# Surgical education in trauma: Physiology, damage control and the DSTC™ course

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Clinical Education & Medical Simulation

*Clin Edu Med Sim*. 2018;1(1):5–10

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**Funding sources**
None declared

**Conflict of interest**
None declared

Received on June 22, 2018
Reviewed on July 23, 2018
Accepted on July 26, 2018

## Abstract

Severe trauma will produce both anatomical organ injury and a severe systemic illness with high mortality, requiring a unique surgical strategy. Attention to physiology, excellent situational awareness, proper surgical technique in different anatomical regions, and a distinct mindset are crucial. Damage Control Surgery (DCS) consists of performing an initial abbreviated operation to halt the bleeding followed by the correction of metabolic derangements. Definitive organ repair will only be performed after the restoration of physiology. Surgical training needs to incorporate these concepts, which are quite distinct from the elective practice. Postgraduate courses, such as the Definitive Surgical Trauma Care (DSTC™) course, aim to provide trainees with both technical and decision-making skills for trauma surgery, particularly in a damage control setting. In these courses, training can occur in a multidisciplinary environment and non-technical skills, such as leadership, communication and situational awareness, are paramount. Educational principles such as debriefing could increase the didactic experience of DSTC™ course participants, particularly after the surgical skills session.

**Key words:** medical education, trauma surgery, Definitive Surgical Trauma Care, Damage Control Surgery

**DOI**
10.17219/cems/93774

## Introduction

Unlike the elective setting, where the emphasis is on anatomy and pathology, trauma surgery mostly focuses on physiology and anatomy. This is because acutely injured patients often die despite complete anatomical repair of injuries, unless proper attention is given to the disturbed physiology.[1–3] Thus, a distinct surgical strategy is warranted. Damage Control Surgery (DCS) is the concept of performing an initial resuscitative operation with the aim of stopping bleeding and controlling contamination, followed by the correction of metabolic derangements in an intensive care setting. Only after full restoration of physiology will definitive organ repair procedures be performed. These procedures will often take place in distinct anatomical regions such as the chest, the abdomen or the pelvis, necessitating ample exposure and a flexible operative strategy. This calls for a rethinking of surgical curricula and sets the stage for the need for specific training.

In this paper, we will briefly review the pathophysiologic implications of traumatic hemorrhage and analyzed the concept of DCS. We will discuss the need for adequate training in both surgical technical skills and strategic thinking in trauma care, and digress one of the current teaching modalities, namely, the Definitive Surgical Trauma Care (DSTC™) course, organized under the auspices of the International Association for Trauma and Surgical Intensive Care (IATSIC). Finally, we will explore the potential impact of the incorporation of more advanced educational principles into this course.

## Physiologic derangements in hemorrhagic shock: What the surgeon should know

Uncontrolled or unrecognized bleeding is the main avoidable cause of death after trauma, with hemorrhagic shock causing a severe metabolic disturbance.[4,5] Because of poor peripheral perfusion, oxygen does not reach the cells and humans, like any eukaryotic multicellular animal dependent upon mitochondrial oxidative phosphorylation, will be unable to produce enough adenosine triphosphate to support cell functions. This will lead to anaerobic glycolysis, producing lactic acid and causing metabolic acidosis. Cellular energetic dysfunction will cause organ failure and cell death, either by necrosis or apoptosis, will ensue. Trauma-induced coagulopathy, a frequent event, is associated with worse prognosis. It is linked to the shock-induced injury to the vascular endothelium, can be worsened by fluid resuscitation and will likely compound the management of patients with active bleeding.[6,7] Current resuscitation protocols of massive transfusion aim to prevent its development.[8]

This state of acidosis and coagulopathy is aggravated by the onset of hypothermia, due to heat loss during resuscitation and decreased cellular metabolism. In fact, the association of acidosis, hypothermia and coagulopathy is known as the "lethal triad of trauma", and is associated with up to 89% mortality.[9]

Even if the initial severe shock state is recognized and corrected, the intense catecholamine response will cause a state of persistent splanchnic hypoperfusion.[10,11] This is believed to be the motor of late post-traumatic multiple organ failure, as the ischemic gut will suffer mucosal barrier failure, immune cell activation and bacterial translocation. Remarkably, both the translocation of bacteria and the circulation of exosomes occur not through the portal vein but through the mesenteric lymph vessels, initiating and amplifying this deleterious response, and causing a syndrome of persistent inflammation and immunomodulation.[12–16] Moreover, direct tissue injury by trauma, or indirect injury by ischemia-reperfusion injury, will cause the release of intracellular damage-associated molecular patterns, such as mitochondrial components. Being descendent from α-proteobacteria, mitochondrial proteins and nucleic acids are highly immunogenic and are largely responsible for the immune activation seen in severe trauma, contributing to the state of persistent sterile inflammation.[17]

Strategies aiming at early and effective control of bleeding will prevent these effects and decrease mortality, not only early mortality in the so-called "golden hour", but also late deaths due to post-traumatic multiple organ failure.[18] One of the strategies aiming at decreasing bleeding is the use of hypotensive resuscitation, consisting of the judicious use of fluids before the operative control of bleeding.[19]

Since traumatic injury is a systemic critical disease and not just the sequela of anatomical organ damage, any surgical strategy should adopt these principles, particularly because surgery itself can serve as second hit to an already severely compromised host.

## Damage Control Surgery

Attempts at definitive treatment of organ injuries in the index operation in a physiologically compromised patient will likely result in the development of the "lethal triad" of acidosis, hypothermia and coagulopathy. Often this happens in spite of satisfactory anatomical repair of vascular injuries.[1] So, instead of trying to perform complete anatomical repair of all injuries, a strategy based on physiology is warranted.

Damage Control Surgery is the concept of performing an initial resuscitative operation with the aim of halting the bleeding, avoiding ischemia and controlling contamination in severely injured patients.[2,9] This is followed by temporary abdominal closure and restoration of physiologic derangements in the intensive care unit. After this,

definitive surgical repair of injuries in an organ-oriented approach is performed in the second-look procedure, usually after 48 h.

Although perihepatic packing has been described more than a century ago, this approach has been revived in the 1990s by Rotondo et al.[9] It was named DCS, after the United States Navy's concept of the procedures needed for a warship to remain afloat after suffering severe structural damage.

Technical skills used in DCS are not necessarily complex procedures. In fact, simple maneuvers such as packing, balloon tamponade, intra-arterial shunts, and pulmonary tractotomy can be adopted with success. The emphasis is to perform only life-saving procedures in the first operation, thus shortening the physiologic insult associated with lengthy procedures. More complex techniques may also be required, especially accessing the retroperitoneal major vessels, the liver or the intrathoracic organs. However, as surgery is a trauma in itself and can serve as a second hit to an already severely ill patient, again the main principle is to act both swiftly and effectively, minimizing the operative insult.

The decision to perform DCS depends upon: the anatomical extent of injuries; the disturbance of physiology and response to resuscitative efforts; and the available resources. Accepted physiologic triggers to decide for DCS include: hypothermia (core temperature under 35°C), significant acidosis (pH less than 7.2, base deficit greater than 15 mmol/L) and/or coagulopathy.[20] However, it is more important to decide for DCS before these metabolic derangements occur, rather than wait for them to install and then decide for DCS. It also must be emphasized that not all patients with abdominal trauma require DCS; conversely, some patients initially presenting in critical condition will improve with adequate resuscitation and might be treated with definitive one-stage surgery.

In abdominal DCS, the first operation ends with temporary abdominal closure. This is usually a laparostomy or open abdomen, thus preserving the fascia for later closure and preventing the abdominal compartment syndrome. Some very important advances in the techniques and technology available for temporary abdominal closure have decreased the complications associated with laparostomies, making this technique safe in severely injured patients.[21]

After correction of acidosis, hypothermia and coagulopathy, and after ensuring full diagnosis and staging of all traumatic injuries in the intensive care unit, the 2$^{nd}$ stage is performed. The aim will be to fully repair damaged organs, complete vascular or bowel anastomosis, resect unrepairable tissue, and, if possible, close the abdomen. Some patients may require further reconstructive surgery of planned ventral abdominal hernia.[22]

Although no randomized controlled trials have evaluated the superiority of DCS, enough retrospective evidence has shown its validity, when properly applied.[23] Interestingly, a therapy stemming from DCS, Direct Peritoneal Resuscitation, consisting of the use of continuous intra-abdominal perfusion of peritoneal dialysis fluid and aiming at improving visceral perfusion, has demonstrated reduced time to definitive abdominal closure, decreased complications and improved survival in a randomized controlled trial of severe trauma patients undergoing DCS laparotomy.[24]

Trauma surgery has fully adopted DCS and nowadays this strategy is also applicable in non-trauma cases and in trauma outside the chest or the abdomen.[25–27]

## Training in trauma and emergency surgery

Classical surgical curricula are usually centered on the treatment of a diseased organ. Focus is placed on the organ, both on the pathological and anatomical staging of the disease, while obviously keeping in mind the patient context. Surgical strategy aims to treat the pathology and restore the anatomy of diseased organs. Decision options are usually limited and are on occasion already predefined in a multidisciplinary meeting, particularly in oncological cases. Furthermore, most surgical curricula are based on the apprenticeship model, whereby the trainee will be exposed to cases of increasing complexity. Repetition is the key educational tool, as the trainee will perform the same procedures with increasing autonomy before moving on to more complex cases. Moreover, with the increasing subspecialization of visceral surgery and development of minimally invasive approaches, many surgical trainees and young surgeons have reduced exposure to open abdominal and thoracic surgery. Finally, work-hour restrictions, loss of appeal of emergency surgery when compared to other more attractive elective surgical subspecialties, as well as litigation issues, have all diminished the interest of surgical trainees in trauma surgery.

Trauma requires a distinctive surgical thought process. Bleeding patients will present with a severe metabolic disturbance and time is scarce as the patient's physiology will become rapidly depleted. Damage control aims to treat life-threatening injuries, placing emphasis on the diseased cells, not only on the injured organ. Furthermore, full anatomical extent of injuries is sometimes impossible to obtain in a reasonable time frame as a delay in obtaining imaging can be deleterious in actively bleeding patients.

Surgical decisions should take this into account and a surgical strategy based on flexibility and attention to physiology is needed. While external and extremity bleeding can be easily controlled, most uncontrollable bleeding occurs inside the chest, the peritoneal cavity or the retroperitoneum, which is why adequate technical skills in exposing injured organs are paramount. Although subspecialisation is inevitable in surgical disciplines, sometimes there is not enough time to obtain consultation in cardiothoracic or vascular surgery, and the general surgeon should be able

to perform life-saving procedures from the neck to the pelvis in a damage-control frame of mind.

Current trauma surgical training programs should incorporate these concepts. Relevant progress has been made recently with the establishment of the Board Certification in Emergency Surgery of the European Union of Medical Specialists. Candidates to this association must be proficient at decision-making and technical skills in surgical emergencies, including cervical, thoracic and abdominal major trauma. However, surgical training during and after the completion of residency programs might not suffice and can be furthered with postgraduate courses. This has been the case with the Advanced Trauma Life Support (ATLS™) Course which began 40 years ago in the USA and since then has successfully trained more than 1 million doctors in more than 60 countries around the world.[18] Since then several other courses have emerged, notably the European Trauma Course (ETC™), which aims to improve trauma team leaders' technical and non-technical skills in management of a severe trauma patient in a multidisciplinary setting.[28] Overall, these courses are designed to improve the management of trauma patients in the emergency room. However, all teaching scenarios end after the transfer of the patient to the operating room. Inasmuch as trauma care is a continuous chain of events, further training in the operative management is not only welcome but also highly needed.

## The Definitive Surgical Trauma Care (DSTC™) course

Established in 1993, the Definitive Surgical Trauma Care (DSTC™) Course aims to improve surgeons' ability in dealing with major trauma in the operating room, with relation to technical skills and decision-making.[3] Organized under the auspices of IATSIC, the course usually lasts 2 or 2 1/2 days and comprises lectures, clinical case discussions and surgical skill laboratory sessions. Live anesthetized animals and/or human cadavers are used for teaching surgical techniques, particularly in the liver and other intra-abdominal organs, the retroperitoneum, the intraabdominal major vessels, and the intrathoracic organs. Overall, over 6,000 surgeons in more than 29 countries have completed the course. Although the impact of the course on the survival of trauma patients has not been assessed yet, the benefit to trainees is likely very high.[29] Other courses, such as the Advanced Operative Trauma Management (ATOM™) and the Advanced Surgical Skills for Exposure in Trauma (ASSET™), have since emerged for postgraduate training in trauma surgery, particularly in North America.[30,31]

Acknowledging that the spectrum of trauma care is highly heterogeneous around the world, the DSTC™ course is flexible enough to meet the participants' training needs. As such, several add-on modules can be used, such as trauma in military and austere environments, and treatment of craniofacial injuries. Also, recent developments like the Resuscitative Endovascular Balloon Occlusion of the Aorta (REBOA), an increasingly used option for patients with exsanguinating abdomino-pelvic trauma, might be easily incorporated into the course program, particularly using non-live tissue haptic simulators.[32]

Inasmuch as trauma management requires both technical skills and surgical decision-making, the DSTC™ program places great emphasis on the discussion of cases, as well as on the training of surgical maneuvers in a live animal model. Damage control techniques and the decision-making process are highlighted during the course. However, although being a major step in preparing surgeons to deal with major trauma, the DSTC™ course still has room for improvement. Knowing that the operative approach to the trauma patient relies heavily on the anesthetic management, the Definitive Anesthetic Trauma Care (DATC™) course was developed for anesthesiologists or anesthesiology residents at advanced levels of training. Our group had the privilege to organize the first DATC™ in the world in Coimbra, Portugal in 2009. The authors regard it as a major contribution to the care of injured patients. Since then, several DATC™ courses have been organized around the world and recently our group collaborated in the first combined DSTC-DATC course in Brazil. The inclusion of operating room nurses in the course is also a welcome addition in the form of the Definitive Perioperative Nurse Trauma Course (DPNTC™), originally organized in Australia and New Zealand, and being run in Portugal since 2005.

All 3 courses (DSTC™, DATC™ and DPNTC™) can be organized simultaneously, achieving high standards, especially in the surgical skills sessions in the live animal model, where the operating room environment is simulated. Not only can repair of anatomical injuries be properly taught in a controlled environment, but the participants can also witness the physiologic consequences of surgical maneuvers, such as total hepatic vascular exclusion or descending aorta clamping, thus improving the trainees' learning experience. Multidisciplinary communication and collaboration between surgeons, anesthesiologists and nurses, indispensable in a real-life severe trauma setting, is also practiced in the joint surgical skills session. Interestingly, the Royal College of Anesthetists recommended in their 2016 guidelines that consultants in trauma resuscitation and anesthesia should undergo periodic training with their fellow surgical consultants.[33]

Nonetheless, in order to improve the didactic value of courses such as the DSTC™, we firmly believe in the inclusion of modern educational principles. For instance, the focus on non-technical skills such as leadership, situational awareness, communication, and task management, increasingly recognized as key factors in the prevention of adverse events, could be easily included in the DSTC™ curriculum, much like as it has happened with the ETC™.[34]

In the latter course, trauma management is thought of as a team process and training already takes place in a multidisciplinary setting. The candidates are motivated to improve in communication and leadership skills, so important in critical care settings. The educational style used in the ETC™ (and other clinical leadership courses) could be easily applied to the DSTC™ setting. One such example is the proper training of closed-loop communication, whereby the surgeon and the anesthesiologist should have a clear, bidirectional exchange of relevant information regarding the patient's injuries and physiology, as well as operative and resuscitation plans. This is a highly relevant issue, as the decision to perform DCS will depend on adequate communication between the surgeon and the anesthesiologist regarding the physiologic status of the patient and the extent of organ injuries. Moreover, many surgical techniques, such as liver packing or vascular clamping, may cause significant hemodynamic consequences and require excellent coordination between both anesthetic and surgical teams. All these issues are even more pressing because, as it is often the case in emergency surgery, surgeons may find themselves working in an action team with other team members they infrequently collaborate with. Although learning non-technical skills is effective in trauma team training simulation, as it increases team performance and can translate into the clinical arena, its effectiveness in surgical scenarios is yet to be proven.[35,36]

Educational techniques such as debriefing could be used to good effect, particularly in the surgical skills session. Immersion in a live model simulation of surgical bleeding can be intense and proper debriefing will very likely improve the trainees' learning experience. This can occur as micro-debriefings during the session, in order to highlight the most important learning point at that stage, especially for more technical tasks. In fact, since debriefing is one of the most important components of simulation-based learning, there is likely a place for a formal debriefing at the end of the surgical skills session, thus enhancing the learning experience of the participants.[37] Corrections at this stage might have a durable effect on the trainees and reinforce the acquisition of new skills. Possibly the greatest impact will be on the acquisition of non-technical skills, such as decision-making, situational awareness and communication. Further research on this subject is needed.

## Conclusions

Being a surgical disease, trauma is quite particular in both the operative techniques and the decision-making process it requires. Excellence at elective surgery does by no means guarantee proficiency in trauma surgery. Detailed attention to physiology, excellent situational awareness, proper surgical technique, and a distinct mindset are paramount. Due to several factors, surgeons in training are less frequently exposed to open major surgery and require deeper formal training in trauma surgery. Surgical training programs should acknowledge the role of courses aiming at the enhancement of both technical and non-technical skills in trauma surgery.

In our opinion, courses such as the DSTC™ have an enormous potential to contribute to achieve these goals and can be recommended to all health professionals involved in the operative management of major trauma. Although unproven in this particular setting, the incorporation of modern educational principles such as debriefing could provide an enhanced learning experience. Furthermore, the DSTC™-DATC™-DPNTC™ courses provide an excellent opportunity for the intraoperative training of trauma teams dealing with the most severely injured patients.

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