

CME

Follow the link from the online version of this article to obtain certified continuing medical education credits

The modern management of incisional hernias

David L Sanders,¹ Andrew N Kingsnorth²

¹Upper Gastrointestinal Surgery, Royal Cornwall Hospital, Truro TR1 3LJ, UK

²Peninsula College of Medicine and Dentistry, Plymouth, UK

Correspondence to: D L Sanders dsanders@doctors.org.uk

Cite this as: *BMJ* 2012;344:e2843

doi: 10.1136/bmj.e2843

Before the introduction of general anaesthesia by Morton in 1846, incisional hernias were rare. As survival after abdominal surgery became more common so did the incidence of incisional hernias.¹ Since then, more than 4000 peer reviewed articles have been published on the topic, many of which have introduced a new or modified surgical technique for prevention and repair. Despite considerable improvements in prosthetics used for hernia surgery, the incidence of incisional hernias and the recurrence rates after repair remain high. Arguably, no other benign disease has seen so little improvement in terms of surgical outcome.

Unlike other abdominal wall hernias, which occur through anatomical points of weakness, incisional hernias occur through a weakness at the site of abdominal wall closure. Why, unlike primary abdominal wall hernias, are the results after repair so poor? Perhaps it is because in the repair of incisional hernias several problems need to be overcome: a multilayered wall structure

of different tissue properties in constant motion has to be sutured; positive abdominal pressure has to be dealt with; and tissues with impaired healing properties, reduced perfusion, and connective tissue deficiencies have to be joined.

This review, which is targeted at the general medical audience, aims to update the reader on the definition, incidence, risk factors, diagnosis, and management of incisional hernias.

Unravelling the terminology

Despite the size of the problem, the terminology used to describe incisional hernias still varies greatly. An internationally acceptable and uniform definition is needed to improve the clarity of communication within the medical community and enable publication data and future studies to be interpreted properly. Table 1 lists the definitions of the commonly (mis)used terms.

How common are incisional hernias?

Incisional hernias are one of the most common complications after abdominal surgery. The true incidence is difficult to determine, as shown by the wide range of published figures in the literature. The reasons for this discrepancy are the lack of standardised definition, the inconsistency of data sources used (which include self reporting by patients, audits of routine clinical examination, and insurance company databases), short length of follow-up (often one year), and the subjectivity of clinical examination.² The reported incidence after a midline laparotomy ranges from 3% to 20% and is doubled if the index operation is complicated by wound infection.³ About 50% of incisional hernias are detected within one year of surgery, but they can occur several years afterwards, with a subsequent risk of 2% a year.^{3 4}

Millions of abdominal incisions are created each year worldwide, so incisional hernias are a major problem, both in terms of morbidity and socioeconomic cost. Although exact figures are unknown, it is estimated that each year 10 000 repairs are performed in the United Kingdom and 100 000 are performed in the United States.⁵

Table 1 | Definitions of incisional hernia and the commonly (mis)used terminology

Term	Definition
Incisional hernia	Any gap in the abdominal wall, with or without a bulge in the area of the postoperative scar, that can be seen or palpated on clinical examination or imaging
Primary incisional hernia	An incisional hernia that has not previously been surgically repaired
Recurrent incisional hernia	An incisional hernia that has previously been surgically repaired
Trocar site hernia	An abdominal wall gap, with or without a bulge in the area of previous cannulation with a laparoscopic trocar, that can be seen or palpated on clinical examination or imaging
Acute wound failure (fascial dehiscence, evisceration, eventration)	The acute breakdown or separation of the fascial tissues, with resulting protrusion of the intra-abdominal contents through a fascial defect but without the presence of a peritoneal sac; this usually occurs in the first 2 weeks of wound healing and always results in formation of an incisional hernia
Primary abdominal wall hernia (epigastric hernia, umbilical hernia, paraumbilical hernia, spigelian hernia)	Hernia of the abdominal wall that is not related to an incision (usually refined by defining the site of the hernia)
Recurrent abdominal wall hernia (recurrent epigastric hernia, umbilical hernia, paraumbilical hernia, spigelian hernia)	Recurrence of a primary hernia of the abdominal wall that has been previously surgically repaired
Ventral hernia	This term should not be used owing to the historical confusion with the definition; In Europe the term ventral hernia has been used interchangeably with incisional hernia; in the United States the term has been used to describe any abdominal wall hernia other than in the groin

SUMMARY POINTS

Incisional hernias are a common complication of abdominal surgery

Incisional hernias can occur many years after the index operation

Surgical site infection doubles the risk of incisional hernia

In case of uncertainty, ultrasonography can help confirm the diagnosis before specialist referral

Laparoscopic repair is generally reserved for small hernias (fascial defect <10 cm), although some surgeons report good results with larger defects

SOURCES AND SELECTION CRITERIA

We searched PubMed from 1970-2012 and Embase and the Cochrane Library from inception using the terms "hernia" and "incisional" (using the Boolean operator AND) and "ventral" (using the Boolean operator OR). The reference lists were also used to identify studies of interest. Both authors independently identified publications for inclusion and differences were resolved by discussion. We gave priority to research published in the past five years and highly regarded older publications.

Table 2 | Patient related risk factors for developing an incisional hernia

Risk factor	Proposed effects on wound healing
Age >65 years	Reduced tissue perfusion and reduced collagen formation
Sex	Some studies suggest that male sex is a risk factor, although others have found no difference between the sexes ^{4,7}
Atherosclerosis	Reduced perfusion to the wound
Diabetes	Reduced inflammatory response; alterations in microcirculation and granulation tissue
Obesity	Increased intra-abdominal pressure; obesity related comorbidities, such as diabetes and increased risk of surgical site infection
Renal failure	Metabolic factors, which prevent formation of normal granulation tissue
Protein deficiency	Important for collagen development
Vitamin C deficiency	An important cofactor in the biosynthesis of collagen
Immunosuppression	Alterations in normal tissue regeneration
Smoking	Alteration in the formation and degradation of collagen, vasoconstriction, and increased mechanical stress from coughing
Drugs and other treatments	Drugs and treatments that cause immunosuppression or reduced vascular perfusion, such as steroids, chemotherapy, and radiotherapy; warfarin, which reduces vitamin K dependent cell-cell adhesion and cell cycle regulation

Who is at risk?

Until recently, incisional hernias were thought to result mainly from a technical failure in the surgical closure of the abdominal wall.⁶ However, we now know that a complex array of patient related, surgical, and postoperative variables influence their development. These variables share a common denominator—they all influence normal wound healing (table 2). Most of the evidence on risk factors has been determined by retrospective studies, and the relative importance of many of the proposed risk factors is poorly understood.

Patient related factors

Associations between surgery for abdominal aortic aneurysm, the presence of other primary abdominal wall hernias, and the development of incisional hernias have repeatedly been documented.⁷⁻⁸ Similarly patients with certain connective tissue diseases (Marfan’s syndrome, osteogenesis imperfecta, and Ehlers-Danlos syndrome) have an increased incidence of incisional hernias.⁹⁻¹⁰ A review article published in 2011, which drew on evidence from 52 publications, concluded that collagen metabolism in patients with a hernia is altered at three levels. The ratio between type I (strong) and type III (weak) collagen is decreased, the quality of collagen is poorer, and collagen breakdown is increased via increased matrix metalloproteinase (MMP) activity.¹¹ However, it has not been established whether these changes are localised to the site of hernia development or whether they affect all body tissues. The relative contribution of collagen deficiencies versus other patient related risk factors for hernia development is also not fully understood (table 2).

Surgical factors

Incisional hernias can occur after any type of laparotomy incision but are most common after midline (especially upper midline) and transverse incisions.⁴ An analysis of 11 publications assessing the incidence of incisional hernia after different abdominal incisions concluded that the risk was 10.5% for midline incisions and 7.5% for transverse incisions.¹² However, many of these publications included variable closure techniques and disease processes.

Several clinical trials and meta-analyses have shown that a continuous closure technique with a simple run-

ning suture is the best option for closure of laparotomy incisions.¹³⁻¹⁵ The use of monofilament slowly resorbable suture material versus non-absorbable or braided material decreases the rate of incisional hernias and reduces the incidence of postoperative pain and wound infection.¹³⁻¹⁵

Experimental studies and randomised clinical trials have shown that a suture length to wound length ratio of at least 4:1, and not more than 5:1, minimises the risk of incisional hernia.¹⁶⁻¹⁸ Traditional surgical teaching recommends that continuous sutures are placed 10 mm from the wound edge and 10 mm apart.¹⁷ However, recently this technique has increasingly been challenged. The large tissue bites have been shown to be associated with an increase in the amount of necrotic tissue and slackening of the stitches, resulting in increased risk of wound infection and the development of an incisional hernia.¹⁹⁻²⁰ In a large randomised controlled trial, small stitches placed 4-6 mm from the wound edge and 4 mm apart (in the aponeurotic layer only) minimised the risk of incisional hernias from 18% to 5.6% (P<0.001) and reduced wound infection rates by 50% (from 10.2% to 5.2%; P<0.02).²¹ This is currently being evaluated in a multicentre randomised controlled trial.¹⁶ Most surgeons still use the large bite method and adoption of the small bite technique will be a major shift in surgical practice.

Postoperative factors

Surgical site infection is commonly documented as the most important independent risk factor for the development of an incisional hernia and is thought to double the risk.⁴ A prospective cohort study showed that factors that increase intra-abdominal pressure in the immediate postoperative phase, such as postoperative ileus, the need for repeated urinary catheterisation, coughing, vomiting, and mechanical ventilation, also increase the risk of incisional hernias.²²

Predicting the risk

A scoring system for predicting the development of early (less than six months after surgery) incisional hernia was published in 2010.²³ The study used linear and multivariate regression models of 42 patient related, surgery related, and perioperative variables. Of these the most significant predictive factors, in order of importance, were fascial suture to incision ratio less than 4.2:1, surgical site infection, time to removal of skin sutures less than 16 days, and body mass index greater than 24. This may provide a useful future tool for preoperative risk assessment and the use of prophylactic mesh, but it still requires prospective and independent validation. Van Ramshorst and colleagues have also published a model for predicting wound abdominal dehiscence risk.²⁴ They identified the major independent risk factors as age, sex, chronic pulmonary disease, ascites, jaundice, anaemia, emergency surgery, type of surgery, postoperative coughing, and wound infection.

Can an incisional hernia be prevented?

Currently the risk of incisional hernia cannot be eliminated except by avoiding a laparotomy incision in the first place. However, the risk can be minimised by reducing systemic risk factors, especially smoking, obesity, and nutritional

bmj.com

Previous articles in this series

- ▶ Diagnosis and management of bone stress injuries of the lower limb in athletes (*BMJ* 2012;344:e2511)
- ▶ The management of overactive bladder syndrome (*BMJ* 2012;344:e2365)
- ▶ Cluster headache (*BMJ* 2012;344:e2407)
- ▶ The management of ingrowing toenails (*BMJ* 2012;344:e2089)

deficiencies, and by optimising diabetic management, even if surgery has to be delayed. The risk can be further minimised by careful attention to surgical technique when closing the abdominal wall. Surgeons should follow the 2008 National Institute for Health and Clinical Excellence guidelines for the prevention and treatment of surgical site infection.²⁵ The guidelines provide a detailed review of preoperative, intraoperative, and postoperative measures to minimise the risk of infection. A systematic review of randomised controlled trials found that preoperative antibiotic prophylaxis (less than two hours before surgery) is beneficial in clean surgery involving a prosthesis, clean contaminated surgery, and contaminated surgery. The most significant difference was seen in colorectal surgery (12.9% surgical site infection with antibiotics versus 40.2% without antibiotics).^{w1}

The role of prophylactic mesh placement in high risk patient groups is unclear. Promising results have been reported in a randomised controlled trial and case series for elective open abdominal aortic aneurysm surgery (rate of incisional hernias: 9.3% v 2.7% at three year follow-up) and after gastric bypass for obesity (rate of incisional hernias 4.4% at two year follow-up v 30% in matched controls).^{w2 w3} However, other small series have reported unacceptably high complication rates.^{w4} Two large multicentre trials assessing prophylactic mesh placement are currently being conducted.

Mention the postoperative risk of incisional hernia when obtaining informed consent from all patients undergoing laparotomy.

How should an incisional hernia be diagnosed?

Most incisional hernias can be diagnosed by a review of the patient's history and by clinical examination. Patients typically present with an abdominal bulge in the region of the surgical scar. On examination the edges of the fascial defect can often be palpated, although an accurate estimation of the size of the defect may be difficult to discern clinically. The size of the peritoneal sac and associated contents is often large, although the fascial defect may be fairly small, particularly in obese patients and after multiple abdominal operations, where there may be numerous small fascial defects. Many incisional hernias are asymptomatic, but 20-50% present with pain. Skin changes as a result of pressure related capillary thrombosis and atrophic muscle fibrosis may occur in large and in longstanding hernias.^{w5}

A PATIENT'S PERSPECTIVE

A few years after having a hysterectomy for endometriosis, which was complicated by a bowel perforation, relaparotomy, and subsequent wound infection, I gradually noticed that I had a bulge in the lower part of my abdomen and that some of my clothes no longer fitted. The bulge started to get much bigger and to cause discomfort, making it difficult for me to complete my normal daily activities. It's hard to explain, but I had a strange sensation that my bowel was spilling out.

I was referred to a specialist, who diagnosed a large and complex incisional hernia. We discussed the options for treatment and I was placed on the waiting list for an open incisional hernia repair, which involved releasing the muscles to fix the hernia (a component separation; fig 1). I was apprehensive because of the problems I had after my original operation, but I knew that I couldn't go on like as I was.

I was in hospital for a week after the operation and had wound drains in. It was difficult after the operation and I took three months to recover fully. I am now getting back to normal and am very grateful to the team that looked after me.

What diagnostic imaging should be used?

Ultrasonography is commonly used to confirm the clinical diagnosis. The sonographic image of a hernia is a fascial gap with protruding hernia contents. The hernia sac should increase in size or change location when the patient coughs. Intestinal structures are characterised by peristaltic movements and air bubbles, whereas the omentum appears as a stationary, highly reflective, space occupying structure.

More detailed diagnostic imaging is indicated in four patient groups^{w6}:

- Obese patients (body mass index >35)
- Patients with recurrent incisional hernias
- Patients with large hernias with loss of domain (abdominal viscera permanently residing outside the abdominal cavity in the hernia sac)
- Patients with pain within the abdominal wall but with no clinically detectable hernia.

In these patients computed tomography (with or withoutValsalva) and particularly multidetector computed tomography, which allows three dimensional reconstruction, is useful. Occult defects are accurately delineated, the contents of the sac defined, and an estimate can be made of the abdominal contents that have lost domain.^{w7}

Does an incisional hernia have to be repaired?

Not every patient who presents with an incisional hernia is suitable for surgical repair, and the risk of surgery must be balanced against the risk of complications if the hernia is left untreated. Between 6% and 15% of incisional hernia repairs are performed because of strangulation or obstructive symptoms.^{w5} However, little information is currently available on the risk of major complications from untreated incisional hernias. Small hernias invariably enlarge with time as a result of the continuous intra-abdominal pressure, diaphragmatic contractions, and increased pressure from coughing or straining.^{w8}

A commonsense approach is advocated. If the patient can safely have general anaesthesia and the chance of successful repair is reasonable, then surgery is indicated. If the patient presents a high anaesthetic risk or surgical repair will be technically difficult, then the size of the fascial defect relative to the hernia, the symptom complex, the patient's age, and the patient's preferences must be carefully considered. In such cases, conservative management may be more appropriate. This decision making process is patient specific and therefore we recommend that all patients are referred for a specialist opinion.

What methods of surgical repair are available?

Despite recent advances in the management of incisional hernias, recurrence rates remain high. The recurrence rate after open suture repair can be as high as 54%, and as high as 36% for open mesh repair; however, in general, recurrence rates are slightly lower, with a mean of about 15%.^{w9} Recurrence rates for laparoscopic repair seem to be comparable to open mesh procedures but laparoscopic repair requires a shorter hospital stay.^{w10} The method of choice for repair of incisional hernias is still debatable. Figure 1 shows the anatomy of the different methods of repair.

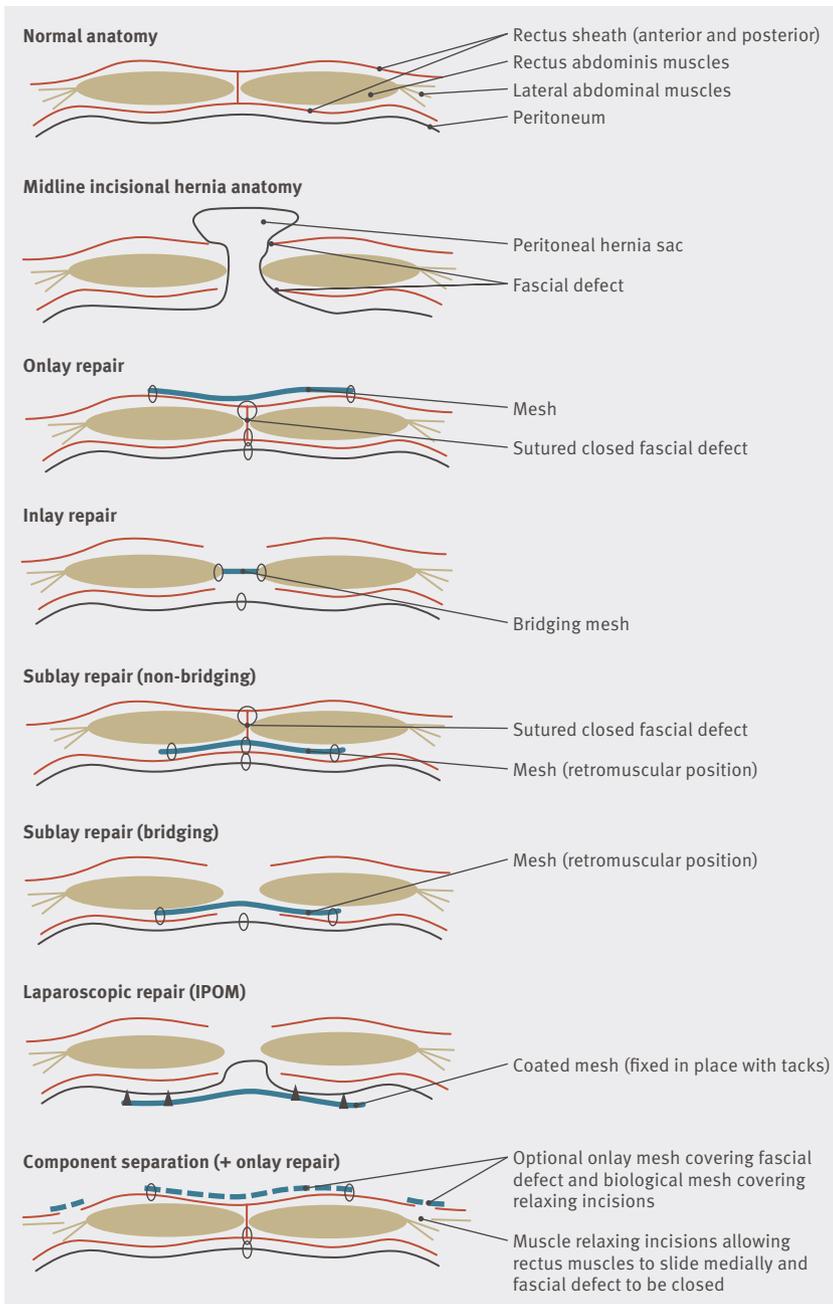


Fig 1 | Simplified anatomy of a midline incisional hernia and options for surgical repair

Interestingly, in a comparative retrospective study of more than 400 incisional hernia operations over 25 years, the most important prognostic factor was found to be the surgeon's experience rather than the repair method used.^{w11}

Mesh versus suture repair

A systematic review found that hernia repair without prosthetic mesh is associated with unsatisfactory recurrence rates of 12-54%, whereas hernia repair with mesh results in recurrence rates of 2-36%.^{w9} It is now accepted that only the smallest (less than 3 cm) incisional hernia should be repaired by primary tissue approximation with sutures.^{w12} A population based study of 10 882 patients in the US found an increase in the frequency of synthetic mesh use from 35% in 1987 to 65% by 1999.^{w14} A recent Cochrane

review of open procedures for the repair of incisional hernia concluded that open mesh repair is superior to suture repair in terms of recurrence but inferior in terms of wound infection and seroma formation on the basis of evidence from three trials.^{w15}

Laparoscopic mesh repair versus open mesh repair

Laparoscopic incisional hernia repair is an emerging technique with promising initial results. A composite or coated mesh (to reduce visceral adhesions) is placed in the intraperitoneal position and the hernia defect is usually not closed. This is referred to as an intraperitoneal onlay mesh (IPOM; fig 1). The advantages of the laparoscopic approach are that it allows the whole of the previous incision to be visualised and small fascial defects to be identified, but it has the disadvantage of relying fully on the strength of the mesh and its fixation.

A 2002 meta-analysis identified 83 studies comparing open and laparoscopic incisional hernia repair from a structured Medline search; it was able to compare 390 patients having open repair with 322 patients having laparoscopic repair.^{w16} Perioperative complications and length of stay were reduced in the laparoscopic group. Another meta-analysis identified 53 studies with a total of 5227 laparoscopic incisional hernia repairs. The rate of hernia recurrence was 3.98%.^{w17} Most of the studies were carried out in speciality centres that carried out large numbers of minimally invasive procedures, the authors concluded that the true recurrence rate is probably higher. Laparoscopic repair has been criticised for producing cosmetically worse results than the open repair because the hernia sac is not excised and the defect is not closed. Furthermore, laparoscopic repair is not always possible for large incisional hernias or when the hernia extends towards the costal margin or pelvis because adequate mesh overlap cannot easily be achieved.^{w17} A 2011 Cochrane review of 10 randomised control trials (including 880 patients) concluded that laparoscopic repair is a safe technique that has a lower risk of wound infection, shorter hospital stay, and is associated with fewer (albeit more severe) complications than open repair.^{w18} However, the data were heterogeneous and most trials had a short length of follow-up.

Techniques for open mesh repair

Three principal types of repair have been described for the open repair of incisional hernia with mesh—the inlay, onlay, and sublay techniques.

In the inlay technique the mesh is placed between the muscles in a bridging position. The mesh is in contact with the viscera (fig 1). Polypropylene mesh anchors to all adjacent tissues and can therefore induce extensive adhesions to viscera if placed in a position where it becomes adjacent to the bowel. Erosion of the mesh then can occur into the intestines—a well recognised drawback of this technique.^{w12} A non-randomised prospective study reported good results with this technique, but these impressive results have not been repeated elsewhere.^{w19} A smaller retrospective analysis compared the inlay, onlay, and sublay techniques. The recurrence rate for the inlay technique was 44%, and two of 23 patients developed

enterocutaneous fistulas.^{w20} Inlay techniques, therefore, are not generally recommended. Furthermore, the force needed to dislocate a bridged mesh is much lower than for a closed defect, and bridging should be a last resort only.^{w21}

In the onlay technique (fig 1), the mesh is placed over the abdominal wall closure in the subcutaneous prefascial space.^{w22} In a systematic review, recurrence rates after this technique varied from 5.5% to 14.8%, with a mean follow-up of one to 6.7 years.^{w23} The main criticisms of this technique are the high rates of wound infections and seroma formation.^{w12 w15}

In the sublay technique, the mesh is placed over the closed posterior rectus sheath and peritoneum (fig 1).^{w24} If the hernia is large and the posterior sheath cannot be closed, the mesh is sometimes used to bridge the defect (fig 1). A systematic review found that the recurrence rate after sublay repair varied from 1% to 23% at a mean follow-up of 1.7 to 6.7 years.^{w23} The European Hernia Society has adopted sublay mesh repair as the gold standard open repair; however, the procedure has been reported as technically more difficult than the onlay technique, with a steeper learning curve and a requirement for more operative time.^{w12 w25}

Chronic pain after incisional hernia repair

Chronic pain (for more than three months postoperatively^{w26}) after incisional hernia repair is poorly documented. A review reported that clinically important pain after open mesh repair of incisional hernia has an incidence of 10-20%.^{w27} The causes of the pain are poorly understood but probably include a combination of mesh associated

inflammation, nerve damage from mesh fixation, nerve entrapment or damage, visceral adhesions to the mesh and fixation points, and tension in the repair. Whether the pain relates to the preoperative symptom complex (as with inguinal hernia repair) is not yet established. The importance of chronic pain is difficult to gauge because of the lack of prospective high quality studies. Patients may think that mild postoperative discomfort is an acceptable consequence of surgery for an unsightly and uncomfortable abdominal swelling, whereas pain that limits daily activity after repair of a small asymptomatic incisional hernia may not be thought acceptable.

Patients who present with chronic pain should be referred back to the operating surgeon. A computed tomogram may be useful to assess whether the pain is related to a recurrence of the hernia or a port site hernia (after laparoscopic repair). If there is no evidence of recurrence, many surgeons adopt a watch and wait approach with referral to chronic pain services. Other surgeons have reported removing fixation tacks or sutures or replacing the mesh, with successful outcome.^{w28 w29} However, no high quality evidence is available to recommend the best way to manage this problem.

Special circumstances

Giant incisional hernias

Patients with giant incisional hernias (fascial defect >10 cm in transverse diameter) and obese patients (body mass index >35) present a surgical and anaesthetic challenge. These patients often have poor quality abdominal wall musculature coupled with multiple comorbid medical problems. A further problem that has to be overcome is

ONGOING RESEARCH

Watchful Waiting Versus Repair of Oligosymptomatic Incisional Hernias (AWARE) <http://clinicaltrials.gov/ct2/show/NCT01349400>

Prevention of Incisional Hernia by Mesh Augmentation After Midline Laparotomy for Aortic Aneurysm Treatment (PRIMAAT) <http://clinicaltrials.gov/ct2/show/NCT00757133>

Prophylactic Mesh Implantation for the Prevention of Incisional Hernia (ProphMesh) <http://clinicaltrials.gov/ct2/show/NCT01203553>

Laparoscopic Versus Open Incisional Hernia Repair (COLIBRI) <http://clinicaltrials.gov/ct2/show/NCT01420757> (completed but not yet published)

TIPS FOR NON-SPECIALISTS

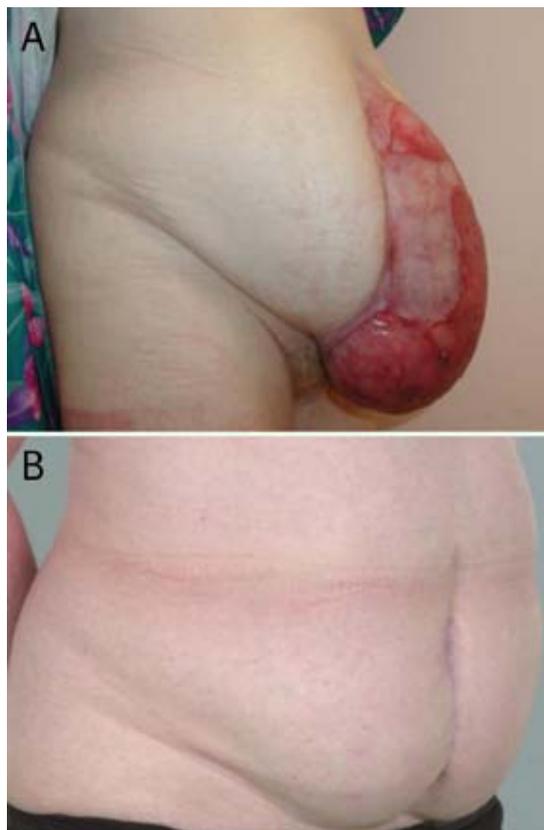
Refer all incisional hernias for a specialist opinion and urgently refer painful hernias and large hernias in which a small fascial defect is suspected

Divarication of the rectus muscles (separation of the rectus muscle with an intact fascia, which usually does not need surgery) may resemble an epigastric hernia; if the diagnosis is uncertain, ultrasonography is useful before referral

Optimise weight, smoking status, and diabetic control before surgery

The positioning of the mesh depends on the type of repair; a small postoperative bulge after laparoscopic hernia repair is normal because the fascial defect is not closed

Fig 2 | Photographs of a patient with a large complex incisional hernia before (A) and after (B) laparotomy



ADDITIONAL EDUCATIONAL RESOURCES

Resources for patients

Patient UK (www.patient.co.uk/health/Hernia.htm)—An overview of all types of hernia, risk factors, and management

For healthcare professionals

Sauerland S, Walgenbach M, Habermalz B, Seiler CM, Miserez M. Laparoscopic versus open surgical techniques for ventral or incisional hernia repair. *Cochrane Database Syst Rev* 2011;3:CD007781

Den Hartog D, Dur AHM, Tuinebreijer WE, Kreis RW. Open surgical procedures for incisional hernias. *Cochrane Database Syst Rev* 2008;3:CD006438

Muysoms FE, Miserez M, Berrevoet F, Campanelli G, Champault GG, Chelala E, et al. Classification of primary and incisional abdominal wall hernias. *Hernia* 2009;13:407-14 (European Hernia Society classification for incisional hernias)

Sanders DL, Kingsnorth AN. Prosthetic mesh materials used in hernia surgery. *Expert Rev Med Devices* 2012;9:159-79

Medscape (<http://emedicine.medscape.com/article/1297226-overview>)—An overview of abdominal wall reconstruction and complex hernias

the risk of serious “loss of domain” once the hernia is repaired, which can result in abdominal compartment syndrome. Loss of domain implies that a proportion of the abdominal contents resides permanently (in a hernia sac) outside the natural abdominal cavity. Returning the contents requires considerable physiological adaptation (predominantly respiratory) if the volume exceeds 20% of the size of the abdominal cavity.^{w8}

Preoperative pneumoperitoneum has been used to overcome the problems of loss of domain by increasing the size of the abdominal cavity before surgery.^{w30} Although this technique may be effective, it has not been widely adopted in the UK. Patients and the surgical technique must be carefully selected, and the team will usually include a hernia specialist, anaesthetist, and plastic surgeon. Patients often need postoperative care in the intensive treatment unit. Dumainian and Denham have updated an algorithm for the management of complex incisional hernias.^{w31}

The component separation technique allows a flap of the rectus muscle, anterior rectus sheath, internal oblique, and transversus abdominus muscle to slide medially, enabling giant hernia defects (up to 20 cm) to be closed (figs 1 and 2).^{w32} This can be reinforced with a prosthetic mesh to supplement the attenuated layers of the abdominal wall and is the technique of choice for giant midline incisional hernias.

Incisional hernia repair and pregnancy

Repair of large incisional hernias in premenopausal women presents special problems because elasticity and expansion of the abdominal wall will be required if the patient subsequently becomes pregnant. Few data are available on the required compliance of the abdominal wall during pregnancy or whether prosthetic mesh reduces the elasticity enough to cause complications during pregnancy.^{w33} There have been a few case reports of successful pregnancies in which the uterus has been within (or part of) the hernia sac.^{w34-w36} Small, asymptomatic incisional hernias can probably be safely left until the completion of a family. Large or symptomatic hernias should be fixed, and in these cases it may be better to avoid the use of mesh and to use a sutured repair such as the shoelace

technique.^{w33} Patients must be warned of the high risk of recurrence with subsequent pregnancy.

Contributors: Both authors contributed with the literature review. DLS wrote the article and ANK reviewed the article and made amendments. DLS is guarantor.

Funding: None received.

All authors have completed the ICMJE disclosure form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years, no other relationships or activities that could appear to have influenced the submitted work

Provenance and peer review: Not commissioned; externally peer reviewed.

Patient consent obtained.

- Sanders DL, Kingsnorth AN. From ancient to contemporary times: a concise history of incisional hernia repair. *Hernia* 2012;16:1-7.
- Fitzgibbons RJ, Richards AT, Quinn TH. Open repair of abdominal wall hernia. In: Ashley SW, ed. *ACS surgery principles and practice*. American College of Surgeons, 2007. www.acssurgery.com/acs/pdf/ACS0527.pdf.
- Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. *Br J Surg* 1985;72:70-1.
- Bucknall TE, Cox PJ, Ellis H. Burst abdomen and incisional hernia: a prospective study of 1129 major laparotomies. *BMJ* 1982;284:931-3.
- Rutkow IM. Demographic and socioeconomic aspects of hernia repair in the United States in 2003. *Surg Clin North Am* 2003;83:1045-51, v-vi.
- Sanders RJ, DiClementi D. Principles of abdominal wound closure. II. Prevention of wound dehiscence. *Arch Surg* 1977;112:1188-91.
- Stevick CA, Long JB, Jamasbi B, Nash M. Ventral hernia following abdominal aortic reconstruction. *Am Surg* 1988;54:287-9.
- Hall KA, Peters B, Smyth SH, Warneke JA, Rappaport WD, Putnam CW, et al. Abdominal wall hernias in patients with abdominal aortic aneurysmal versus aortoiliac occlusive disease. *Am J Surg* 1995;170:572-5; discussion 75-6.
- Giroto JA, Malaisrie SC, Bulkely G, Manson PN. Recurrent ventral herniation in Ehlers-Danlos syndrome. *Plast Reconstr Surg* 2000;106:1520-6.
- Klinge U, Binnebosel M, Mertens PR. Are collagens the culprits in the development of incisional and inguinal hernia disease? *Hernia* 2006;10:472-7.
- Henriksen NA, Yadete DH, Sorensen LT, Agren MS, Jorgensen LN. Connective tissue alteration in abdominal wall hernia. *Br J Surg* 2011;98:210-9.
- Carlson MA, Ludwig KA, Condon RE. Ventral hernia and other complications of 1000 midline incisions. *South Med J* 1995;88:450-3.
- van 't Riet M, Steyerberg EW, Nellensteyn J, Bonjer HJ, Jeekel J. Meta-analysis of techniques for closure of midline abdominal incisions. *Br J Surg* 2002;89:1350-6.
- Hodgson NC, Malthaner RA, Ostbye T. The search for an ideal method of abdominal fascial closure: a meta-analysis. *Ann Surg* 2000;231:436-42.
- Ceydeli A, Rucinski J, Wise L. Finding the best abdominal closure: an evidence-based review of the literature. *Curr Surg* 2005;62:220-5.
- Harlaar JJ, Deerenberg EB, van Ramshorst GH, Lont HE, van der Borst EC, Schouten WR, et al. A multicenter randomized controlled trial evaluating the effect of small stitches on the incidence of incisional hernia in midline incisions. *BMC Surg* 2011;11:20.
- Jenkins TP. The burst abdominal wound: a mechanical approach. *Br J Surg* 1976;63:873-6.
- Cengiz Y, Blomquist P, Israelsson LA. Small tissue bites and wound strength: an experimental study. *Arch Surg* 2001;136:272-5.
- Israelsson LA, Jonsson T. Suture length to wound length ratio and healing of midline laparotomy incisions. *Br J Surg* 1993;80:1284-6.
- Harlaar JJ, van Ramshorst GH, Nieuwenhuizen J, Ten Brinke JG, Hop WC, Kleinrensink GJ, et al. Small stitches with small suture distances increase laparotomy closure strength. *Am J Surg* 2009;198:392-5.
- Millbourn D, Cengiz Y, Israelsson LA. Effect of stitch length on wound complications after closure of midline incisions: a randomized controlled trial. *Arch Surg* 2009;144:1056-9.
- Makela JT, Kiviniemi H, Juvonen T, Laitinen S. Factors influencing wound dehiscence after midline laparotomy. *Am J Surg* 1995;170:387-90.
- Veljkovic R, Protic M, Gluhovic A, Potic Z, Milosevic Z, Stojadinovic A. Prospective clinical trial of factors predicting the early development of incisional hernia after midline laparotomy. *J Am Coll Surg* 2010;210:210-9.
- Van Ramshorst GH, Nieuwenhuizen J, Hop WC, Arends P, Boom J, Jeekel J, et al. Abdominal wound dehiscence in adults: development and validation of a risk model. *World J Surg* 2010;34:20-7.
- Welsh A. *Surgical site infection: prevention and treatment of surgical site infection*. RCOG Press, 2008.

Accepted: 12 April 2012