We looked at different size groups and studied whether the recurrence rate was dependent on the size of the hernia, and it was not. As I have shown earlier, we found that the recurrence rates of small incisional hernias, smaller than 10 cm^2, are still very high.

The fourth question was about the Ramirez component separation technique. Yes, we are looking into the Ramirez technique and mesh repair. At this moment, we are participating in a Dutch trial that will establish whether the use of a mesh should be incorporated in the Ramirez technique for additional strengthening of the abdominal wall. The Ramirez technique without mesh offers better results than just plain suture repair, but recurrence rates are still quite high.

Dr. Charles E. Lucas (Detroit, Michigan): No paper at this meeting highlights our total ignorance about the physiology of wound healing than does this paper. As world surgeons, we really have to look at the cause for this terrible problem, rather than discarding suture repair. We have to think of a physiologic solution and not a mechanical solution.

We know that smoking interferes with wound healing. Do you have any comparison between nicotine use in your 2 groups? Is there any investigation being done by your unit into the amount of collagen or elastin in the tissues of the patients that have recurrence versus those that don't have recurrence?

Dr. J. W. A. Burger (Rotterdam, the Netherlands): The first question was about smoking. In the current study we did not find that smoking was a risk factor for incisional hernia recurrence. We do, however, believe that it is.

Regarding your second question on collagen and elastin, we are definitely looking into that both experimentally and clinically. We are trying to identify patients who may have a connective tissue disorder associated with decreased collagen and elastin amounts. However, for obvious reasons, it was not possible to incorporate this in this update of this clinical trial.

Dr. Carlos A. Pellegrini (Seattle, Washington): Presumably this series included mostly patients repaired by the open technique and a lot of the recurrences seen in the mesh patients may have been due to infectious problems of the wound. In these days, as you know, many hernias like this, less than 6 centimeters, are treated with laparoscopic technique, which doesn't

involve opening any wounds. Do you have any comments on the role of laparoscopy and tension-free repair with mesh repair may do to these results?

Dr. J. W. A. Burger (Rotterdam, the Netherlands): All of our patients were operated on by the open technique. Regarding laparoscopy, to this moment, there are no large randomized trials proving that laparoscopy is either better or worse than the open technique. I personally feel that laparoscopy could be beneficial because the abdominal wall adjacent to the defect, where wound healing is bound to be poor, is left alone. However, there is no proof of that yet.

Dr. David W. Easter (San Diego, California): I actually like mesh. But I wonder if you have proven your point. I note you use 1 centimeter bites for your fascial closure with suture and at least a 2 centimeter overlap for your mesh. Haven't you proven that 1 centimeter bites are ineffective and that mesh doesn't matter?

Dr. J. W. A. Burger (Rotterdam, the Netherlands): Regarding the suture technique and how we placed the sutures at 1 centimeter intervals and at least 1 centimeter from the wound edge: we applied the rules of Jenkins and Israelsson, who reported that we have to suture with a suture to wound length ratio of at least 4 to 1. That is how we did it.

Regarding the overlap of the mesh. Two centimeters may actually be too little. We think we may have lower recurrence rates if we increase the overlap of the mesh, and nowadays we do.

Dr. Josef E. Fischer (Boston, Massachusetts): Your conclusions are really recurrence based. But you also have a difference in complications, which perhaps if you had 150 more patients in each group and with the same rate of complications that would have been a statistically significant difference.

Now, if you look at the difference of complications, as you well know, some of them are pretty serious complications, such as mesh erosion in the bowel, which is getting to be an increasing problem, which I see a fair number of those patients. Have you looked at the cost, the long-term cost of the differences between the two groups? Because it doesn't take too many mesh bowel fistulas to give a very substantial difference in outcome if one is looking at cost.

Dr. J. W. A. Burger (Rotterdam, the Netherlands): Regarding your first question about the number of complications, the trial was not meant to look at complications as a primary endpoint, so, unfortunately, the number of patients may be too low to prove significant differences. We will never know until a new trial, which studies complications prospectively, is presented.

Regarding the severity of the complications and the costs, we have not looked at the cost specifically, which is quite difficult retrospectively. Enterocutaneous fistulas are severe com-

plications, but so were the burst abdomen and the strangulated hernia in the suture repair group. Furthermore, we looked at the number of reoperations in both groups, and we found that only 12% of mesh repair patients had undergone subsequent hernia repair, compared to 35% of suture repair patients. So costs are made here as well. Moreover, most of the suture repair patients got a mesh repair the second time.

Dr. Stephen J. Mathes (San Francisco, California): I appreciate your paper and especially your long-term follow-up. My question relates to several areas.

One question relates to the geography of the incisional hernia and recurrence rates. Were more of those in the midline or were some of those recurrences occurring laterally or in proximity to the inguinal region? In those instances, can you describe how you handled the repair where there was no fascia available? For instance, did you attach into bone or into the costal margin?

Second, in our review of our experience to this group several years ago, we found that there was a difference in how you had to manage patients depending on their skin stability or skin coverage over the hernia. And I wondered if you might comment: Was there a group of patients who didn't have stable skin or presented with radiated abdominal walls? Did that make a difference in your recurrence rate whether you used mesh or the suture technique?

Dr. J. W. A. Burger (Rotterdam, the Netherlands): Regarding location of the hernia, they were all midline incisional hernias, and recurrence was defined as a recurrence within 7 centimeters of the original location of the hernia. We did not encounter problems with fascia in the pubic region or in the costal region and I cannot answer the question how we would have done it had it occurred. We did not encounter skin problems either. I think this is because we included small incisional hernias, smaller than 6 centimeters in diameter.

Dr. Lawrence W. Way (San Francisco, California): My question is really very similar to Dr. Fischer's question. But leaving cost aside, it seems to me that you need to take into account all of your outcomes and not focus entirely or so heavily on the recurrence rate, because these enterocutaneous fistulas are really a major problem and they don't seem to be as common in the suture closures. We have a steady stream of these patients. And the morbidity is really huge.

And the ultimate question is, how many recurrences equal one enterocutaneous fistula? You can subjectively or in some way or another weight these various outcomes and recalculate your feelings about the 2 operations. I would say that another cutaneous fistula with infection and all the terrible difficulty in fixing it equals about 10 recurrences, in my view. If you have a sprinkling of those throughout, you really have to think about it.

Dr. J. W. A. Burger (Rotterdam, the Netherlands): What I can say about that is that I know of the possible effects of enterocutaneous fistulas. In our 2 patients, the course was not so dramatic.

However, if we are talking about one enterocutaneous fistula equating many recurrences, taking recurrence for granted, we should keep in mind that an operation which results in almost 70% recurrence is not a good operation, whatever the alternative may be. If you do not want to perform mesh repair, that does not necessarily mean you should perform suture repair, because we now know that recurrence rates are incredibly high.

Dr. Haile T. Debas (San Francisco, California): Dr. Burger, this is one comment you don't have to answer. I just rise to make a short and obvious comment on the 4 papers presented this morning. They are all double-blind prospective clinical trials. As such, this morning's papers present something of a watershed. We have arrived in the era of evidence-based surgical practice. And I want to congratulate the committee.

Dr. R. Scott Jones (Charlottesville, Virginia): I would like to make a comment about this presentation and discussion, and I want to extend congratulations to the presenter, Dr. Burger, who did the best presentation I think I have ever heard and he handled the questions from a tough bunch of people better than I could possible have imagined. And you have really made my day. Thank you.

9 | Evaluation of New Prosthetic Meshes for Ventral Hernia Repair

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Surgical Endoscopy, in press.

ABSTRACT

BACKGROUND

In hernia repair and in laparoscopic hernia repair in particular, direct contact between mesh and abdominal organs cannot always be avoided. Several mesh materials and composite meshes have been developed to decrease subsequent adhesion formation. Recently, new meshes were introduced. In an experimental rat study, their value was established and compared to meshes already available on the market.

METHODS

In 200 rats, 8 different meshes were placed intraperitoneally and in direct contact with abdominal viscera. The following meshes were tested: polypropylene (Prolene), e-PTFE (Dualmesh), polypropylene-polyglecaprone composite (Ultrapro), titanium-polypropylene composite (Timesh), polypropylene with carboxymethylcellulose-sodium hyaluronate coating (Sepramesh), polyester with collagen-polyethylene glycol – glycerol coating (Parietex Composite), polypropylene-polydioxanone composite with oxidized cellulose coating (Proceed) and bovine pericardium (Tutomesh). At 7 and at 30 days postoperatively, adhesion formation, mesh incorporation, tensile strength, shrinkage and infection were scored by two independent observers.

RESULTS

Parietex Composite, Sepramesh and Tutomesh resulted in decreased surface coverage with adhesions, while Prolene, Dualmesh, Ultrapro, Timesh and Proceed resulted in increased adhesion coverage. Parietex Composite, Prolene, Ultrapro and Sepramesh resulted in the most mesh incorporation. Dualmesh and Tutomesh resulted in significantly increased shrinkage. There were no differences in mesh infection. Parietex Composite and Dualmesh resulted in a moderate inflammatory reaction, compared to a mild reaction in the other meshes.

CONCLUSION

Parietex Composite and Sepramesh combine minimal adhesion formation with maximum mesh incorporation and tensile strength. We recommend use of these meshes for hernia repair in which direct contact with the abdominal viscera cannot be avoided.

INTRODUCTION

Incisional hernia is a frequent complication of abdominal surgery with an incidence of 2-20%[1-5]. In the United States, 4 to 5 million laparotomies are performed annually[6], which implies that at least 400,000–500,000 incisional hernias develop each year. Incisional hernia repair is performed approximately 200,000 times per year[7]. In the Netherlands, 100,000 laparotomies and 3,900 incisional hernia repairs are performed annually (data obtained from Prismant[8]). These data imply that in both countries, and probably in general, 4% of patients undergoing a laparotomy will undergo subsequent incisional hernia repair.

Incisional hernia repair can be performed either by primary closure, in which case the defect in the abdominal wall is closed by suturing the edges of the defect in the abdominal wall together, or by mesh repair, in which case a prosthetic mesh is implanted. Recent results from a randomized-controlled trial prove that the use of a prosthetic mesh for hernia repair results in a reduction of the hernia recurrence rate[9,10]. In prosthetic mesh hernia repair, direct contact between mesh and abdominal viscera cannot always be avoided. Moreover, direct contact is inherent to laparoscopic hernia repair, which became more popular in recent years, because it may result in a decreased incidence of postoperative complications and a shorter hospital stay[11]. However, contact of abdominal viscera with foreign material, such as prosthetic mesh, may lead to an inflammatory response and adhesion formation[12,13]. Inflammation and adhesion formation can induce chronic pain [14-16], intestinal obstruction[14,17-19], infertility[15,20] and enterocutaneous fistulas[21,22]. In addition, adhesions can complicate future surgery[23].

Currently, the most commonly used mesh is made of polypropylene. It is relatively inexpensive, easy to handle and well incorporated in the abdominal wall. Polypropylene may however cause significant adhesion formation. New meshes were developed as an alternative for polypropylene. Important developments were the introduction of expanded polytetrafluoroethylene and composite meshes that carry an anti-adhesive barrier on the visceral side of the mesh. However, these meshes did not provide a final solution, because a reduction of adhesion formation was often associated with a reduction of mesh incorporation or an increase in susceptibility to infection. Recently, new meshes were introduced. Their value has not yet been established.

The purpose of our study was to determine whether four newly introduced meshes are able to combine a decrease in adhesion formation with adequate mesh incorporation, high tensile strength and low susceptibility to infection. Furthermore, we wanted to establish whether the new meshes are an improvement compared to meshes already available. In a rat experimental study, adhesion formation, tensile strength, shrinkage, infection rate and tissue response were studied and compared after 7 and 30 days.

MATERIALS AND METHODS

STUDY DESIGN

Male Wistar rats were divided into two groups: A and B. Groups A and B were subdivided into eight groups corresponding with the eight meshes that were tested. After the animals were humanely killed (group A after 7 days, group B after 30 days), adhesion formation, mesh incorporation, tensile strength, shrinkage, mesh infection and tissue response were scored and compared. The number of animals needed in each group was established using a power analysis. To be able to establish differences deemed significant, in group A 10 animals were needed per mesh, while in group B 15 animals were needed per mesh. Therefore, group A contained 80 animals, while group B contained 120 animals.

ANIMALS STUDIED

Male inbred rats of the Wistar strain, weighing 300-350 grams, were obtained from Harlan, Zeist, the Netherlands. They were bred under specific pathogen free conditions, kept under standard laboratory conditions (temperature 20-24°C, relative humidity 50-60%, 12h light/12h dark) and were fed with standard rat chow (Hope farms, Woerden, the Netherlands) and water ad libitum (pH 4.2-4.7). The experiment adhered to the rules of the Dutch Animal Experimentation Act and was approved by the animal experimentation ethics committee (DEC-consult).

TABLE 1. Meshes included in the experiment

Material	Brand name	Manufacturer
Polypropylene	Prolene	Ethicon, Inc., Somerville, NJ, USA
Expanded Polytetrafluoroethylene	DualMesh	W.L. Gore & Associates, Inc., Flagstaff, AZ, USA
Polypropylene-Polyglecaprone Composite	Ultrapro	Ethicon inc., Somerville, NJ, USA
Polyester with Collagen-Polyethylene Glycol – Glycerol Coating	Parietex Composite	Sofradim, Trévoux, France
Polypropylene with Carboxymethylcellulose-Sodium Hyaluronate Coating	SepraMesh	Genzyme Biosurgery, Inc., Cambridge, MA, USA
Titanium-Polypropylene Composite	Ti-mesh	GfE Medizintechnik GmbH, Nürnberg, Germany
Bovine Pericardium	TutoMesh	Tutogen Medical GmbH, Neunkirchen a. Br., Germany
Polypropylene-Polydioxanone Composite with Oxidized Cellulose Coating	Proceed	Ethicon, Inc., Somerville, NJ, USA

MATERIALS

Table 1 presents the materials and the brand names of the eight meshes tested. Monofilament polypropylene 5-0 sutures were used for mesh fixation and closure of the abdominal wall. Multifilament polyglyconate 5-0 sutures were used for closure of the skin.

PROCEDURE

The experiment was performed under aseptic conditions, using a modification of a validated rat-model, previously described by Alponat and Hooker[24,25]. At the start of the experiment the animals were anesthetized using isoflurane/N2/O2 inhalation and buprenorfin analgesia (0.05 mg/kg subcutaneously). The abdomen was shaved and cleaned with alcohol 70%, after which a midline skin incision of 5 cm was made and skin flaps were raised. Subsequently, the abdominal cavity was opened with a 4 cm midline incision through the linea alba. A sterile mesh, measuring 2.5 x 3.5 cm, was placed in a sublay position (intraperitoneally) and fixated transmuscularly with 6 sutures (polypropylene 5-0). The abdominal wall was closed over the mesh with a running 5-0 polypropylene suture. The skin was closed with a running 5-0 polyglyconate suture.

MEASUREMENTS

ADHESION FORMATION

After 7 (group A) or 30 days (group B) the animals were anesthetized and killed by cardiac incision. The ventral abdominal wall was removed through a full thickness incision (including skin) around the mesh. Adhesions were cut and the abdominal wall, including mesh, was removed. Two independent observers assessed adhesion coverage of the surface of the mesh, using a scoring system. A grid was placed over the mesh, dividing it into 24 equal squares, facilitating accurate estimation of adhesion formation. In case of inter-observer variance, the mean was scored.

INCORPORATION

The edge of the mesh was divided into twenty equal stretches. Mesh incorporation was defined as the percentage of the edge of the mesh that was incorporated in the abdominal wall. Incorporation was scored by two independent observers. In case of inter-observer variance, the mean was scored.

TENSILE STRENGTH

The tensile strength of the tissue that adhered to and incorporated the mesh was measured on a dynamometer. Half of the mesh was freed from the abdominal wall, while the other half of the mesh remained attached to the abdominal wall. The first half of the mesh, which was

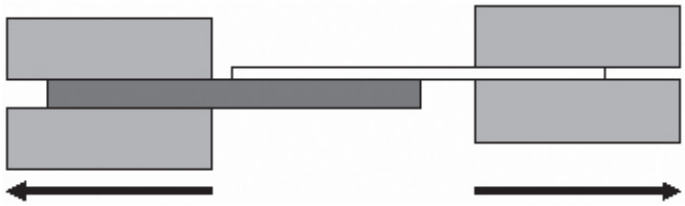

FIGURE 1. Model used to measure tensile strength on dynamometer.

freed from tissue, was fixed in a clamp. The abdominal wall lateral to the second half of the mesh, which was still attached to the abdominal wall, was fixed in a second clamp (figure 1). The mesh was pulled from the abdominal wall at a continuous rate of 100 mm/min. The maximum force (N) required to release the mesh from the abdominal wall was recorded.

MESH SHRINKAGE

Mesh shrinkage was defined as the projection of mesh surface and was measured with a caliper by two independent observers. By measuring projection, curling and wrinkling of the mesh were included in addition to actual shrinkage of the mesh. Shrinkage was defined as the relative loss of surface compared to the original size of the mesh (%).

MESH INFECTION

Mesh infection was defined as the presence of pus or infected seroma at the time of sacrifice. Cultures were taken only when these symptoms of overt infection were present

TISSUE RESPONSE

Of each group, two meshes with adjacent abdominal wall were fixed in 10% neutral buffered formalin. After routine tissue processing, sections were cut and stained with haematoxylin & eosin. Sections were microscopically studied at a 250x magnification. The degree of inflammation was scored using a grading scale. Grade 1 represents mild inflammatory reaction with giant cells, occasional lymphocytes and plasma cells. Grade 2 represents moderate reaction with giant cells and increased numbers of admixed lymphocytes, plasma cells, eosinophils and neutrophils. Grade 3 represents severe inflammatory reactions with micro-abscesses.

STATISTICAL ANALYSIS

The incidence of direct bowel adhesions and mesh infection was compared using Fisher's exact test. Comparison of adhesion formation, incorporation, tensile strength and shrinkage was compared using a one-way ANOVA, after a normal distribution and homogeneity were ascertained. A p-value smaller than 0.05 was considered significant. Statistical analysis was performed using SPSS statistical software package (SPSS®, Chicago, Illinois, USA).

RESULTS

During the procedure, one rat in the Prolene group (7 days) and one rat in the Proceed group (30 days) died. The cause of death was probably anesthesia related. During the postoperative period one rat from the Ultrapro group (30 days) died. Autopsy did not reveal the cause of death.

ADHESIONS

At seven days, Tutomesh resulted in the smallest percentage of mesh surface covered with adhesions (2.4%). Tutomesh resulted in significantly less adhesion formation than all other meshes, except Parietex Composite (3.9%). Other meshes that showed a decrease in adhesion formation were Sepramesh (25.2%) and Proceed (33.6%). Prolene, Dualmesh, Ultrapro and Timesh showed extensive adhesion formation 7 days postoperatively (table 2).

TABLE 2. Adhesion coverage of mesh surface at day 7 (%). Comparison of meshes and associated p-values.

	Coverage (%)	Prolene	Dual-Mesh	Ultrapro	Parietex Comp.	Sepra-Mesh	Ti-mesh	Tuto-Mesh	Proceed
Prolene	55.2	-	1	1	<0.001	0.002	1	<0.001	0.081
DualMesh	66.3	1	-	1	<0.001	<0.001	1	<0.001	0.001
Ultrapro	57.9	1	1	-	<0.001	<0.001	1	<0.001	0.019
Parietex Composite	3.9	<0.001	<0.001	<0.001	-	0.094	<0.001	1	0.001
SepraMesh	25.2	0.002	<0.001	<0.001	0.094	-	<0.001	0.049	1
Ti-mesh	60.3	1	1	1	<0.001	<0.001	-	<0.001	0.006
TutoMesh	2.4	<0.001	<0.001	<0.001	1	0.049	<0.001	-	0.001
Proceed	33.6	0.081	0.001	0.019	0.001	1	0.006	0.001	-

At 30 days, Tutomesh showed the least adhesions formation (4.4%). There was no significant difference between Tutomesh, Parietex Composite (11.2%) and Sepramesh (10.4%). Most adhesions were seen in the Prolene group (54.1%). However, there was no significant difference between Prolene, Ultrapro (45.2%), Timesh (44.5%) and Proceed (38.5%) (table 3).

TABLE 3. Adhesion coverage of mesh surface at day 30 (%). Comparison of meshes and associated p-values.

	Coverage (%)	Prolene	Dual-Mesh	Ultrapro	Parietex Comp.	Sepra-Mesh	Ti-mesh	Tuto-Mesh	Proceed
Prolene	54.1	-	0.009	1	<0.001	<0.001	1	<0.001	0.567
DualMesh	29.3	0.009	-	0.585	0.260	0.160	0.687	0.009	1
Ultrapro	45.2	1	0.585	-	<0.001	<0.001	1	<0.001	1
Parietex Composite	11.2	<0.001	0.260	<0.001	-	1	<0.001	1	0.002
SepraMesh	10.4	<0.001	0.160	<0.001	1	-	<0.001	1	0.001
Ti-mesh	44.5	1	0.687	1	<0.001	<0.001	-	<0.001	1
TutoMesh	4.4	<0.001	0.009	<0.001	1	1	<0.001	-	<0.001
Proceed	38.5	0.567	1	1	0.002	0.001	1	<0.001	-

MESH INCORPORATION

At 7 days, the percentage of mesh edge incorporated was highest for Parietex Composite (75%). Dualmesh (29%, p<0.001), Timesh (34%, p<0.001) and Tutomesh (2%, p<0.001) showed significantly less incorporation, while there was no significant difference between Parietex Composite (75%), Prolene (60%), Ultrapro (56%), Sepramesh (54%) and Proceed (49%) (further data not shown). At 30 days, Parietex Composite still showed the most incorporation, although this percentage had decreased to 49.8%. There was no significant difference be-

TABLE 4. Incorporation of mesh edge at 30 days (%). Comparison of meshes and associated p-values.

	Incorporation (%)	Prolene	Dual-Mesh	Ultra-pro	Parietex Comp.	Sepra-Mesh	Ti-mesh	Tuto-Mesh	Proceed
Prolene	34.7	-	1	1	0.354	1	1	<0.001	1
DualMesh	24.3	1	-	1	0.001	0.048	1	0.115	1
Ultrapro	34.7	1	1	-	.423	1	1	<0.001	1
Parietex Composite	49.8	0.354	0.001	0.423	-	1	0.004	<0.001	0.027
SepraMesh	43.3	1	0.048	1	1	-	0.115	<0.001	0.583
Ti-mesh	26	1	1	1	0.004	0.115	-	0.048	1
TutoMesh	7	<0.001	0.115	<0.001	<0.001	<0.001	0.048	-	0.005
Proceed	29.7	1	1	1	0.027	0.583	1	0.005	-

tween Parietex Composite, Prolene, Ultrapro and Sepramesh. Dualmesh, Timesh, Tutomesh and Proceed showed significantly less incorporation (table 4).

TENSILE STRENGTH

At 7 days, the highest tensile strength was seen in the Prolene group (11.7N). However, there were no significant differences between the meshes. At 30 days, Parietex Composite showed the highest tensile strength (14.2N), but there were no significant differences with Prolene (11.9N), Ultrapro (12N), Sepramesh (13.4N), Timesh (10.2N) and Proceed (11.8N). Only Dualmesh (6.2N, $p=0.035$) and Tutomesh (2.8N, $P<0.001$), showed significantly lower tensile strength (further data not shown).

SHRINKAGE

Ultrapro showed the least loss of mesh surface at 7 days (1.52%). There were few significant differences between most groups: only Dualmesh (45.9%) and Tutomesh (16%) showed significantly more shrinkage than all other meshes. At 30 days, Sepramesh showed the least shrinkage (7%), but this was not significantly different from that in Prolene (11.3%), Ultrapro (11.7%), Parietex Composite 15.3%), Timesh (16.9%) and Proceed (13.1%). Only Tutomesh (44.3%, $p<0.001$) and Dualmesh (44.2%, $p<0.001$) resulted in significantly more shrinkage than all other meshes (further data and p-values not shown for reasons of conciseness).

TISSUE RESPONSE

Histological evaluation of the meshes showed a grade 1, mild foreign body reaction to almost all meshes with limited numbers of giant cells and lymphocytes present. Only Dualmesh and Parietex Composite elicited grade 2 responses, with numerous giant cells. For Parietex Composite, this reaction was located at the abdominal wall side of the mesh and not at the visceral side.

INFECTION

Mesh infection was a rare occasion. Only one infection was observed, in a Sepramesh rat (30 days) (NS). Non-infected seromas were found in 4 Proceed animals and 2 Timesh animals.

DISCUSSION

Our study shows that Parietex Composite and Sepramesh currently are the best options for open hernia repair in which contact with abdominal viscera cannot be avoided and for laparoscopic hernia repair. This is evidenced by our results that showed that both meshes resulted in a significant decrease in adhesion formation and increased mesh incorporation and tensile strength. Furthermore, both meshes did not result in increased shrinkage or susceptibility to

infection. Two new meshes that were specifically designed for intraperitoneal use and were introduced recently, did not show a decrease in adhesion formation or increased incorporation and tensile strength. Therefore, these two meshes do not seem to provide an improvement to meshes already available.

The most surprising result of the current study is the disappointing performance of several meshes that were specifically designed for intraperitoneal use (Dualmesh, Timesh, Proceed). Several studies reported a decrease in adhesion formation after use of these meshes [26-31]. However, other results are in line with ours [32,33]. Why the performance of Dualmesh and Timesh compares poorly with that in other reports cannot be concluded from this study. However, the current study was performed using a validated model and the study-size compared well with similar studies. Furthermore, no adverse events were encountered during the experiment.

The ideal design of a mesh that prevents adhesion formation and promotes incorporation and tensile strength probably complies with basic rules. The visceral side of the mesh should be smooth, non-erosive, anti-adhesive and should not be easily susceptible to infection. This visceral barrier should be present for at least one week, because this is the timeframe in which adhesion formation takes place[34]. The ventral side of the mesh should be macroporous, allowing for fibroblast ingrowth, while a foreign body reaction may actually be necessary for incorporation and high tensile strength. Continued severe inflammation on the other hand may actually decrease mesh incorporation and tensile strength[35].

Of those meshes studied, Prolene and Ultrapro meet the fewest requirements. Although the results for both meshes serve as control only in this study, they confirm that intraperitoneal placement of these meshes results in increased adhesion formation. However, neither of both meshes was designed for intraperitoneal use and high tensile strength and extensive tissue incorporation were confirmed. Moreover, mesh shrinkage was negligible and no mesh infection was seen. Dualmesh has been reported to prevent adhesion formation, mainly because of its smooth visceral surface[30]. This could not be confirmed in the current study. We hypothesize that the material e-PTFE results in adhesion formation, despite a non-erosive microporous surface. Furthermore, the macroporous ventral side of the mesh, which is designed to initiate incorporation, did not succeed in doing so. Shrinkage and curling of the mesh were extensive and were probably caused by extensive adhesion formation. The pronounced foreign body reaction to e-PTFE, which has been described previously, may be the cause of both adhesion formation and shrinkage[27,36]. Parietex Composite's collagen coating and Sepramesh's cellulose-hyaluronate coating appear to be effective adhesion barriers. While these barriers are absorbed within several weeks, both meshes showed minimal adhesion formation at 30 days post operation. Parietex Composite and Sepramesh also scored well

with regard to incorporation and tensile strength, while there was no increased incidence of infection. Timesh was designed specifically for intraperitoneal use, but did not perform well in the current study. Timesh is a composite mesh in which polypropylene is coated with inert titanium. The fact that there was extensive adhesion formation after implantation of Timesh suggests that the inertness of the mesh material is of less importance in adhesion formation than the macrostructure of the mesh. In the case of Timesh, the macrostructure is rough and macroporous. This erosive structure is probably what causes adhesion formation. Tutomesh has an impressive anti-adhesive capability, which is probably caused by both a smooth surface and very mild foreign body reaction. However, these properties result in the near absence of incorporation and low tensile strength. Proceed composite has a smooth surface designed to prevent adhesion formation. However, it is less smooth than that of other composite meshes with anti-adhesive barriers. Furthermore, the barrier applied is oxidized cellulose, which may not prevent mesh adhesions as effectively as anticipated, as was reported previously[37]

All meshes were evaluated after 7 days and after 30 days after implantation. The reason for this dual assessment was the fact that these two time points represent different phases of wound healing. At 7 days, the inflammatory phase has just ended and the proliferative phase has just started. According to Baptista et al, all adhesions have formed now[34]. After 30 days, the proliferative phase has ended and the remodeling phase has started. It is to be expected that neoperitoneum has formed and has covered the prosthetic material. Our results show that in general the number of adhesions decreased at 30 days compared to 7 days. Parietex was an exception. The slight increase in adhesion formation may be caused by the absorption of the collagen film on the visceral side. This, however, contradicts Baptista's assumption that all adhesions form within seven days. The tensile strength was recorded as a comparative measure and reflects tissue incorporation, tissue response and remodeling of the tissue response. Although the remodeling phase, and therefore collagen formation, has only just begun at 30 days post surgery, a small effect is already discernable, resulting in increased tensile strength at 30 days compared to 7 days. Shrinkage was more pronounced after 30 days compared to 7 days and was probably caused by contraction, inherent to the proliferative wound healing phase.

We conclude that several of the meshes that are currently available perform well with regard to tissue incorporation, tensile strength, mesh shrinkage and mesh infection. Our study identifies two meshes that combine these beneficial properties with decreased adhesion formation. We therefore recommend use of these meshes, either Parietex Composite or Sepramesh, when the mesh is placed in direct contact with the abdominal viscera.

REFERENCES

1. Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. Br J Surg 1985; 72(1):70-1.
2. Lewis RT, Wiegand FM. Natural history of vertical abdominal parietal closure: Prolene versus Dexon. Can J Surg 1989; 32(3):196-200.
3. Sugerman HJ, Kellum JM, Jr., Reines HD, et al. Greater risk of incisional hernia with morbidly obese than steroid-dependent patients and low recurrence with prefascial polypropylene mesh. Am J Surg 1996; 171(1):80-4.
4. Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. Ann Surg 2000; 231(3):436-42.
5. Hoer J, Lawong G, Klinge U, et al. [Factors influencing the development of incisional hernia. A retrospective study of 2,983 laparotomy patients over a period of 10 years]. Chirurg 2002; 73(5):474-80.
6. National Center for Health Statistics. Combined Surgery Data (NHDS and NSAS) Data Highlights. http://www.cdc.gov/nchs/about/major/hdasd/combtab.htm. 1996.
7. Franz MG, Kuhn MA, Nguyen K, et al. Transforming growth factor beta(2) lowers the incidence of incisional hernias. J Surg Res 2001; 97(2):109-16.
8. Prismant. Utrecht, the Netherlands: National Medical Registration; 2002.
9. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
10. Burger JW, Luijendijk RW, Hop WC, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004; 240(4):578-83; discussion 583-5.
11. Goodney PP, Birkmeyer CM, Birkmeyer JD. Short-term outcomes of laparoscopic and open ventral hernia repair: a meta-analysis. Arch Surg 2002; 137(10):1161-5.
12. Law NH, Ellis H. Adhesion formation and peritoneal healing on prosthetic materials. Clinical Materials 1988; 3:95-101.
13. Luijendijk RW, de Lange DC, Wauters CC, et al. Foreign material in postoperative adhesions. Ann Surg 1996; 223(3):242-8.
14. Monk BJ, Berman ML, Montz FJ. Adhesions after extensive gynecologic surgery: clinical significance, etiology, and prevention. Am J Obstet Gynecol 1994; 170(5 Pt 1):1396-403.
15. diZerega GS. Biochemical events in peritoneal tissue repair. Eur J Surg Suppl 1997(577):10-6.
16. Duffy DM, diZerega GS. Adhesion controversies: pelvic pain as a cause of adhesions, crystalloids in preventing them. J Reprod Med 1996; 41(1):19-26.
17. Ellis H. The clinical significance of adhesions: focus on intestinal obstruction. Eur J Surg Suppl 1997(577):5-9.
18. Menzies D, Ellis H. Intestinal obstruction from adhesions--how big is the problem? Ann R Coll Surg Engl 1990; 72(1):60-3.
19. Menzies D. Postoperative adhesions: their treatment and relevance in clinical practice. Ann R Coll Surg Engl 1993; 75(3):147-53.
20. Drollette CM, Badawy SZ. Pathophysiology of pelvic adhesions. Modern trends in preventing infertility. J Reprod Med 1992; 37(2):107-21; discussion 121-2.
21. Leber GE, Garb JL, Alexander AI, et al. Long-term complications associated with prosthetic repair of incisional hernias. Arch Surg 1998; 133(4):378-82.
22. Bageacu S, Blanc P, Breton C, et al. Laparoscopic repair of incisional hernia: a retrospective study of 159 patients. Surg Endosc 2002; 16(2):345-8.
23. Suslavich FJ, Turner NA, King PS, et al. Intraabdominal adhesions: intraoperative US. Radiology 1989; 172(2):387-8.
24. Alponat A, Lakshminarasappa SR, Yavuz N, et al. Prevention of adhesions by Seprafilm, an absorbable adhesion barrier: an incisional hernia model in rats. Am Surg 1997; 63(9):818-9.

25. Hooker GD, Taylor BM, Driman DK. Prevention of adhesion formation with use of sodium hyaluronate-based bioresorbable membrane in a rat model of ventral hernia repair with polypropylene mesh--a randomized, controlled study. Surgery 1999; 125(2):211-6.
26. Alimoglu O, Akcakaya A, Sahin M, et al. Prevention of adhesion formations following repair of abdominal wall defects with prosthetic materials (an experimental study). Hepatogastroenterology 2003; 50(51):725-8.
27. Demir U, Mihmanli M, Coskun H, et al. Comparison of prosthetic materials in incisional hernia repair. Surg Today 2005; 35(3):223-7.
28. Gonzalez R, Rodeheaver GT, Moody DL, et al. Resistance to adhesion formation: a comparative study of treated and untreated mesh products placed in the abdominal cavity. Hernia 2004; 8(3):213-9.
29. Matthews BD, Mostafa G, Carbonell AM, et al. Evaluation of adhesion formation and host tissue response to intra-abdominal polytetrafluoroethylene mesh and composite prosthetic mesh. J Surg Res 2005; 123(2):227-34.
30. Matthews BD, Pratt BL, Pollinger HS, et al. Assessment of adhesion formation to intra-abdominal polypropylene mesh and polytetrafluoroethylene mesh. J Surg Res 2003; 114(2):126-32.
31. Schug-Pass C, Tamme C, Tannapfel A, et al. Biocompatibility of Laparoscopically Placed Intra-Abdominal Meshes. In: Köckerling, F, Surgical Techniques, Science Med dr. Sperber, Hanover, 1-9. 2004.
32. Borrazzo EC, Belmont MF, Boffa D, et al. Effect of prosthetic material on adhesion formation after laparoscopic ventral hernia repair in a porcine model. Hernia 2004; 8(2):108-12.
33. Duffy AJ, Hogle NJ, LaPerle KM, et al. Comparison of two composite meshes using two fixation devices in a porcine laparoscopic ventral hernia repair model. Hernia 2004.
34. Baptista ML, Bonsack ME, Felemovicius I, et al. Abdominal adhesions to prosthetic mesh evaluated by laparoscopy and electron microscopy. J Am Coll Surg 2000; 190(3):271-80.
35. Klosterhalfen B, Klinge U, Henze U, et al. [Morphologic correlation of functional abdominal wall mechanics after mesh implantation]. Langenbecks Arch Chir 1997; 382(2):87-94.
36. Hengirmen S, Cete M, Soran A, et al. Comparison of meshes for the repair of experimental abdominal wall defects. J Invest Surg 1998; 11(5):315-25.
37. Fitzgibbons RJ, Jr., Salerno GM, Filipi CJ, et al. A laparoscopic intraperitoneal onlay mesh technique for the repair of an indirect inguinal hernia. Ann Surg 1994; 219(2):144-56.

10| Discussion

J.W.A. Burger

HERNIA ETIOLOGY

The first question we wanted to answer is: "what causes incisional hernia?" In our study "*Evidence of a clinical relationship between incisional and inguinal hernia*", we investigated whether a clinical relationship between inguinal and incisional hernia exists. Our results show that such a clinical relationship between incisional and inguinal hernia indeed exists. Moreover, both diseases were related to other types of hernia, such as umbilical hernia, hiatus hernia, epigastric hernia and burst abdomen. Finally, a strong relationship between incisional hernia, inguinal hernia and abdominal aortic aneurysm was established.

This study was the first to report a clinical relationship between incisional and inguinal hernia, although previous studies have reported a relationship between incisional hernia and aortic aneurysm[1-5] and inguinal hernia and aortic aneurysm[1,4,6-8]. The fact that these two types of hernia were related to aortic aneurysm is considered suggestive of an underlying connective tissue disorder that causes the degeneration of the abdominal wall as well as the vascular wall of the abdominal aorta. Our results support a relationship between abdominal wall hernia and aneurysm: 38% of patients with incisional and inguinal hernia had been or would be diagnosed with an abdominal aortic aneurysm.

Several other authors have tried to identify specific connective tissue disorders in hernia patients. A decrease in the collagen I/III ratio was reported[9-13], possibly caused by an imbalance in the matrix metalloproteinases, which are the principal enzymes degrading collagen[14-16]. Smoking may cause an imbalance in protease and antiprotease[17], while it is also associated with increased collagenolysis and inhibited collagen repair[18,19]. Our results cannot confirm or rebut these results. However, almost 55% of patients with incisional and inguinal hernia were active smokers (compared to 17-24% in the general population > 55 yrs[20]). Moreover, the fact that 36% of patients with both types of hernia suffered one or more incisional hernia recurrence, that 33% had one or more inguinal hernia recurrence and that 28% had a bilateral inguinal hernia strengthens our belief that patients with both incisional and inguinal hernia form a specific patient population, in which the chance of identifying a metabolic connective tissue disorder is high.

An unexpected result of this study was that patients with both incisional and inguinal hernia have an extremely high chance of developing aortic aneurysm. When both the incisional and inguinal hernia were diagnosed, 19% of patients had already been diagnosed with aortic aneurysm. However, 19% of patients had not yet, but would be diagnosed with aortic aneurysm in the near future (median three years). This means that our results have clinical implications too. Physicians should be aware that patients with a history of both inguinal and incisional hernia are at risk for aortic aneurysm development.

The second incisional hernia development study we performed aimed to establish the duration of the interval between abdominal surgery and the development of incisional hernia. The results of our study *"Incisional hernia: early complication of abdominal surgery"* show that incisional hernia develops during the first postoperative month. This is evidenced by the fact that we could predict incisional hernia by measurements performed on CT-scans made within one month of surgery.

The fact that incisional hernias can be predicted by measuring the distance between the edges of the rectus abdominis muscles implies that in patients developing incisional hernia, the rectus abdominis muscles are yielding. This is conceivable given the mainly transverse pulling forces of the lateral abdominal muscles, provided a defect is present. Therefore, yielding of the rectus abdominis muscles can only be accounted for by the development of a defect in the linea alba. The most plausible explanation for the development of such a defect within weeks of surgery is the tearing of sutures through abdominal wall tissue. We therefore endorse the hypothesis that early development of incisional hernia indicates perioperative factors, such as suture technique, as the main cause of incisional hernia.

In our first study we established a clinical relationship between incisional and inguinal hernia, suggesting an underlying connective tissue disorder. Our second study, in which we studied postoperative CT-scans of patients having undergone a midline laparotomy, suggests perioperative factors are the main cause of incisional hernia. Although this may seem contradictory, it need not be. In our study on the relationship between incisional and inguinal hernia, we included 1334 patients with incisional hernia. Only 121 of these patients also had an inguinal hernia. These patients with both types of hernia in their medical history are likely to suffer from an underlying connective tissue disorder. However, the remaining 1213 patients did not have an inguinal hernia and in these patients other factors, such as perioperative factors, are likely to have played a role. Moreover, the development of incisional hernia may be multifactorial. A connective tissue disorder does not exclude perioperative factors as an additional factor facilitating hernia development. Conversely, good surgical technique may prevent incisional hernia development, even in patients with a predisposition for hernia development.

Our results show that CT-scans can positively identify developing incisional hernias within one month of surgery. In some cases, these observations could be made within days of surgery. These results are consistent with the only comparable study available[21,22]. Our results also show that the clinical diagnosis incisional hernia was made much later in all patients and in some cases up to years after surgery. In retrospective, these late incisional hernias were visible on CT-scans made during the first postoperative month. The explanation is that incisional hernias may in some cases become clinically manifest years after their development, because the defect remains small and asymptomatic for years. The defects gain size later,

allowing for protrusion of abdominal content and visible bulging and complaints. Increasing weight, deterioration of physical status and increasing age may play a role in these late clinical manifestations of a long time present disorder. A study by Rodriguez et al confirms that many incisional hernias that were diagnosed on a CT-scan, had in fact not been diagnosed clinically[23].

The question arises whether the knowledge that incisional hernias develop within one month of surgery could be beneficial to the individual patient. We believe that the early development of incisional hernia implicates perioperative factors such as suture technique and wound infection as the main cause of incisional hernia development. We therefore think that surgeons should focus on technique. Correct suture technique, using non-absorbable or slowly absorbable suture materials and ensuring a 4:1 suture length to wound length ratio reduces the patient's chance of developing incisional hernia. Adequate wound care may prevent wound infection rates or decrease its severity. Another question is whether patients should undergo an early CT-scan to diagnose a developing incisional hernia. Searching for occult incisional hernias and subsequent repair would be highly controversial, because it is unclear whether the patient would benefit from such an approach. It is doubtful whether costs and irradiation could be answered for. Moreover, careful examination in an outpatient department setting should be sufficient to detect incisional hernia at an early stage, well before problems due to incisional hernia size arise.

HERNIA PREVENTION

The second question we wanted to answer in the current thesis is "how can we prevent incisional hernia?" In our review of the literature *"Abdominal incisions: techniques and postoperative complications"* incisional hernia rates associated with different types of incision were compared. The most commonly used incision, the midline incision, is associated with a high incidence of incisional hernia. The lateral paramedian incision, the unilateral transverse and Pfannenstiel incisions on the other hand are associated with low hernia rates.

The midline incision results in incisional rates of 7-23% and was associated with increased postoperative pain. Unilateral transverse incisions for cholecystectomy resulted in significantly less incisional hernias than the midline incision. On the other hand, bilateral transverse incisions did not result in less incisional hernias than the midline incision. Paramedian incisions were associated with incisional hernia rates of 0-1% in randomized trials with adequate follow-up. However, the excellent results of the paramedian incision apply only to the lateral paramedian technique, in which the rectus sheath is incised laterally and the rectus abdomi-

nis muscle is retracted laterally. The Pfannenstiel incision in the lower abdomen is associated with hernia rates of approximately 1%.

There are several possible reasons why the midline incision causes more incisional hernias than other incisions. The direction of muscle fibers in the abdominal wall is mainly transverse. Therefore, muscle contraction retracts vertical wound edges laterally. The midline incision cuts through the avascular linea alba, which may result in impaired wound healing. Moreover, a midline incision cuts the linea alba fibers perpendicularly. When a transverse incision is used, Langer's lines of cleavage are followed, as well as the direction of the nerves and segmental blood vessels and the direction of the oblique and transverse muscle fibers, resulting in muscle splitting rather than muscle cutting. In transverse incisions, contraction of the abdominal wall muscles does not retract the wound edges, but actually approximates them. In addition, the transverse incision wound is situated in richly vascularized muscular tissue, which may benefit wound healing. The midline and the lateral paramedian incision on the other hand are vertical incisions: they cut the aponeurotic fibers perpendicularly and are subject to lateral retraction of wound edges by the abdominal wall muscles. However, the midline incision is associated with the highest incisional hernia rate, while the lateral paramedian incision is associated with the lowest. Therefore, perpendicular cutting of fibers and lateral retraction of wound edges may not be the principle factors in hernia development. The lateral paramedian incision cuts the rectus sheath, which is more richly vascularized than the linea alba. Moreover, splintage of the wound in the lateral paramedian incision results in a so-called shutter mechanism. The rectus muscle remains intact and is located medially to the wound. Therefore, abdominal wall muscle contraction brings the wound edges together in stead of separating them[24].

In spite of the benefits of using transverse and lateral paramedian incisions, most surgeons still choose the midline incision for major abdominal surgery. The reason for this choice is quick and easy access to the whole abdominal cavity and the retroperitoneum in combination with maximum exposure. These qualities make the midline approach especially suitable for emergency and exploratory surgery. However, surgeons should be cautious with its use, because it is associated with a high incidence of incisional hernia. Moreover, in elective surgery, an alternative is almost always available. Transverse and oblique incisions are especially suitable for unilateral operations, such as open cholecystectomy, bariatric surgery, ileocecal resection and right hemicolectomy. Even when a small transverse incision has to be extended to a large bilateral one, the incisional hernia rate is not higher than after a midline incision[25]. The lateral paramedian incision offers adequate exposure for all types of elective surgery, including exploratory operations. The Pfannenstiel incision could be used for surgery of the lower colon and rectum and for pelvic surgery.

In conclusion, it appears that a change of practice could bring about a significant reduction in incisional hernia incidence. In addition to choosing alternative incisions, the application of laparoscopy could further reduce incisional hernia rates, because it is associated with low incisional hernia rates. Laparoscopy is now considered standard for several procedures, such as cholecystectomy, splenectomy, endocrine surgery, fundoplication and appendectomy. Finally, a significant part of incisional hernia repairs is performed without the use of a prosthetic mesh. Although retrospective data and a randomized controlled trial[26] have shown that mesh repair is superior to suture repair with regard to hernia recurrence, in 2002, Dutch surgeons still refrained from using a mesh in 40% of incisional hernia repairs[27]. Implementation of mesh repair for all incisional hernias could further reduce the incidence of incisional hernia by reducing the number of recurrences.

We applied the previous data to the Dutch situation. In our study *"Possible gains of optimizing surgical techniques in preventing incisional hernia"* a survey of all surgical abdominal procedures that are performed in the Netherlands was performed. Afterwards, we estimated how the application of alternative incisions and mesh repair could theoretically reduce incisional hernia rates, applying incisional hernia rates for each specific incision as they were reported in the literature. For abdominal surgery and hernia repair in the Netherlands, the hypothetical reduction in incisional hernia incidence is 64%. The largest part of this reduction can be achieved by replacing the midline incision by the lateral paramedian incision. Use of the lateral paramedian incision for vascular procedures and elective exploratory surgery is responsible for a significant reduction in incisional hernia incidence as well, as is implementation of mesh hernia repair of incisional hernia.

We consider these estimations to be realistic. With regard to the feasibility of the proposed alternative incisions and techniques we consulted the literature and experts in the field. We acknowledged that complete abolishment of midline incisions was not conceivable. Only incisional hernia incidences that were obtained by literature review of studies with adequate follow-up were applied. Moreover, the superiority of the lateral paramedian incision over the midline incision and mesh repair over suture repair, responsible for the reduction in hernia incidence, was proven in randomized controlled trials.

HERNIA TREATMENT

The third question we asked ourselves was "how should we treat incisional hernia". Our study *"Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia"* provides further evidence that mesh repair of incisional hernia is superior to suture repair. Recurrence is more frequent after suture repair than after mesh repair. Our study is the

first to report evidence that recurrence continues to occur up to ten years after surgery. The incidence of hernia repair related complications, the cosmetic result and patient satisfaction is comparable for both procedures. Suture repair results in more abdominal pain than mesh repair.

The 10-year cumulative recurrence rate after suture repair was 63%, while the recurrence rate after mesh repair was more favorable, but still disappointing with 32%. Thirty-five percent of suture repair patients underwent one or more subsequent hernia repairs, compared to 12% of mesh repair patients. A subgroup analysis of patients with small incisional hernias ($\leq$10 cm^2) provides conclusive evidence that even small incisional hernias should always be repaired with prosthetic mesh. Moreover, mesh repair may actually be more rewarding for small incisional hernias, because the recurrence rate after mesh repair of a small incisional hernia is only 17%. Suture repair of small incisional hernia is associated with a 67% recurrence rate.

The results of the long-term follow up of the randomized controlled trial of incisional hernia repair are in line with the available retrospective literature. In general, mesh repair is associated with decreased incisional hernia rates. However, no other randomized controlled trials are available. In 2002, a randomized controlled trial by Korenkov et al was discontinued due to the severity of mesh repair related complications[28]. Still, Korenkov reported that suture (Mayo) repair of incisional hernia was safe and did not result in higher recurrence rates, although Mayo repair was associated with unacceptable recurrence rates in retrospective series[29,30]. Our results show that long-term follow-up is warranted in any study on incisional hernia recurrence, because hernia continues to occur up to 10 years after surgery. Median follow-up in Korenkov's trial was only 13-14 months. With regard to the high incidence of mesh infection, we hypothesize that it was caused by the unfavorable onlay technique that was used in the Korenkov trial.

Although the superiority of mesh repair with regard to recurrence has been established, there are drawbacks to the use of mesh. Mesh repair has been associated with adhesion formation, abdominal pain, discomfort and with serious complications such as enterocutaneous fistula and bowel obstruction. Our study does not reveal any difference in scar or superficial pain between mesh and suture repair patients. Moreover, abdominal pain was less frequent (18 vs. 39%) and less intense in patients having undergone mesh repair. Abdominal pain in suture repair patients may however have been influenced by the high incidence of recurrence in these patients. With regard to hernia repair related complications, we found no significant difference between mesh and suture repair. However, incisional hernia repair was associated with serious complications. Two mesh repair patients developed enterocutaneous fistula. Although numbers are too small to reach significance, we believe that the importance of

this finding is determined by the severity of the complication. On the other hand, the occurrence of a burst abdomen and a strangulated hernia in the suture repair group may equal the enterocutaneous fistulas in complication severity.

The occurrence of mesh repair related complications is associated with adhesiogenic, inflammatory and erosive properties of mesh materials used. Theoretically, patients in whom contact between the mesh and abdominal viscera cannot be avoided are especially at risk. The occurrence of mesh related complications may be prevented by the application of new mesh materials with less adhesiogenic, inflammatory and erosive properties. At the same time, in order to prevent hernia recurrence, mesh incorporation and tensile strength of mesh adherence to the abdominal wall should not be compromised.

In an experimental study entitled "*Evaluation of new prosthetic meshes for ventral hernia repair*" we tried to identify the ideal mesh material for incisional hernia repair. Eight meshes were tested. Our results show that when contact between mesh and abdominal viscera cannot be avoided, meshes with protective visceral layers result in decreased adhesion formation and adequate tensile strength. The anti-adhesive capacity of these meshes is attributable to an absorbable visceral barrier that elicits a mild inflammatory response and protects the bowels from the erosive mesh surface during the first week(s). Conversely, macroporous visceral mesh surfaces are adhesiogenic, regardless of the anti-inflammatory properties of the material. With regard to incorporation and adherence, a macroporous (erosive) surface on the abdominal wall side of the mesh, as well as a moderate foreign body response, appear to be beneficial.

The use of three types of mesh resulted in a decrease in adhesion formation. These meshes were a polypropylene mesh with carboxymethylcellulose-sodium hyaluronate coating (Sepramesh™), a polyester mesh with collagen-polyethylene glycol – glycerol coating (Parietex Composite™) and bovine pericardium mesh (Tutomesh™). Sepramesh and Parietex Composite also performed well with regard to mesh incorporation and adherence to the abdominal wall. Other meshes that were recently introduced and were specifically designed for intraperitoneal use could not decrease adhesion formation and therefore appear to offer no new advantages. This study suggests that Sepramesh and Parietex Composite are currently the most suitable meshes for incisional hernia repair when contact with the abdominal viscera cannot be avoided. Their application will reduce adhesion formation and may decrease the incidence of mesh repair associated complications.

PERSPECTIVES

Today we know that we can prevent many incisional hernias by choosing alternative incisions and optimizing suture technique. We also know we should use a mesh whenever repairing an incisional hernia. What we do not know, is why one patient develops an incisional hernia and the other does not. Moreover, our prevention strategies are far from perfect; incisional hernia continues to be a common complication, while incisional hernia treatment results are still disappointing. When considering what we can improve in the future, wound healing is what comes to mind. We should try to really understand what is going on in the patient who is developing incisional hernia. When we find out what the deficiency is, we subsequently may be able to influence it. Successful administration of growth factors in experimental models would be a first important step. By improving wound healing, we hopefully will be able to prevent incisional hernia occurrence and recurrence altogether and thus provide a permanent solution to the problem.

REFERENCES

1. Adye B, Luna G. Incidence of abdominal wall hernia in aortic surgery. Am J Surg 1998; 175(5): 400-2.
2. Hall KA, Peters B, Smyth SH, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. Am J Surg 1995; 170(6):572-5; discussion 575-6.
3. Holland AJ, Castleden WM, Norman PE, et al. Incisional hernias are more common in aneurysmal arterial disease. Eur J Vasc Endovasc Surg 1996; 12(2):196-200.
4. Papadimitriou D, Pitoulias G, Papaziogas B, et al. Incidence of abdominal wall hernias in patients undergoing aortic surgery for aneurysm or occlusive disease. Vasa 2002; 31(2):111-4.
5. Raffetto JD, Cheung Y, Fisher JB, et al. Incision and abdominal wall hernias in patients with aneurysm or occlusive aortic disease. J Vasc Surg 2003; 37(6):1150-4.
6. Cannon DJ, Casteel L, Read RC. Abdominal aortic aneurysm, Leriche's syndrome, inguinal herniation, and smoking. Arch Surg 1984; 119(4):387-9.
7. Lehnert B, Wadouh F. High coincidence of inguinal hernias and abdominal aortic aneurysms. Ann Vasc Surg 1992; 6(2):134-7.
8. Pleumeekers HJ, De Gruijl A, Hofman A, et al. Prevalence of aortic aneurysm in men with a history of inguinal hernia repair. Br J Surg 1999; 86(9):1155-8.
9. Friedman DW, Boyd CD, Norton P, et al. Increases in type III collagen gene expression and protein synthesis in patients with inguinal hernias. Ann Surg 1993; 218(6):754-60.
10. Klinge U, Si ZY, Zheng H, et al. Abnormal collagen I to III distribution in the skin of patients with incisional hernia. Eur Surg Res 2000; 32(1):43-8.
11. Klinge U, Si ZY, Zheng H, et al. Collagen I/III and matrix metalloproteinases (MMP) 1 and 13 in the fascia of patients with incisional hernias. J Invest Surg 2001; 14(1):47-54.
12. Klinge U, Zheng H, Si Z, et al. Expression of the extracellular matrix proteins collagen I, collagen III and fibronectin and matrix metalloproteinase-1 and -13 in the skin of patients with inguinal hernia. Eur Surg Res 1999; 31(6):480-90.
13. Klinge U, Zheng H, Si ZY, et al. Synthesis of type I and III collagen, expression of fibronectin and matrix metalloproteinases-1 and -13 in hernial sac of patients with inguinal hernia. Int J Surg Investig 1999; 1(3):219-27.
14. Bellon JM, Bajo A, Ga-Honduvilla N, et al. Fibroblasts from the transversalis fascia of young patients with direct inguinal hernias show constitutive MMP-2 overexpression. Ann Surg 2001; 233(2):287-91.
15. Bellon JM, Bujan J, Honduvilla NG, et al. Study of biochemical substrate and role of metalloproteinases in fascia transversalis from hernial processes. Eur J Clin Invest 1997; 27(6):510-6.
16. Zheng H, Si Z, Kasperk R, et al. Recurrent inguinal hernia: disease of the collagen matrix? World J Surg 2002; 26(4):401-8.
17. Cannon DJ, Read RC. Metastatic emphysema: a mechanism for acquiring inguinal herniation. Ann Surg 1981; 194(3):270-278.
18. Jorgensen LN, Kallehave F, Christensen E, et al. Less collagen production in smokers. Surgery 1998; 123(4):450-5.
19. Read RC. Why do human beings develop groin hernias. In: Fitzgibbons, R.J., Jr, Greenburg, A.G., eds. Nyhus and Condon's hernia. Philadelphia: Lippincott Williams & Wilkins; 2002; 3-8.
20. Meijer WT, Grobbee DE, Hunink MG, et al. Determinants of peripheral arterial disease in the elderly: the Rotterdam study. Arch Intern Med 2000; 160(19):2934-8.
21. Playforth MJ, Sauven PD, Evans M, et al. The prediction of incisional hernias by radio-opaque markers. Ann R Coll Surg Engl 1986; 68(2):82-4.
22. Pollock AV, Evans M. Early prediction of late incisional hernias. Br J Surg 1989; 76(9):953-4.

23. Rodriguez HE, Matsumura JS, Morasch MD, et al. Abdominal wall hernias after open abdominal aortic aneurysm repair: prospective radiographic detection and clinical implications. Vasc Endovascular Surg 2004; 38(3):237-240.
24. Donaldson DR, Hall TJ, Zoltowski JA, et al. Does the type of suture material contribute to the strength of the lateral paramedian incision? Br J Surg 1982; 69(3):163-5.
25. Fassiadis N, Roidl M, Hennig M, et al. Randomized clinical trial of vertical or transverse laparotomy for abdominal aortic aneurysm repair. Br J Surg 2005; 92(10):1208-11.
26. Luijendijk RW, Hop WC, van den Tol MP, et al. A comparison of suture repair with mesh repair for incisional hernia. N Engl J Med 2000; 343(6):392-8.
27. Prismant. Utrecht, the Netherlands: National Medical Registration; 2002.
28. Korenkov M, Sauerland S, Arndt M, et al. Randomized clinical trial of suture repair, polypropylene mesh or autodermal hernioplasty for incisional hernia. Br J Surg 2002; 89(1):50-6.
29. Luijendijk RW, Lemmen MH, Hop WC, et al. Incisional hernia recurrence following "vest-over-pants" or vertical Mayo repair of primary hernias of the midline. World J Surg 1997; 21(1):62-5; discussion 66.
30. Paul A, Korenkov M, Peters S, et al. Unacceptable results of the Mayo procedure for repair of abdominal incisional hernias. Eur J Surg 1998; 164(5):361-7.

Summary

Chapter 1 introduces the subject of this thesis: incisional hernia. Incisional hernia is a protrusion of abdominal contents through a defect in the abdominal wall that develops in the scar of a previous laparotomy. Risk-factors for incisional hernia development, such as age, smoking, wound infection, obesity and surgical technique are introduced.

Incisional hernia is a common complication of abdominal surgery with an incidence of 10-20%. In the Netherlands, approximately 10,000-20,000 patients develop an incisional hernia each year. The patient with an incisional hernia usually presents with a bulge in a laparotomy scar that may grow if intra-abdominal pressure is elevated. The incisional hernia tends to cause only mild discomfort at first. Later on, once the incisional hernia has grown in size, it may cause severe discomfort and even disability.

In 2001, almost 4,000 patients underwent incisional hernia repair in the Netherlands. In the majority of patients, elective repair of the incisional hernia can be performed. In some patients, the incisional hernia becomes incarcerated or hernia contents strangulated. In this situation emergency surgery is needed. During incisional hernia repair, the defect in the abdominal wall is closed by either suturing the edges of the incisional hernia together or by inserting a prosthetic mesh to bridge the defect.

Knowledge of the abdominal wall anatomy is essential for understanding and studying incisional hernia development. **Chapter 2** is an anatomical study of the anterior abdominal wall. The muscular, vascular and nervous anatomy of the abdominal wall is described and depicted in figures.

Chapter 3 is a retrospective study in which we tried to establish a clinical relationship between incisional and inguinal hernia. In patients with incisional hernia, patients with inguinal hernia and patients with both incisional and inguinal hernia, the prevalence of hiatus hernia, umbilical hernia, epigastric hernia, burst abdomen and abdominal aortic aneurysm was established and compared.

Our results show that patients with both incisional and inguinal hernia had a significantly higher prevalence of hiatus hernia, umbilical hernia, burst abdomen and aortic aneurysm than patients with incisional hernia or inguinal hernia alone. The prevalence of aortic aneurysm was 38% in patients with incisional and inguinal hernia, compared to 10% in patients with incisional hernia and 5% in patients with inguinal hernia. Nineteen percent of patients that had been diagnosed with both incisional and inguinal hernia would be diagnosed with aortic aneurysm within several years. Further analysis of patients with both incisional hernia and inguinal hernia revealed high recurrence rates, a high incidence of bilateral inguinal hernia and a high number of active smokers.

We conclude that incisional and inguinal hernia are related. Moreover, patients diagnosed with both types of hernia are at risk for aortic aneurysm. The chance of identifying an underlying connective tissue disorder is high in patients with incisional hernia, inguinal hernia and aortic aneurysm in their history.

Chapter 4 is a retrospective study in which we tried to determine the length of the interval between surgery and incisional hernia development. Because the strength of a wound in the abdominal wall depends on the sutures during the first weeks after surgery, it has been suggested that early development of incisional hernia is caused by perioperative factors, such as surgical technique and wound infection. Late development may imply other factors, such as connective tissue disorders and impaired wound healing.

Patients who underwent a midline laparotomy and had a CT-scan of the abdomen within the first postoperative month were identified retrospectively. The distance between both rectus abdominis muscles was measured on these CT-scans, after which several parameters were calculated to predict incisional hernia development. Incisional hernia development was established clinically through chart review, or by an outpatient clinic visit.

The average and maximum distances between the left and right rectus abdominis muscles were significantly larger in patients with subsequent incisional hernia development than in patients without incisional hernia. Ninety-two percent of incisional hernia patients had a maximum distance between the rectus abdominis muscles of more than 25 mm, compared to only 18% of patients without incisional hernia. Although we found that incisional hernia development was visible on CT-scans made within one month of surgery, the clinical diagnosis incisional hernia was made much later in all patients.

We conclude that incisional hernia occurrence can be predicted by measuring the distance between the rectus abdominis muscles on a postoperative CT-scan made within one month

of surgery. Although incisional hernia develops within a month of surgery, clinical manifestation may take years. Our results indicate perioperative factors, such as suture technique, as the main cause of incisional hernia.

Chapter 5 is a review of types of incision for laparotomy. The choice of incision for a laparotomy depends on the area that needs to be exposed, the elective or emergency nature of the operation and the surgeon's preference. The choice of incision may however have its influence on the occurrence of postoperative wound complications. A review of the literature was performed identifying prospective randomized trials, as well as retrospective studies with sufficient follow-up that compared incisions for laparotomy.

Significant differences in wound infection and wound dehiscence rates were not reported in the literature. Transverse, oblique and paramedian incisions caused significantly less incisional hernias than midline incisions. However, trials comparing large (bilateral) transverse and midline incisions did not show significant differences. Four trials comparing lateral paramedian with midline incisions reported incisional hernia rates of 0% after the lateral paramedian incision.

We conclude that transverse or oblique incisions should be preferred for small unilateral operations. The lateral paramedian incision should be used for major elective laparotomies. Use of the midline incision should be restricted to emergency operations in which fast access to the abdominal cavity or maximum exposure is necessary.

Chapter 6 reviews hernia prevention strategies. Surgical technique is probably the most important risk factor for incisional hernia development. Incisional hernia rates after several types of incision were described in chapter 5. Other important factors are suture technique, suture material, suture length and hernia repair technique. With regard to suture material, the available literature shows that either non-absorbable material, such as nylon or polypropylene, or slowly absorbable material, such as polydioxanone, should be used. Mass closure of the abdominal wall is better than separate closing of the abdominal wall layers. A suture length wound length ratio of at least 4:1 should be achieved, which means that the suture should always be at least four times as long as the wound. Finally, in incisional hernia repair, prosthetic mesh should always be used to prevent incisional hernia recurrence.

Chapter 7 is a continuation of the studies described in chapters 5 and 6. To effectuate incisional hernia prevention, we estimated how a change of surgical practice could reduce incisional hernia incidence in the Netherlands. We first studied how the incidence of incisional hernia after abdominal procedures could be reduced by choosing alternative incisions. Seventy-thousand abdominal procedures in general surgery performed in 2001 in the Netherlands were included in the analysis. For all procedures we established what the routinely used type of incision was. We then considered whether alternatives were available and subsequently

calculated the incisional hernia reduction that would result from use of these alternatives. Incisional hernia rates were retrieved from the available literature. In addition, we calculated the effect of a change of practice with regard to incisional hernia repair. Although it was proven that mesh repair results in decreased recurrence rates, many surgeons still perform suture repair.

Our results show that 64% of incisional hernias may be avoided by choosing alternative incisions and by always performing mesh repair for incisional hernia. We therefore conclude that a change of surgical practice alone may greatly reduce the incidence of incisional hernia.

Chapter 8 presents the results of the long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. The objective of this study was to determine the best treatment for incisional hernia, taking into account recurrence, complications, discomfort, cosmetic result and patient satisfaction. Between 1992 and 1998 181 patients with a primary or first time recurrent midline incisional hernia were randomly assigned to suture or mesh repair. In 2003, long-term follow-up was obtained.

The 10-year cumulative rate of recurrence was 63% for suture repair and 32% for mesh repair. In patients with small incisional hernias, the recurrence rate was 67% after suture repair and 17% after mesh repair. In the mesh repair group, 17% suffered a complication, compared to 8% in the suture repair group (NS). Abdominal pain was more frequent in suture repair patients, but there was no difference in scar pain, cosmetic result and patient satisfaction.

We conclude that mesh repair results in a lower recurrence rate and less abdominal pain. Suture repair of incisional hernia should therefore be abandoned.

Chapter 9 presents an experimental study in which we compared meshes that are used for ventral hernia repair. In hernia repair and in laparoscopic hernia repair in particular, direct contact between mesh and abdominal organs cannot always be avoided. However, direct contact may lead to an inflammatory response and erosion, which may induce adhesion formation. Adhesion formation is associated with chronic abdominal pain, bowel obstruction and infertility. Moreover, inflammation and erosion may cause enterocutaneous fistula.

In 200 rats, 8 meshes were placed intraperitoneally and in direct contact with abdominal viscera. The meshes tested were: polypropylene (Prolene), e-PTFE (Dualmesh), polypropylene-polyglecaprone composite (Ultrapro), titanium-polypropylene composite (Timesh), polypropylene with carboxymethylcellulose-sodium hyaluronate coating (Sepramesh), polyester with collagen-polyethylene glycol – glycerol coating (Parietex Composite), polypropylene-polydioxanone composite with oxidized cellulose coating (Proceed) and bovine pericardium (Tutomesh). Adhesion formation, mesh incorporation, adherence, shrinkage and infection were scored by two independent observers.

Parietex Composite, Sepramesh and Tutomesh resulted in decreased adhesion formation. Parietex Composite, Prolene, Ultrapro and Sepramesh resulted in good mesh incorporation and adherence. There were few differences with regard to shrinkage and mesh infection.

We conclude that Parietex Composite and Sepramesh combine minimal adhesion formation with maximum mesh incorporation and adherence. Therefore, these two meshes are currently the most suitable for hernia repair in which contact with abdominal viscera cannot be avoided.

Samenvatting

Hoofdstuk 1 is de introductie van het onderwerp van dit proefschrift: de littekenbreuk. De littekenbreuk is een uitstulping van buikinhoud door een defect in de buikwand dat is ontstaan in het litteken van een eerdere laparotomie. Risicofactoren voor het ontstaan van een littekenbreuk, zoals leeftijd, roken, wondinfectie, obesitas en chirurgische techniek worden toegelicht.

De littekenbreuk is een veel voorkomende complicatie van abdominale chirurgie met een incidentie van 10-20%. In Nederland ontwikkelen jaarlijks 10.000-20.000 patiënten een littekenbreuk. Een patiënt met een littekenbreuk presenteert zich doorgaans met een zwelling in een laparotomielitteken die soms groter wordt bij persen. In eerste instantie ondervindt de patiënt meestal slechts milde klachten. Later kunnen, mede door toename van de breukomvang, ernstige klachten en zelfs invaliditeit ontstaan.

In 2001 ondergingen in Nederland bijna 4.000 patiënten een littekenbreukcorrectie. Doorgaans vindt deze operatie electief plaats. Bij sommige patiënten echter raakt de breuk bekneld. In dit geval is een spoedoperatie noodzakelijk. Tijdens een littekenbreukcorrectie wordt het defect in de buikwand gesloten, ofwel door de randen van het defect aan elkaar te hechten, ofwel door een kunststof matje te plaatsen om het defect te overbruggen.

Kennis van de anatomie van de voorste buikwand is onontbeerlijk bij het bestuderen van de ontwikkeling van de littekenbreuk. **Hoofdstuk 2** is een anatomische studie van de voorste buikwand, waarin de anatomie van de spieren, bloedvaten en zenuwen wordt beschreven en in figuren afgebeeld.

Hoofdstuk 3 is een retrospectieve studie waarin wij probeerden een klinische relatie tussen de littekenbreuk en de liesbreuk aan te tonen. De prevalentie van hernia diafragmatica, navelbreuk, hernia epigastrica, fasciedehiscentie en aneurysma van de abdominale aorta werd bepaald in patiënten met een littekenbreuk, patiënten met een liesbreuk en patiënten met zowel een littekenbreuk als een liesbreuk. Onze resultaten tonen aan dat de prevalentie van hernia diafragmatica, navelbreuk, fasciedehiscentie en aneurysma van de abdominale aorta significant hoger is in patiënten met een littekenbreuk en een liesbreuk dan in patiënten met alleen een littekenbreuk of alleen een liesbreuk. De prevalentie van abdominaal aneurysma was 38% in patiënten met zowel een littekenbreuk als een liesbreuk, vergeleken met 10% in patiënten met alleen een littekenbreuk en 5% in patiënten met alleen een liesbreuk. Bij negentien procent van de patiënten die bekend waren met een littekenbreuk en een liesbreuk zou binnen enkele jaren een abdominaal aneurysma worden vastgesteld. Verdere analyse van de patiënten met een littekenbreuk en een liesbreuk bracht een hoge incidentie van recidief hernia, bilaterale liesbreuk en een hoog percentage rokers aan het licht.

Wij concluderen dat de littekenbreuk en de liesbreuk inderdaad verwante aandoeningen zijn. Patiënten met een littekenbreuk en een liesbreuk hebben een verhoogd risico op het ontstaan van een abdominaal aneurysma. Onderzoek naar een onderliggende bindweefselaandoening kan het beste gedaan worden in de patiëntengroep met zowel een littekenbreuk, een liesbreuk als een abdominaal aneurysma.

Hoofdstuk 4 is een retrospectieve studie waarin we probeerden de duur van het interval tussen de laparotomie en het ontstaan van de littekenbreuk vast te stellen. Omdat de sterkte van de wond gedurende de eerste weken met name wordt bepaald door de hechtingen, gaat men ervanuit dat het vroeg ontstaan van een littekenbreuk wordt veroorzaakt door peroperatieve factoren, zoals hechttechniek en wondinfectie. Het laat ontstaan van een littekenbreuk zou wijzen op andere oorzaken, zoals een bindweefselaandoening of slechte wondgenezing.

Patiënten die een mediane laparotomie ondergingen en bij wie binnen een maand na de operatie een CT-scan van de buik werd gemaakt werden retrospectief geïdentificeerd. Op de CT-scans werd de afstand tussen de beide rectus abdominis spieren gemeten, waarna verschillende parameters werden berekend met als doel het ontstaan van een littekenbreuk te voorspellen. Een littekenbreuk werd vastgesteld door middel van statusonderzoek of door een poliklinisch consult.

De gemiddelde afstand en de maximale afstand tussen de rectus abdominis spieren was significant hoger in patiënten die later een littekenbreuk zouden ontwikkelen dan in patiënten die geen littekenbreuk zouden ontwikkelen. Tweeënnegentig procent van de littekenbreukpatiënten had een maximale afstand tussen de rectus abdominis spieren van meer dan 25 mm, vergeleken met 17% van de patiënten die geen littekenbreuk ontwikkelde. Hoewel de littekenbreuken vastgesteld konden worden op CT-scans die binnen een maand na de

operatie werden gemaakt, werden de littekenbreuken in alle gevallen pas veel later klinisch gediagnosticeerd.

Wij concluderen dat het ontstaan van een littekenbreuk kan worden voorspeld door de afstand tussen de rectus abdominis spieren te meten op een CT-scan die binnen een maand na de operatie wordt gemaakt. Het klinisch manifest worden van de breuk kan echter jaren op zich laten wachten. Peroperatieve factoren, zoals hechttechniek, zijn waarschijnlijk de belangrijkste rsiscofactoren voor het ontstaan van de littekenbreuk.

Hoofdstuk 5 is een overzichtsartikel waarin verschillende soorten laparotomiën worden beschreven. De keus voor een bepaalde incisie wordt bepaald door het gebied waarin moet worden geopereerd, de vereiste snelheid en de voorkeur van de chirurg. De incisie heeft echter ook invloed op het optreden van postoperatieve complicaties. In dit overzichtsartikel worden prospectief gerandomiseerde trials en retrospectieve studies met voldoende follow-up beschreven waarin de incidentie van postoperatieve complicaties na verschillende incisies werd vergeleken.

Er waren geen significante verschillen met betrekking tot wondinfectie en fasciedehiscentie. Dwarse en schuine incisies resulteerden in significant minder littekenbreuken dan mediane laparotomiën. Studies waarin grote (bilaterale) dwarse en mediane laparotomiën werden vergeleken toonden echter geen verschil. Vier prospectief gerandomiseerde studies rapporteerden een littekenbreuk incidentie van 0% na de laterale paramediane incisie.

Wij concluderen dat dwarse of schuine incisies de voorkeur hebben bij kleine unilaterale operaties. De laterale paramediane incisie moet gebruikt worden voor grote electieve abdominale chirurgie. Gebruik van de mediane laparotomie moet beperkt blijven tot die situaties waarin zeer snelle toegang tot de buik vereist is, of wanneer maximaal overzicht over de gehele buikholte noodzakelijk is.

Hoofdstuk 6 geeft een overzicht van hernia preventie methoden. Chirurgische techniek is waarschijnlijk de belangrijkste risicofactor voor het ontwikkelen van een littekenbreuk. De incidentie van littekenbreuk na verschillende soorten incisies werd beschreven in hoofdstuk 5. Andere belangrijke factoren zijn hechttechniek, hechtmateriaal, lengte van de draad en de toegepaste techniek bij correctie van een littekenbreuk. Met betrekking tot hechtmateriaal is aangetoond dat ofwel niet-absorbeerbaar materiaal, zoals nylon of polypropylene, ofwel langzaam absorbeerbaar materiaal, zoals polydioxanone, moet worden gebruikt. De lagen van de buikwand moeten niet laag voor laag gesloten worden, maar in een steek gevat worden. De draadlengte-wondlengte ratio moet tenminste 4:1 zijn, hetgeen betekent dat de gebruikte hechtdraad tenminste 4 maal zo lang moet zijn als de wond. Tenslotte moet bij littekenbreukcorrectie te allen tijde een kunststof matje worden gebruikt teneinde een recidief te voorkomen.

Hoofdstuk 7 borduurt voort op de hoofdstukken 5 en 6. In dit hoofdstuk probeerden wij in te schatten in hoeverre een verandering in chirurgisch handelen zou kunnen leiden tot een verlaging van de incidentie van littekenbreuk. Eerst bestudeerden wij hoe de incidentie van littekenbreuk zou kunnen worden verlaagd door de toepassing van alternatieve incisies. Alle 70.000 buikoperaties die in 2001 in Nederland door chirurgen werden uitgevoerd werden hierbij betrokken. Voor elke procedure werd vastgesteld wat de gebruikelijke benadering is. Daarna werd bekeken of gunstiger alternatieven beschikbaar waren en werd berekend hoeveel littekenbreuken door toepassing van deze alternatieven voorkomen zouden kunnen worden. De incidentie van littekenbreuken na de verschillende soorten incisies werd door middel van literatuuronderzoek vastgesteld. Ook werd het effect van het routinematig plaatsen van een kunststof mat bij littekenbreukcorrectie meegenomen. Een groot aantal chirurgen sluit littekenbreuken namelijk nog steeds primair, hoewel is aangetoond dat correctie met mat leidt tot een forse vermindering van het aantal recidieven.

Onze resultaten tonen dat 64% van de littekenbreuken voorkomen zou kunnen worden door te kiezen voor alternatieve incisies en littekenbreukcorrectie met mat. Wij concluderen dat een verandering in het chirurgisch handelen zou kunnen leiden tot een forse verlaging van de incidentie van de littekenbreuk.

Hoofdstuk 8 is een beschrijving van de resultaten van de lange termijn follow-up van een prospectief gerandomiseerd klinisch onderzoek naar het primair sluiten versus correctie met kunststof mat van een littekenbreuk. Het doel van deze studie was de beste behandeling van de littekenbreuk vast te stellen, waarbij recidief, complicaties, pijn, cosmetisch resultaat en tevredenheid in de analyse betrokken werden. Tussen 1992 en 1998 werden 181 patiënten gerandomiseerd voor primair sluiten of correctie met mat van een primaire of eerste recidief littekenbreuk. In 2003 werd de lange termijn follow-up afgerond.

De 10-jaar cumulatieve incidentie van recidief littekenbreuk was 63% na primair sluiten en 32% na correctie met mat. Het recidief percentage na correctie van kleine littekenbreuken was 67% na primair sluiten en 17% na correctie met mat. Zeventien procent van de patiënten bij wie een mat werd geplaatst maakte een complicatie door, vergeleken met 8% van de patiënten bij wie de breuk primair werd gesloten (NS). Buikpijn kwam vaker voor bij patiënten bij wie de littekenbreuk primair werd gesloten, maar er was geen verschil in de incidentie van littekenpijn, cosmetisch resultaat en tevredenheid.

Wij concluderen dat littekenbreukcorrectie met kunststof mat leidt tot een lager recidiefpercentage en minder buikpijnklachten. Bij littekenbreukcorrectie moet dehalve altijd een kunststof mat geplaatst worden.

Hoofdstuk 9 is een experimentele studie waarin 8 kunststof matten worden vergeleken die gebruikt worden voor littekenbreukcorrectie. Bij breukchirurgie, en met name bij laparoscopische breukchirurgie, is het niet altijd mogelijk direct contact tussen de kunststof mat en

de buikorganen te voorkomen. Dit contact kan echter leiden tot een ontstekingsreactie en erosie van het darmoppervlak met adhesievorming tot gevolg. Adhesies kunnen chronische buikpijn, ileus en infertiliteit veroorzaken. Bovendien zouden de ontstekingsreactie en de erosie kunnen leiden tot het ontstaan van enterocutane fistels.

In 200 ratten werden 8 kunststof matten intraperitoneaal, direct tegen de buikorganen aan geplaatst. De matten die werden getest zijn: polypropyleen (Prolene), e-PTFE (Dualmesh), polypropyleen-polyglecaprone composiet (Ultrapro), titanium-polypropyleen composiet (Timesh), polypropyleen met carboxymethylcellulose-sodium hyaluronzuur beschermlaag (Sepramesh), polyester met collageen-polyethyleen glycol – glycerol beschermlaag (Parietex Composite), polypropyleen-polydioxanone composiet met geoxideerd cellulose beschermlaag (Proceed) en bovien pericard (Tutomesh). Adhesievorming, mat ingroei, verankering van de mat aan de buikwand, krimp en infectie werden gescoord door twee waarnemers.

Parietex Composite, Sepramesh en Tutomesh resulteerden in minder adhesievorming dan de andere matten. Parietex Composite, Sepramesh, Prolene en Ultrapro groeiden goed in en waren stevig verankerd aan de buikwand. Wat betreft krimp en infectie werden weinig verschillen waargenomen.

Wij concluderen dat Parietex Composite en Sepramesh minimale adhesievorming combineren met goede ingroei en verankering. Daarom zijn deze twee kunststof matten op dit moment het meest geschikt voor breukchirurgie waarbij direct contact met de buikorganen niet voorkomen kan worden.

Conclusions

- There is a relationship between incisional hernia and inguinal hernia.
- The probability of identifying an underlying connective tissue disorder is high in patients who have incisional hernia, inguinal hernia and abdominal aortic aneurysm.
- Patients with incisional hernia and inguinal hernia are at risk for abdominal aortic aneurysm development.
- Developing incisional hernias can be identified on CT-scans made within one month of surgery.
- The fact that incisional hernia develops within one month of surgery indicates perioperative factors as the main cause of incisional hernia development.
- Use of the lateral paramedian and transverse incisions could significantly decrease incisional hernia rates.
- Implementation of alternative incisions and mesh repair for incisional hernia could reduce the incidence of incisional hernia with 64%.
- To prevent incisional hernia recurrence, incisional hernia should always be repaired with a prosthetic mesh, regardless of the size of the defect.
- Mesh repair of incisional hernia is not associated with more complications than suture repair.
- Mesh repair of incisional hernia is associated with less chronic abdominal pain than suture repair.
- Sepramesh and Parietex Composite are associated with maximum tensile strength, maximum tissue incorporation and minimum adhesion formation.

Curriculum Vitae

Jacobus Willem Annes (Pim) Burger was born in Dordrecht on July 19th 1976. In 1994 he finished secondary school (Gymnasium-β) and started his medical training at the medical school of the Erasmus University Rotterdam. In 1998 he was a researcher at the Transplantation and Liver Surgery Clinic of the Helsinki University Hospital (Prof. dr. K. Höckerstedt). In December 2001 he graduated (MD), after which he obtained a research position at the Department of General Surgery of the Erasmus University Medical Center (Prof. dr. J. Jeekel). He started his surgical training at the IJsselland Hospital in Capelle aan den IJssel in September 2004 (dr. I. Dawson) and will continue it at the Erasmus University Medical Center in Rotterdam in September 2008.

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