Chapter 12
To Close or Not to Close: Managing the Open Abdomen

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Deployment Experience:

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BLUF Box (Bottom Line Up Front)

1. Leave the abdomen open to save time needed for closure, allow for second looks, and prevent abdominal compartment syndrome.
2. Return to the operating room based on patient physiology and not an arbitrary time.
3. Temporary closures should control heat loss, fluid shifts, and contain and PROTECT viscera.
4. Close the abdomen if you can. When in doubt, leave the abdomen open.
5. Beware of abdominal compartment syndrome: drop in urine output, abdominal distention, and increased ventilator requirements.
6. Reverse factors causing open abdomen: control contamination and sepsis, judicious use of fluids, improve ventilator status.
7. Avoid further loss of abdominal domain – use adjuncts to prevent fascial retraction.
8. The primary factor in success or failure of obtaining fascial closure is YOU – be aggressive and aim for closure within 5–7 days of injury.
9. Avoid planned ventral hernia and the associated high rate of fistulae.

As long as the abdomen is open, you control it. Once closed it controls you.

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No matter what your previous experience or surgical practice has been, you will extensively use and be exposed to damage control abdominal surgery and the open abdomen in combat or disaster surgery. If you are looking for level I evidence based medicine on how to approach and manage these patients, you are out of luck. You may have seen multiple different techniques of temporary abdominal closure and approaches to achieving definitive abdominal closure, many of which claim to be the optimal approach. Like most things in surgery, there is more than one way to achieve an excellent outcome for your patient. The critical factors are to develop a thorough understanding of the basic principles and pitfalls of open abdominal management, as well as your local capabilities and limitations. This chapter outlines a general approach to the open abdomen based on years of experience with combat casualties in the Iraq and Afghanistan conflicts. The basic principles outlined here are universal, but the details and techniques can and should be adapted or adjusted based on your individual situation and the realities on the ground.

Why Leave the Abdomen Open?

The abdomen is left open in specific circumstances: as part of a damage control strategy, planned second look operations, and prevention of abdominal compartment syndrome. This is no different than what is done for civilian trauma. However, in the combat setting the open abdomen will be used much more liberally for several additional reasons. In general, combat injuries will be more severe and more often multi-system. Multiple fragment wounds or blast injuries have a higher potential for missed injuries or progression of injury that can be identified at a second look operation. Limited time, limited supplies, and multiple casualties waiting for an operation will often mandate rapid temporary closure even in situations where you might otherwise perform a definitive closure. And don't forget to consider the evacuation process – you cannot monitor your patients for missed injuries or the development of catastrophic abdominal complications or compartment syndrome if they are on a helicopter or airplane.

Damage control surgery is required for the seriously injured patient, when it is critical to get in and get out and avoid the lethal triad of metabolic acidosis, coagulopathy, hypothermia. Rapid initial surgeries have specific goals: control hemorrhage by ligating, repairing or shunting injured vessels or packing solid organ or pelvic injuries. Contamination must be controlled by identifying injuries to bowel and repairing, diverting, or stapling ends without any attempt at anastomosis. By accomplishing only what is absolutely necessary, the patient can be taken to the ICU to continue resuscitation and prepare the patient for more definitive operations when they are more stable. The abdomen is closed temporarily with either skin closure only with whip stitch or penetrating towel clamps, or more commonly with temporary dressings detailed below.

Packing is an essential component of damage control if bleeding from solid organ or venous injury is present. The abdomen is packed, temporary closure is achieved, and the patient is stabilized prior to further treatment of the injuries.

Packing must provide enough pressure to tamponade bleeding, but care must be taken to not compress the inferior vena cava and decrease venous return to the heart. Hypovolemia is often present in this scenario, exacerbating the problem. If patients cannot be stabilized after packing, reassessment of the packing and temporary closure should be undertaken. Although time is a critical factor in these patients, do not just assume that a panicked abdominal packing is an adequate damage control procedure. **An extra 10 or 20 min in the OR to assure that you have adequate hemorrhage and contamination control is much preferred to watching your patient bleed out from their abdominal wound in the ICU**. Abdominal compartment syndrome is still possible with vacuum-closures and other temporary closures, and may prompt an early return to the operating room or a bedside laparotomy in the ICU.

The abdomen should always be left open if a second look is planned. This is especially useful if the second look will be done by another surgeon at a higher level of care. Clearly dead bowel should be resected, however it is not always obvious if bowel cannot be saved. If there is a question of bowel viability at the initial surgery, an extensive resection of potentially viable bowel should be avoided and a second look should be planned. Bowel viability may improve with continued resuscitation, and prevention of extensive resection is necessary to avoid short gut syndrome. Anastomoses in a patient with potential for deterioration are risky and so are often better served by delay until a subsequent return to the OR. An ostomy could be avoided if the patient remains stable after the initial operation, and an ostomy can be formed at the second look if the situation for an anastomosis is not ideal. A failed anastomosis that is not immediately recognized can lead to overwhelming sepsis requiring significant fluid resuscitation and virtually guarantee an open abdomen that is difficult to close.

It is critical to identify abdominal compartment syndrome (ACS) and predict patients who may develop this syndrome. Unfortunately we have no absolute measures for predicting which casualties will go on to develop ACS. Patients that are already acidotic, hypothermic and coagulopathic are the highest risk for ACS, and should be left open. Other high risk factors are patients receiving massive transfusion or large volume resuscitation, large thermal injuries, high grade liver injuries, and mesenteric vascular injuries. The abdominal domain is limited, and excessive visceral or retroperitoneal edema, blood, gas, ascites or stool can cause systemic life-threatening problems. Abdominal compartment syndrome can occur in patients without intra-abdominal injuries (secondary ACS) in cases of substantial bowel or retroperitoneal edema from massive fluid resuscitations or systemic inflammatory responses with capillary leak causing extensive interstitial edema. Clinical signs of ACS include a tight and distended abdomen, hypotension, low urine output, and rising ventilatory peak pressures. This clinical picture should prompt immediate opening or re-opening of the abdominal cavity. One exception to this rule is the patient who has a purely secondary ACS, which is usually due to massive volume resuscitation and the buildup of tense abdominal ascites. This is commonly seen in injured patients with significant burns. A quick bedside ultrasound or diagnostic tap can identify the presence of massive ascites, and these patients may be better managed by large volume paracentesis or placement of a percutaneous drain.

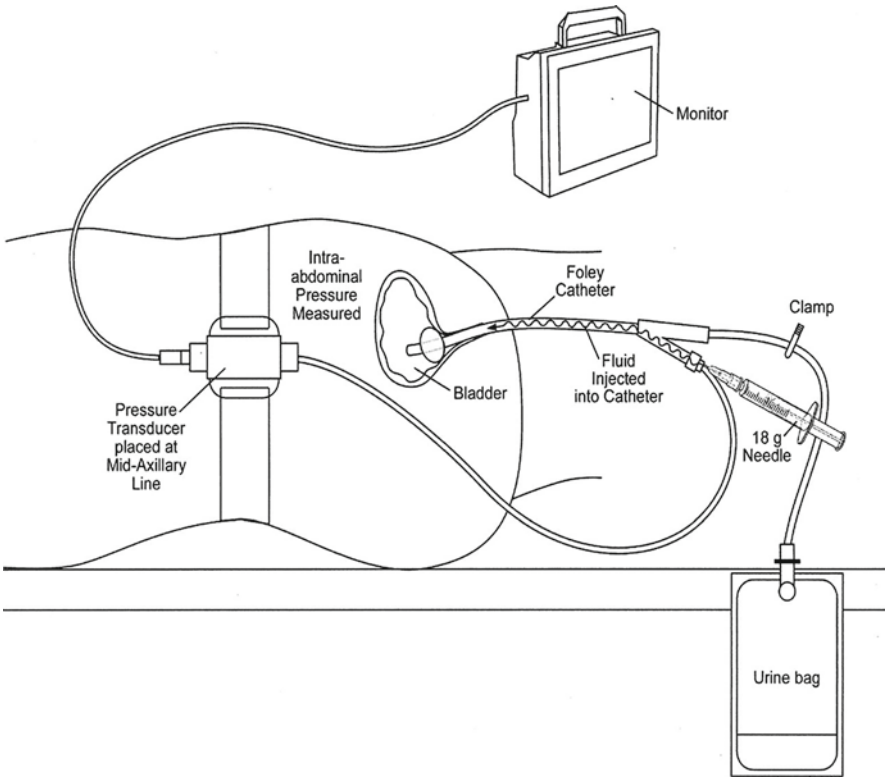

Fig. 12.1 Demonstration of bladder pressure measurement. Reproduced with permission, Mullens et al., JACC 51(3), 2008

Measurements of intra-abdominal pressure are useful for identifying impending or active ACS, and are usually achieved by indirect methods. Bladder pressure is most commonly used (Fig. 12.1): the bladder is decompressed with a Foley catheter, 50–200 cc of sterile saline is infused into the catheter, and the catheter is then clamped distal to the area of pressure measurement. A pressure transducer with a needle (like that used for arterial pressure measurements) is used to puncture the hub of the Foley as shown in Fig. 12.1. The transducer should be zeroed at the symphysis pubis with the patient in a supine position and then allow the waveform time to equilibrate. Although bladder pressure is most commonly used, you can measure intra-abdominal pressure via any hollow structure in the abdominal cavity. Alternative methods of indirect measurements include intra-gastric (NG tube) or inferior vena cava pressure through the femoral vein. If pressure transducing equipment is not available, see Appendix A for a low-tech bedside method of estimating bladder pressure.

Although every patient may respond differently, organ dysfunction increases with increasing intraabdominal pressure (IAP), and a value of >25 mmHg has been suggested as a target for decompression. Reopening and reexploration is recommended for anyone with a pressure above 35 mmHg. One pitfall you have to take into consideration is that these pressure cutoffs generally apply to normotensive patients.

Abdominal compartment syndrome can occur with bladder pressures of less than 20 in patients with hypotension! Think of the abdominal cavity like the cranial vault – the perfusion pressure will be a function of the mean arterial pressure (MAP) minus the abdominal compartment pressure. Therefore, if the MAP is already low, then even an abdominal pressure of 15 can result in a perfusion pressure that is inadequate. Remember that abdominal compartment syndrome is a **clinical diagnosis** – no single test is absolutely necessary for the diagnosis and treatment of ACS. A patient with a tight abdomen and who is difficult to ventilate should have consideration given to opening the abdomen. When in doubt – open a closed abdomen or leave the abdomen open.

How to Temporarily Close the Open Abdomen

Intra-abdominal contents must be protected from desiccation and from insensible losses. Temporary closures have been used to achieve this goal, and many different types of closure have been described. The most common method of temporary closure involves using any type of plastic occlusive barrier such as large sterile irrigation bags or Steri-Drape® (3M®, St. Paul, MN) plastic sheeting with small slits cut in the plastic to allow egress of fluid. A sterile X-ray cassette cover will also work very well – use a scalpel to make multiple small slits in the plastic to allow fluid to flow into the vacuum component. This sheeting is then tucked under the fascia down to the pericolic gutters (Fig. 12.2), ensuring that all exposed bowel is covered and protected from direct contact with any sponge material. Laparotomy sponges or operative towels are then placed over the plastic barrier, with drains

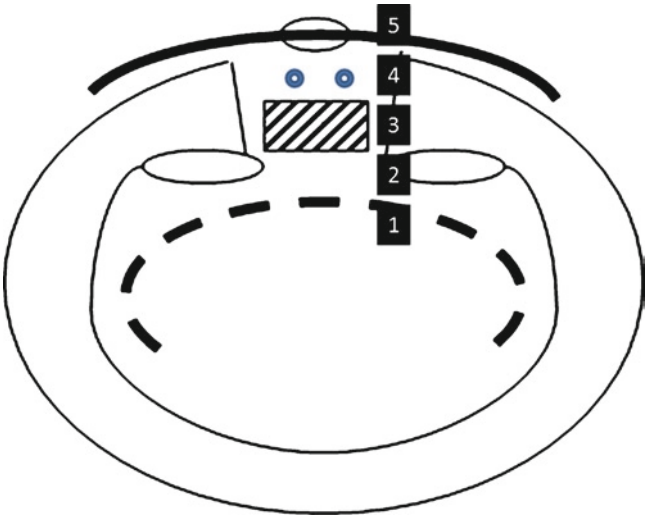

Fig. 12.2 Plastic draping tucked underneath the fascia to the pericolic gutters (1). Mesh to fascial edges for serial closure and prevention of retraction (2). Towels, lap sponges or KCI® V.A.C. sponges (3). JP, NGT, or chest tube drains (4). Ioban® or KCI® adherent dressing (5)

within or on top of the sponges. An occlusive dressing like Ioban® (3M®, St. Paul, MN) is then used to seal the wound. Fluid egress is achieved with large tubes (often nasogastric tubes with the air vent portion of the sump drain tied into a knot, chest tubes or 2 JP drains) placed on top of the towels or gauze and underneath the occlusive dressing with attachment to continuous wall suction. It is important to create a "mesentery" with the Ioban® around the tube used to prevent leaks and pressure on the skin (Fig. 12.3a, b).

Fig. 12.3 Demonstration of temporary abdominal closures. (**a**) Irrigation bag, gauze and JP drains shown after Ioban® removed; (**b**) Operative blue towel over a chest tube and covered with Ioban dressing. A mesentery is formed over the Ioban® to prevent leaks; (**c**) Abdominal wound vac closure with skin edges sutured partially closed over vac sponge to maintain tension and prevent retraction

An excellent option that is now commercially available is the temporary abdominal closure kits or "Abdominal Wound-Vac" (V.A.C.® dressing, Kinetic Concepts, Inc.). This all-in-one sterile pre-packaged kit provides a polyurethane foam dressing sandwiched in between perforated plastic sheeting, large oval vac sponges, adhesive drapes, and an adhesive pad with suction tubing. The sponges can be secured to the skin edges with several staples, or alternatively the skin can be sutured closed (fully or partially) over the top of the sponges. The suction tubing is then connected to a self-contained vacuum device which can provide varying levels of continuous or intermittent suction and fluid collection. It has been our experience that the use of negative pressure systems for temporary abdominal closure greatly improves the ease of postoperative nursing and wound care, and also improves the rates of early primary fascial closure.

The method of closure used is not as important as following the basic principles of visceral coverage and protection, fluid and contamination control, maintenance of abdominal domain, prevention of fascial retraction, and prevention of compartment syndrome. You should develop an agreed upon method of temporary abdominal closure with your group of colleagues, and have all materials pre-packaged and readily available to minimize operative delays. If you develop a well considered standard algorithm for temporary abdominal closure, open abdomen management, and abdominal closure then you will see improved results, decreased complications, and improved fascial closure rates.

Serial Abdominal Closure

Successful final closure involves planning ahead. Reversal of causative factors, prevention of fascial retraction, and avoidance of the visceral block adhering to the abdominal wall are the most important considerations. Reversal of causative factors including judicious use of fluids (strategies and end points of resuscitation are covered in another chapter), controlling contamination, preventing and treating sepsis, and improving ventilator status to prevent visceral edema from high positive end expiratory pressure (PEEP). Figure 12.4 demonstrates an algorithm outlining the approach and timeline for closure of the open abdomen. Ideally, primary closure should be achieved within 7–10 days, and should be accomplished in the majority of open abdomens (70–90%). If you are not able to achieve primary closure within this time period, prevention of fascial retraction and serial closure should be initiated.

Prevention of fascial retraction involves some method of adherence of the fascia to hold on to the edges as the inevitable retraction occurs. We have frequently used mesh as a serial closure device (Figs. 12.5a–d). Goretex Dualmesh® is sewn to the fascial edges to contain the abdominal contents and prevent fascial retraction. A wound vacuum dressing is placed over the mesh. The wound vacuum sponges are changed every 2–4 days, and the mesh is lifted to determine if abdominal domain can be reclaimed. This is often once or twice a week, with a couple of centimeters trimmed

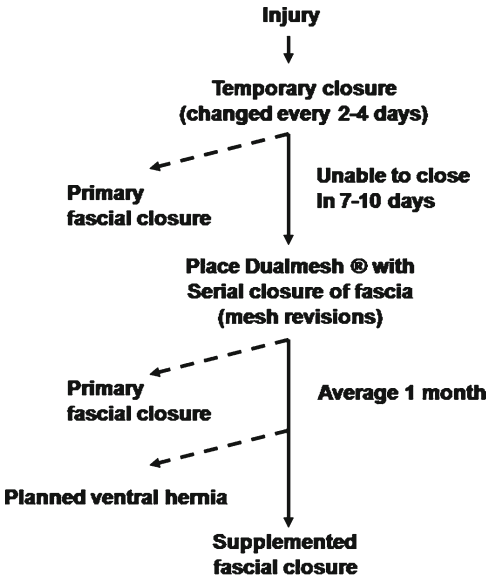

Fig. 12.4 Timeline for abdominal closure

off the middle of the mesh each time and reapproximated with Prolene® or PDS® suture. Serial closure techniques that provide traction to the fascial edges may result in macerated fascial edges that need to be debrided to allow proper healing and avoid hernia recurrence. Our previous closures have required supplemental material to finally close the abdomen once serial closure is complete and the Dualmesh® prosthesis has been removed; of note is the fact that the Dualmesh® is ALWAYS a temporary "bridge" and never should be left as the definitive closure material; it is contaminated (by definition) and must be explanted once it completes its "job" as a bridge temporary abdominal containment material. Polypropylene mesh has been used as the final replacement mesh, with very low infection and fistula formation rates in our experience. Biologic mesh seems ideal in a contaminated field, but has a high rate of failure and will most certainly lead to a planned ventral hernia, as the biologic material bridging a fascial gap does not become fascia; it becomes scar and that means a ventral hernia. We have recently modified our technique with placement of a 10–10 plastic drape (Steri-Drape® from 3M®, St. Paul, MN) beneath the Dualmesh®, which prevents adherence of the abdominal wall to the visceral block. This allows more movement of the abdominal wall and increases the possibility of primary closure. It also allows access to the underside of the fascia for underlay mesh if desired.

Inability to place mesh or failures of serial closure has required planned ventral hernia (PVH). In this technique, if there is no granulation tissue, vicryl mesh is sewn to the fascial edges. If there is adequate skin and subcutaneous tissue that can be mobilized to cover the wound, then primary skin closure can be performed over multiple subcutaneous closed-suction drains. If there is inadequate native abdominal

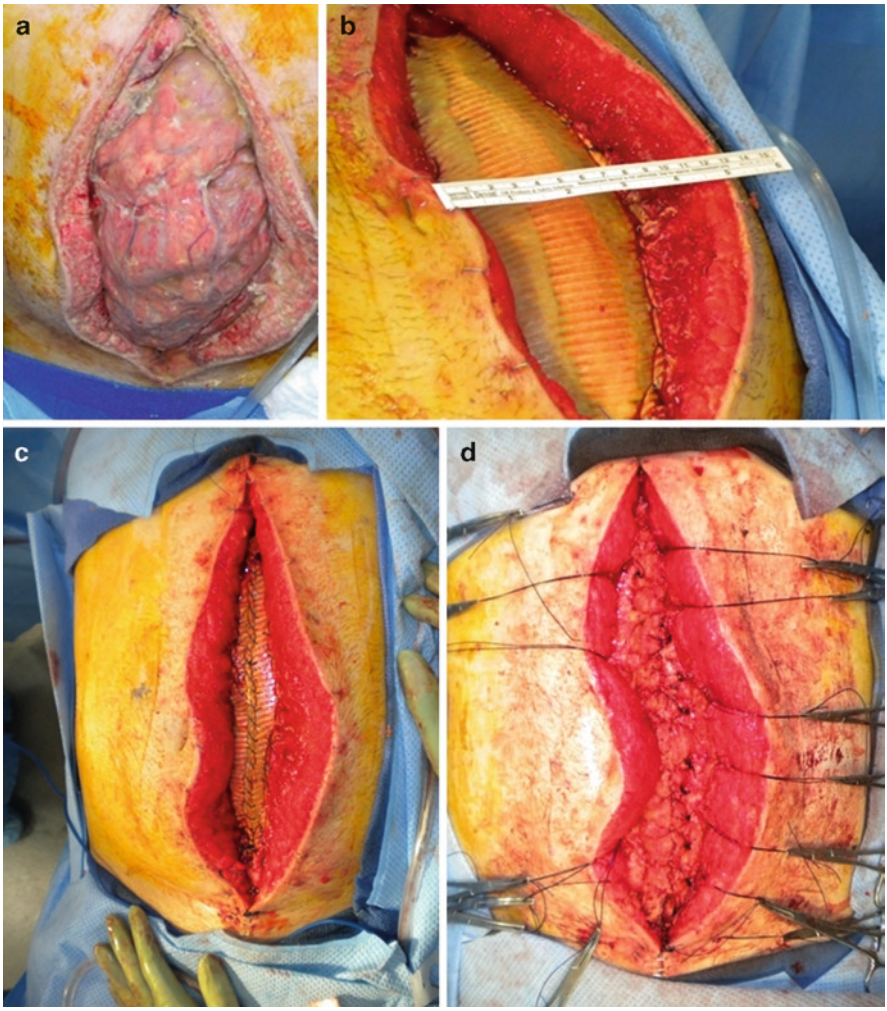

Fig. 12.5 (**a**) Open abdomen. (**b**) Dualmesh® sewn to fascial edges. (**c**) Mesh revision of Dualmesh®. (**d**) Dualmesh® removed and fascia primarily closed. A FlexHD® underlay was placed in this patient

skin, then coverage must be provided by other means. Once an adequate granulation bed has formed over the Vicryl mesh, a split thickness skin graft is placed over the granulation tissue and viscera. This results in a large hernia that can be repaired in 6–12 months. This method of closure is associated with a high rate of enterocutaneous fistulas. We seek to avoid PVH at all costs, and in our published experience and long-term follow-up this method should be and is unnecessary in wounded warriors. The techniques described in this article and our publications that avoid PVH are the standard in 2009 and beyond.

Complex Abdominal Wall Reconstruction: Component Separation

One basic principle is that you will usually be better off from a closure and infection standpoint if you can achieve fascial reapproximation with native tissue and avoid the use of prosthetic mesh. However, if there is a large fascial gap that cannot come together without undue tension, then the traditional answer has been placement of a mesh bridge. An alternative and increasingly popular approach being used by both civilian and military trauma surgeons is the technique of component separation, or "separation of parts" closure of the abdominal wall. This is a technique that should be understood by all combat surgeons, and is particularly useful in situations where you may have limited availability of mesh products (and almost never have access to biologic mesh).

Fascia of the abdominal wall can be manipulated with components separation of the fascial layers (Figs. 12.6 and 12.7). Complete components separation in some surgeon's hands can theoretically bridge gaps up to 20 cm, but is associated with significant reherniation rates. A more reasonable expectation for this technique is to bridge gaps of 5–15 cm. In planning for this type of repair, one requirement is that

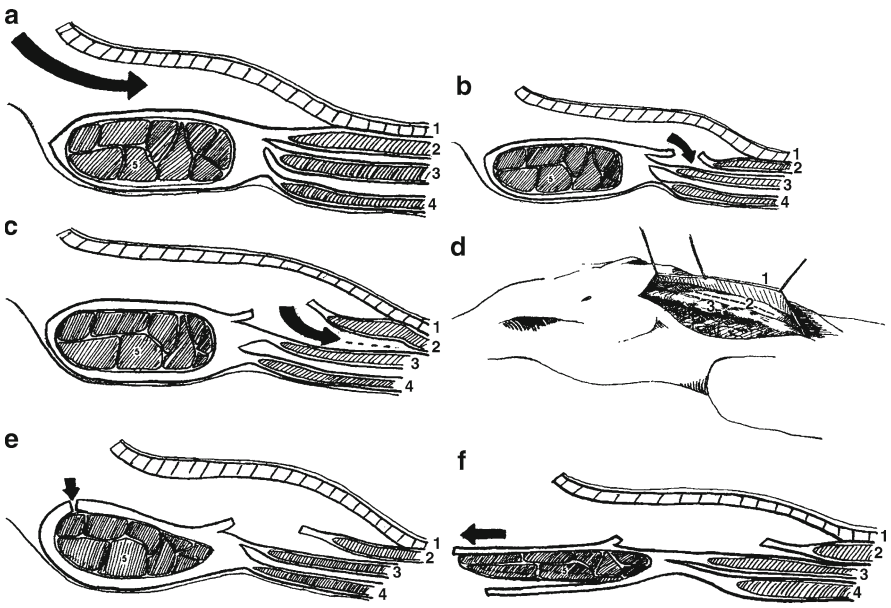

Fig. 12.6 Components separation technique. (**a**) Subcutaneous flaps are raised over the rectus and external oblique; (**b**) Longitudinal division of the external oblique aponeurosis at its insertion into the anterior rectus sheath; (**c**) and (**d**) The external oblique is freed from the internal oblique as far laterally as possible; (**e**) and (**f**) If additional length is needed, the medial rectus sheath is opened longitudinally and the rectus muscle is mobilized off of the posterior sheath. (Reprinted with permission from J Am Coll Surg 2003;196:32–37)

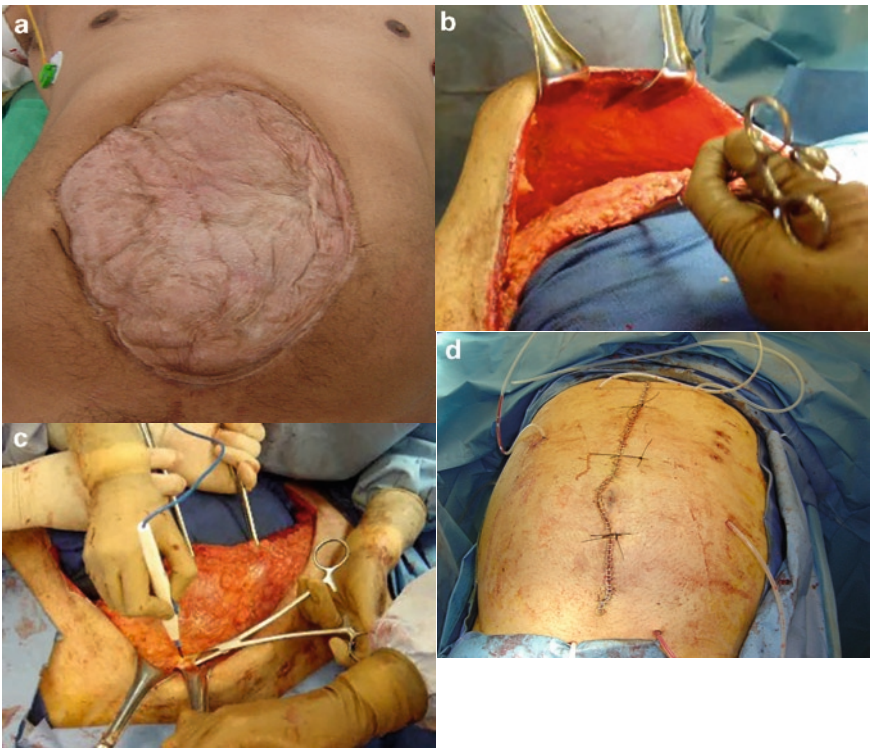

Fig. 12.7 Component separation procedure following damage control laparotomy. (**a**) Large ventral hernia with skin graft on bowel; (**b**) skin flaps are raised circumferentially over anterior rectus sheath and external oblique aponeurosis; (**c**) division of the external oblique aponeurosis as it inserts into the lateral rectus sheath; (**d**) excess skin is resected and closed primarily over drains

you must have the majority of the rectus muscle and sheath intact, which can be assessed with a preoperative CT scan or intraoperatively. Identify the anterior rectus sheath and raise lateral skin flaps circumferentially until you can identify the lateral rectus border and the insertion of the external oblique aponeurosis. The external oblique aponeurosis is then divided longitudinally from the costal margin to the inguinal ligament. You should see a flimsy layer of fat and wispy connective tissue below the aponeurosis – if you see muscle then you are too far medial or lateral. Grasp and elevate the cut edge of the aponeurosis laterally while retracting the rectus muscle medially. This exposes the connective tissue layer deep to the aponeurosis which can be divided all the way out to the mid-axillary line. If this does not provide enough mobilization for fascial closure, then the rectus muscle can be rolled anteriorly allowing longitudinal division of the posterior rectus sheath. This will provide an additional 2–3 cm on each side. The fascial edges can now be approximated primarily with running or interrupted suture – we prefer interrupted figure of 8 Prolene. The "open book" is a variation of components separation where the lateral aspect of the rectus sheath is incised on both sides of the abdominal wall,

and folded medially to form a new midline. The medialized edges are then sewn together. There are now multiple series reporting excellent functional results with low complication rates and low recurrent herniation using the modern component separation approach.

Supplemental closures materials are available with individualized benefits and complications. Plastic mesh (polypropylene, Goretex®) is associated with increased adhesions, fistulas, and infections. They are best used in a noncontaminated field with interposed tissue such as peritoneum or omentum to decrease wound complications. Biologic mesh (Alloderm®, Surgisis®, FlexHD®) became rapidly popular for their advertised strength and ability to withstand infection or contamination. However, the accumulation of experience has revealed that these materials have a high failure rate (>50%) when used as a fascial bridge or when subjected to exposure and desiccation in open wounds or with vacuum closure. However, they may be the only good option in a contaminated field to provide temporary closure and protection. There is also a growing anecdotal experience of improved outcomes with the component separation technique when the fascial closure is reinforced with a biologic mesh underlay or overlay. We have used this technique with excellent results, and recommend the material be placed in the underlay position with at least 4–6 cm of overlap and that moderate tension be achieved to prevent laxity.

Specific Pitfalls and How to Avoid them

Specific pitfalls in open abdomen management include not leaving an abdomen open that should be, not recognizing the need to reexplore or adjust dressings, enterocutaneous fistula formation, allowing retraction of fascia or adherence of the visceral block to the underlying abdominal wall, and leaving packs in the abdomen. All of these can be avoided or minimized with a standard and careful team approach to these patients.

Abdominal compartment syndrome (ACS) must be either prevented or treated promptly when recognized. Temporary closures will not prevent the need to reexplore if a surgical treatment is necessary, and ACS still occurs with temporary packing. One of the most common causes of ACS in the patient with an open abdomen from trauma is recurrent intra-abdominal hemorrhage. This should be rapidly recognized by a dropping hematocrit, hemodynamic changes, and bloody output from the abdominal wound. This should prompt immediate re-exploration which should be performed in the operating room. **Do not attempt an exploration for bleeding at the bedside!** If it is suspected that the temporary closure is simply too tight, then the vacuum suction can be released, any skin closure should be opened, or the dressing can be removed and replaced under no tension. Alternatively, if the fascia was not fully opened at the initial operation, then extension of the incision may be needed. Chemical paralysis of the patient, particularly if there is any obvious agitation or increased muscle tone, can often improve the situation or temporize until definitive intervention can be accomplished.

Enterocutaneous fistula is a miserable complication in the open abdomen patient, and prevention is the best strategy. Usually any type of primary repair of these fistulae is doomed to failure, and your goal should be to achieve adequate control and drainage. To prevent this complication optimize nutrition, close the abdomen as soon as possible, and protect the underlying bowel at all times. If a fistula develops, try to convert it to an enterocutaneous fistula by achieving adequate drainage well off of the midline. If you are unable to do this, then you are left with the very difficult problem of an enteroatmospheric fistula draining directly into your open abdominal wound. This is an entirely different and more difficult entity, since it will continuously soil the abdominal cavity, wound, and fascial edges. The lack of surrounding skin precludes the placement of an ostomy appliance or other device to easily control the effluent. Your goal now should be to mature the fistula and surrounding tissue to a point where an ostomy appliance can be applied while also protecting the remaining exposed bowel. If the skin can be closed above and below the fistula, then it can be converted to a "floating ostomy" directly in the midline wound. If not, then placement of a wound vac sponge with a defect cut out directly over the fistula will allow drainage and placement of an ostomy appliance while also protecting and maturing the surrounding tissue. Alternatively, the fistula(ae) can be intubated with a drainage tube (Malecot catheters) which is brought through the wound vac sponge (see Fig. 12.8).

Loss of the abdominal domain is associated with retraction of fascia, so use supplemental material if necessary to prevent retraction. If you maintain some degree of tension on the skin by partial or complete closure over the vac sponges, you will prevent some degree of fascial retraction. The visceral block will adhere to the underlying abdominal wall and decrease your chances of primary closure, so ensure that plastic sheeting goes all the way down to the pericolic gutter. This will also provide an access to the fascia for supplemental underlay of mesh. Finally, always remember to double check the entire abdominal cavity for retained packs and get an X-ray before final closure; the sponge count is always unreliable in damage control surgery.

Final Points

Damage control surgery is an excellent tool in seriously injured patients. Open abdomen management is required for many of these patients. If there is a doubt about visceral edema, contamination, or need for second looks, then plan for the worst case scenario and leave the abdomen open. This is especially true if there will be a discontinuity of care providers in the evacuation chain. Eventually, the abdomen should be closed within several weeks of the primary injury. Keep the end goal in mind and set yourself up for a successful closure with protection of viscera, prevent fascial retraction and adherence of viscera to the abdominal wall, and control factors contributing to the loss of abdominal domain. There are many techniques available to assist with abdominal closure. Serial abdominal closure allows reclaiming the abdominal domain over time. Mesh is available

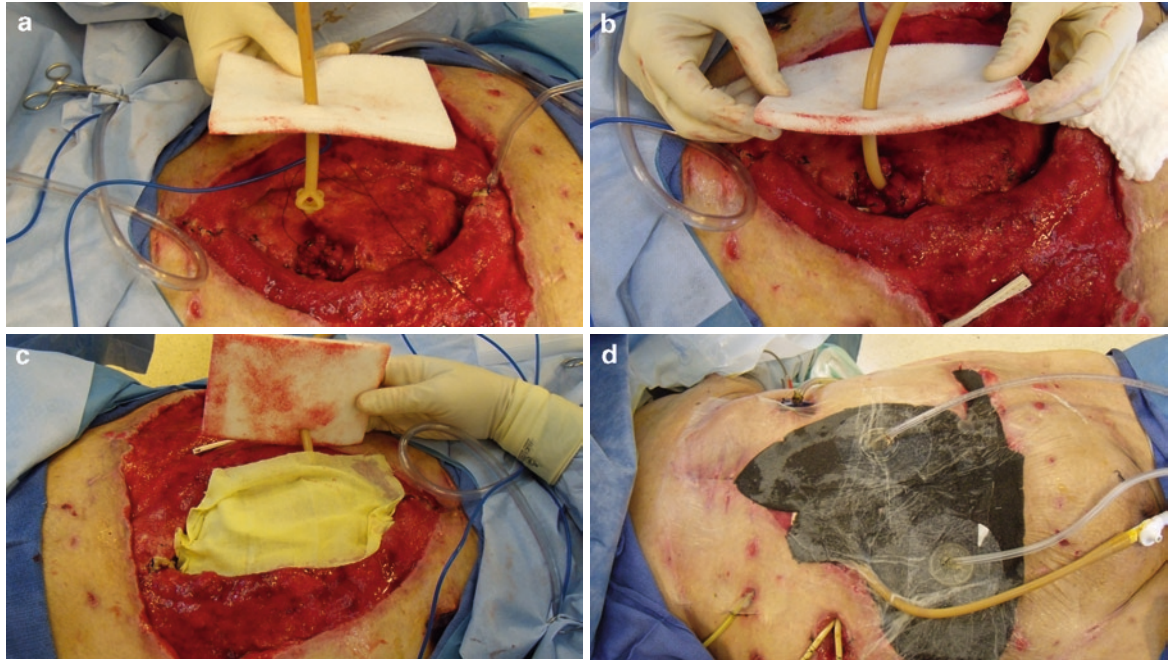

Fig. 12.8 Wound vac and Malecot drain management of an open abdomen with enterocutaneous fistula. (**a**) 20 French Malecot drain is brought through a hole in a *white wound vac sponge*; (**b**) The fistula is intubated with the drain and sponge is cut to fit the defect; (**c**) A layer of non-adhesive dressing (Xeroform shown) is applied between the vac sponge and exposed viscera; (**d**) Completed dressing with standard *black vac sponges*

for final closure, although timing and choice of mesh materials as described in this and other articles from the authors, will impact success rates. Components separation is another excellent technique available to assist with abdominal closure. Above all else: when in doubt, leave the abdomen open!