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The open abdomen: practical implications for the practicing surgeon

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Abstract. The open abdomen is a necessary sequela after damage-control surgery or abdominal compartment syndrome. Management of the patient in the intensive care unit continues to evolve, with considerations of fluid resuscitation, enteral nutrition, and supportive care. Management of the abdominal contents incorporates several basic techniques and considerations: appropriate temporary covering, enteric injury repair in most patients, placement of an anastomosis in an area of the abdomen with minimal manipulation without exposure to the atmosphere, acquiring enteral access for initiation of enteral nutrition, and ultimate abdominal closure. An understanding of these complex factors is instrumental for the practicing surgeon.

It is truly an honor to give the Edgar J. Poth Memorial Lecture, so named after the 15th president of the Southwestern Surgical Congress. Although the recognition of the utility of open-abdomen management occurred after his period of scientific investigation, I would like to think that this topic might have been one of interest to Dr. Poth. I begin by acknowledging that when most people hear the phrase "open abdomen," they think that this happens only in the realm of trauma. Because many practicing surgeons try to avoid trauma call after completing their residencies, they feel they will never encounter this entity. These patients, in fact, are seen by the general surgeon: the medical intensive care unit (ICU) consult for abdominal compartment syndrome (ACS) in the pancreatitis patient after large volume resuscitation, the patient with perforated diverticulitis and feculent peritonitis who is in septic shock, or the gunshot wound to the superior mesenteric artery requiring complex reconstruction.

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The following is a brief overview of my address this morning. In discussing the open abdomen, the first question is, How did we arrive here? The most common etiologies resulting in an open abdomen are ACS and damage-control surgery (DCS), whether DCS for trauma or general surgery. I will discuss these etiologies and the indication for leaving the abdomen open for each. The next issue of concern is the temporary closure options that are available to enable transport to the ICU. In the ICU, there are some management considerations that are unique to the open-abdomen patient. Next, how should one prepare for repeat laparotomy, including intraoperative questions and the plan for definitive abdominal closure? Finally, what are some of the complications you might encounter during the hospital course of the patient with an open abdomen?

Abdominal Compartment Syndrome

The ACS is typified by intra-abdominal hypertension due to either intra-abdominal injury (primary) or following massive resuscitation (secondary) (Fig. 1).[1–8] Some causes of primary ACS include solid-organ injuries, bowel perfora-

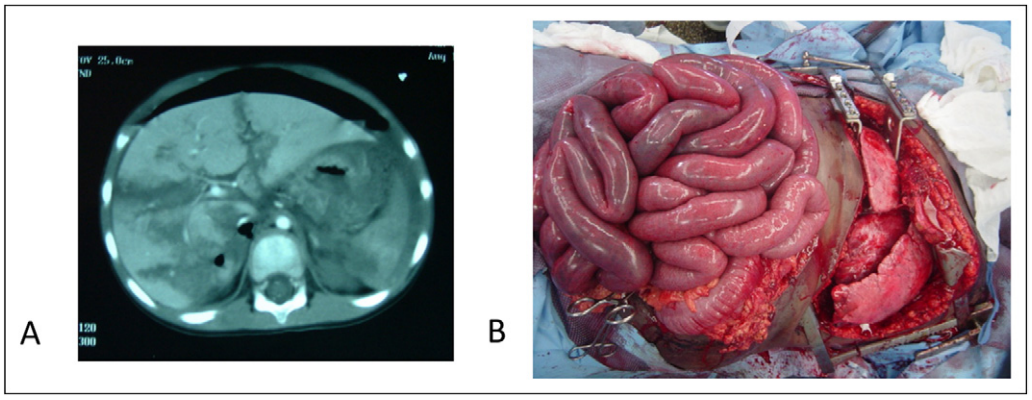

Figure 1 The ACS can be due to a primary intra-abdominal process such as a liver injury (A) or resuscitation-associated visceral and retroperitoneal edema such as that seen in a patient undergoing massive resuscitation for a gunshot wound to the heart (B).

tions or obstruction, ruptured vasculature, and postoperative hemorrhage. Secondary ACS may be due to any etiology requiring large-volume resuscitation, including both crystalloid and blood products. This includes patients with extremity trauma, isolated head or chest trauma, pancreatitis, liver failure, and overt sepsis. In these cases, intra-abdominal hypertension is due to resuscitation-associated bowel edema, retroperitoneal edema, and large quantities of ascitic fluid.

Increased abdominal pressure affects multiple organ systems (Fig. 2). The ACS, however, is defined by intra-abdominal hypertension causing such end-organ sequelae as decreased urine output, increased pulmonary pressures, decreased preload and subsequent cardiac dysfunction, and even elevated intracranial pressure.[1] The first key is that you have to think of the diagnosis of ACS. In any critically ill or injured patient, there are many etiologies that could cause low urine output and cardiopulmonary woes. But if intra-abdominal hypertension does not occur to you as a potential cause of the patient's low urine output or cardiovascular collapse, rather than the patient's associated hypovolemic shock or sepsis or cardiac contusion, you will miss the diagnosis of ACS and the window for intervention. The pitfall to avoid is that physical examination cannot definitively diagnose intra-abdominal hypertension. Although the patient may have a markedly distended abdomen that is suggestive of the diagnosis, your examination may reliable only about 40% of the time. A diagnosis of intra-abdominal hypertension is obtained by measuring the patient's bladder pressure. To measure a patient's bladder pressure, 50 mL of saline is instilled into the bladder via the aspiration port of a 3-way Foley catheter with the drainage tube clamped; after waiting for 30 to 60 seconds to allow the detrusor musculature to relax, pressure measurement with a manometer at the pubic symphysis is performed.[9] There are several conditions in which the bladder pressure may not be reflective of the intra-abdominal pressure. This includes patients with external compression on the bladder such as pelvic packing, those with bladder rupture, marked adhesive disease, and patients with a neurogenic bladder.

Although we measure the actual pressure within the abdominal cavity, the real question is, When does intra-abdominal hypertension become ACS? ACS, by definition, is intra-abdominal hypertension causing end-organ sequelae. So it

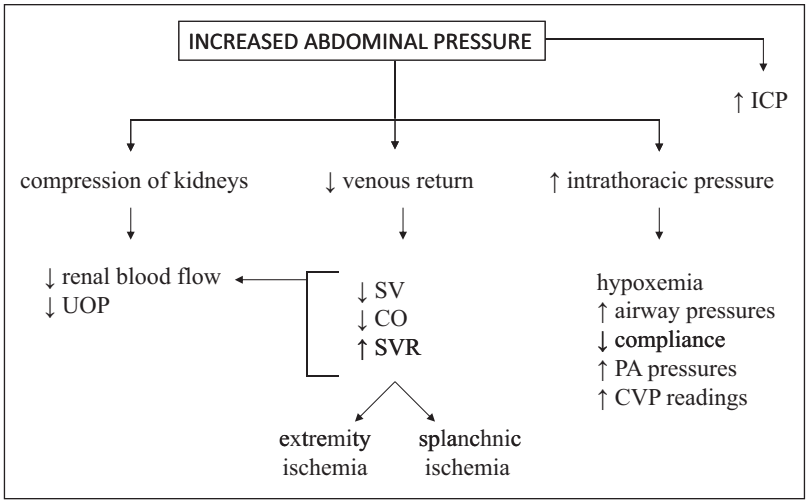

Figure 2 Increased abdominal pressure affects multiple organ systems.

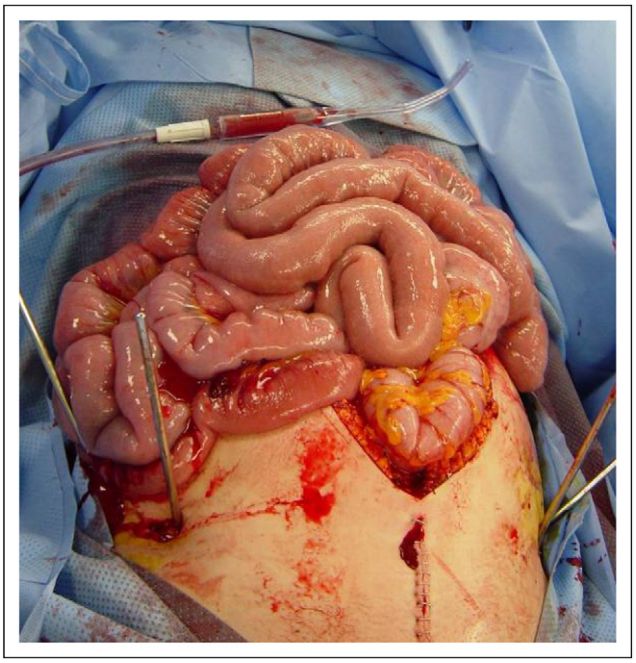

Figure 3 Midline laparotomy permits decompression in ACS patients with evacuation of peritoneal fluid or blood and egress of the edematous bowel.

is not a single bladder pressure alone, but the combination of the bladder pressure measurement and end-organ sequelae (decreased urine output, increased pulmonary pressures, and decreased cardiac output) that is required for the diagnosis. Organ failure can occur over a wide range of recorded bladder pressures; there is not a single measurement of bladder pressure that prompts therapeutic intervention, except >35 mm Hg. If the patient has ACS, however, emergent decompression is indicated; mortality is directly affected by decompression.[10]

Decompression is typically performed via a midline laparotomy incision performed in the operating room; this allows egress of peritoneal fluid or blood as well as evisceration of the edematous bowel (Fig. 3). In patients who are too unstable for transport to the operating room, you can bring the operating room to the ICU for bedside decompressive laparotomy (Fig. 4). Bedside laparotomy is easily accomplished, precludes transport in hemodynamically compromised patients, and requires minimal equipment (scalpel, suction, cautery, and abdominal temporary closure dressings). Patients with significant intra-abdominal fluid as the primary component of their ACS may be candidates for decompression via a percutaneous drain.[11–13] Removing a significant amount of ascites might lower the intra-abdominal pressures enough to prevent laparotomy. Differentiation of those amenable to such drainage is determined by bedside ultrasound, hence obviating a trip to the operating room for a critically ill patient.

One pitfall in patients with ACS, and actually in all open-abdomen patients, is to assume that because the patient has an open abdomen, that he or she cannot have recurrent intra-abdominal hypertension and associated ACS.[14] Therefore, even in patients with a temporary abdominal covering or particularly with wound vacuum-assisted closure (VAC) devices, measurement of bladder pressures in patients who are unstable or have low urine output is an important adjunct. Additionally, what appears as a satisfactory temporary coverage at the end of the case may not allow for the expected postoperative resuscitation-related swelling of the bowel and retroperitoneum (Fig. 5). Therefore, leave room in your temporary covering for visceral expansion to prevent subsequent intra-abdominal hypertension and ACS.

Damage-Control Surgery

The other etiology of the open abdomen is patients undergoing DCS. The term “damage control” was coined by

Figure 4 In unstable patients, the operating room team and equipment are brought to the bedside for decompressive laparotomy.

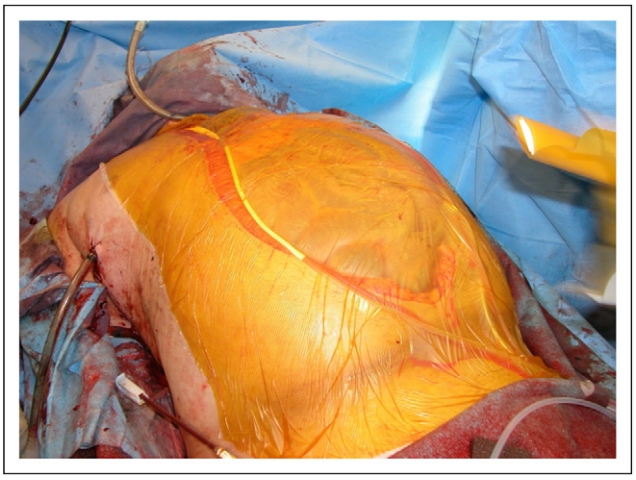

Figure 5 If the Ioban component of the patient's temporary coverage is pulled snuggly across the abdominal wall, postoperative resuscitation-related swelling of the bowel and retroperitoneum within the confined space may result in recurrent ACS.

the US Navy during World War II and was defined as those procedures and skills used to maintain or restore the watertight integrity, stability, or offensive power of a warship. This military term is used today to describe the management of the surgical equivalent of a sinking ship. The fundamentals of DCS are to limit the operation to essential interventions, namely, controlling hemorrhage and limiting enteric contamination, in patients who are dying because of the lethal triad of hypothermia, coagulopathy, and acidosis.[15–18] Indications to limit the initial operation and institute DCS techniques are a clinical decision, along with objective signs of persistent temperature $< 35°C$, arterial pH < 7.2, base deficit > 15 mmol/L (or >6 mmol/L in patients aged > 55 years), and international normalized ratio or partial thromboplastin time $> 50\%$ of normal. Aborting the operation enables one to return the patient to the surgical ICU for resuscitation and correction of the coagulopathy. Once physiologic restoration is complete, the patient is returned to the operating room for definitive repair of injuries. These techniques are not limited to trauma patients; although most references are in the postinjury patient, DCS can be used in general surgery patients as well.[19]

At the initial laparotomy, the operative techniques of damage control are temporary measures. Definitive repair of injuries is delayed until the patient is physiologically replete. To halt hemorrhage, vascular structures are ligated, repaired, or shunted, and solid organs are packed with laparotomy pads. To limit enteric content spillage, there are several available options. Small gastrointestinal injuries to the stomach, duodenum, small intestine, and colon may be controlled with a rapid whipstitch of 2-0 Prolene (Ethicon Endo-Surgery, Cincinnati, OH) or PDS (Ethicon Endo-Surgery). Complete transection of the bowel or segmental damage is often controlled using a gastrointestinal anastomosis stapler, with resection of the injured segment. Alternatively, open ends of the bowel may be ligated using umbilical tapes to limit spillage. The bowel is then left in discontinuity. Limiting an operation in a patient circling in the bloody viscous cycle or preventing the ACS after massive resuscitation is a wise decision. Do not hesitate to leave the abdomen open in these patients. After all, open abdomens are temporary. At least in the vast majority of cases.

For any patient relegated to the open abdomen, temporary coverage of the abdominal viscera is necessary. The first option of temporary closure is "towel clipping." This entails placing penetrating towel clips, 2 to 3 cm apart, to approximate the skin for the entire midline laparotomy incision (Fig. 6). This technique rapidly closes the abdomen. However, it may limit the use of angiography because of the metal clamps' obscuring one's view on imaging; additionally, patients may develop ACS during the ensuing resuscitation because of a tight closure. This approach is currently used as a temporary measure in the operating room to give anesthesia time to catch up; after towel clipping, the abdomen is closed, blood products are administered, and the patient's adverse physiology is corrected before reopening the abdomen for a final inspection for surgical bleeding prior leaving the operating room. The second option for temporary closure is the Bogota bag closure (Fig. 7). This temporary silo is constructed of a sterile 3-L genitourinary irrigation bag or x-ray cassette cover that is sutured to the skin; this contains the edematous bowel while providing excellent decompression. Although there are no issues with angiography or fluoroscopy, this technique may take longer to complete coverage.

The third option for temporary closure is 1010 Steri-Drape (3M Health Care, St Paul, MN) and Ioban (3M Health Care) closure (Fig. 8). This is our preferred method of temporary closure at initial laparotomy because it affords bowel coverage while allowing egress of the abdominal contents with effective decompression; additionally, it can be accomplished quite rapidly. In this technique, the bowel is covered with a fenestrated subfascial 1010 Steri-Drape; small holes are cut in the plastic drape with a scalpel to allow fluid to pass through the drape while not allowing the Ioban to stick to the underlying bowel. The drape is placed

Figure 6 Towel clip closure of the abdominal skin.

Figure 7 Bogota bag closure of the abdomen with a sterile 3-L genitourinary irrigation bag sutured to the skin.

over the bowel and tucked under the fascia. Occasionally, two drapes must be used to cover all the protruding viscera. The Steri-Drape may be covered with a blue towel or lap pad; however, if there is concern about the viability of the bowel, this step should be omitted. Placing the Ioban directly on the 1010 Steri-Drape enables one to observe if any of the bowel becomes ischemic. Two Jackson-Pratt drains are placed along the fascial edges to control reperfusion-related ascitic fluid. The tubing is run cephalad to provide better occlusion with the Ioban. Everything is then covered using a large Ioban. This method of closure is easy and quick to apply. Additionally, should the patient require angiography, this temporary closure is compatible with fluoroscopy, unlike towel clipping for skin closure.

Intensive Care Unit Management

After the operation, the patient is transported to the ICU for physiologic restoration. Management of the patient with an open abdomen is not markedly different from the care of any critically ill patient. The guiding principles in such cases include directed resuscitation, rewarming techniques, correction of coagulopathy and acidosis, lung protective ventilation (once resuscitated), strategies to prevent ventilator-associated pneumonia, treatment of adrenal suppression, and management of hyperglycemia. There are some issues that are specific to the patient with an open abdomen: fluid administration, nutrition support, and management of enteric injuries.

The initial period of acute resuscitation, typically lasting for the first 12 to 24 hours after injury, involves goal-directed resuscitation with initial volume loading to attain adequate preload, followed by judicious use of inotropic agents or vasopressors.[20] The resuscitation of the severely ill patient may require what appears to be an inordinate amount of volume and blood products, with infusion volumes of 10 L during the initial 6 to 12 hours required. Optimizing fluid administration is a challenging aspect of early patient care, balancing cardiac performance versus generating marked visceral and retroperitoneal edema. At

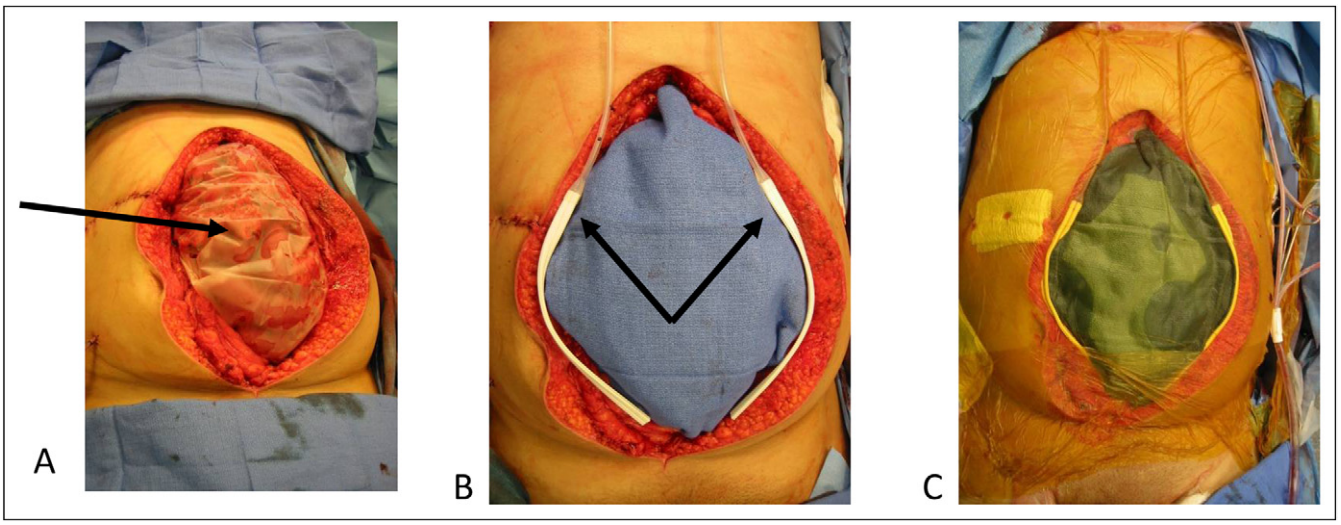

Figure 8 Closure with 1010 Steri-Drape and Ioban begins with placement of a fenestrated 1010 Steri-Drape over the bowel and under the fascia (A). Two Jackson-Pratt drains are placed along the fascial edges (B) with the tubing run cephalad, followed by coverage with an Ioban (C).

times, you can practically see the bowel swelling in front of you. One consideration in patients with markedly edematous bowel after their resuscitation is direct peritoneal resuscitation, a technique promulgated by the Louisville group.[21] After instillation of peritoneal dialyzate, they showed increased blood flow, decreased bowel edema, and increased rates of fascial closure. Although early colloid administration may be appealing in these patients, evidence to date does not support this concept.[22] Finally, gentle diuresis in the open-abdomen patient may be entertained after completed resuscitation.

Enteral nutrition (EN) has been advocated in the critically ill surgical patient. In patients sustaining major abdominal trauma, the reduction in septic complications with the institution of early EN is particularly notable.[23–28] Despite these studies illustrating the importance of EN in the trauma population, there remains hesitancy about enteral feeding in postinjury patients with an open abdomen. This may relate to issues of enteral access, concerns about bowel edema, or questions of intestinal motility and enterocyte functionality. The three studies specifically addressing EN in the open-abdomen patient have conflicting findings. One study reports increased fascial closure rates with the initiation of EN before postinjury day 4,[29] while the other 2 show no impact of EN on abdominal closure rates.[30,31] Additionally, one study suggests a reduced incidence of ventilator-associated pneumonia with early EN,[30] while the others show similar rates of infectious complications between those started on EN versus those kept nil per os.[29,31]

The most recent evaluation of feeding the open abdomen through the Western Trauma Association multicenter trials group had the largest patient cohort to date, with almost 600 patients from 11 institutions.[32] When EN versus nil per os status was compared in the study population, definitive fascial closure was significantly higher in those patients receiving EN; however, final closure was significantly later in the EN group, and the total number of abdominal operations was significantly higher in the EN group. For those patients with bowel injuries, logistic regression was performed, controlling for site, Injury Severity Score, mechanism of injury, closure at second laparotomy, and total 24-hour infused volume; this demonstrated no significant association between EN and fascial closure, complication rate, or mortality. For those patients without bowel injuries, however, logistic regression confirms that EN is associated with higher fascial closure rates, decreased complications, and decreased mortality. That study concluded that EN in the postinjury open abdomen was feasible. Therefore, once resuscitation is complete, initiation of EN should be considered in all injured patients. EN in patients with bowel injuries does not appear to alter fascial closure rates, complications, or mortality; hence EN appears to be neither advantageous nor detrimental in these patients. Prospective randomized controlled trials are warranted to further clarify the role of EN in this subgroup. For patients without bowel injuries, EN in the open abdomen is associated with a marked increase in successful fascial closure, a decrease in complications, and a decrease in mortality. Although higher fascial closure rates and lower complications have been previously suggested, this is the first study to identify a significant difference in mortality between postinjury open abdomen patients receiving EN compared with those remaining nil per os.

Return to the Operating Room

After normalization of physiologic parameters, typically after 12 to 24 hours in the ICU, the patient is returned to the operating room for definitive repair of injuries. The key questions that cross my mind as I am taking a patient with an open abdomen back to the operating room are (1) What is the best way to manage a bowel injury, anastomosis or stoma? (2) What type of bowel repair do I plan to do, a stapled or sutured anastomosis? (3) If I perform a bowel anastomosis or repair, can I effectively hide the suture line, and where should this be placed within the abdomen? (4) What type of feeding tubes will I use? If these are going to be placed operatively, is this operation the right time to put in the gastrostomy or jejunostomy tube? And finally, (5) If I cannot close the patient's fascia today, what is my plan to get his or her abdomen definitively closed?

Let's consider the first question, anastomosis versus stoma for a bowel injury. With the option of delayed definitive management of enteric injuries in DCS patients, the question of primary repair/anastomosis versus stoma creation has been posed. A recent Western Trauma Association multicenter study of over 200 patients with enteric injuries requiring a postinjury open abdomen found that the minority of patients suffer abdominal complications.[33] There does, however, appear to be an increase in leak rate as one progresses toward the left colon. Leak rates after anastomosis were 3% for right colon injuries, 20% for the transverse colon, and 45% for left colon injuries. In addition to the increase in anastomotic leak rate in patients with left colon injuries, there is an increasing leak rate based on time to fascial closure; those patients with fascial closure beyond day 5 had a 4 times higher likelihood of developing an anastomotic leak. Others have demonstrated a similar relationship between increasing number of days to abdominal closure and complications[34]; those patients closed after 8 days had a significantly higher complication rate compared with those closed earlier. In addition to the Western Trauma Association multicenter study, 4 additional studies support the safety of bowel repair in patients with the postinjury open abdomen.[35–38] Therefore, repair or anastomosis of identified injuries should be considered in all patients; however, in those patients with left colon injuries or a marked delay in abdominal closure, colostomy should be considered.[33,39]

Regarding questions 2 and 3, what type of bowel repair should be done, and where should it be hidden? Although

studies to date do not show a clear superiority of hand-sewn to stapled anastomosis, there appears to be a trend toward more anastomotic leaks and intra-abdominal abscesses with stapled bowel repairs. When enteric repairs or anastomoses are performed, they should be placed deep within the pelvis or central abdomen under multiple loops of bowel, or out laterally under the abdominal wall. The bowel in the open abdomen patient becomes more friable and adherent with prolonged exposure to the atmosphere. At repeat laparotomy, the abdomen does not need to be thoroughly reexplored nor the bowel eviscerated. The integrity of the suture lines and anastomoses do not need to be investigated at each repeat operation unless the patient has clinical evidence of an intra-abdominal complication. One caveat in this population of open-abdomen patients is the opportunity to identify potential or actual anastomotic leak while the abdomen is still open[38]; identification of a leak while the abdomen is still open facilitates fecal diversion and drainage.

Regarding question 4, how should enteral access be obtained, and when should feeding tubes be placed? In multiply injured patients, postresuscitation visceral edema can be daunting. Therefore, there may be hesitancy to place a jejunostomy through the edematous bowel wall; however, this can be safely performed.[40] However, in patients with a persistent open abdomen requiring multiple repeat laparotomies, manipulation or marked movement of enteral access sites could cause injury with fistula formation. Therefore, operative gastrostomy and jejunostomy tubes should not be placed until closure of the fascia is well under way. Alternatively, nasojejunal access is also a viable option in the open abdomen for early EN.

One of the ultimate goals of the open abdomen, however, is getting it closed. Coverage of the enteric contents is the most critical step in the management of the bowel after DCS. Leaving the bowel exposed to the atmosphere can result in enteroatmospheric fistulas, which are notoriously difficult to manage. The ideal coverage for the bowel is native fascia, so primary closure is the goal, either with early fascial closure or sequential fascial closure techniques. Other options for bowel coverage include prosthetic fascial closure with either mesh or biologics; this is a topic worthy of an entire lecture in and of itself. Another option includes bowel coverage with skin grafts and planned ventral hernia; once the skin graft has separated from the underlying bowel, approximately 9 months later, one can remove the skin graft and perform a component separation.

Our preferred approach in Denver for those patients who are not closed at second laparotomy is the sequential fascial

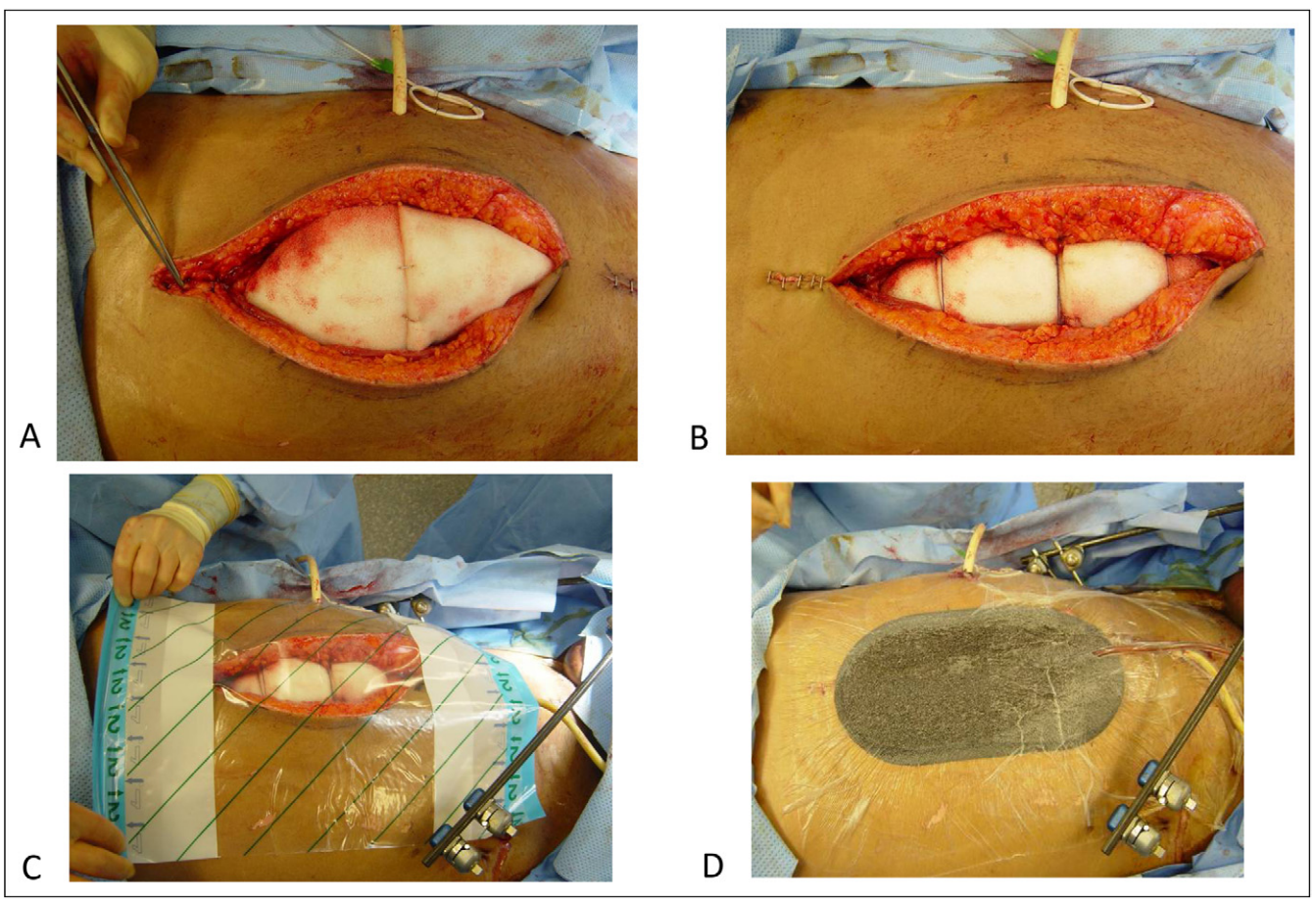

Figure 9 Overlapping white cover the bowel (A) and #1 PDS sutures are placed over the white sponges to prevent fascial retraction (B). Adhesive dressing covers the adjacent 5 to 10 cm of skin, and the central portion is cut away (C). Black VAC sponges, placed on top of the white sponges and plastic-protected skin are affixed with an occlusive dressing and standard suction is applied (D).

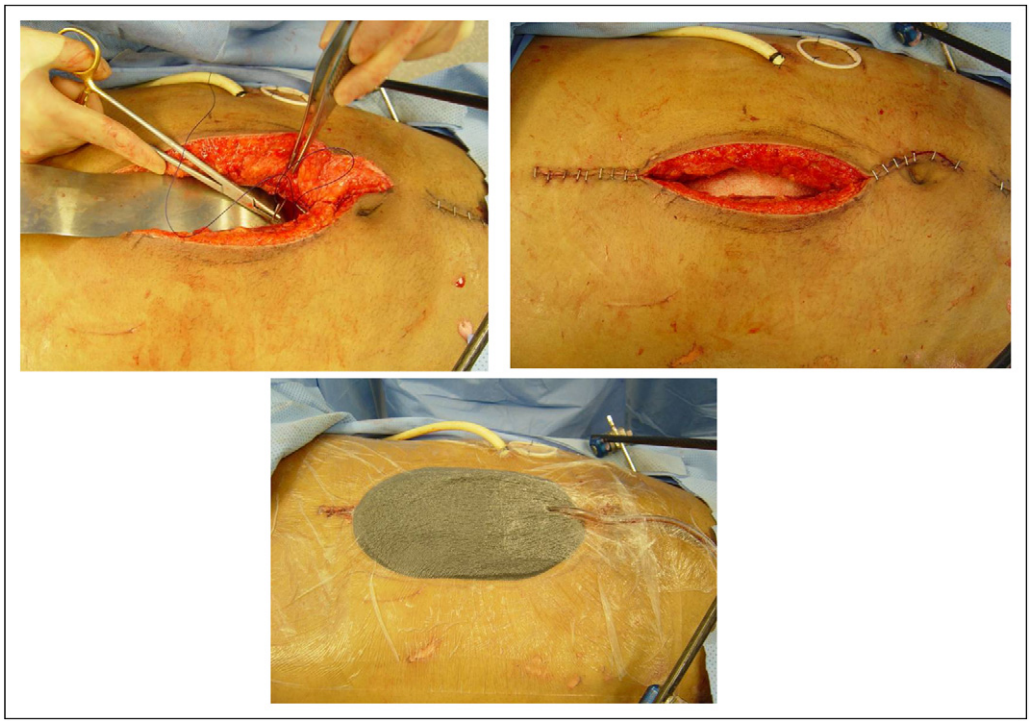

Figure 10 At repeat laparotomy, fascia is closed until tension precludes further closure; skin is closed over approximated fascia and sponge sandwich with fascial sutures is reapplied.

closure technique,[41,42] a modification of Miller et al's[43] described VAC technique. In our described technique, closure is sequentially performed with the combination of a wound VAC as well as constant fascial tension with sutures. Multiple white VAC sponges are overlapped like patchwork to cover the bowel; to prevent bowel from extruding between the white sponge edges, the edges are stapled together with a skin stapler. The white sponges not only cover the bowel but are also placed under the fascial edges. The fascia is then placed under moderate tension over the white sponges with #1 PDS sutures; the PDS sutures are full thickness fascial bites (1–2 cm) placed approximately 5 cm apart in an interrupted fashion. The sticky clear plastic VAC covering is then placed over the entire white sponge patchwork and the adjacent 5 to 10 cm of skin. The central portion of the clear plastic is removed by cutting along the wound edges, leaving only that which is adherent to the skin (this protects the skin from the black wound VAC sponge). One to 2 large black VAC sponges are placed on top of the white sponges and plastic-protected skin (there is no need to trim the black sponges to fit the wound edges with this technique); the black sponges are affixed with an occlusive dressing, and standard suction tubing is placed.

Patients are returned to the operating room for sequential fascial closure and replacement of the sponge sandwich every 2 days, with a resulting decrease in the fascial defect (Fig. 9). Fascial sutures are placed using #1 PDS in an interrupted fashion from both the superior and inferior di-

Figure 11 Fascia and skin are closed, and enteral access is seen exiting from the lateral abdomen; residents rejoice at the bedside.

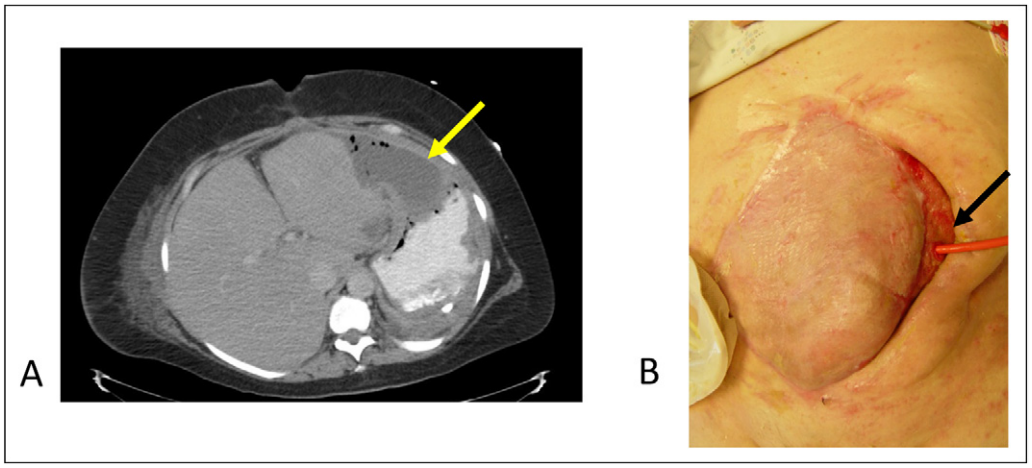

Figure 12 Complications observed in the open-abdomen patient include intra-abdominal abscesses (A) and enteroatmospheric fistula (B).

rections until tension precludes further closure; skin is closed over the fascial closure with skin staples. As the fascial defect closes, the number of white sponges used diminishes. Of note, the abdomen is not reexplored, nor is the bowel eviscerated at each return to the operating room; rather, the fascial sutures are placed and the white sponges slowly removed. Only if there is concern for an intra-abdominal abscess should a complete washout of the abdomen be performed on repeated trips to the operating room. Once partial fascial closure is accomplished (the superior and inferior fascial sutures placed until the fascia cannot be pulled together without tension), new white and black sponges are placed in the same technique to form a sandwich. Each time the patient goes to the operating room, the superior and inferior fascia is closed several centimeters, and the number of white sponges required diminishes. This process is repeated every 48 hours (Fig. 10). Gastrostomy and needle catheter jejunostomy tubes may be placed before complete VAC closure, typically at the second VAC change day, and should exit the abdominal wall lateral to the aforementioned closure. Eventually, the entire length of the fascia is closed using interrupted sutures, followed by the skin with skin staples (Fig. 11). And finally, a few quick examples of some of the more common and morbid complications observed in the open-abdomen patient, intra-abdominal abscess and enteroatmospheric fistula (Fig. 12).

In summary, open abdomens are necessary sequelae after DCS or ACS, but they do save lives. Management of the patient in the ICU continues to evolve, with considerations of fluid resuscitation, EN, and supportive care. Management of the bowel incorporates several basic techniques and considerations: appropriate temporary covering, a consideration of bowel repair in most patients, placement of the anastomosis in an area of the abdomen with minimal manipulation without exposure to the atmosphere, and a consideration of enteral access for initiation of EN while the abdomen is still open. And finally, the importance of fascial closure cannot be emphasized enough. Thank you.

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