

Chapter 2

Damage Control

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History

Originally a naval term, damage control (DC) is a simple and useful idea referring to the ability of a battleship to absorb adversarial fire while maintaining mission integrity. After rapid assessment, the vessel is basically compartmentalized, eventually sacrificing the damaged areas in order to save the ship as a whole. The goal is minimal repair of devastating damage to facilitate return to a safe harbor.

Building on the foundations led by Burch and Stone in the 1980s, Rotondo and Schwab described DC in 1993. Since then, DC has become the standard of care for the management of severely injured trauma patients. Recently, its application has also been extrapolated to other surgical specialties. Today, it is relatively common to see DC applied to general surgical, vascular, thoracic, as well as orthopedic patients [5, 6]. The guiding principle behind surgical DC is immediate and abbreviated management of severe and life-threatening conditions with definitive surgical management deferred to a period after physiologic stabilization.

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Fig. 2.1 Damage control for intra-abdominal sepsis from acute bowel ischemia



Indications

While its utilization has been the cornerstone of severe blunt and penetrating abdominal trauma care in the past two decades, it is not without morbidity. There is increased risk for gastrointestinal fistulas, infections, abscesses, and multiple-organ dysfunction syndrome (MODS). Therefore, it is vital not to use DC indiscriminately, but to have some selection criteria. For this purpose, the three parameters (intraoperative pH < 7.2, temperature < 93 °F, blood loss > 10 units of packed red blood cells) as defined by Asensio et al. can be useful. Common indications for damage control in trauma are multisystem injuries with competing treatment priorities, multicavitary injuries with shock, major abdominal vascular injuries, complex hepatic injuries, hypothermia, metabolic acidosis, coagulopathic state, and exsanguinating patients. It is important to recognize the clinical picture early on to initiate a DC operation without delay. In severely injured patients, the lethal triad of hypothermia, acidosis, and coagulopathy will inevitably develop, reinforcing each other's negative effects and causing the so-called vicious cycle. Early intervention with combining aggressive hemorrhage and contamination control with resuscitation and rewarming measures will ameliorate the effects of the lethal triad.

Ideally, one should stay well ahead of the operation and consider the physiology, injury pattern, trauma burden, as well as resources at hand even before the operation begins. All these factors will go into play as one makes the decision between definitive repair versus damage control. The earlier the decision is made, the more effective the team can rally to get the patient off the table alive (Figs. 2.1, 2.2).

Technique

Damage control uses a multiphasic approach and can be divided into four different stages. Management of each of these stages requires coordination, communication, and leadership. A decision to proceed with damage control has to be taken early on before the occurrence of physiologic exhaustion.

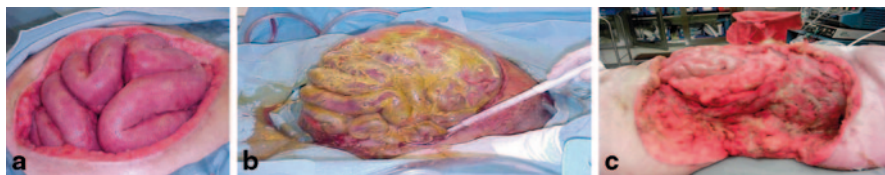


Fig. 2.2 a Abdomen left open secondary to significant bowel edema. b, c Necrotizing soft tissue infection of abdominal wall with resulting peritoneal defect

Stage 0: Prehospital and Preoperative Phase

Prehospital resuscitation with limited crystalloid of the trauma patient in extremis begins until arrival to the trauma bay, where damage control resuscitation with a 1:1:1 ratio of blood component therapy is initiated. Hypothermia has to be prevented with external rewarming measures. Communication with the anesthesia team about the operative plan and the ongoing resuscitation efforts is crucial.

Stage I: Operative Phase

An abbreviated laparotomy, with the primary goals of controlling hemorrhage and then intestinal spillage is performed. To achieve rapid hemostasis, large vessels can be repaired or shunted, small vessels ligated, liver packed, large wound tracts tamponaded with a balloon catheter, injured solid organs such as the spleen and kidney removed. Intestinal spillage should be managed with suture closure of smaller and stapling of larger injuries leaving the gastrointestinal tract in discontinuity. At the end of the procedure, the abdomen should be left open in order to prevent the development of abdominal compartment syndrome (ACS) while enabling easy reentry into the abdomen. Currently, the most widely used temporary abdominal closure techniques are the commercially available Abthera (KCI, San Antonio, TX) and the Barker wound vacuum pack (see Chaps. 1 and 4). Both of them are vacuum-assisted devices that provide the benefit of visceral protection, control of drainage, and preservation of fascia for latter definite closure. As previously mentioned, more antiquated techniques like the Bogotá bag, towel-clip and skin-only closure are generally slower, can provide neither adequate effluent control nor preservation of fascia. In case of severe liver bleeding with multiple packs in the right upper quadrant, the skin-only and towel-clip closure techniques may occasionally provide a desirable tamponade effect.

Stage II: Resuscitative Phase in the Intensive Care Unit

The goal of this phase is restoration of patient's physiologic state. Each individual component of the lethal triad (acidosis, hypothermia, coagulopathy) is corrected.

The resuscitation is completed using established end points. A concerted effort is made to prevent under and over resuscitation; the former being associated with an increased incidence of MODS, the latter with secondary ACS and difficulty achieving primary fascial closure. A vigilant reassessment is performed in the intensive care unit (ICU) to monitor the patient for the early development of secondary ACS which is possible notwithstanding an open abdomen with temporary closure. When recognized, this condition mandates immediate decompression and reexploration at the bedside if necessary. Other indications for early reexploration are worsening acidosis despite adequate resuscitation and continuous bleeding despite normothermia and correction of the coagulopathic state. Otherwise, following normalization of physiology, most patients are returned to the operating room in 48–72 h for reexploration.

Recently, direct peritoneal resuscitation (DPR) was evaluated as a resuscitation strategy in severely injured trauma patients with hemorrhagic shock requiring damage control surgery, and the impact on time to definitive fascial closure was among the end point studied. Twenty patients undergoing standardized wound closure and adjunctive DPR were identified and matched to 40 controls by Injury Severity Score (ISS), age, gender, and mechanism of injury. The DPR technique consists of suffusing the peritoneal cavity with a hypertonic glucose-based peritoneal dialysis solution. Previously, animal studies have shown this treatment to cause microvascular vasodilation and increase visceral and hepatic blood flow; reversal of endothelial cell dysfunction; improve survival and downregulation of the inflammatory response; reversal of established microvascular constriction; normalization of capillary perfusion density; and normalization of systemic water compartments.

Patients receiving adjunctive DPR in this small study were closed in 4.4 ± 1.7 days compared to 7.0 ± 3.4 days in the control patients. The percentage of patients undergoing primary fascial closure was also considerably increased in the group of patients receiving adjunctive peritoneal resuscitation. The odds ratio for primary fascial closure was 10.7:1 for those undergoing DPR ($p=0.01$), as opposed to traditional management [7].

Although further study is needed, the addition of adjunctive DPR to the damage control strategy appears to be a promising adjunct that shortens the interval to definitive fascial closure without affecting overall resuscitation volumes.

Another novel intervention hypothesized to improve early primary fascial closure rates is administration of hypertonic (3%) saline which reduces resuscitation-induced intestinal edema in animals. This was demonstrated in a small study by Harvin and colleagues who used this method in conjunction with normal saline as an adjunct to facilitate early closure [1].

Stage III: Reoperative Phase

Formal exploration is performed in the operating room. As the patient's physiologic state has been restored, standard operating times can now be applied. The goal at

this stage is to identify any missed injuries, definitively repair injured viscera and vascular structures, and possibly restoring intestinal continuity versus exteriorization of bowel segments. Packs are carefully removed and a thorough washout with crystalloid irrigation solution is performed. If possible, primary closure of the fascia is achieved. If the abdomen cannot be closed at this stage because more procedures are needed (e.g., if the bowel is too edematous for anastomotic creation or because of increased tension), then a temporary closure is employed.

A retrospective review from the University of Texas showed that 34 % of DC laparotomies could be closed at the first take back. Their data demonstrated that vacuum-assisted closure at initial laparotomy was an independent predictor of closure at the first reexploration. However, postoperative intra-abdominal pressure (IAP) and postoperative elevated INR were predictive of closure failure at this stage [2].

Stage IV: Definitive Abdominal Closure Phase

A significant number of patients will require multiple return trips to the operating room for regular washouts and repeated attempts to close the fascia primarily in a delayed fashion. Overall, definitive fascial closure is achieved in 85 % of the cases as demonstrated in a prospective observational study by University of Southern California investigators. With the application of biologic mesh, some authors have reported an improvement in this rate. A systematic review by van Hensbroek [3] demonstrated that the sequential closure techniques using the Wittmann Patch (90 %), or the dynamic retention sutures (85 %) have the highest primary closure rate. The wound VAC showed a rate of 60 %, which can be increased to more than 80 % with application of interrupted fascial sutures at the wound apices at each subsequent VAC change. Generally, achieving primary fascial closure beyond 10 days becomes less likely. During this time, maintaining a negative fluid balance may facilitate earlier closure. Closure of the fascia will significantly reduce the rate of enteroatmospheric fistula, which is a feared complication of the open abdomen. Other common complications are intra-abdominal abscess, sepsis, and pneumonia (see Chap. 8). In an abdomen that will not close, a viable option is interval treatment of a planned ventral hernia. For this purpose, the fascial defect can be bridged with mesh (biologic or synthetic) and covered with a split-thickness skin graft after granulation is formed, usually after 5 days.

Summary

Damage control techniques and preventive measures to avoid the development of ACS are now standards of care in the management of traumatic shock [4]. Complications can then be avoided by not attempting to close the fascia under excessive tension and maintaining abdominal domain during the recovery phase. Multiple attempts at fascial closure can then be safely performed either primarily or with the

use of biologic material to bridge the fascial gap during initial hospitalization. It is no longer acceptable to commit the posttrauma open-abdomen patient to a large ventral hernia and delayed reconstruction except for unusual circumstances where a prolonged inflammatory response precludes early fascial approximation. The surgeon needs to be aware of unique challenges presenting in each of the individual stages to assure the desirable outcome.

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