# Temporary Abdominal Closure

# 40

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## Introduction

With the increased use of damage control surgery and the improved knowledge related to abdominal compartment syndrome, surgeons are increasingly faced with the problem of how to manage the open abdomen. Primary closure, when appropriate, remains the repair of choice. This is not always feasible due to the need for future surgery, the physiologic nature of the patient, or for technical reasons. Treatments range from simple to quite complex procedures to facilitate planned hernia repairs or delayed primary closure, depending on the clinical situation. Mastering temporary abdominal closure is essential to surgeons successfully treating patients with open abdomens and complex abdominal wall pathology.

## Abdominal Compartment Syndrome/Damage Control Surgery

### History

Since its first description by Stone et al. [1], the concept of damage control surgery has gained widespread acceptance in trauma surgery patients and even in complex abdominal operations and procedures. The recognition and understanding of the physiology of abdominal compartment syndrome has also improved the outcome of acutely ill trauma and complex general surgery patients. Although the concept of damage control surgery and abdominal compartment syndrome has improved outcomes, this has left surgeons with the novel and daunting task of abdominal wall management in acutely ill patients. This presents the unique challenge of trying to obtain both temporary and ultimately definitive abdominal closure for patients.

## Rationale for the Open Abdomen

In general, damage control principles are applied to multiply injured patients with what has been referred to as the lethal triad of death, which includes acidosis, coagulopathy, and hypothermia. These damage control principles can also be applied in general surgery operations when patients have severe systemic disease, instability, and the lethal triad. The rationale related to damage control surgery is to perform a focused, timely surgical operation to help address the immediate surgical problem (e.g., bleeding or contamination). Following this, the patient can be resuscitated, coagulopathies can be addressed, the patient can be warmed, and acidosis managed in the intensive

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care unit. In these cases, the abdomen can be left open with methods described in this chapter. When the patient's condition improves, more definitive surgeries, and, if needed, multiple reoperations can be undertaken.

## Physiologic Consequences of Intra-abdominal Hypertension and Abdominal Compartment Syndrome

The physiologic understanding of intra-abdominal hypertension and abdominal compartment syndrome leading to multi-system organ dysfunction has greatly increased over the last two decades. The initial physiologic insult or critical illness leads to systemic inflammatory response, inflammation, and cytokine release with resulting capillary leak. This in turn often requires ongoing fluid resuscitation that will cause more tissue edema (including bowel and mesenteric edema) and can increase intra-abdominal hypertension and start a lethal chain of events if no intervention is undertaken.

Abdominal compartment syndrome can affect many organ systems often due to direct compression. Cardiac effects include decreased cardiac output, decreased venous return due to compression of the vena cava, and elevated intrathoracic pressures. Increased intra-abdominal pressures can also affect the pulmonary system by elevating the diaphragm, reducing lung volume, decreasing functional residual capacity, and increasing peak airway pressures. Gastrointestinal manifestations are related to decreased cardiac output and compression on the mesenteric veins, which can lead to decreased intestinal perfusion, increased bowel edema, and possibly intestinal ischemia. The effects of abdominal compartment syndrome on the renal system are also related to decreased cardiac output and direct compression of the renal veins and parenchyma, which can cause reduced blood flow to the kidney, congestion and edema, and in some cases renal failure. Increased intra-abdominal pressures also can affect the central nervous system by causing increases in central venous and intracranial pressures and decreased cerebral perfusion pressure related to increased intrathoracic and superior vena caval pressures.

The recognition of intra-abdominal hypertension and abdominal compartment syndrome in the early stages is critical because the cascading effect can ultimately end in organ failure and death. Knowledge of the effects on the different organ systems and accurate diagnosis, which usually require bladder pressure monitoring, are a key feature for positive outcomes for these complex patients.

## Options for Temporary Abdominal Closure

### Open Packing/Planned Ventral Hernia

One of the earliest and perhaps the simplest methods of managing the open abdomen is open packing with a plan for future skin grafting and ventral hernia repair. Various techniques on how to pack the abdomen have been described, and many "home-made" devices have been used at different institutions. The majority of techniques described used dressings placed on the abdomen without causing trauma or fistula formation. Before the commercially available vacuum-assisted wound closure device, many surgeons devised a vacuum device by placing towels, chest tubes or other drains, and an occlusive dressing that facilitated suction.

Despite the different descriptions and techniques, the goal in many of these initial cases was for the viscera to granulate in the midline of the open abdomen and then to undertake split thickness skin grafting. After skin grafting is completed and the abdominal viscera are properly covered, surgeons might wait up to 1 year before excising the skin graft and repairing the incisional hernia (Fig. 40.1a–f). One way to help with the timing of the hernia surgery is to use a "pinch" test. For this test, the skin graft overlying the viscera is pinched. If it is soft and pliable when rubbed between the fingers, there should be an adequate plane for dissection without enterotomies.

Although open packing and planned ventral hernia repair is a safe and effective method that is

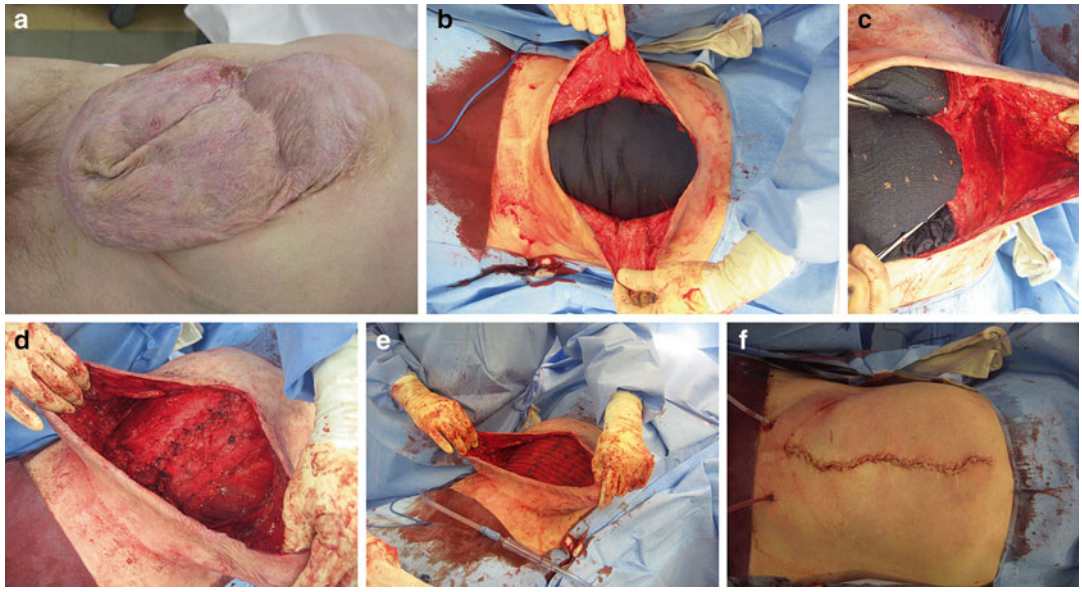


**Fig. 40.1** (**a**) Patient with previous open abdomen treated with split thickness skin grafting now ready for abdominal wall reconstruction. (**b**) Large fascial defect once adhesiolysis has been performed. Skin graft was easily resected from abdominal contents. (**c**) Abdominal wall reconstruction using an external oblique component separation to allow for midline closure. (**d**) Primary midline closure obtained by using bilateral external oblique component separation. (**e**) Hernia repair with buttressing of midline closure with onlay large pore polypropylene. (**f**) Abdominal wall reconstruction with skin closure and two drains used in subcutaneous space

reproducible by most surgeons, there are many downsides to this technique, which limit its current widespread use. Perhaps the biggest drawback of this technique is the large ventral hernia with significant soft tissue deficit that is created and the very difficult operation that is required to repair it. During the initial era of damage control laparotomy and abdominal compartment syndrome, patient survival was considered a successful outcome. The large hernia was often considered a minor point and, in some cases, was left untreated. Because of extreme complexity of resultant hernias, researchers investigated different options to treat the open abdomen during the acute phase to avoid this planned hernia repair or at least minimize the defects that were created.

## Towel Clip Closure/Skin Closure

Towel clip closure is perhaps one of the simplest and fastest ways to achieve temporary abdominal closure. It involves placing penetrating towel clips approximately 1 cm off the skin edge and 1 cm apart (Fig. 40.2). Many clips are required. An adherent plastic drape can be added to minimize the manipulation of the clips and possibly provide improved sterility. The benefit of this technique is that it is rapid and cost-effective. Unfortunately, it does not provide a long-term solution to abdominal closure and is typically used when a patient will need reoperation or multiple reoperations with the ultimate plan for either primary closure or alternative open abdomen treatment techniques depending on the clinical scenario.

Another rapid method in patients requiring a reoperation is simple skin closure with a large suture. This is usually done in a running fashion and allows closure of the skin but not the fascia. It is slightly easier to manage for nurses and ancillary staff than the towel clips, as this is a more familiar scenario.

While these two techniques have the benefits of low cost, simplicity, and speed of closure, they must be monitored closely in patients who are at risk for abdominal compartment syndrome because there is some compression caused by skin closure alone. Both of these

techniques can be quickly reversed in patients that develop abdominal compartment syndrome by removing the clips or cutting the sutures and placing the appropriate dressing for an open abdomen per the surgeon's discretion. With the introduction of other techniques, many surgeons have abandoned the towel clip and simple skin closure techniques.

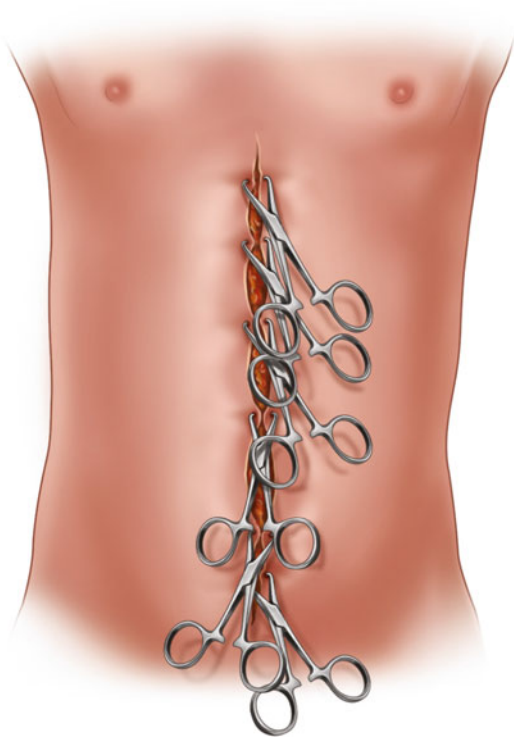

**Fig. 40.2** Towel clip closure showing multiple towel clips used to reapproximate the skin

## Silastic Closure/Bogota Bag

A resident in a hospital in Bogotá, Colombia (Oswaldo Borraez) first described the use of a silastic bag for closure of the abdomen, commonly referred to as the Bogota bag. This technique involves suturing of a 3 L sterile intravenous fluid bag to the fascial or skin edges. The benefits of this type of closure are that it is readily available, is easy to accomplish, facilitates visualization of the abdominal contents through the clear bag, and it protects the abdominal viscera (Fig. 40.3a–b). The limitations of this technique are that it can be difficult in patients with large volume of fluid loss, it provides only a small amount of fascial or skin retraction, it does not allow for removal of fluid that may be infectious or may precipitate an ongoing SIRS response, and it is not a definitive abdominal closure.

## Zipper-Based Repairs

Zipper-based closures were popularized by Stone et al. [1] and may be used with conventional or commercially based zippers that are sutured to the skin or fascia. This technique allows easy access to the abdominal cavity if

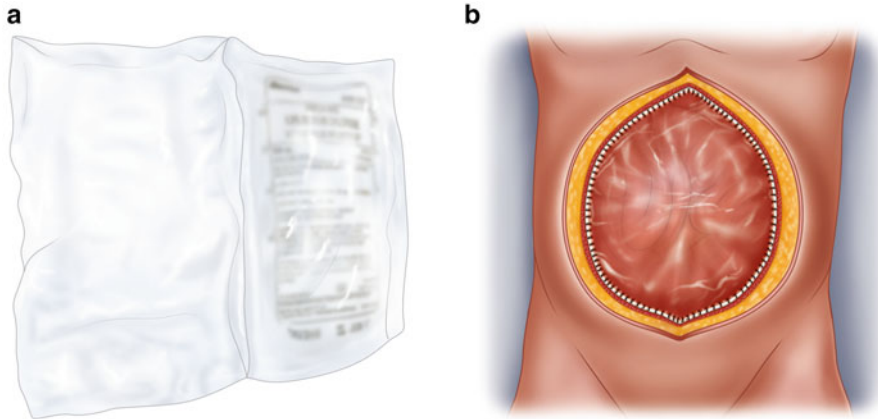


**Fig. 40.3** (**a**) A 3-L intravenous fluid bag used for a Bogota bag closure. (**b**) Suturing the sterile bag to the fascial edges is rapid and allows visualization of the bowel

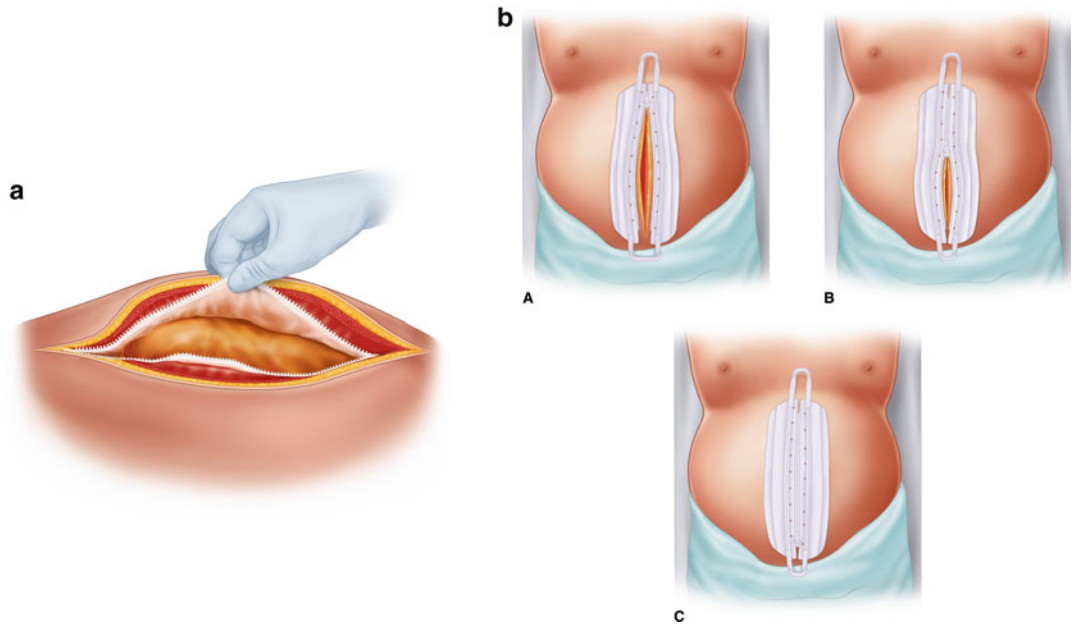


**Fig. 40.4** (**a**) Zipper sutured to fascial edges to allow easy access to abdominal cavity in patients that will need multiple reoperations. (**b**) Zippers can also be sutured to the skin to allow easy access to the abdominal cavity

reoperations are needed and prevents some lateral retraction of the fascia if sewn to the fascia. Although a novel approach at the initial time of development, this technique has been replaced by some alternatives based on similar principles and is not widely used nowadays (Fig. 40.4).

## Wittmann Patch

One of the problems associated with many forms of temporary abdominal closure is that retraction of the fascia makes delayed primary closure or future hernia repair more difficult. The use of the Wittmann Patch™ (Starsurgical, Inc., Burlington, WI), first reported by Teichman et al. [2], Wittmann et al. [3, 4], and Aprahamian et al. [5], involves suturing two Velcro®-like materials to the midline fascia. The Velcro-like material can be fastened together as overlapping sheets (Fig. 40.5a–c). This device can be used alone or in combination with other open abdomen techniques such as the ABThera™ (Kinetic Concepts, Inc., San Antonio, TX). As bowel and intra-abdominal edema improve, the Velcro material can be tightened to bring the fascial edges closer to the midline to ultimately achieve primary closure. If the patient requires several surgeries, the Velcro material can be unfastened and the intra-abdominal cavity can be easily entered.

The potential advantages of this technique are that it allows easy access to the abdominal cavity in patients that require future operations and that it places tension on the midline fascia that helps prevent later retraction. The disadvantages of a Wittmann Patch include potential ischemic and tension damage to the fascia, as well as the inability to remove fluid that may be infectious or may precipitate an ongoing SIRS response when used alone.

## Mesh Based Techniques

The use of mesh has been reported as an adjunct for temporary abdominal closure and also when attempting primary closure. The use of synthetic meshes such as polytetrafluoroethylene (PTFE)

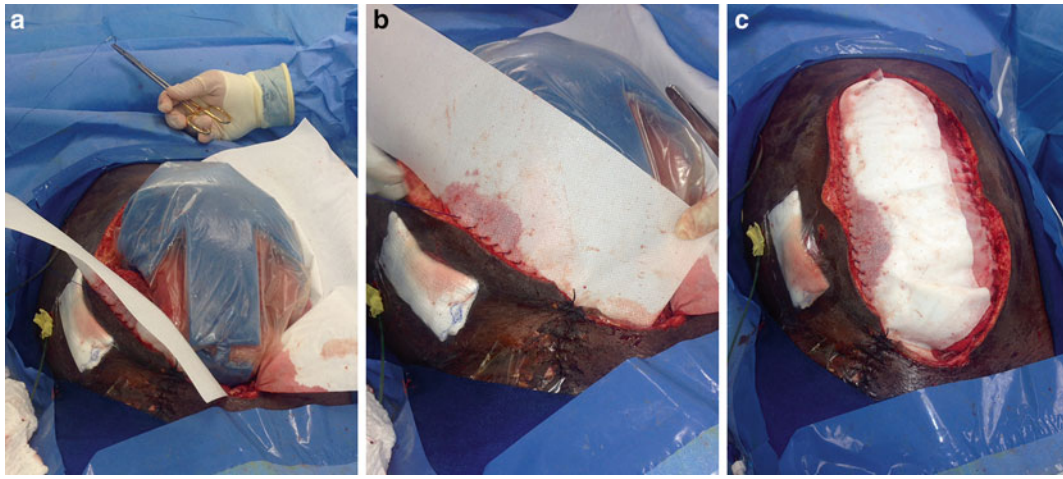


**Fig. 40.5** (**a**) The Wittmann Patch™ being sutured to the edge of the fascia and being used in conjunction with an ABThera™ (Kinetic Concepts, Inc., San Antonio, TX). (**b**) Suturing of the Wittmann Patch™ to the right fascial edge of the open abdomen. (**c**) Wittmann Patch™ once it has been sutured to both fascial edges and overlapped in the midline. These Velcro like patches can be gradually brought closer and closer together and ultimately help achieve primary fascial closure

and polypropylene, and bioabsorbable meshes such as Vicryl® (Ethicon, Cincinnati, OH) and Dexon™ (Covidien, Mansfield, MA) have been reported. As initially described, the mesh was sutured to the fascial edges to allow granulation tissue to develop and to support a split-thickness skin graft. With concern for infection risk associated with permanent synthetic meshes, the bioabsorbable synthetic meshes became the mainstay mesh for temporary abdominal closure, although hernias would often develop long term due to the resorption of the mesh.

In recent years, there has been increasing research related to mesh, and new categories of mesh such as biologic and synthetic absorbable meshes have evolved. Despite limited literature describing efficacy and the true role of these products in the management of the open abdomen and hernia repair, the use of these products has increased substantially. Due to the low risk of infection and good granulation tissue associated with the biologic meshes and likely the synthetic absorbable meshes, the use of these products in temporary abdominal closure has increased. Suturing of a biologic mesh to the midline fascia and placing a wound V.A.C. has become an efficacious and easy, although very expensive, means of temporary abdominal closure. Despite the ease and low risk of side effects, this type of closure will likely result in future hernia formation and is recommended when the surgeon does not believe that primary closure will be possible.

As surgeons gain more experience with temporary abdominal closure, the ultimate goal is primary fascial closure. To this end, another technique related to the use of mesh for temporary closure is serial mesh excision. In this technique, a mesh is sutured to the midline fascia and as bowel wall and intra-abdominal edema decrease, an elliptical piece of the mesh is excised and sutured back together bringing more tension on and medializing the fascial edges (Fig. 40.6a–g).

## Negative Pressure Therapy/ Wound Vac

Perhaps the most commonly used method for temporary abdominal closure involves the use of the Vacuum Assisted Closure® device (V.A.C®; Kinetic Concepts, Inc., San Antonio, TX). The components of the commercially available ABThera™ (Kinetic Concepts, Inc., San Antonio,

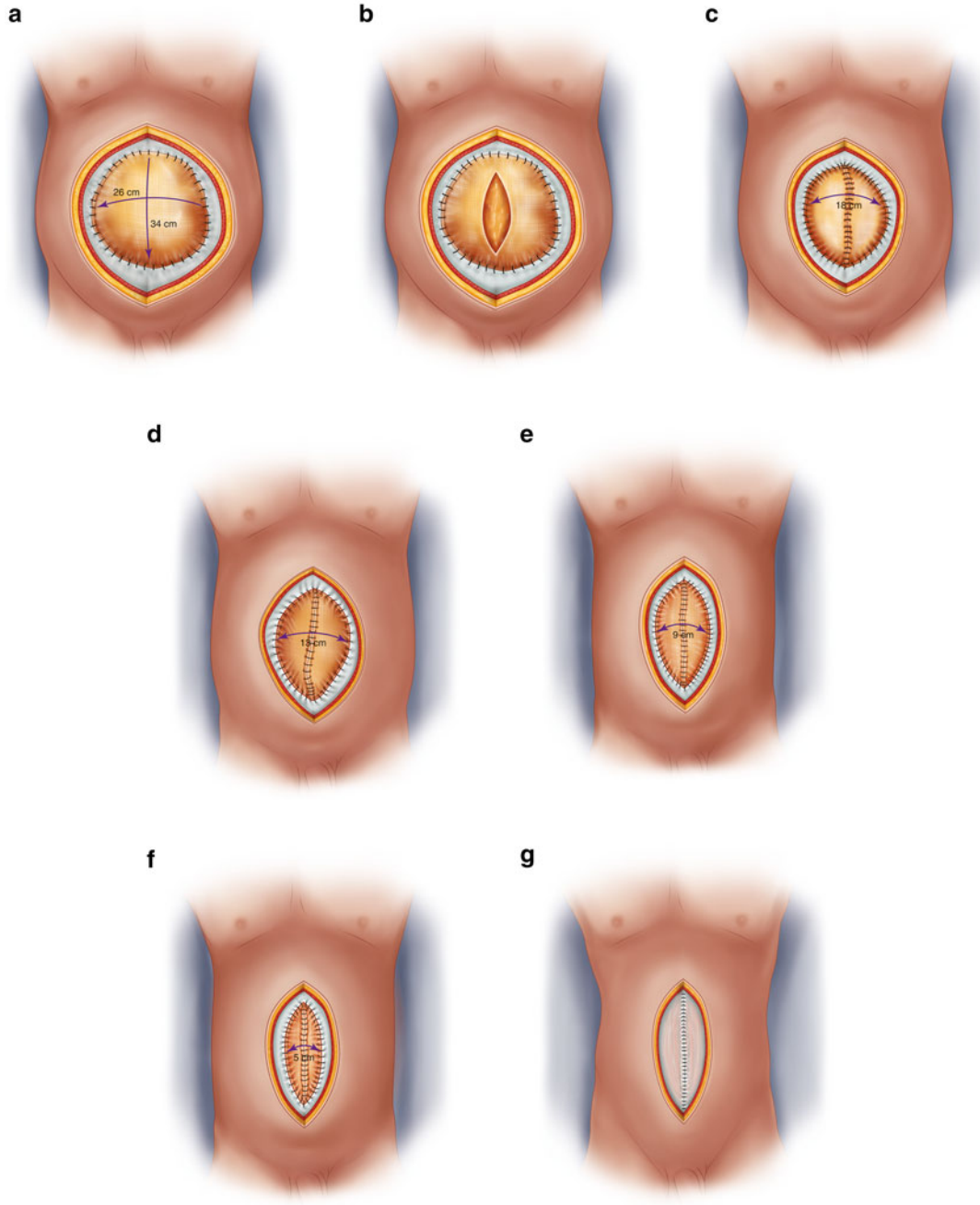


**Fig. 40.6** (**a**) Open abdomen with large defect. ePTFE mesh sutured to fascial edges with plan for serial mesh excision. (**b**) Center portion of the ePTFE mesh is cut in an elliptical fashion and then sutured back to bring fascial edges closer together. (**c**) Large ePTFE mesh has been excised and fascial edges are now brought closer together decreasing the defect. (**d**) With further mesh excision, the fascial edges are brought closer together. (**e**) Further mesh excision with now a much smaller fascial defect. (**f**) Fascial defect with small, only 5 cm defect and ready for primary fascial closure. (**g**) Ultimate primary fascial closure achieved by serial mesh excision

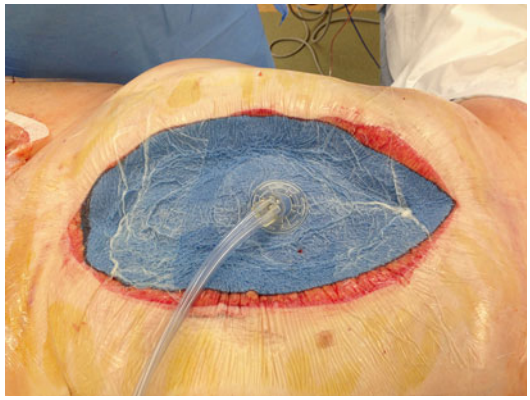

**Fig. 40.7** The commercially available ABThera™ (Kinetic Concepts, Inc., San Antonio, TX) is placed into an open abdomen. This technique is rapid and easy to learn especially for surgeons who are familiar with the wound vac

TX) open abdomen negative pressure therapy unit include a polyethylene sheet that acts as a visceral retractor, a polyurethane sponge that is placed above the sheet in the abdominal wound, and an adherent dressing that is placed over the sponge with suction tubing that can be attached to a suction apparatus to apply vacuum pressure (Fig. 40.7). This is a relatively simple technique that can be done quickly and prevents retraction of the fascia by the suction and vacuum that is applied in the wound. The V.A.C. can be easily changed at the bedside in the intensive care unit or in the operating room.

The potential and reported benefits of the ABThera are that it facilitates easy access to the abdominal cavity in patients requiring reoperation, provides medial tension, limits fascial retraction, reduces edema, helps remove fluid and infected material from the abdominal cavity, and helps protect the viscera from the external environment. Because of its ease of use and efficacy, the ABThera has become a mainstay in the treatment of open abdomens and temporary abdominal closure.

## Dynamic Fascial Closure Systems

One main evolution in the care of patients with open abdomens is an emphasis on providing temporary abdominal closure when needed. The goal is still achieving primary fascial closure when reoperations are no longer needed, and the edema related to the initial insult has subsided. Currently, the philosophy of accepting an open abdomen and planned ventral hernia repair, although still a necessity in some patients, has evolved to using techniques that can help achieve delayed primary fascial closure.

Dynamic fascial closure systems were designed to allow abdominal components to expand with resulting edema to prevent abdominal compartment syndromes and allow gradual, adjustable tension that can be placed on the fascia as the clinical scenario improves.

The ABRA® abdominal wall closure system (Canica Designs, Almonte, ON, Canada) is indicated for use in patients with abdominal compartment syndrome or other complex abdominal conditions when there is an open abdomen. The system components include a perforated silicone sheet that acts as a visceral retractor, silicone elastomers that are placed full thickness through the abdominal wall and provide continuous dynamic force to help close the wound, and button tails with pads that help distribute the compression force over a wide area of skin to allow easy tightening of the elastomers. This device is also used in conjunction with negative pressure wound therapy (Fig. 40.8a–d).

The ABRA abdominal wall closure system is indicated for full-thickness, retracted midline abdominal defects with the goal of primary closure. This dynamic wound closure system works by allowing elastomers to provide graduated tension to different parts of the wound at different times. Over the course of the patient's illness, the elastomers can be tightened at the bedside, and abdominal massage can help to redistribute the tension in the abdominal cavity. After the edema has resolved and the patient's clinical course improves, the ABRA device can be removed and primary fascial closure completed, obviating the need for mesh, skin grafting, or planned ventral hernia repair (Fig. 40.9). The proposed benefits of the ABRA are that it allows primary fascial closure, alleviates the need for mesh, preserves fascia margins, restores normal physiology, and allows bedside dressing changes.

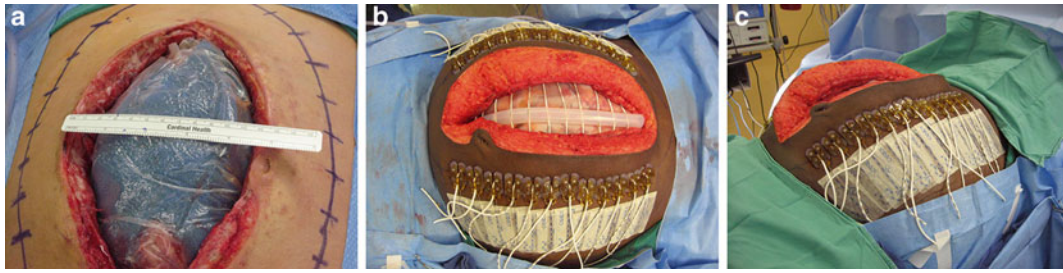


**Fig. 40.8** (**a**) Open abdomen with large defect. Markings on the abdominal wall of 5 cm away from wound edge and 3 cm apart to illustrate where elastomers should be placed. Stab incisions with a knife or bovie may be made at these points. (**b**) Open abdomen with ABRA® abdominal wall closure system (Canica Designs, Almonte, ON, Canada). The perforated silicone sheet has been placed to protect the viscera. The elastomers have been placed 5 cm away from the wound and 3 cm apart. A spacer is placed in the wound to coordinate the elastomers. The button pads and tails have been placed. (**c**) Side view of the button pads and tails that are placed to help hold the elastomers. Placement of a surgical drape such as Ioban™ (3M, Saint Paul, MN) (not shown in picture) may help minimize skin trauma from the button pads and tails. (**d**) View of abdomen once ABRA® abdominal wall closure system (Canica Designs, Almonte, ON, Canada) has been placed with wound vac

**Fig. 40.9** A patient with open abdomen who had ABRA® (Canica Designs, Almonte, ON, Canada) placed and has undergone primary fascial closure with no evidence of recurrent hernia at 1-year follow-up

## Enteroatmospheric Fistulas

Patients who develop an enteroatmospheric fistula during treatment for an open abdomen are another clinical challenge. Source control is essential and is often difficult to achieve without reoperations and application of multiple techniques. The abdomen that is open for more than 5–7 days is at greatest risk of developing this complication. It is difficult to contain a fistula's output because an ostomy appliance is usually not effective. The effluent continues to drive the inflammatory response and can precipitate the formation of more fistulas and prevent healing.

Foley catheter placement through the fistula should not be attempted, because it will result in limited effluent control and an increase in fistula size. Porous, petroleum-based, non-adherent dressing can be laid on the bowel surrounding the fistula with white foam placed over the fistula. GranuFoam™ (Kinetic Concepts, Inc., San Antonio, TX) can then be cut to the size of the wound (not covering the white foam) and a transparent adherent dressing applied. A superficial

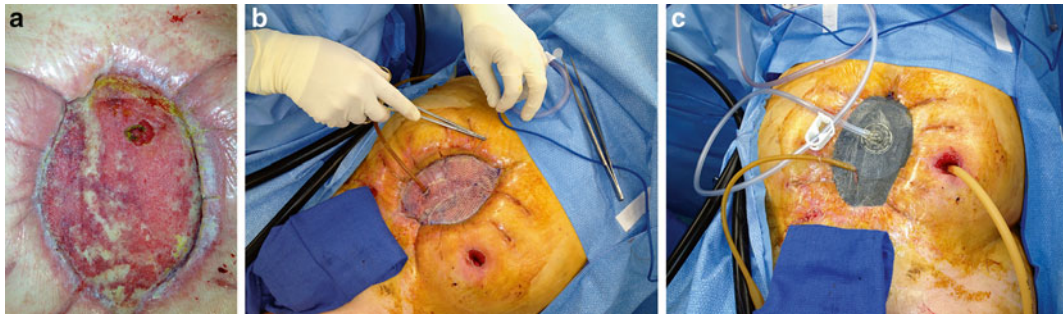


**Fig. 40.10** (**a**) Open abdomen with enteroatmospheric fistula. There is a good bed of granulation tissue that would be amenable to split thickness skin grafting. (**b**) Split thickness skin grafting of open wound. Foley catheter is placed in fistula in attempts to drain and patient also has left lower quadrant colostomy. (**c**) Wound vac placed over split thickness skin graft with drains in fistula as well as colostomy

portion of the white foam can then be excised and the V.A.C. tubing system applied. The pressure should be adjusted to the lowest pressure that prevents leakage around the stoma. A standard baby bottle nipple can also be used for effluent control. A small hole is cut in the nipple to allow placement of a Foley with its balloon slightly inflated. The bowel is covered with a non-adherent, petroleum-based dressing as described previously. A standard V.A.C. is applied to the remainder of the wound leaving the fistula uncovered by foam. The nipple can be placed over the fistula and isolated with stoma paste or an Eakin ring with GranuFoam™ placed around the nipple. The adherent drape can then be applied and the V.A.C. set to a standard setting with the Foley placed to gravity drainage. These two techniques often work well for proximal fistulas when effluent is mostly liquid.

The fistula ring can be instituted for distal fistulas when the effluent is thicker. This requires a round piece of GranuFoam to be sandwiched between adherent VAC tapes. An Eakin ring is then applied to the base of the fistula ring. A small hole is created in the center of the ring the size of the fistula. Non-adherent, petroleum-based dressing is applied to exposed bowel, excluding the fistula, and a standard V.A.C. is applied. The suction device is placed away from the site of the fistula, and an ostomy appliance is placed over the fistula ring. Certainly, there are surgical techniques that can be used to facilitate fistula closure, but these are beyond the scope of this chapter. Standard tenants of fistula management including TPN therapy, nutritional optimization, and delayed (up to 6 months) definitive surgical procedures to decrease inflammation in the abdomen should all be applied on a case by case basis. In patients with enteroatmospheric fistulas, attention is often placed on fistula management and control, and abdominal closure techniques are often not employed. These patients often require open abdomen management, and the goals of therapy are shifted to closing and controlling the fistula rather than abdominal wall closure. Early skin grafting can help manage these fistulas and convert them from an enteroatmospheric fistula into a standard fistula (Fig. 40.10a–c). Definitive abdominal wall reconstruction and closure are often delayed until the fistula is healed. When the fistula doesn't heal, single-stage or double-stage abdominal wall reconstructions with fistula takedowns can be undertaken depending on the clinical condition.

## Outcomes

There are few prospective or comparative studies on which to base decision-making regarding temporary abdominal closure, since this is a heterogeneous population and involves many different strategies, techniques, and outcome measures.

Several reports from single centers using one technique or protocol to manage open abdomens show good success rates and achievement

of primary fascial closure; however, few are comparative studies. Meta-analyses and systemic reviews have shown improvements in primary fascial closure rates and lower mortality rates using the Wittmann patch, VAC systems, and dynamic retention sutures [6, 7]; however, firm conclusions cannot be made due to the limited nature of the data.

## How to Choose

With limited data to guide treatment of the open abdomen, the surgeon is left with several options. The treatment used is often based on previous experience, comfort level, and patient outcomes. Certain centers may have treatment protocols for patients with open abdomens, and often these result in high rates of fascial closure.

When evaluating a patient with an open abdomen requiring temporary abdominal closure, the clinical picture must first be evaluated, and desired outcomes must be established. In some patients, primary abdominal closure is likely not possible, so the main priority is patient survival. In these cases, many of the techniques described in this chapter will suffice, and, often if the patient survives, skin grafting and planned ventral hernia repair can be used. In these cases, the V.A.C. works quite well since it is easy to apply and facilitates superb fluid management.

In other cases, the patient's clinical status improves substantially, and primary fascial closure should be attempted. In these cases, it is important to use one of the techniques for temporary abdominal closure that prevents fascial retraction. These techniques are at the surgeon's discretion and include the V.A.C., Wittmann patch, and dynamic fascial closure systems. Surgeons must also use sound clinical judgment regarding how difficult the abdomen will be to close.

Patients who are not obese, have minimal abdominal edema, and do not require multiple reoperations, are often easy to close. In this situation, a V.A.C. is a good option that provides adequate coverage, fluid management, and limits fascial retraction until the patient's abdomen can be closed in a few days. In patients that are more challenging (e.g., morbidly obese patients, patients with existing hernias, patients requiring multiple reoperations with large amounts of edema), the Wittmann patch or dynamic fascial closure system are good options that allow for graduating levels of tension that can be adjusted to prevent fascial retraction. We have begun to use the dynamic fascial closure systems in these cases due to our belief that that the fascia is perhaps healthier and stronger after primary closure, since no sutures are placed in the midline fascia (elastomers are placed several centimeters off the midline fascia). This is not supported by known data at this time.

In most circumstances, techniques used to treat an open abdomen should rely on some mechanism to prevent fascial retraction, split thickness skin grafting, and planned ventral hernia repair. Due to the lack of objective data on what techniques to use and when to attempt closure, surgeons must rely on their clinical judgment and experience. We are currently studying objective abdominal tension measurements to help establish guidelines to determine the appropriate time to close an abdomen and the best closure techniques to use.

## Conclusions

Knowledge and experience with temporary abdominal closure is increasingly important, as damage control surgery and open abdomens are more commonplace. Several different techniques can be used for primary closure, and their use depends on the patient's clinical status and the desired treatment goals. In most cases, primary fascial closure can be achieved using sound surgical techniques and attentiveness to the patient. Achieving primary fascial closure has evolved from simple packing methods and planned ventral hernia repair to more dynamic means of closure. Additional study is needed to evaluate these new methods and outcomes.

## References


1. Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. Ann Surg. 1983;197(5):532–5.
2. Teichmann W, Eggert A, Wittmann DH, Bocker W. Zipper as a new method of temporary abdominal wall closure in abdominal surgery. Chirurg. 1985; 56(3):173–8.
3. Wittmann DH, Aprahamian C, Bergstein JM. Etappenlavage: advanced diffuse peritonitis managed by planned multiple laparotomies utilizing zippers, slide fastener, and velcro analogue for temporary abdominal closure. World J Surg. 1990;14(2): 218–26.
4. Wittmann DH, Aprahamian C, Bergstein JM, Edmiston CE, Frantzides CT, Quebbeman EJ, et al. A burr-like device to facilitate temporary abdominal closure in planned multiple laparotomies. Eur J Surg. 1993;159(2):75–9.
5. Aprahamian C, Wittmann DH, Bergstein JM, Quebbeman EJ. Temporary abdominal closure (TAC) for planned relaparotomy (etappenlavage) in trauma. J Trauma. 1990;30(6):719–23.
6. Quyn AJ, Johnston C, Hall D, Chambers A, Arapova N, Ogston S, et al. The open abdomen and temporary abdominal closure systems—historical evolution and systematic review. Colorectal Dis. 2012;14(8): e429–38.
7. Boele van Hensbroek P, Wind J, Dijkgraaf MG, Busch OR, Goslings JC. Temporary closure of the open abdomen: a systematic review on delayed primary fascial closure in patients with an open abdomen. World J Surg. 2009;33(2):199–207.