

Claudia E. Goettler, Peter V. Giannoudis,  
and Michael F. Rotondo

---

## 2.1 Historical Management of Injury

Trauma surgery is just general surgery, but faster and under blood. – Anonymous

As the majority of trauma resuscitation and operation was historically performed by general surgeons, the practice of trauma and surgical critical care developed slowly as a general surgical subspecialty by those with special interest in this patient population. Surgical procedures for injury care, therefore, have been based entirely on elective general surgical procedures. Hence, injury to the stomach would receive an operative approach similar to that of a perforated ulcer. This was gradually modified by war experiences. Patients from the war zone generally had massive

destructive wounds, and there was also delay to definitive care. This resulted in the development of novel operative techniques for trauma, such as pyloric exclusion and distal rectal washout, some of which have stood the test of time and some of which have not.

---

## 2.2 Failure of a General Surgical Approach in Trauma

The operation was a success but the patient died anyway. – Anonymous

Since general surgeons have long been trained to identify and repair operatively any diagnosed injury or disease, prolonged operative procedures for definitive repair were the norm. Patients who bleed during elective operative procedures either have control maneuvers instituted prior to the vascular incision as in vascular surgery or rapid pressure or clamp control of inadvertent vascular injury during a case. Additionally, hemorrhage nearly always occurs only moments before control is achieved when the patient is already in an operating suite, draped, and in many cases already open.

This is radically different from the physiologic pattern in trauma patients who are injured minutes to hours prior to arriving in the operating room and hence have been bleeding for an extended period of time prior to instituting surgical control. Additionally, this bleeding results in

---

C.E. Goettler  
Division of Trauma and Surgical Critical Care,  
Department of Surgery, Brody School of Medicine  
East Carolina University, Greenville,  
North Carolina, USA

P.V. Giannoudis  
Department of Trauma and Orthopedic Medicine,  
University of Leeds, Leeds General Infirmary,  
Leeds, UK

M.F. Rotondo (✉)  
Division of Trauma and Acute Care Surgery,  
Department of Surgery, University of Rochester  
School of Medicine and Dentistry, Rochester,  
New York, USA  
e-mail: [mfrsurg1@gmail.com](mailto:mfrsurg1@gmail.com)

difficulty in obtaining rapid surgical control by obscuring the operative field and tissue planes. Similarly, intestinal contamination, ongoing prior to operative control, results in an increased degree of contamination by virtue of both the length of contamination time and the high energy of intestinal content distribution.

Finally, elective general surgeons usually have time and information, such as imaging and history, to allow planning for operative procedures, even if only during the brief initial workup. In contrast, surgeons faced with a trauma patient do not know what disease process they will find on opening, even when guided by a CT scan, resulting in further delay in control while determining injuries. Moreover, these patients are more likely to be unstable and/or unresponsive, resulting in less information and time for operative planning.

Taken in their entirety, these factors – delay in operative presentation, unknown pathology at the start of operation, difficult and delayed control of hemorrhage, and contamination – result in a major difference between general surgical and trauma patients. This is the concept of physiologic exhaustion that is found commonly in traumatized patients and occasionally in emergency general surgical patients. While elective general surgical patients should be fully evaluated and optimized before surgery, and emergency general surgical patients should be briefly “tuned-up” prior to surgery with fluid boluses, blood, and/or antibiotics, many trauma patients cannot wait even minutes for operative intervention due to extreme instability. These patients do not have any physiologic reserve and arrive in the OR in extremis. They may not tolerate the time under anesthesia needed to complete a full operative exploration and repair. Hence, using traditional approaches, these patients died either on the table during the course of their operation or shortly thereafter, due to ongoing nonmechanical bleeding, usually from coagulopathy or from subsequent multisystem organ failure. The underpinning for damage control is that the patient is incapable of undergoing a traditional operative approach due to physiological exhaustion and thus needs an abbreviated initial operation controlling only hemorrhage and contamination to expedite the aggressive resuscitation in the intensive care unit.

## 2.3 The Development of the Abbreviated Laparotomy

He who fights and runs away, may live to fight another day. – JA Aulls, 1876

Gradually, changes in the operative approach toward this group of extremely ill trauma patients began to be discussed and published in the literature. Stone and colleagues were the first to describe aborting a laparotomy by the use of abdominal packing when intraoperative coagulopathy developed [1]. This report was published in 1983. Several subsequent reports of this technique, specifically for hepatic injury, and then a large series showing survival advantage by Burch and colleagues followed [2]. Unfortunately, adoption of this technique was slow and in some cases was deemed a failure to finish operating or an attempt to shift work to another time.

The next iteration of this technique by Rotondo and colleagues resulted in renaming this care pattern “Damage Control” [3]. It should be noted that despite the name, derived from the navy ship damage management, this was a civilian trauma development rather than military. The “Damage Control” sequence was defined. Since then, and with a new name, the technique has become increasingly accepted and has resulted in undoubted decreases in mortality.

## 2.4 Basic Tenants of Damage Control

### 2.4.1 Damage Control Part 0: Rapid Transport to Definitive Care

A crucial part of salvage in the selected extremely unstable trauma patients is the rapid transportation to a center capable of providing definitive care. The most direct method of transportation with the fewest delays in transitional facilities is necessary to maximize survival [4]. During this period, judicious resuscitation should be under

way. The traditional approach of normalizing vital signs in patients with prolonged transport times is inadvisable. Permissive hypotension, resuscitating patients to goal systolic pressure of approximately 90 mmHg with concomitant signs of end-organ perfusion, allows for adequate tissue perfusion while decreasing the potential for clot disruption from increased hydrostatic pressures. For patients who present with injury complexes generally leading to hemodynamic instability or those who exhibit instability, this approach should be extended in the trauma resuscitation area at the trauma center where Damage Control Resuscitation (blood-plasma-platelets), limiting crystalloids and utilizing goal-directed hemostatic resuscitation, is preferred. Damage Control Resuscitation, the details of which are covered in subsequent chapters of this text, complements the Damage Control Surgery Concept, and when utilized together, mortality can be significantly reduced.

#### **2.4.2 Damage Control Part 1: Rapid Control of Hemorrhage and Contamination**

Operative intervention is focused on full exposure and rapid hemorrhage control. For major hepatic injury, packing is optimal, though multiple other more time-consuming methods may be necessary. Major vascular injury that cannot be safely treated by ligation can be considered for vascular shunting. However, ongoing arterial bleeding, whether in a viscera or cavity, will not be controlled by packing alone – surgical control is required. Intestinal contamination should be controlled by whipstitch, intestinal ligation, or stapling. No attempts at formal resection are undertaken, and the intestine is left discontinuous. Details of management of specific organs are found in further chapters. The abdomen is closed by one of many quick temporary methods. The entire operative intervention should take about 1 h and certainly no longer than 90 min. Effective utilization of Damage Control Resuscitation may indeed extend this window of operative intervention.

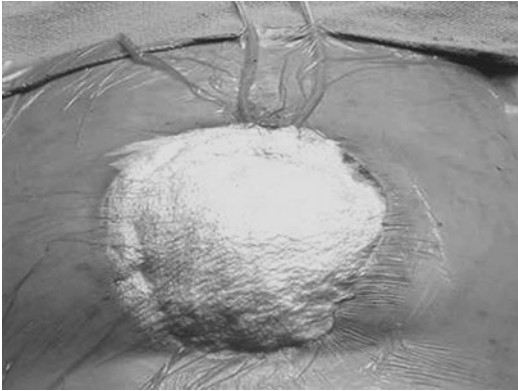
#### **2.4.3 Damage Control Part 2: Resuscitation**

Once out of the operating room, attention is turned to full resuscitation in the intensive care unit. Coagulopathy, anemia, acidosis, electrolyte abnormalities, and hypothermia should be aggressively corrected. Normalization of physiology is an indication to return for definitive operative care and is usually accomplished in 24–36 h. With the advent and effective use of Damage Control Resuscitation techniques, the frequency and degree of physiologic perturbation is decreasing, and the time to normalization is reduced.

However, patients who fail to improve or have subsequent worsening of parameters must be considered as having either ongoing bleeding or a missed injury. These patients are returned to the operating room as an emergency for another look, which should be thought of as a return to Damage Control Part 1, with limited goals of hemorrhage control, identification of injury, and prevention of ongoing contamination. In some patients, several cycles through Damage Control Parts 1 and 2 may be necessary.

#### **2.4.4 Damage Control Part 3: Return for Completion of Operative Repairs**

When fully resuscitated and physiologically normalized, patients will tolerate a second surgical insult and longer operative times. They are then returned to the operating room for unpacking, second look, and definitive management of injuries. During this operation, all injuries should be clearly identified and repaired, including recreation of intestinal continuity. The luxury of the second look as well as potential difficulties with abdominal wall closure has led to an increase in primary anastomosis for colonic injuries, with good results. Feeding access should be considered in all of these patients. About half of this selected population will be able to tolerate primary fascial closure during this operation. The remainder is managed with sequential closure methods, primary allograft closure, or granulation and skin grafting (Figs. 2.1 and 2.2).



**Fig. 2.1** As edema resolves, the defect becomes smaller and may be able to be closed primarily. The vacuum dressing is easily and inexpensively created with plastic sheeting against the bowels, gauze, drains, and an adhesive dressing



**Fig. 2.3** Once the skin graft can be separated from the underlying intestines, the patient can undergo component separation and reconstruction of the abdominal wall



**Fig. 2.2** Abdominal defects that cannot be closed primarily are allowed to granulate, usually via absorbable mesh, and then are skin grafted

hemostatic techniques – visceral edema is more limited and definitive closure rates are now steadily climbing [5].

The remaining patients are treated with a temporizing method, such as vicryl mesh and skin grafting, until they have completely recovered from their metabolic insult. Typically, these patients will be at home for 6–9 months, recovering mobility and optimal nutritional condition during which time the skin graft separates from the underlying intestines. At this time, an elective return to the operating room is undertaken for abdominal closure, with component separation and/or mesh or allograft, as well as stoma reversal if needed (Fig. 2.3). Long-term outcomes in these patients have been shown to be quite good.

#### 2.4.5 Damage Control Part 4: Definitive Abdominal Closure

A section of patients managed with Damage Control cannot be safely closed at the completion of Damage Control Part 3, either due to high intra-abdominal pressures or contamination requiring repeated washouts. Some can be closed subsequently during their hospital course. Historically 50–60 % of Damage Control patients were discharged with definitive abdominal closure but with the application of Damage Control Resuscitation and concomitant goal-directed

### 2.5 Indications for Damage Control

#### 2.5.1 Early Decision Making

In order for patients to benefit from a Damage Control sequence, the decision to abort operative intervention must be made early. It should be considered even prior to the arrival of the patient if there is hypotension in transport or in the trauma resuscitation area. While hypotension may well resolve with resuscitation, it is an early indicator that the patient is not prepared to tolerate a pro-

longed operation. Elevated lactate and base deficit are also early warning signs of physiologic derangement. While neither alone is an indicator for abbreviated laparotomy, they should induce the thought process. Absolute indicators will be discussed below; however, it cannot be stressed enough that a Damage Control operation should take only 60–90 min, and hence the decision to abort should be made early in the operation. Waiting to abort until the patient has reached physiologic exhaustion makes salvage extremely unlikely and results in almost certain death.

### 2.5.2 Triad of Death

There is extensive evidence that coagulopathy, acidosis, and hypothermia all interact to worsen each other in a vicious spiral that eventually results in ongoing hemorrhage and death. Early recognition of any of these findings is an indicator for Damage Control Resuscitation as well as a Damage Control abbreviated laparotomy. While many studies indicate varying absolute numbers, temperature less than 34, pH less than 7.2 (or base excess greater than 8 in a patient with a corrected pH due to hyperventilation), and/or laboratory or clinical evidence of coagulopathy should result in initiation of the Damage Control Approach [6]. Continued interaction with the anesthesia team is necessary to maintain awareness of these factors while operating. There is growing evidence of improved outcomes with layering damage resuscitation into damage control laparotomy. Clearly as our understanding of resuscitation has evolved over the last 15 years and refinement of Damage Control Surgery has ensued, survival rates continue to improve [7, 8].

### 2.5.3 Associated Injuries

Other injuries may contribute to the decision to interrupt laparotomy. Patients with multiple intra-abdominal injuries should be considered for abbreviated laparotomy at each stage of repair, as the time necessary for complete repair becomes rapidly prohibitive. This is seen in patients with

multiple widely spaced intestinal injuries or combined vascular and intestinal injuries. Other sources of blood loss also contribute, though they are of lesser immediate concern, such as extremity fractures and lacerations; but they cause concern as the loss of blood from these is often underestimated when hidden either by the skin or the drapes. Similarly orthopedic injuries can and should be temporized in these patients [9].

Multi-compartment injuries also call for Damage Control, such as management of hemorrhage of the abdomen and the chest. Clearly, full management of abdominal injuries and closure would compromise a patient who also requires thoracic exploration. Hence, rapid termination and temporization within one compartment followed rapid control and temporization within another compartment cuts the total operative time, blood loss, and heat and evaporative losses. This will rarely result in patients with Damage Control dressings on both abdominal and thoracic incisions or on combined abdominal and sternotomy incisions (Fig. 2.4).

Any other potentially life-threatening extra-abdominal injury that requires timely intervention is an indicator to stop operating after hemorrhage and contamination control and provide a temporary closure. This allows for more rapid evaluation of these associated injuries such as severe intracranial injury or aortic transection, as well as early and aggressive correction of coagulopathy, which could contribute to mortality in these injuries. This is also the most efficient way to get patients with liver or pelvic injuries to angiogram if indicated.



**Fig. 2.4** Damage control of combined sternotomy and laparotomy. Note massive abdominal distention



Lastly, the variability of the physiologic reserve should be assessed for the patient. Older patients and/or those with comorbidities are likely to be intolerant of long operative times and should have frequent reassessment of the need for abortion of the procedure.

### 2.5.4 Predicted or Present Abdominal Compartment Syndrome

While abdominal compartment syndrome was a pervasive problem 20 years ago, it is encountered far less frequently now with the use of Damage Control Resuscitation. Nonetheless, prediction of patients who are likely to develop abdominal compartment syndrome, and therefore selectively leaving these patients open with a temporary abdominal closure rather than closing fascia still remains an important adjunct to Damage Control Surgery. This is done even in patients with definitive completion of their operation to prevent the cascade of physiologic injury occurring with abdominal compartment syndrome. Patients at risk for developing massive visceral edema are those who have received more than 10–15 units of blood products and/or more than 5 L of crystalloid [10]. Additionally, any patient with increasing peak ventilatory pressures of more than 10 points at fascial approximation is at extremely high risk.

### 2.5.5 Planned Reoperation

Finally, temporary abdominal closure can be done in any patient who requires further evaluation prior to completion of repair of injuries, such as planned second look or serial washouts or debridement.

## 2.6 Expansion of Damage Control Principles

With the success of the Damage Control sequence in visceral trauma and its general adoption by the trauma community, it is increasingly utilized in other traumatic injuries [11, 12]. Vascular and

now orthopedic injuries are treated by Damage Control techniques, which is the focus of this text. The utilization of this technique can be expected to improve the limb salvage, though data from large studies are not yet available. Additionally, the concept of damage control and the lethal triad has also spilled over into general surgery and is likely resulting in improved outcomes in this population as well.

## 2.7 Summary and Conclusion

The evolution of the abbreviated laparotomy or “Damage Control” for trauma has improved patient survival by decreasing the operative stress on patients in physiologic exhaustion. This technique requires rapid control of bleeding and contamination, temporary abdominal closure, and then intensive care resuscitation of physiology with return to the operating room for eventual definitive operative repair. This sequence should be utilized in patients with coagulopathy, acidosis, and hypothermia. While mortality in a subset of critically ill trauma patients has decreased with this modality, these patients have a very high incidence of morbidity and frequently require prolonged hospitalization and multiple operative procedures. The addition of Damage Control Resuscitation has not only decreased mortality further but also reduced morbidity. The success of Damage Control in management of abdominal pathology has led to the expansion of the concept into orthopedic and vascular trauma and into all aspects of surgical care.

## References

1. Stone HH, Strom PR, Mullins RJ. Management of the major coagulopathy with onset during laparotomy. *Ann Surg.* 1983;197:532–5.
2. Burch JM, Ortiz VB, Richardson RJ, Martin RR, Mattox KL, Jordan GL. Abbreviated laparotomy and planned reoperation for critically injured patients. *Ann Surg.* 1992;215:476–84.
3. Rotondo MF, Schwab CW, McGonigal MD, Phillips III GR, Fruchterman TM, Kauder DR, Latenser BA, Angood PA. “Damage control”: an approach for improved survival in exsanguinating penetrating abdominal injury. *J Trauma.* 1993;3:375–82.

4. Sagraves SG, Rotondo MF, Toschlog EA, Schenarts PJ, Bard MR, Goettler CE. Brief interval transfer (BIT): the morbid consequence of delay to the trauma center in a rural patient demographic (abstract). *J Trauma*. 2002;53(6):1209.
5. Loftus T, Jordan JR, Croft CA, Smith RS, Efron PA, Mohr AM, Moore FA, Brakenridge SC. Temporary abdominal closure for trauma and intra-abdominal sepsis: different patients, different outcomes Published ahead of print October 2016. [http://journals.lww.com/jtrauma/Abstract/publishahead/Temporary\\_abdominal\\_closure\\_for\\_trauma\\_and.99337.aspx](http://journals.lww.com/jtrauma/Abstract/publishahead/Temporary_abdominal_closure_for_trauma_and.99337.aspx).
6. Morris JA, Eddy VA, Blairman TA, Rutheford EJ, Sharp EW. The staged celiotomy for trauma: issues in unpacking and reconstruction. *Ann Surg*. 1993;217:576–86.
7. Duchesne JC, Kimonis K, Marr AB, et al. Damage control resuscitation in combination with damage control laparotomy: a survival advantage. *J Trauma*. 2010;69:46–52.
8. Joseph B, Azim, A, Zangbar B, Bauman ZM, O’Keeffe T, Ibraheem K, Kulvatunyou N, Tang A Latifi, R, Rhee P Improving mortality in trauma laparotomy through the evolution of damage control resuscitation: analysis of 1,030 consecutive trauma laparotomies. Published ahead of print October 2016 [http://journals.lww.com/jtrauma/Abstract/publishahead/Improving\\_mortality\\_in\\_trauma\\_laparotomy\\_through.99319.aspx](http://journals.lww.com/jtrauma/Abstract/publishahead/Improving_mortality_in_trauma_laparotomy_through.99319.aspx).
9. Cué JI, Cryer HG, Miller FB, Richardson JD, Polk Jr HC. Packing and planned reexploration for hepatic and retroperitoneal hemorrhage: critical refinements of a useful technique. *J Trauma*. 1990;30:1007–13.
10. Pape HC, Giannoudis P, Krettek C. The timing of fracture treatment in polytrauma patients: relevance of damage control orthopedic surgery. *Am J Surg*. 2002;183:622–9.
11. Reilly PM, Rotondo MF, Carpenter JP, Sherr SA, Schwab CW. Temporary vascular continuity during damage control: intraluminal shunting of proximal superior mesenteric artery injury. *J Trauma*. 1995;39(4):757–60.
12. Rasmussen TE, Clouse WD, Jenkins DH, et al. The use of temporary vascular shunts as a damage control adjunct in the management of wartime vascular injury. *J Trauma*. 2006;61:8–12.

Damage Control Management in the Polytrauma Patient

Pape, H.-C.; Peitzman, A.B.; Rotondo, M.F.; Giannoudis, P.V. (Eds.)

2017, XI, 338 p. 95 illus., 58 illus. in color., Hardcover

ISBN: 978-3-319-52427-6