Damage Control Surgery and the Open Abdomen

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Management of the open abdomen incorporates tenants of intensive care unit and operative care of the critically ill patient. While several etiologies may result in the requirement for an open abdomen, goals of care are similar to all: temporary coverage of the viscera, appropriate critical care to include fluid resuscitation and nutrition support, treatment of the underlying etiology, attempts at fascial coverage and prevention or treatment of complications. This article will discuss each of these core components of open abdomen management in turn.

Etiologies of the Open Abdomen

The most common scenarios that lead to a patient requiring an open abdomen include abdominal compartment syndrome (ACS) and damage control surgery (DCS) [1–4]. Primary abdominal compartment syndrome is typified by intraabdominal hypertension (IAH) due to an intraabdominal injury or disease process; some examples include solid organ injuries, ruptured vasculature, and postoperative hemorrhage. Secondary ACS occurs following a large volume resuscitation involving both crystalloid and blood products. Patients may also have a combination of primary and secondary ACS in cases such as severe acute pancreatitis. Regardless of the underlying process, once end organ sequelae are identified with IAH, decompression of the ACS is necessary. The final potential scenario is the role of the open abdomen in preventing the development of ACS. In some cases, at the end of an operation, closure of the abdomen may precipitate IAH. In this scenario, leaving the abdomen open to prevent the progression of IAH to ACS, particularly in patients that are predicted to need further resuscitation volumes, is wise.

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Open abdomen management is also a necessary component of DCS. In DCS techniques, the goal is to limit the operation to key components: control of hemorrhage, re-establishing all essential vascular conduits, and limiting enteric contamination. In patients who are dying due to the lethal triad of hypothermia, coagulopathy, and acidosis, this abbreviated laparotomy permits physiologic restoration in the surgical intensive care unit (SICU). Resuscitation of the critically ill and injured patient, as DCS can be performed for both trauma and emergency general surgery cases, occurs concurrently with management of the patient's open abdomen.

Techniques of Temporary Closure

For patients relegated to an open abdomen, temporary coverage of the abdominal viscera is critical. Historically, temporary closure of the abdomen was performed with "towel clipping." This process entails placing penetrating towel clips through the skin only, 2–3 cm apart, down the length of the midline laparotomy incision. While this is a rapid abdominal closure technique, patients often develop ACS during the ensuing resuscitation. Also of historical interest is Bogota bag closure of the abdomen. A silo approach to contain the protruding bowel is constructed using either a sterile 3 L irrigation bag or a sterile X-ray cassette cover which is sewn to the skin; Jackson-Pratt (JP) drains are positioned along the external edges of the suture and an occlusive Ioban covering is placed over the entire abdominal wall.

Currently the most commonly used techniques of temporary abdominal closure are adaptations of the "homemade vacpack" or commercially available negative pressure wound therapy (NPWT) systems [5, 6]. The author's preferred method of temporary closure at initial laparotomy is an adaptation of Barker's technique termed the "10-10 drape and Ioban closure." The bowel is covered with a fenestrated 1010 steri-drape (3M Health Care, St. Paul, MN) that is then placed circumferentially under the fascia of the midline laparotomy

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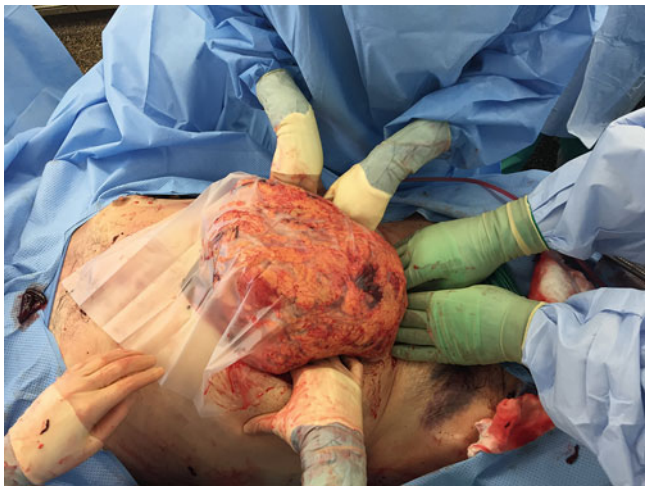

Fig. 38.1 Temporary closure at initial laparotomy is performed using the "10-10 drape and Ioban closure." The first step is covering the viscera with a fenestrated 1010 steri-drape that is placed circumferentially under the abdominal wall

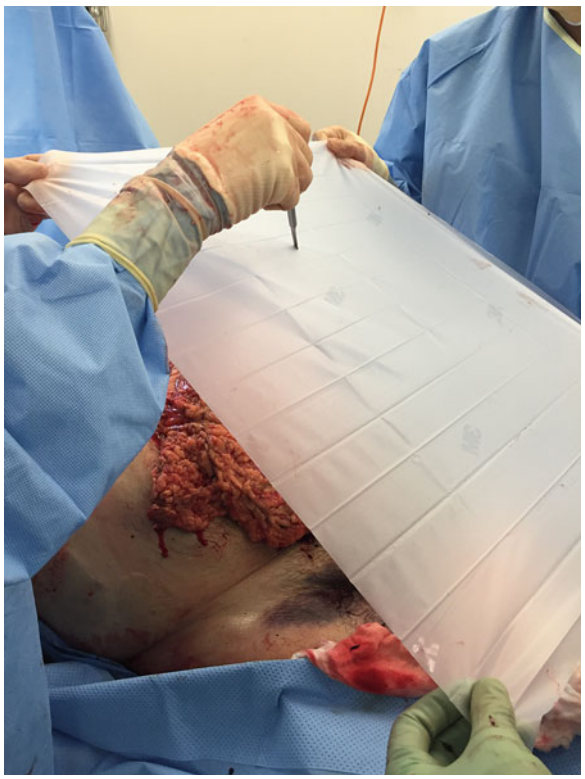

Fig. 38.2 A scalpel is used to create small slits in the plastic drape

incision (Fig. 38.1). The fenestrations in the plastic drape are made with a scalpel blade to create small slits rather than large apertures (Fig. 38.2). This permits intraabdominal fluid and blood to pass through the plastic while preventing the Ioban from sticking to the bowel. Occasionally, two drapes must be used in an overlapping technique to protect and contain all of the protruding intestines.

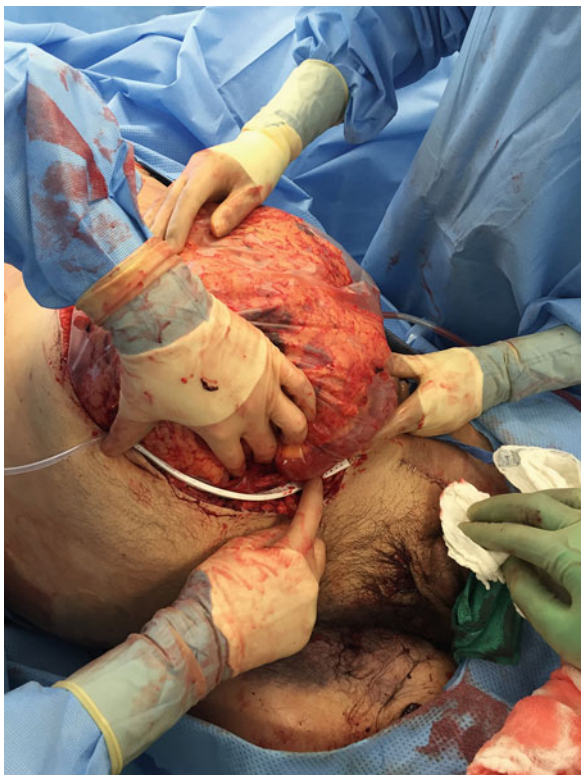

Fig. 38.3 JP drains are placed along the fascial edges in the subcutaneous space

Two JP drains are placed on top of the plastic 1010 drape, in the subcutaneous space of the midline incision, just above the fascial edges (Fig. 38.3); the drains control the egress of reperfusion-related ascitic fluid. Management of the drains is best done by running the drain tubing cephalad from the midline wound (Fig. 38.4); once the Ioban covering is placed, this tube location provides a more effective closed suction system. Once the 1010 drape and JP drains are in place, an Ioban covers everything including the adjacent abdominal wall (Fig. 38.5). When placing this temporary dressing, one should anticipate bowel swelling secondary ongoing resuscitation and therefore leave adequate space. Ensuring the plastic drape is redundant rather than pulled tight over the abdominal contents is important. Likewise, when applying the Ioban occlusive dressing, leaving some expansion room by not pulling the Ioban taut is critical.

There are multiple advantages to the "10-10 drape and Ioban closure" technique. First, it affords bowel coverage while allowing egress of the abdominal contents and effective decompression. Second, it can be accomplished quite rapidly. Third, without placement of a sponge, blue towel, or laparotomy pad over the 1010 plastic drape, one can directly visualize the bowel and can identify early ischemia or bleeding. Fourth, should the patient require angiography, this temporary closure is compatible with fluoroscopy. And finally, the components of the closure technique are readily

Fig. 38.4 The JP drain tubing is run cephalad from the midline wound for a more effective closed suction system once the Ioban is placed

Fig. 38.5 An Ioban covers the 1010 drape, JP drains, and the adjacent abdominal wall

available in all operating rooms and comparatively inexpensive. Commercially available NPWT systems may also be utilized for temporary closure. There are a variety of sponge options and occlusion devices that are available. While NPWT plays a crucial role for patients who require an open abdomen past the initial 24 h [7], early utilization of these techniques is not mandatory.

ICU Management of the Open Abdomen Patient

Following decompressive laparotomy for ACS or abbreviated laparotomy for DCS, the patient is transported to the intensive care unit (ICU) for physiologic restoration. The guiding principles of critical care management such as rewarming techniques, correction of coagulopathy and acidosis, lung protective ventilation, prevention of ventilator associated pneumonia, treatment of adrenal suppression, and management of hyperglycemia predominate. There are, however, some specific management concerns that pertain to the open abdomen patient worth addressing.

During the early resuscitation of the patient, careful fluid balance is crucial. The well-meaning clinician may attempt to optimize the patient's hemodynamics with initial volume loading to attain adequate preload. However, an understanding of the sequelae of crystalloid resuscitation in patients with an open abdomen is paramount. Attempts at volume loading may only lead to further visceral edema and development of ascitic fluid [8]. Judicious use of inotropic agents or vasopressors should be encouraged [9]. Balancing cardiac performance versus generating retroperitoneal edema and intestinal swelling is one of the most challenging aspects in optimizing patients' fluid administration. Although early colloid administration with albumin may be appealing, evidence to date does not support this concept. Finally, the role of gentle diuresis in patients with a persistent open abdomen, 24 h following their completed resuscitation may be entertained [10] but earlier reports question its utility [11].

One pitfall to avoid in the ICU management of these patients is the presumption that a patient with a widely open abdomen cannot have IAH and subsequent hemodynamic compromise. Monitoring bladder pressures, an easy bedside metric of IAH, should be performed in open abdomen patients, particularly if they are unstable or have a low urine output.

One of the newer modalities in the management of the open abdomen patient that has shown promise is the use of direct peritoneal resuscitation [12]. In this technique, catheters (either 19F round Blake drains or Davol drains) are placed along the retroperitoneum to infuse hypertonic dialysate into the abdomen (Fig. 38.6). The dialysate then bathes the abdominal contents and is removed through the JP drains located next to the abdominal wall fascia just under the temporary closure dressings. This continuous infusion of dialysate causes the edematous bowel to shrink over 24–48 h. The specific protocol is infusion of a 2.5 % hypertonic glucose-based peritoneal dialysis solution (Delflex; Fresenuis USA) at a rate of 1.5 mL/kg/h. Early reports demonstrate an increase in fascial closure rates, with a faster time to closure and fewer abdominal complications [13]. One caveat for those performing this technique: standard wound VAC sponges, particularly the white sponge that may be used on

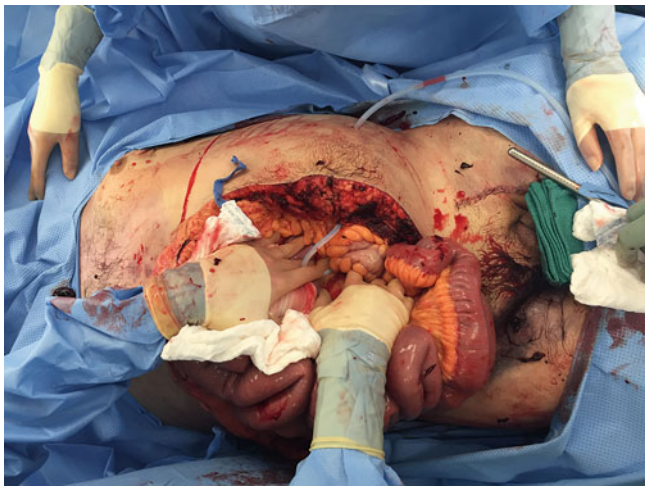

Fig. 38.6 For direct peritoneal resuscitation, a 19 Fr round Blake drains is placed through a separate stab incision in the abdominal wall and positioned along the retroperitoneum at the root of the mesentery to infuse hypertonic dialysate into the abdomen

exposed viscera, do not permit the dialysate to be suctioned out of the abdomen, and hence should not be used; temporary closure with the "10-10 drape and Ioban closure" of the abdomen or a homemade vacpack is advocated. The role of direct peritoneal resuscitation in patients with bowel repairs, enteric anastomoses, significant liver injuries, or vascular grafts has not been elucidated, but anecdotally appears to be safe.

Nutritional support is one of the cornerstones of ICU management of critically ill patients. There may be hesitation in starting enteral nutrition for those patients with an open abdomen or marked visceral edema. However, multiple studies support the use of EN in the open abdomen patient once deranged physiology is corrected [14–17]. In the largest study population to date, performed by the Western Trauma Association multicenter trials group, EN was associated with a higher abdominal closure rates (albeit with a longer time until closure) and a reduction in mortality compared to those patients who were kept *nil-per-os* [14]. The optimal EN formulation, necessary quantity, and location of delivery (stomach versus duodenum/jejunum) remain areas of active investigation. One consideration suggested by a single institution's experience is quantification of protein loss related to the open abdomen [18]; direct measurement of the albumin rich ascitic fluid that is removed from the abdomen suggests the addition of up to 2 g of nitrogen to the patient's daily protein requirement for every liter of abdominal fluid output. The effect of additional protein supplementation and its impact on patient outcome has not been studied to date.

Additional adjuncts that impact outcomes or alter management in the open abdomen patient population have been reported in single-study publications. Hypertonic saline (3 % sodium chloride) administered at a rate of 30 mL/h as maintenance fluid is associated with increased fascial closure rates compared to standard crystalloid maintenance fluids [19]. Vasopressor use has been implicated in cases of anastomotic failure following damage control surgery [20]. Damage control resuscitation, although initiated in the trauma bay, has important implications during the first 24 h of the patients management; higher plasma to red cell ratios impacts fascial closure rates and should not be abandoned during the ICU phase of resuscitation [21]. Finally, patients with an open abdomen do not require mechanical ventilation unless they have associated respiratory failure; small patient series suggest extubation in patients with an open abdomen, even in the acute phase of management, is feasible [22].

Considerations at Repeat Laparotomy

Following normalization of physiologic parameters, typically after 12–24 h in the ICU, the patient is returned to the operating room for definitive repair and attempts at fascial closure. There are some key questions that should be entertained prior to the operation: (1) If there is a bowel injury or the bowel is in discontinuity, should this be managed with an anastomosis or a stoma, (2) if a bowel anastomosis or repair is performed, can the suture line be "hidden" in the abdomen, (3) what type of enteral access should be placed, (4) if the fascia cannot be closed at this operation, what is the plan to definitively close the patient's abdomen?

Regarding the first question, should one perform an intestinal anastomosis versus a stoma, there are some guiding principles. First, the location of the injury or resection may be the deciding factor. Patients with a proximal small bowel injury should undergo anastomosis if technically possible; the morbidity and fluid balance challenges of a proximal stoma are too great. Distal ileal lesions and colonic injuries, however, provide more of a critical decision point, with either anastomosis or stoma being technically feasible. Although the largest study of penetrating colon injuries to date supports primary anastomosis in all patients [23], this study did not specifically analyze patients requiring an open abdomen. Five studies have specially addressed the question of primary repair/anastomosis versus stoma creation in a delayed fashion in patients requiring an open abdomen [24–28]. All but one of these studies are single-institution analyses of a small population of patients [25–28]. The Western Trauma Association multicenter trials study is the largest report to date, with over 200 patients with enteric injuries requiring a post-injury open abdomen [24]. In reviewing this literature cohort, the minority of patients suffer abdominal complications. In general, bowel repair in patients with the post-injury open abdomen appears safe, with similar anastomotic leak rates and abscess rates between patients undergoing immediate anastomosis, delayed anastomosis, and stoma formation. Two of the five published reports do, however, issue a cautionary note in relation to colonic wounds, particularly as one progresses along the colon toward the left

side [24, 27]. For patients undergoing primary repair/anastomosis, there is a reported increase in leak rate as one progresses toward the left colon, with a 3 % leak rate on the right, 20 % leak rate in the transverse, and 45 % leak rate with left colon/sigmoid repairs.

The timing of abdominal closure may also impact the decision to perform even a diverting stoma. There appears to be an increasing leak rate based upon time to fascial closure. The Western Trauma Association study demonstrated that patients with fascial closure beyond day 5 sustained a leak rate 4 times that of those already closed [24]. Two additional studies demonstrated a similar relationship between delayed timing of abdominal closure and significantly higher complications including anastomotic leak [29, 30]. Therefore, repair or anastomosis of identified injuries should be considered in all patients—however in those patients with left colon injuries or marked delay in abdominal closure, colostomy should be considered.

The next concern is question number 2, where to hide a newly fashioned anastomosis. With prolonged exposure to the atmosphere, the bowel in the open abdomen patient becomes more friable and adherent. Manipulation of the viscera, even simply the repeated placement and removal of temporary abdominal dressings, can result in a breakdown of an anastomosis and a resultant enteroatmospheric (EA) fistula. Therefore, enteric repairs or anastomoses should be placed deep within the pelvis or central abdomen under multiple loops of bowel, or out laterally under the abdominal wall.

Additionally, at repeat laparotomy, the abdomen does not need to be thoroughly re-explored 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 intraabdominal complication.

Placement of feeding tubes for enteral nutrition access is the third question one must consider upon return to the operating room. Early enteral nutrition, whether the abdomen is open or recently closed, is crucial in the critically ill patient. Options for enteral access include nasogastric tubes, Dobhoff tubes placed into the duodenum, nasojejunal tubes placed via endoscopy, and operatively placed gastrostomy and jejunostomy tubes. There may be hesitancy to place operative jejunostomy tubes through the edematous bowel wall; however, this can be safely performed [31]. In patients with a persistent open abdomen requiring multiple repeat laparotomies, however, manipulation or marked movement of enteral access sites (i.e., gastrostomy and jejunostomy tubes) can cause injury with leakage, tube dislodgement, or fistula formation. For this reason, gastrostomy and jejunostomy tubes should not be placed until closure of the fascia is well underway. Alternatively, nasogastric, nasoduodenal, or nasojejunal access is a viable option for early enteral nutrition and does not create an additional enterotomy with potential for leakage or complication.

Abdominal Closure

The final, and perhaps most critical step in the management of the open abdomen patient is closure of the abdomen. Leaving bowel exposed to the atmosphere for a prolonged time will result in EA fistulas which are notoriously difficult to manage. The ideal coverage for the bowel is native fascia, so primary closure is the goal. At the first return to the operating room, the majority of patients can achieve fascial closure of their abdomen [32]. If there is a question of success, towel clipping the abdomen closed can demonstrate effective closure prior to placement of fascial sutures. Monitoring airway pressures while re-approximating the fascia temporarily may assist in the determination of successful closure without creating significant IAH.

If early complete fascial closure of the abdomen is not possible, there are several options. Currently, sequential fascial closure techniques are the most attractive [33]. There are multiple published techniques but the majority involve three key components: (1) fascial tension toward the midline to prevent lateral retraction and loss of abdominal domain, (2) vacuum-assisted control of abdominal effluent and reduction of abdominal viscera within the abdominal cavity, and (3) methodic return to the operating room every 24–48 h for attempts at further fascial closure [33, 34]. Options to provide midline traction of the fascia include simple sutures (over the top of the sponges used in the vacuum-assisted closure) or commercially available bridging devices such as the Wittman patch (Starsurgical, Inc, Burlington, WI) [35, 36].

Other options for bowel coverage include prosthetic fascial closure with either mesh or biologics. Closure of the subcutaneous tissue and skin over top of these prosthetics often prevents desiccation and evisceration should the prosthetic fail. If one questions the use of prosthetics, a skin-only closure with planned hernia is always an option. In patients truly relegated to the open abdomen, in which no closure can be accomplished, a final option for bowel coverage is skin graft placement directly onto the granulating intestines [37]. Skin grafting can be surprisingly successful in this location with subsequent healing. Delayed abdominal wall reconstruction with component separation is performed once the skin graft has separated from the underlying bowel, approximately 9–12 months later.

Complications of the Open Abdomen

Some of the most common complications observed in patients with an open abdomen are ubiquitous to any patient undergoing a laparotomy: abscess, anastomotic leak, and enterocutaneous (EC) fistula. In general, these complications are treated using the similar approaches. One caveat in this population of open abdomen patients is the opportunity to

identify an anastomotic leak while the abdomen is still open; according to one published report, the majority of patients with an anastomotic leak were identified while the abdomen was still open, facilitating diversion and drainage [26].

One of the most vexing complications of the open abdomen is an EA fistula. The optimal management technique is prevention through a combination of careful manipulation of the bowel and aggressive abdominal closure techniques. For those that develop an EA fistula, most commonly seen in a "frozen abdomen," spontaneous sealing seen commonly in EC fistulas will not occur due to the lack of soft tissue covering the tract. If one can mobilize the adjacent soft tissue (abdominal wall or even just skin), the fistula tract can be intubated and then covered to promote a drainage tract and permit healing. For those that cannot obtain coverage, other options for EA fistula control have been suggested. Attempts at sealing the fistula aperture with fibrin glue and biologic dressing (acellular dermal matrix or cadaveric skin) can be attempted [38, 39]. A "fistula patch" made of a flexible silica gel lamellar which can be placed inside the lumen of the bowel through the EA fistula site has also been described [40]. If there is ongoing peritoneal contamination due to the EA fistula, control may be obtained using a "floating stoma" [41]. NPWT appears to have the greatest success in management of EA fistulas. A variety of techniques have been suggested with a variety of modification in either suction, control of fistula effluent, or composition of sponges [42–46].

Summary

In summary, understanding the management of the open abdomen is necessary for any clinician treating patients with either the ACS or following DCS. Considerations of fluid resuscitation, enteral nutrition, and supportive care continue to evolve. Management of the bowel incorporates several basic techniques and thoughts: appropriate temporary covering, a consideration of bowel repair in the majority of patients, placement of the anastomosis within the abdomen with both minimal manipulation and atmospheric exposure, and consideration of enteral access for initiation of nutrition support while the abdomen is still open. Early aggressive attempts at fascial closure remain pivotal to prevent the myriad of complications that can develop.

References

1. Kirkpatrick AW, Roberts DJ, De Waele J, et al. Intra-abdominal hypertension and the abdominal compartment syndrome: updated consensus definitions and clinical practice guidelines from the World Society of the Abdominal Compartment Syndrome. Intensive Care Med. 2013;39(7):1190–206.
2. Balogh ZJ, Lumsdaine W, Moore EE, Moore FA. Postinjury abdominal compartment syndrome: from recognition to prevention. Lancet. 2014;384(9952):1466–75.
3. Rotondo MF, Schwab CW, McGonigal MD, et al. "Damage control": an approach for improved survival in exsanguinating penetrating abdominal injury. J Trauma. 1993;35:375–82. Discussion 382–3.
4. Lee JC, Peitzman AB. Damage-control laparotomy. Curr Opin Crit Care. 2006;12:346–50.
5. Barker DE, Kaufman HJ, Smith LA, Ciraulo DL, Richart CL, Burns RP. Vacuum pack technique of temporary abdominal closure: a 7-year experience with 112 patients. J Trauma. 2000;48(2):201–6. Discussion 206–7.
6. Roberts DJ, Zygun DA, Grendar J, et al. Negative-pressure wound therapy for critically ill adults with open abdominal wounds: a systematic review. J Trauma Acute Care Surg. 2012;73(3):629–39.
7. Cheatham ML, Demetriades D, Fabian TC, et al. Prospective study examining clinical outcomes associated with a negative pressure wound therapy system and Barker's vacuum packing technique. World J Surg. 2013;37(9):2018–30.
8. Joseph B, Zangbar B, Pandit V, et al. The conjoint effect of reduced crystalloid administration and decreased damage-control laparotomy use in the development of abdominal compartment syndrome. J Trauma Acute Care Surg. 2014;76(2):457–61.
9. Moore FA, McKinley BA, Moore EE, et al. Inflammation and the host response to injury, a large-scale collaborative project: patient-oriented research core—standard operating procedures for clinical care. III. Guidelines for shock resuscitation. J Trauma. 2006;61:82.
10. Regli A, De Keulenaer B, De Laet I, et al. Fluid therapy and perfusional considerations during resuscitation in critically ill patients with intra-abdominal hypertension. Anaesthesiol Intensive Ther. 2015;47(1):45–53.
11. Webb LH, Patel MB, Dortch MJ, et al. Use of a furosemide drip does not improve earlier primary fascial closure in the open abdomen. J Emerg Trauma Shock. 2012;5(2):126–30.
12. Weaver JL, Smith JW. Direct peritoneal resuscitation: a review. Int J Surg. 2015;S1743-9191:1224–8.
13. Smith JW, Garrison RN, Matheson PJ, et al. Direct peritoneal resuscitation accelerates primary abdominal wall closure after damage control surgery. J Am Coll Surg. 2010;210(5):658–64.
14. Burlew CC, Moore EE, Cuschieri J, et al. Who should we feed? A Western Trauma Association multi-institutional study of enteral nutrition in the open abdomen after injury. J Trauma Acute Care Surg. 2012;73:1380–8.
15. Collier B, Guillamondegui O, Cotton B, et al. Feeding the open abdomen. JPEN J Parenter Enteral Nutr. 2007;31:410–5.
16. Dissanaike S, Pham T, Shalhub S, et al. Effect of immediate enteral feeding on trauma patients with an open abdomen: protection from nosocomial infections. J Am Coll Surg. 2008;207:690–7.
17. Byrnes MC, Reicks P, Irwin E. Early enteral nutrition can be successfully implemented in trauma patients with an "open abdomen". Am J Surg. 2010;199:359–63.
18. Cheatham ML, Safcsak K, Brzezinski SJ, Lube MW. Nitrogen balance, protein loss, and the open abdomen. Crit Care Med. 2007;35:127–31.
19. Harvin JA, Mims MM, Duchesne JC, et al. Chasing 100%: the use of hypertonic saline to improve early, primary fascial closure after damage control laparotomy. J Trauma Acute Care Surg. 2013;74(2):426–30. Discussion 431–2.
20. Fischer PE, Nunn AM, Wormer BA, et al. Vasopressor use after initial damage control laparotomy increases risk for anastomotic disruption in the management of destructive colon injuries. Am J Surg. 2013;206(6):900–3.
21. Phelan HA, Wolf SE, Schreiber M, et al. Higher ratios of plasma to red blood cells are associated with increased rates of abdominal closure after damage control laparotomy. AAST annual meeting presentation, 2012.

22. Campion EM, Glass NE, Pieracci FM, et al. Take out the tube! Patients with an open abdomen can be successfully extubated. SWSC annual meeting abstract, 2016.
23. Demetriades D, Murray JA, Chan L, Committee on Multicenter Clinical Trials, American Association for the Surgery of Trauma, et al. Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. J Trauma. 2001;50(5):765–75.
24. Burlew CC, Moore EE, Cuschieri J, et al. Sew it up! A Western Trauma Association multi-institutional study of enteric injury management in the post-injury open abdomen. J Trauma. 2011;70(2): 273–7.
25. Miller PR, Chang MC, Hoth JJ, et al. Colonic resection in the setting of damage control laparotomy: is delayed anastomosis safe? Am Surg. 2007;73:606–9.
26. Kashuk JL, Cothren CC, Moore EE, et al. Primary repair of civilian colon injuries is safe in the damage control setting. Surgery. 2009;146:663–70.
27. Weinberg JA, Griffin RL, Vandromme MJ, et al. Management of colon wounds in the setting of damage control laparotomy: a cautionary tale. J Trauma. 2009;67:929–35.
28. Chavarria-Aguilar M, Cockerham WT, Barker DE, et al. Management of destructive bowel injury in the open abdomen. J Trauma. 2004;56(3):560–4.
29. Miller RS, Morris Jr JA, Diaz Jr JJ, et al. Complications after 344 damage-control open celiotomies. J Trauma. 2005;59: 1365–71.
30. Anjaria DJ, Ullmann TM, Lavery R, Livingston DH. Management of colonic injuries in the setting of damage-control laparotomy: one shot to get it right. J Trauma Acute Care Surg. 2014;76(3):594–8. Discussion 598–600.
31. Cothren CC, Moore EE, Ciesla DJ, et al. Post-injury abdominal compartment syndrome does not preclude early enteral feeding following definitive closure. Am J Surg. 2004;188:653–8.
32. Dubose JJ, Scalea TM, Holcomb JB, AAST Open Abdomen Study Group, et al. Open abdominal management after damage-control laparotomy for trauma: a prospective observational American Association for the Surgery of Trauma multicenter study. J Trauma Acute Care Surg. 2013;74(1):113–20.
33. Burlew CC, Moore EE, Johnson JL, et al. 100% Fascial approximation can be achieved in the post-injury open abdomen. J Trauma. 2012;72:235–41.
34. Dennis A, Vizinas TA, Joseph K, et al. Not so fast to skin graft: transabdominal wall traction closes most "domain loss" abdomens in the acute setting. J Trauma Acute Care Surg. 2013;74(6):1486–92.
35. Weinberg JA, George RL, Griffin RL, et al. Closing the open abdomen: improved success with Wittmann Patch staged abdominal closure. J Trauma. 2008;65(2):345–8.
36. Haddock C, Konkin DE, Blair NP. Management of the open abdomen with the abdominal reapproximation anchor dynamic fascial closure system. Am J Surg. 2013;205(5):528–33.
37. Cheesborough JE, Park E, Souza JM, Dumanian GA. Staged management of the open abdomen and enteroatmospheric fistulae using split-thickness skin grafts. Am J Surg. 2014;207(4):504–11.
38. Girard S, Sideman M, Spain DA. A novel approach to the problem of intestinal fistulization arising in patients managed with open peritoneal cavities. Am J Surg. 2002;184(2):166–7.
39. Jamshidi R, Schecter WP. Biological dressings for the management of enteric fistulas in the open abdomen: a preliminary report. Arch Surg. 2007;142(8):793–6.
40. Wang G, Ren J, Liu S, Wu X, Gu G, Li J. "Fistula patch": making the treatment of enteroatmospheric fistulae in the open abdomen easier. J Trauma Acute Care Surg. 2013;74(4):1175–7.
41. Subramaniam MH, Liscum KR, Hirshberg A. The floating stoma: a new technique for controlling exposed fistulae in abdominal trauma. J Trauma. 2002;53(2):386–8.
42. Goverman J, Yelon JA, Platz JJ, Singson RC, Turcinovic M. The "Fistula VAC," a technique for management of enterocutaneous fistulae arising within the open abdomen: report of 5 cases. J Trauma. 2006;60(2):428–31.
43. Layton B, Dubose J, Nichols S, et al. Pacifying the open abdomen with concomitant intestinal fistula: a novel approach. Am J Surg. 2010;199(4):e48–50.
44. Rekstad LC, Wasmuth HH, Ystgaard B, Stornes T, Seternes A. Topical negative-pressure therapy for small bowel leakage in a frozen abdomen: a technical report. J Trauma Acute Care Surg. 2013;75(3):487–91.
45. Di Saverio S, Villani S, Biscardi A, Giorgini E, Tugnoli G. Open abdomen with concomitant enteroatmospheric fistula: validation, refinements, and adjuncts to a novel approach. J Trauma. 2011;71(3):760–2.
46. D'Hondt M, Devriendt D, Van Rooy F, et al. Treatment of small-bowel fistulae in the open abdomen with topical negative-pressure therapy. Am J Surg. 2011;202(2):e20–4.