Abdominal wound dehiscence and incisional hernia

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Abstract

Abdominal wound dehiscence and incisional hernias are common problems facing the general surgeon. Both can be thought of as forms of 'wound failure' and the risk factors are similar for both. Some of these may be avoided by sound surgical technique and correct patient preparation. The management of wound dehiscence ranges from simple dressings to emergency surgery to close a 'burst abdomen' followed by a period of intensive care. The management of incisional hernias is a much bigger topic and encompasses various surgical techniques. This review will describe the aetiology of wound failure and the management of acute wound dehiscence. It will then go on to cover in more detail the assessment of patients presenting with incisional hernia as well as outlining the main surgical options available and some of the auxiliary techniques that are used to aid repair. Lastly the topic of laparostomy closure, an increasing problem due to the increasing numbers of patients undergoing major surgery, and the use of Vacuum Assisted Closure devices are briefly reviewed.

Keywords dehiscence; hernia; hernia repair; incisional hernia; incisional hernia repair; laparostomy; VAC therapy; vacuum assisted closure; ventral hernia; wound dehiscence; wound failure

Introduction

Abdominal wound dehiscence and incisional hernia can both be thought of as forms of wound failure, which may be defined as the failure of the incision to heal and to maintain the normal anatomy of the abdominal wall.

Wound dehiscence is an acute wound failure[1] and can be defined as the partial or complete disruption of any or all layers of a surgical wound. This can range from a relatively minor breakdown of the skin and subcutaneous tissue to a complete failure of the entire wound with evisceration, or 'burst abdomen'. The incidence of abdominal wound dehiscence ranges from 0.25–3% with an associated mortality of up to 25%[2,3] and is most often seen at around 1 week post surgery.[2,4]

Incisional hernia (Figure 1) is a chronic wound failure and presents some time after surgery, often at follow-up clinics or as a new referral. The incidence varies between 5% and 15% following vertical midline incisions at one year follow up. More than 50% of incisional hernias occur in the first year post-operatively and 90% of incisional hernias occur within three years of surgery.[5–7]

Cause and prevention

The causes of acute and chronic wound failure are similar. Poor surgical technique and wound infection can cause acute dehiscence; acute dehiscence is the commonest cause of incisional hernia which is preceded by wound infection in nearly 50%.[5] There are a number of other risk factors that predispose to wound failure. These can be divided into preoperative (patient related) factors, operative (surgical) factors and postoperative factors (Table 1). There is evidence that, in many cases, wound failure after abdominal wall closure is dependent on the surgeon.

Many of these risk factors are not readily avoidable, but sound surgical technique with appropriate suture material, good bites of tissue (>1 cm), properly laid knots with sufficient throws and avoidance of excessive tension is important. If possible, the restoration of normal anatomy during the closure of abdominal wounds should be attempted. In the midline, this means apposition of the linea alba and, in lateral or horizontal incisions, closure of tendinous, aponeurotic and fascial structures (e.g. posterior and anterior rectus sheath) in layers. The optimal technique for closing a midline incision is mass closure with a continuous slowly absorbable monofilament suture.[8–10] The use of a slowly absorbable material, such as PDS, appears to provide sufficient strength for a long enough period to allow the wound to heal, whilst reducing other complications such as persistent wound pain and suture sinus. Whilst there is little evidence of its superiority over interrupted sutures in randomised trials,[11] a continuous suture ensures that tension is distributed evenly along the length of the wound and is a popular technique because of its safety, efficacy and speed. A suture length to wound length ratio of at least 4:1 should be used, allowing a minimum of 1 cm bites at 1 cm intervals, and is associated with a lower rate of incisional hernia.[12]

The choice of incision is a further consideration. There has been a growing interest in transverse incisions which provide excellent access to most parts of the abdomen. This approach has been found to have a lower incidence of both early and late complications including wound dehiscence and incisional hernia.[13]

Incisional hernia at port sites following laparoscopic surgery is also a recognised complication with an incidence of up to 3.6%.[14] These usually remain unreported until a complication occurs. The midline supra- or subumbilical port site used during many procedures should be closed with a slowly absorbable monofilament suture. Consideration should also be given to closing port sites of 10 mm or more elsewhere, especially when they have been stretched, for example, to remove a gallbladder.

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Figure 1 A large incisional hernia.

It is particularly important to identify the existence of a pre-existing umbilical hernia when using an umbilical port, and to ensure that the defect is properly defined and repaired at the end of the procedure.[15]

In addition to sound surgical technique, the risk of infection must also be minimised. This can be achieved through:

- Ensuring that the skin is shaved as late as possible
- Adequate skin preparation
- Appropriate use of prophylactic antibiotics for high-risk patients and procedures.

Risk factors for wound dehiscence after laparotomy

Preoperative/patient factors

- Age (>65)
- Male
- Smoker
- Obesity
- Diabetes
- Hypoalbuminaemia/malnutrition
- Sepsis
- Anaemia
- Uraemia
- Malignancy
- Chemotherapy/radiotherapy
- Steroid use

Operative factors

- Emergency surgery
- Re-operation
- Bowel (dirty) surgery
- Suture type and technique

Postoperative factors

- Mechanical ventilation
- Haemodynamic instability
- Increased intraabdominal pressure
- Ascites
- Wound infection

Table 1

Minimal dissection of tissue, good haemostasis and the selective use of drains can reduce postoperative formation of a seroma or haematoma and subsequent infection that could lead to dehiscence.

Management of wound dehiscence

Superficial wound dehiscence can often be managed conservatively. This involves regular inspection and dressing of the wound. If the dehiscence has been caused by an infected collection then the opening of the wound and the resulting drainage may allow subsequent healing by secondary intention. Remaining sutures or skin clips that prevent the wound from opening sufficiently to allow drainage should be removed. If there is ongoing infection or surrounding cellulitis then antibiotics will be required. Large superficial dehiscences may require debridement of infected and necrotic tissue as well as careful selection of appropriate packing and dressing materials. More advanced techniques such as vacuum dressings may also be required. Specialist tissue viability nurses often have a lot to offer and should be involved in difficult cases. A fit patient with a clean, non-infected wound may benefit from delayed primary closure which usually results in a superior cosmetic outcome. The management plan should be discussed with the patient and reassurance offered. Many patients find the sudden 'opening-up' of their wound distressing.

A complete dehiscence, or 'burst abdomen', due to disruption of the fascial layers with exposure of the viscera will require emergency surgery. This involves debridement of the wound edges as necessary with removal of previous suture material and re-suturing, often with 'retention sutures'. Interrupted heavy 1/0 non-absorbable suture is used taking large bites from the wound edge (>3 cm) and including all layers. A plastic sleeve may be used over the suture where it overlies the skin to prevent it from cutting into the skin (Figure 2). However, whilst retention sutures may allow satisfactory closure of the abdomen, there is evidence that this technique does not reduce the incidence of later incisional hernia.[16] Occasionally it becomes clear that such a closure will have serious effects on the patient, such as compromising ventilation or risking abdominal compartment syndrome. In such cases it will be necessary to leave the patient with a laparostomy. Such patients may become seriously ill with sepsis and organ failure, and are best managed in a HDU or ICU.

Management of incisional hernias

Most patients with incisional hernias, at least initially, have few symptoms. At presentation up to 25% of patients are asymptomatic.[17] If symptoms occur, they commonly consist of:

- Restriction of movement or of wearing certain clothes
- Embarrassment due to disfigurement
- Discomfort or pain.

Such patients usually present to the general surgical outpatient clinic. Less commonly they may present as an emergency with:

- Bowel obstruction
- Ischaemic bowel
- Spontaneous rupture of the contents of the hernia (rare).

Figure 2 A 'burst abdomen' resutured using retention sutures. Source: D J Leaper, Cardiff University, Cardiff, UK.

Assessment

Clinical examination should be in the standing and supine positions to allow easy identification of the hernia, which may not be initially obvious if small. It may be necessary to ask the patient to cough or carry out a Valsalva manoeuvre to exaggerate the hernia. The edges of the defect can usually be palpated and the size of the defect should be noted because it may influence surgical technique. The reducibility of the hernia should be assessed.

Imaging

Radiological investigation may be required in obese patients with small hernias that are difficult to show clinically, and those with very large complicated hernias.

Ultrasound examination may show a fascial defect and provide a measurement of the size and identification of the contents of the hernial sac. However, this modality is highly operator dependent and time-consuming.

MRI is increasingly used in selected patients, and may be particularly useful in the assessment of recurrent hernias where it allows visualisation of the existing mesh and identification of adhesions.[18]

CT is particularly helpful to fully assess large complex hernias, recurrent hernias or hernias with multiple defects, and is the modality of choice.[19,20] Occult defects are identified, the contents of the sac are more clearly defined and estimation of the 'loss of domain' of the abdominal contents can be made.

Loss of domain is where large hernia sacs develop with abdominal contents permanently residing outside of the abdominal cavity and retraction of the normal musculature of the abdominal wall. A proportion of the abdominal contents have therefore 'lost domain' within the abdomen. Attempts to reduce the contents into the remaining peritoneal cavity are likely to result in abdominal compartment syndrome if significant loss of domain (about 20%) is present.[21]

Surgical repair of incisional hernia

Only the smallest hernias (<3–4 cm) should be repaired with a suture technique.[22,23] A suitable technique for such a hernia is the Mayo repair, whereby the fascial edges are closed with a 2 cm overlap using interrupted monofilament suture, and reinforced with a continuous running suture (Figure 3). However, attempts at repairing larger hernias with such a technique are associated with an increased risk or recurrence.[24] Most incisional hernias are therefore repaired using one of several techniques that employ mesh. The down side to the use of mesh, however, is an increased rate of infection.[25]

Choice of mesh

The ideal mesh should be non-absorbable, biocompatible, preserve the physiological elasticity of the abdominal wall and allow proper integration with the surrounding tissue.[26] Polypropylene (Prolene®, Marlex® etc) and polyethylene (e.g. Mersilene®) meshes are commonly used; they are flexible and easily cut to size. They allow excellent tissue ingrowth, but they become anchored to adjacent tissues and are not suitable for techniques that allow the mesh to come into contact with abdominal contents. If this happens, extensive adhesions to the viscera form and erosion of the mesh into the intestines may occur.

Traditional polypropylene meshes with a small pore size cause a relatively long lasting inflammatory reaction with a stiff scar plate. Newer lightweight meshes (e.g. Vypro®) with a larger pore size (3–5 mm) and a corresponding reduction in the amount of polypropylene result in better tissue integration, a more flexible scar net, and a reduced inflammatory response.[27,28]

The number of meshes available for intraperitoneal use has increased significantly over recent years with the advent of laparoscopic hernia repair. These fall into three categories:

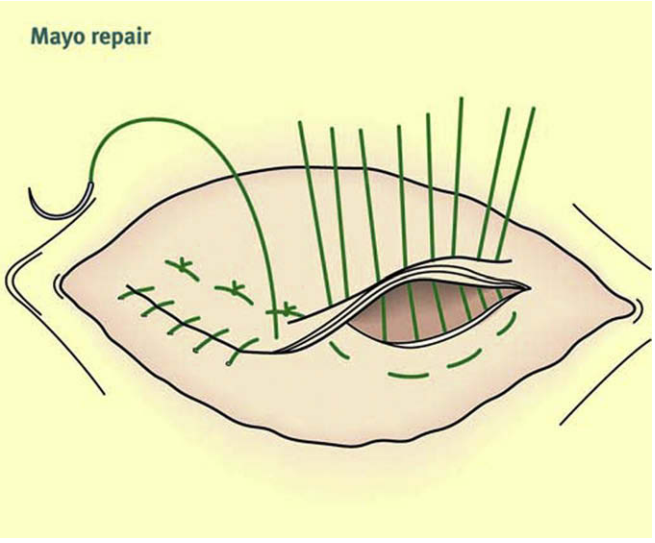

Figure 3

expanded polytetrafluoroethylene (ePTFE), composite meshes and biological meshes.

ePTFE meshes (Goretex®, Dualmesh® etc) have been shown to cause few adhesions and can be used safely in direct contact with the abdominal contents.[29] Composite meshes comprise a polypropylene (Proceed®, Sepramesh®, Composix® etc) or polyethylene (e.g. Parietex Composite®) mesh layer with some form of barrier layer. The traditional mesh provides strength and allows incorporation into the abdominal wall while the barrier layer prevents adhesion of the underlying viscera. It is important to ensure that such meshes are inserted the correct way up. Biological meshes are acellular extracellular matrix materials derived from humans or animals. In theory such meshes become vascularised and colonised by host cells leading to partial or complete remodelling. There is therefore great interest in the use of such materials in contaminated environments as there is a theoretical possibility that infections can be cleared.[30] Examples of such materials include porcine dermal collagen (Permacol®) and human dermis (AlloDerm®, FlexHD®). Cost and a lack of long term evidence currently limit the routine use of biological meshes.

There is currently insufficient evidence from randomised controlled trials to form generalised recommendations about which mesh should be used for incisional hernia repair.[31,32] The choice will ultimately depend largely on surgeon preference and cost, taking into account the general principles outlined above.

Open repair

Three general techniques may be used during open mesh repair of incisional hernias – onlay, inlay and sublay (Figure 4).

The initial approach is identical regardless of the technique of mesh placement. The old scar and redundant skin are excised and the underlying hernia sac defined by careful dissection from the surrounding tissues. The hernia sac is opened, adhesions between the contents and the sac are divided and the sac is excised.

For an onlay repair, a border of at least 5 cm around the fascial edge is exposed by raising skin flaps. The fascial edges are brought together using continuous non-absorbable monofilament suture, applying the rule of 1 cm bites at 1 cm intervals. A mesh is placed to cover the suture line and overlap by at least 5 cm in all directions. The mesh must lie flat, with no folds and no tension, and is secured with further non-absorbable suture to the underlying fascia. The skin is closed over the mesh.[33] Tissue glue may be sprayed beneath the flaps to reduce seroma formation if the skin flaps are particularly large. Suction drains should be placed beneath the flaps. The onlay technique is versatile and lends itself to repair of hernias in all quadrants of the abdomen. It gives excellent results for the repair of major incisional hernias when combined with components separation and fibrin sealant.[34]

The inlay technique involves suturing a mesh to the fascial edges without initially closing the defect. This requires the correct choice of mesh (as outlined above) because it will lie in contact with the viscera. One series of 350 patients reported excellent results with an inlay technique,[35] although other groups have had less success with recurrence rates of up to 44% (higher than those for onlay and sublay repairs) and enterocutaneous fistulas developing at the edges of the mesh where

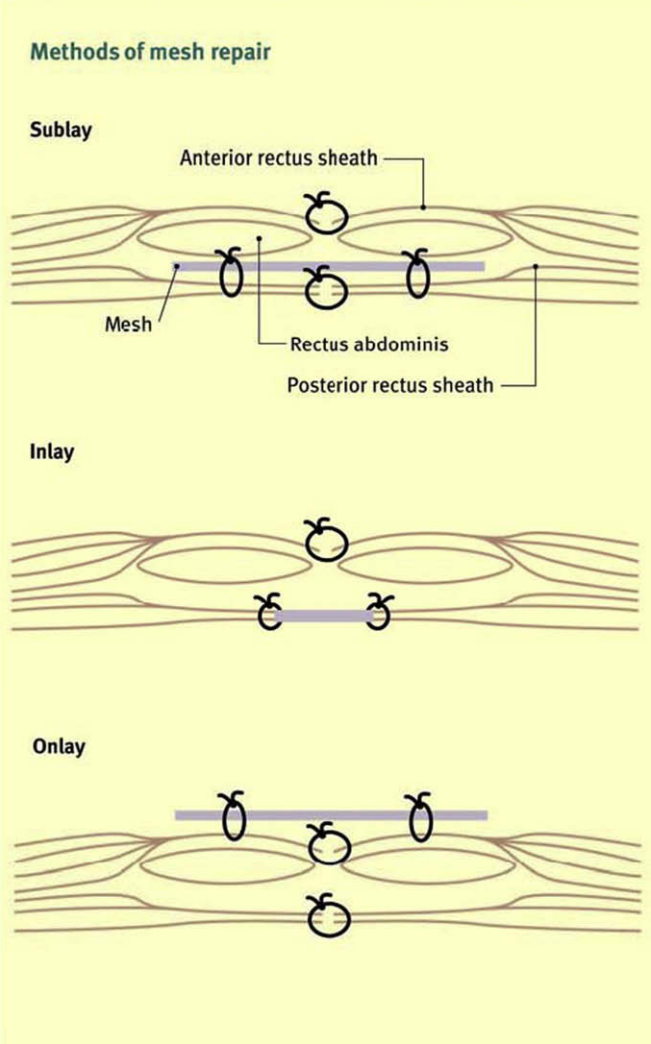

Figure 4

constant friction caused bowel damage.[36] Inlay techniques are not recommended unless there is a substantial defect that cannot be bridged or closed using other procedures.

For the sublay technique, the posterior rectus sheath and peritoneum (the peritoneum only below the arcuate line) is closed and the mesh is placed above this.[37] The rectus muscles are allowed to return to their natural position and cover the mesh. The anterior rectus sheath is closed. This can be a complex operation and is only really useful in the midline. Variations on the technique can be used away from the midline with the mesh positioned, for example, between the internal and external oblique muscle layers.[38]

Laparoscopic repair

With the increasing popularity of laparoscopic surgery, the laparoscopic repair of incisional hernias is becoming the technique of choice for many surgeons. This technique has the potential to offer all the benefits of other laparoscopic techniques such as a reduction in postoperative pain, early mobilisation and shorter hospital stay. However the learning curve is probably longer than that for open repair, and there is the potential for problems such as bowel injury, which may go unnoticed, and

significant bleeding, which may be difficult to control, leading to open conversion or reoperation in a number of cases. However, recent studies suggest the overall conversion and complication rates are low.[39–41] In terms of recurrence, outcomes do not seem to differ significantly between open and laparoscopic repair.[42,43] Laparoscopic repair is particularly useful for the repair of recurrent hernias following a previous open repair, when a repeat open procedure may be difficult due to the distorted anatomy and existing mesh/scar tissue.

Port placement requires some consideration for laparoscopic hernia repair. A pneumoperitoneum is created and appropriate ports (usually at least one 10 mm camera port and two 5 mm operating ports) are inserted. For large, complex hernias, multiple ports on both sides of the abdomen may be required. Great care is needed during initial port insertion as this will often be away from the midline and umbilicus, and there may be adherent bowel below the abdominal wall; an open insertion technique or the use of an optical trocar are appropriate methods. The insertion of subsequent ports under vision may also be difficult if the view is obscured by adherent bowel.

The intraperitoneal onlay mesh (IPOM) is the most common technique used for laparoscopic repair (Figure 5). Adhesions between the hernia contents and anterior abdominal wall/hernia sac are divided so that the contents may be reduced. This is the most time-consuming part of the operation, and requires a careful mix of electrocautery or ultrasonic scalpel to prevent excessive bleeding, as well as sharp dissection with scissors in proximity to bowel to avoid thermal injury. The size of the defect is measured, following release of the pneumoperitoneum, and a mesh is shaped to cover and overlap the defect by 3–5 cm.[44] The mesh may be labelled (left, right, top, bottom) to aid positioning and is then carefully rolled up and introduced via one of the ports. Once inside the abdominal cavity, the mesh is unrolled and positioned over the defect. This is aided by the placement of four or more sutures on the mesh, prior to inserting it into the abdomen, which can be grasped using a suture passer, such as the Endoclaw®, and used to pull the mesh up onto the abdominal wall. The mesh is then secured in place with a 'double crown' of metal tacks. These may be reinforced with slowly absorbable monofilament transfascial sutures passed from outside, through the abdominal wall and mesh and back outside with the aid of the suture passer using small stab incisions. However, there is evidence that tacks alone are sufficient, and some surgeons believe the use of transfascial sutures leads to increased postoperative pain.[41] The port sites are closed in the standard manner, and stab incisions closed with glue or steristrips.

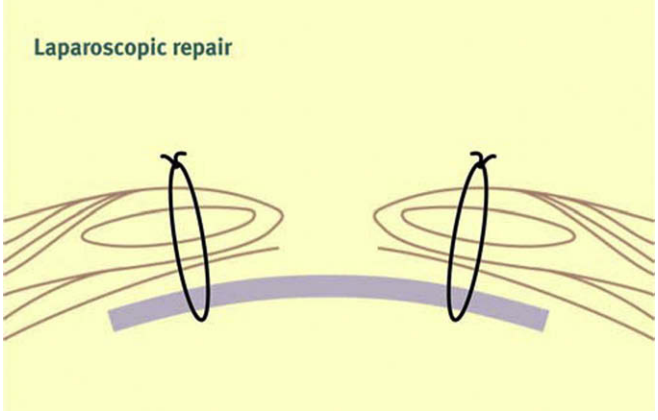

Figure 5

Some surgeons believe that the hernial defect should be closed with re-approximation of the linea alba during laparoscopic repair, and several techniques have been described to achieve this; this is not a routine part of the procedure and because of this, as well as the fact that excess skin is not removed, there is often a persistent bulge following the repair of a large hernia. This should be explained to the patient prior to surgery, who may otherwise assume that the repair has failed.

Despite the increasing tendency to laparoscopic repair, there is little evidence of a significant benefit over open repair in terms of recurrence rates and there remain a number of patients in whom laparoscopic repair is not possible. Relative contraindications to laparoscopic repair include:

- Multiple recurrent hernias or extensive previous abdominal surgery where adhesions are likely to be too dense
- Hernias presenting acutely with possible ischaemic bowel
- Hernias where there is loss of domain and therefore the contents cannot be easily returned into the abdominal cavity
- If other gastrointestinal surgery (e.g. bowel resection) is indicated.

Components separation

The Ramirez components separation technique allows enlargement of the abdominal wall surface by separating muscle layers without damaging the innervation or blood supply to the muscles. The technique allows advancement of the rectus abdominis muscle, anterior rectus sheath and internal oblique up to 10 cm towards the midline. This can cover a defect of up to 20 cm if performed on each side.[45] It involves the detachment of the external oblique aponeurosis from the rectus muscle and the development of a plane between the external and internal oblique aponeuroses. An additional procedure is the further mobilisation of the rectus by incising the posterior rectus sheath at its medial border ('sliding door' technique).[46] The components separation technique is particularly useful when supplemented with an onlay mesh repair. The fascial edges are closed in the midline. The repair is then covered with a mesh, which can be sutured to the divided edges of the external oblique with a continuous suture (Figure 6).[34]

Auxiliary techniques

A number of other techniques can be used to aid the repair of large incisional hernias, particularly when there is loss of domain.

Relaxing techniques involve multiple small incisions in fascial layers or at muscular attachments. Care must be taken to preserve the blood supply and innervation of the abdominal wall and sufficient fascia must be preserved to maintain the overall strength of the abdominal wall.

Preoperative measures to increase the volume of the abdominal cavity have also been described.

Progressive pneumoperitoneum may be achieved by placement of a catheter in the peritoneal cavity under local anaesthesia followed by gradual insufflations of air or carbon dioxide.[47,48] The

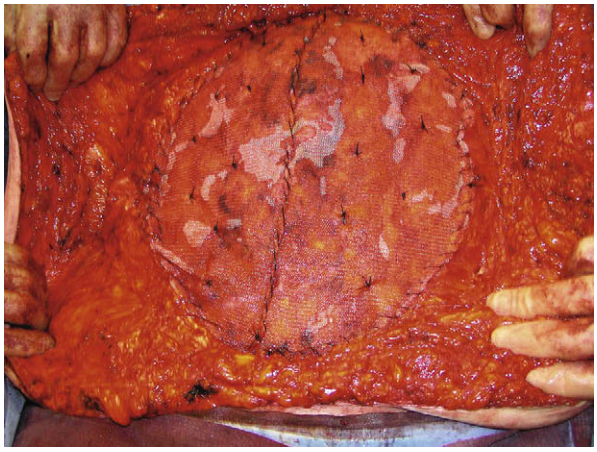

Figure 6 Onlay mesh repair, in this case combined with a Ramirez Component Separation. The mesh has been secured to the underlying fascia and, at its lateral borders, to the divided external oblique aponeuroses. A continuous suture has also been placed in the midline overlying the closure of the fascial layer beneath.

size of the peritoneal cavity is increased and adhesions elongated resulting in:

- Easier dissection
- Reduction of oedema
- Improved diaphragmatic tone
- Cardiorespiratory adaptation.

Pneumoperitoneum is rarely used due to the complexity of the procedure and the availability of other procedures (e.g. components separation).

Tissue expanders placed in the subcutaneous or submuscular space for a few months before surgery is another option.[49] This technique is particularly useful when the anatomy of the abdominal wall is severely distorted due to:

- Trauma
- After removal of large tumours/congenital abnormalities.

Special cases

Women of childbearing age with symptomatic hernias of the anterior abdominal wall may undergo surgery before further pregnancies. The hernia sac is freed and the hernia reduced as described above for open mesh repair. Mesh should be avoided because it will severely limit the elasticity and expansion of the abdominal wall. The defect is repaired using a suture method such as the shoelace or onlay darn techniques, the descriptions of which are beyond the scope of this review.[50]

There are a number of other special cases in which incisional hernias may develop and which require modified repair techniques (Table 2). The underlying principles of defining the anatomy, reducing the hernia and carrying out a tension-free repair still hold. Mesh is often used and in some cases may be anchored to bone (e.g. during the repair of hernias occurring at the iliac crest after its use as a donor site for bone graft).

Closure of a laparostomy

A laparostomy may be performed after a wide range of surgical procedures where closure of the abdomen is not possible, where closure would cause abdominal compartment syndrome leading to bowel ischaemia and respiratory compromise or to facilitate re-exploration.[51] The closure of a laparostomy is one of the most challenging procedures facing the hernia surgeon. The procedure must be carefully planned, starting from the moment the decision is made to leave an abdomen open, and may require input from intensivists, respiratory physicians and plastic surgeons.

The aims of the procedure are to provide adequate soft tissue coverage of the viscera and restoration of function of the abdominal wall. It may be possible to close a laparostomy soon after it is formed following an initial period of resuscitation and recovery in an ICU. The likelihood of fascial closure correlates with the cause of the laparostomy.[52] Closure is most likely after laparotomy for trauma. Laparotomies for gastrointestinal sepsis are more likely to be closed using supplementary mesh, and definitive closure is least likely if the underlying condition is pancreatitis.

Different techniques are required if closure is not achieved within 1–3 weeks. By this time, the exposed viscera are covered with a layer of granulation tissue and the options are skin grafting or the placement of a temporary absorbable mesh. This effectively produces a 'planned' incisional hernia that may be repaired subsequently.

If primary fascial closure is not possible, definitive closure must be undertaken at a later stage once the patient is well and other complications (e.g. sepsis, fistulas) have been managed. A variety of techniques and auxiliary procedures, similar to those described for incisional hernia repair, may be used.

Special cases of incisional hernia

- Parastomal hernias
- Lumbar hernias
- Iliac crest hernias after harvest of bone for grafting
- Subxiphoid hernias following median sternotomy
- Incisional hernias after nephrectomy

Table 2

Vacuum assisted closure

The use of topical negative pressure therapy (Vacuum Assisted Closure or VAC therapy) to promote wound debridement and healing was first described for the treatment of open fractures.[53] It has since been successfully applied to a wide variety of wounds and its use is now commonplace. There are, however, a number of contraindications (Table 3). Care also needs to be taken when

Contraindications to VAC therapy

- Malignancy in the wound
- Untreated osteomyelitis
- Non-enteric and unexplored fistulae
- Necrotic tissue with eschar (prior debridement required)

Table 3

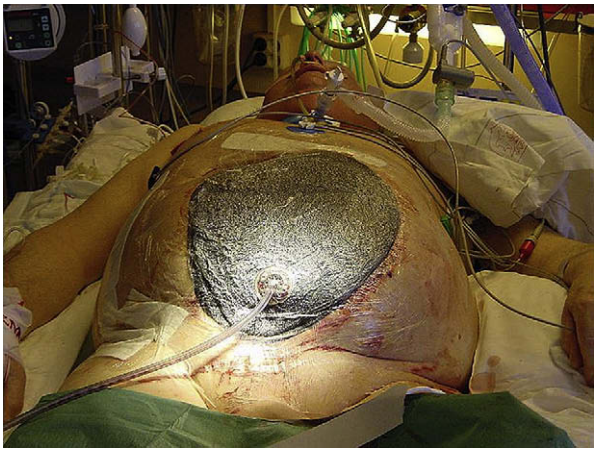

Figure 7 VAC dressing applied to a laparostomy.

there are exposed blood vessels or organs as these will need to be protected before the dressing is applied.

The application of a VAC dressing can be quite complex and is best achieved with the aid of someone experienced in the technique. Basically, the dressing consists of a piece of foam which is cut to the size of the wound and inserted into it to fill any cavity or space between the wound edges. This is then covered by an occlusive dressing. It is important that a good seal is obtained to prevent the loss of the vacuum. A specially designed suction tube is then placed over a hole in the inclusive dressing and connected to the vacuum pump.

Various theories about the mode of action exist, including the removal of interstitial fluid and decreased oedema, the alteration of factors such as proinflammatory cytokines and matrix metalloproteinases, the promotion of blood flow and the stimulation of protein and matrix synthesis and angiogenesis.[54]

VAC therapy can be used successfully in the management of wound dehiscence to aid healing and is increasingly used in the management of laparostomy (Figure 7). The bowel loops are separated from the fascia and the constant negative pressure helps to prevent the fascial edges from retracting. The result is that primary fascial closure can be achieved in significantly more patients, even several days following the initial laparotomy.[55] ◆

REFERENCES

1 Carlson MA. Acute wound failure. *Surg Clin North Am* 1997 Jun; **77**(3): 607–36.

2 Spiliotis J, Tsiveriotis K, Datsis AD, et al. Wound dehiscence: is still a problem in the 21th century: a retrospective study. *World J Emerg Surg* 2009 Apr 3; **4**(1): 12.

3 Waqar SH, Malik ZI, Razzaq A, Abdullah MT, Shaima A, Zahid MA. Frequency and risk factors for wound dehiscence/burst abdomen in midline laparotomies. *J Ayub Med Coll Abbottabad* 2005 Oct; **17**(4): 70–3.

4 Rodriguez-Hermosa JI, Codina-Cazador A, Ruiz B, et al. [Risk factors for acute abdominal wall dehiscence after laparotomy in adults]. *Cir Esp* 2005 May; **77**(5): 280–6.

5 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 Mar 27; **284**(6320): 931–3.

6 O'Dwyer PJ, Courtney CA. Factors involved in abdominal wall closure and subsequent incisional hernia. *Surgeon* 2003 Feb; **1**(1): 17–22.

7 Mudge M, Hughes LE. Incisional hernia: a 10 year prospective study of incidence and attitudes. *Br J Surg* 1985 Jan; **72**(1): 70–1.

8 van't Riet M, Burger JW, van Muiswinkel JM, Kazemier G, Schipperus MR, Bonjer HJ. Diagnosis and treatment of portal vein thrombosis following splenectomy. *Br J Surg* 2000 Sep; **87**(9): 1229–33.

9 Rucinski J, Margolis M, Panagopoulos G, Wise L. Closure of the abdominal midline fascia: meta-analysis delineates the optimal technique. *Am Surg* 2001 May; **67**(5): 421–6.

10 Weiland DE, Bay RC, Del SS. Choosing the best abdominal closure by meta-analysis. *Am J Surg* 1998 Dec; **176**(6): 666–70.

11 Fagniez PL, Hay JM, Lacaine F, Thomsen C. Abdominal midline incision closure. A multicentric randomized prospective trial of 3,135 patients, comparing continuous vs interrupted polyglycolic acid sutures. *Arch Surg* 1985 Dec; **120**(12): 1351–3.

12 Israelsson LA, Jonsson T, Knutsson A. Suture technique and wound healing in midline laparotomy incisions. *Eur J Surg* 1996 Aug; **162**(8): 605–9.

13 Grantcharov TP, Rosenberg J. Vertical compared with transverse incisions in abdominal surgery. *Eur J Surg* 2001 Apr; **167**(4): 260–7.

14 Bergemann JL, Hibbert ML, Harkins G, Narvaez J, Asato A. Omental herniation through a 3-mm umbilical trocar site: unmasking a hidden umbilical hernia. *J Laparoendosc Adv Surg Tech A* 2001 Jun; **11**(3): 171–3.

15 Azurin DJ, Go LS, Arroyo LR, Kirkland ML. Trocar site herniation following laparoscopic cholecystectomy and the significance of an incidental preexisting umbilical hernia. *Am Surg* 1995 Aug; **61**(8): 718–20.

16 Gislason H, Viste A. Closure of burst abdomen after major gastrointestinal operations—comparison of different surgical techniques and later development of incisional hernia. *Eur J Surg* 1999 Oct; **165**(10): 958–61.

17 Nieuwenhuizen J, Kleinrensink GJ, Hop WC, Jeekel J, Lange JF. Indications for incisional hernia repair: an international questionnaire among hernia surgeons. *Hernia* 2008 Jun; **12**(3): 223–5.

18 Kirchhoff S, Ladurner R, Kirchhoff C, Mussack T, Reiser MF, Lienemann A. Detection of recurrent hernia and intraabdominal adhesions following incisional hernia repair: a functional cine MRI-study. *Abdom Imaging* 2009 Mar 21.

19 Toms AP, Dixon AK, Murphy JM, Jamieson NV. Illustrated review of new imaging techniques in the diagnosis of abdominal wall hernias. *Br J Surg* 1999 Oct; **86**(10): 1243–9.

20 Ianora AA, Midiri M, Vinci R, Rotondo A, Angelelli G. Abdominal wall hernias: imaging with spiral CT. *Eur Radiol* 2000; **10**(6): 914–9.

21 Kingsnorth AN, Sivarajasingham N, Wong S, Butler M. Open mesh repair of incisional hernias with significant loss of domain. *Ann R Coll Surg Engl* 2004 Sep; **86**(5): 363–6.

22 Kingsnorth A, LeBlanc K. Hernias: inguinal and incisional. *Lancet* 2003 Nov 8; **362**(9395): 1561–71.

23 Hesselink VJ, Luijendijk RW, de Wilt JH, Heide R, Jeekel J. An evaluation of risk factors in incisional hernia recurrence. *Surg Gynecol Obstet* 1993 Mar; **176**(3): 228–34.

24 Mittermair RP, Klingler A, Wykypiel H, Gadenstatter M. Vertical Mayo repair of midline incisional hernia: suggested guidelines for selection of patients. *Eur J Surg* 2002; **168**(6): 334–8.

25 Burger JW, Luijendijk RW, Hop WC, Halm JA, Verdaasdonk EG, Jeekel J. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. *Ann Surg* 2004 Oct; **240**(4): 578–83.

26 Schumpelick V, Klinge U, Junge K, Stumpf M. Incisional abdominal hernia: the open mesh repair. *Langenbecks Arch Surg* 2004 Feb; **389**(1)**:** 1—5.

27 Klinge U, Klosterhalfen B, Birkenhauer V, Junge K, Conze J, Schumpelick V. Impact of polymer pore size on the interface scar formation in a rat model. *J Surg Res* 2002 Apr; **103**(2)**:** 208—14.

28 Klinge U, Junge K, Stumpf M, Ap AP, Klosterhalfen B. Functional and morphological evaluation of a low-weight, monofilament polypropylene mesh for hernia repair. *J Biomed Mater Res* 2002; **63**(2)**:** 129—36.

29 Koehler RH, Begos D, Berger D, et al. Minimal adhesions to ePTFE mesh after laparoscopic ventral incisional hernia repair: reoperative findings in 65 cases. *JSLS* 2003 Oct; **7**(4)**:** 335—40.

30 Campanelli G, Catena F, Ansaloni L. Prosthetic abdominal wall hernia repair in emergency surgery: from polypropylene to biological meshes. *World J Emerg Surg* 2008; **3:** 33.

31 Eriksen JR, Gogenur I, Rosenberg J. Choice of mesh for laparoscopic ventral hernia repair. *Hernia* 2007 Dec; **11**(6)**:** 481—92.

32 den HD, Dur AH, Tuinebreijer WE, Kreis RW. Open surgical procedures for incisional hernias. *Cochrane Database Syst Rev* 2008;(3): CD006438.

33 Chevrel JP. [The treatment of large midline incisional hernias by "overcoat" plasty and prothesis (author's transl)]. *Nouv Presse Med* 1979 Feb 24; **8**(9)**:** 695—6.

34 Kingsnorth AN, Shahid MK, Valliattu AJ, Hadden RA, Porter CS. Open onlay mesh repair for major abdominal wall hernias with selective use of components separation and fibrin sealant. *World J Surg* 2008 Jan; **32**(1)**:** 26—30.

35 Hamy A, Pessaux P, Mucci-Hennekinne S, Radriamananjo S, Regenet N, Arnaud JP. Surgical treatment of large incisional hernias by an intraperitoneal Dacron mesh and an aponeurotic graft. *J Am Coll Surg* 2003 Apr; **196**(4)**:** 531—4.

36 de Vries Reilingh TS, van GD, Langenhorst B, et al. Repair of large midline incisional hernias with polypropylene mesh: comparison of three operative techniques. *Hernia* 2004 Feb; **8**(1)**:** 56—9.

37 Rives J, Lardennois B, Pire JC, Hibon J. [Large incisional hernias. The importance of flail abdomen and of subsequent respiratory disorders]. *Chirurgie* 1973 Jun; **99**(8)**:** 547—63.

38 Stumpf M, Conze J, Prescher A, et al. The lateral incisional hernia: anatomical considerations for a standardized retromuscular sublay repair. *Hernia* 2009 Feb 12.

39 Carlsen CG, Gaarden M, Lundhus E, Nielsen J. [Initial experiences with laparoscopic incisional hernial repair]. *Ugeskr Laeger* 2009 Mar 30; **171**(14)**:** 1182—5.

40 Heniford BT, Park A, Ramshaw BJ, Voeller G. Laparoscopic ventral and incisional hernia repair in 407 patients. *J Am Coll Surg* 2000 Jun; **190**(6)**:** 645—50.

41 Baccari P, Nifosi J, Ghirardelli L, Staudacher C. Laparoscopic incisional and ventral hernia repair without sutures: a single-center experience with 200 cases. *J Laparoendosc Adv Surg Tech A* 2009 Feb 13.

42 Bingener J, Buck L, Richards M, Michalek J, Schwesinger W, Sirinek K. Long-term outcomes in laparoscopic vs open ventral hernia repair. *Arch Surg* 2007 Jun; **142**(6)**:** 562—7.

43 Ballem N, Parikh R, Berber E, Siperstein A. Laparoscopic versus open ventral hernia repairs: 5 year recurrence rates. *Surg Endosc* 2008 Sep; **22**(9)**:** 1935—40.

44 LeBlanc KA. Incisional hernia repair: laparoscopic techniques. *World J Surg* 2005 Aug; **29**(8)**:** 1073—9.

45 Ramirez OM, Ruas E, Dellon AL. "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. *Plast Reconstr Surg* 1990 Sep; **86**(3)**:** 519—26.

46 Kuzbari R, Worseg AP, Tairych G, et al. Sliding door technique for the repair of midline incisional hernias. *Plast Reconstr Surg* 1998 Apr; **101**(5)**:** 1235—42.

47 Mason EE. Pneumoperitoneum in the management of giant hernia. *Surgery* 1956 Jan; **39**(1)**:** 143—51.

48 Dumont F, Fuks D, Verhaeghe P, et al. Progressive pneumoperitoneum increases the length of abdominal muscles. *Hernia* 2009 Apr; **13**(2)**:** 183—7.

49 Tran NV, Petty PM, Bite U, Clay RP, Johnson CH, Arnold PG. Tissue expansion-assisted closure of massive ventral hernias. *J Am Coll Surg* 2003 Mar; **196**(3)**:** 484—8.

50 Abrahamson J, Gorman J. Pregnancy and ventral hernia repair. *Hernia* 2000 Dec; **4**(4)**:** 187—91.

51 Schachtrupp A, Fackeldey V, Klinge U, et al. Temporary closure of the abdominal wall (laparostomy). *Hernia* 2002 Dec; **6**(4)**:** 155—62.

52 Tsuei BJ, Skinner JC, Bernard AC, Kearney PA, Boulanger BR. The open peritoneal cavity: etiology correlates with the likelihood of fascial closure. *Am Surg* 2004 Jul; **70**(7)**:** 652—6.

53 Fleischmann W, Strecker W, Bombelli M, Kinzl L. [Vacuum sealing as treatment of soft tissue damage in open fractures]. *Unfallchirurgie* 1993 Sep; **96**(9)**:** 488—92.

54 Parrett B, Bayer L, Orgill D. Use of microdeformational wound therapy in difficult wounds. *Operat Tech Gen Surg* 2006 Dec; **8**(4)**:** 192—6.

55 Subramonia S, Pankhurst S, Rowlands BJ, Lobo DN. Vacuum-assisted closure of postoperative abdominal wounds: a prospective study. *World J Surg* 2009 Feb 23.

