Damage Control in Abdominal Surgery

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Abstract

Damage Control Surgery (DCS) is established as a life-saving procedure in severely injured patients. In addition to the trauma, hemorrhage and tissue hypoperfusion, a secondary systemic injury, by inflammatory mediator release, contributes to acidosis, coagulopathy, and hypothermia and leads to multi system organ failure. It is necessary to identify patients unable to tolerate a traditional approach due to the present or impending state of shock. Use of an abbreviated laparotomy is focused only on control of bleeding and contamination to limit surgical insult and allow for aggressive resuscitation in an Intensive Care Unit (ICU) to regain physiological reserves. Only after correction of acidosis, hypothermia and shock are definitive repairs attempted. Closure of the abdominal wound has developed thanks to a better understanding of the importance of Intraabdominal Hypertension (IAH) and Abdominal Compartment Syndrome (ACS). A good knowledge of DCS has led to a significant increase in survival of severely injured patients. The authors provide an overview of the DCS approach, as well as the indications for DCS and DCS sequence, followed by a discussion of DCS-associated complications.

Keywords: Severely injured patients; Abdominal trauma; Damage control surgery; Laparotomy

Introduction

Damage control surgery (DCS) has been established as a life-saving procedure to control hemorrhage, prevent contamination and protect from further injury in severely traumatized patients [1-7]. The term “damage control” reportedly originated from the United States Navy and it represents “the capacity of a ship to absorb damage and maintain mission integrity” [1]. In surgery, “damage control” refers to those maneuvers designed to ensure patient survival. Although first described formally in the civilian trauma population, DCS has been used in the military to facilitate prompt surgical control of bleeding and contamination and early evacuation of injured soldiers, with resultant improvement in survival rates [1-5]. The concept of abbreviated surgery aimed primarily at arresting bleeding was first introduced by Pringle in 1908 [8]. Halsted and Schroeder individually reported their success at arresting bleeding following liver trauma by packing the liver. In 1913 Halsted [9] described modifications and refinements to the then well established practice of packing. While some discussions of using an abbreviated laparotomy can be found during the American Civil War and World Wars, after that period it was generally dismissed as poor surgical care. Stone et al. [10] demonstrated improved survival in 1983 with abdominal packing for the exsanguinating hypothermic and coagulopathic trauma patient. Once hemodynamic stability was restored and the coagulopathy corrected, definitive surgical repairs were completed later. This strategy resulted in the survival of 11/17 patients felt to have a lethal coagulopathy. The application of these techniques to trauma patients continued to evolve over the next several years [5]. Damage control surgery was popularized again in the late 1980’s as a method of salvaging critically ill patients with physiologic compromise due to massive hemorrhage [2,3]. In 1993, Rotondo and Schwab [3] coined the term ‘damage control surgery’, demonstrating the survival benefit with it, and showing a improvement in mortality (11% to 77%) in patients with combined visceral and major vascular injury using the three phase approach.

The principles and sequence of damage control include an abbreviated laparotomy for control of massive bleeding and contamination, secondary correction of abnormal physiological parameters in an intensive care setting, followed by a planned definitive reexploration for correction of anatomical derangements.

A review by Shapiro et al. [1] of over 1000 damage control patients showed an overall 50% survival. The improvement in survival for severe trauma patients comes with under-standing the fundamental differences of physiology and anatomy between elective surgery patients and emergency
Indications for Damage Control Surgery

Table 1: Indications for Damage Control Surgery.

<table>
<thead>
<tr>
<th>Physiological Factors</th>
<th>Characterization of Injury severity</th>
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<tr>
<td>1. Hypotension&lt; 90 mmHg systolic pressure</td>
<td>1. Inability to establish hemostasis</td>
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<td>2. Hypothermia (temperature &lt; 35°C)</td>
<td>2. High energy blunt abdominal/chest trauma</td>
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<tr>
<td>3. Acidosis (pH&lt; 7.2 or base deficit &gt; 8)</td>
<td>3. Multiple penetrating abdominal/chest injuries</td>
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<td>4. Coagulopathy (increase in PT and/or PTT, thrombocytopenia, hypofibrinoginemia)</td>
<td>4. Combined visceral injury with major vascular trauma</td>
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<td>5. Prohibitive operative time needed for definitive repair (&gt;90 minutes)</td>
<td>5. Major intra-abdominal vascular injury</td>
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<td>7. Massive abdominal contamination</td>
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<td></td>
<td>8. Life-threatening extra-abdominal injuries</td>
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<td></td>
<td>9. Abdominal wall reconstruction failure (IAH, ACS)</td>
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PT: Prothrombin; PTT: Partial Thromboplastin Time; pRBC: Packed Red Blood Cells; IAH: Intraabdominal Hypertension; ACS: Abdominal Compartment Syndrome

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Indications for Damage Control Surgery

One of the most challenging aspects of DC strategy remains identifying which patients should be “damage controlled.” The lethal nature of exsanguinations and profound shock causing the “lethal triad” of hypothermia/acidosis/coagulopathy has been well described, but it is clinically difficult to recognize in the dynamics of patient arrival, resuscitation and diagnosis. Perhaps the most critical factor is that an early decision needs to be made in these first few minutes. The patient’s physiology should be the primary determinant in the need for damage control surgery and open abdomen techniques (Table 1).

Hypothermia begins at the time of insult, due to shock, prolonged exposure and injury severity [14]. Several studies have acknowledged the significant relationship between hypothermia and death [1,12]. Hypothermic patients are predisposed to arrhythmia, have reduced cardiac output, increased systemic vascular resistance, and a left shift in their oxygen hemoglobin saturation curves. Temperatures below 35°C cause platelet dysfunction as well as a dysfunction of the intrinsic and extrinsic clotting cascades.

The lethal nature is well known of persistent metabolic acidosis due to hypoperfusion of tissue in the traumatized patient. Placement of a pulmonary artery catheter and an arterial line are essential to help guide therapy. Traditional endpoints of resuscitation must be tracked: urine output, lactate clearance, and measuring mixed venous oxygen saturation. Aggressive measures include control of hemorrhage, stabilizing systolic blood pressure, elevation of temperature, optimization of oxygen delivery via aggressive resuscitation with blood products and the use of inotrops when needed.

The clinically observed coagulopathy in severe injury patients is not always confirmed by lab tests, suggesting that mechanisms other than concentration of clotting factors or number of platelets are involved. The coagulopathic state of the exsanguinating trauma patient is dilutional in nature, but both the coagulation cascades, as well as the platelets are affected with platelet dysfunction. The fibrinolytic system is also activated following massive tissue damage, shock, and hypothermia. As part of its multifactorial nature, the essence of this phenomenon are hypothermia as well as acidosis. The injured patients may have prolongation of the PT, elevation of Ddimer levels, and reduction of both fibrinogen and antithrombin III levels. Early aggressive resuscitation with blood products is necessary to correct the coagulopathy and prevent further physiological deterioration, using packed red blood cells, plasma and platelets.

Complex blunt injury patterns, multiple penetrating injuries, injuries across multiple compartments, or combined vascular and visceral injuries, also lend themselves to damage control approach (Table 1). Additionally, open abdomen techniques with damage control surgery, lend themselves to improved effluent control, while providing ease of peritoneal cavity accessibility in those trauma patients with a septic abdomen, and reducing the potential for ACS [15,16].

We should always keep in mind that there are significant variations in physiological reserves across the patient populations. The elderly with multiple comorbidities tend to have less tolerance for surgical procedures due to poor preexisting reserves. Young patients may hide progression to physiological exhaustion until hemodynamic collapse.

Damage Control Sequence

In the beginning, damage control surgery was described by the three main steps: abbreviated laparotomy, ICU resuscitation, and planned re-operation with definitive repair. Addition of a prehospital initial evaluation stage (Ground Zero) and separation of definitive abdominal wall closure occurred as their importance became
more evident. During the initial evaluation period the exact end-point of resuscitation is debated. Rapid control of the airway and placement of large IV access devices and immediate resuscitation with RBC’s and plasma are the therapeutic procedures. Traditionally, crystalloids have been given to restore normal vital parameters, but permissive hypotension, resuscitating patients to goal systolic pressure of approximately 90 mmHg with concomitant signs of end organ perfusion, is gaining favor, especially in patients with long transport times to definitive care [17-20]. Prompt transport to the hospital is essential. Upon arrival, a team effort occurs where the best method is to perform horizontal resuscitation (as opposed to vertical resuscitation performed with limited personnel) according to the recommendations made by the Advanced Trauma Life Support (ATLS) program supported by the American College of Surgeons. Damage control resuscitation continues until surgical control of the bleeding can be performed. Furthermore, the use of blood product allows volume expansion with oxygen carrying capacity and reversal of coagulopathy.

The aggressive transfusion policy of Red Blood Cells (RBC), Fresh Frozen Plasma (FFP), and platelets, applied in a proportion of 1:1:1 (pRBC: FFP: platelets), can be combined with permissive hypotension [21,22].

**Stage I**

**Initial laparotomy and temporary**

**Abdominal closures:** The initial laparotomy focuses on control of hemorrhage and visceral contamination before the depletion of the patient’s physiological reserves and initiation of the acquired coagulopathy that develops. A different technique exists for emergency control bleeding sources, to allow restoration during the ICU resuscitation stage before definitive repair later [23-26]. Visceral contamination control can often be attained using simple suturing or stapling techniques to control defects or rapidly remove injured segments and often require external drainage with closed suction systems.

**Liver injuries**

Major bleeding from the liver and complex hepatic injuries, grades IV and V (American Association for the Surgery of Trauma Organ Injury Scale, AAST-OIS) continue to challenge even experienced trauma surgeons [27-29]. The close anatomical relationship with the vena cava and the triple system of blood vessels (hepatic inflow and outflow) places control of bleeding in the foreground in liver injury. In addition, it should be noted that the liver represents a place of synthesis of all coagulation factors except factor VIII. In a situation of severe bleeding, coagulation factors are quickly disrupted by consumption, reduced synthesis and degradation, with the threatening coagulopathy. In severe liver injury (AAST III-VI) under conditions of coagulopathy, hypothermia and acidosis, the DCS concept should be applied to stop the bleeding. This approach does not allow extensive and complex surgical procedures during the initial laparotomy, but they can be performed after resuscitation in the ICU, during the planned re-operation (“staged repair”).

Initial surgery involves quick direct and indirect bleeding control procedures and/or perihepatic tamponade. Depending on the site of the injury, mobilization of the right lobe may be necessary, which can be achieved by dividing the triangular and coronary ligaments that attach the liver to the diaphragm. If the retrohepatic vena cava is injured, mobilizing the right lobe can lead to massive hemorrhage that may be difficult to control [27-29].

**Techniques for liver reparation**

Large liver lacerations may be managed using either continuous suture or interrupted horizontal mattress sutures (extensive hepatorrhaphy). These sutures are passed through the hepatic capsule, traverse the parenchyma at a depth of about 2 cm from the lacerated surface, and exit at the opposite side through the capsule. However, this approach is burdened by complications such as ischemic necrosis, “dead space” with an accumulation of blood and bile, lack of effective bleeding control of the deep blood vessels and the high incidence of haemobilia. It is optimal to use the techniques of direct control, such as hepatotomy or resectional debridement with selective vascular ligation (Figure 1).

A tamponade for deep cleft in the parenchyma, after selective ligation of the blood vessels, can use the omental flap. Finally the management of complex hepatic injuries may require the use of some of the most complex surgical techniques in the trauma surgeon’s armamentarium, including extensive hepatotomy and hepatorrhaphy with selective deep vessel ligation, formal lobectomy, non-anatomic resection and debridement [27-29].

**Pringle maneuver**

The Pringle Maneuver (PM) is very helpful in controlling bleeding
bleeding during the first 24–48h, when reoperation is usually planned. Other indications for perihepatic packing are listed in (Table 2). Perihepatic tamponade complications are related to excessive compression of the liver and vena cava, which may result in ischemia and necrosis of the liver parenchyma, reducing the flow through the vena cava, with a decrease in cardiac inflow and deterioration of circulatory dynamics. Other complications may be portal vein thrombosis, pulmonary atelectasis and hyperventilation. Septic complications should not be neglected. However the most important complications are related to the increase in abdominal pressure and the high risk of Abdominal Compartment Syndrome (ACS). For this reason it is very important to regularly control abdominal pressure by manometry, and timely and adequate correction of abdominal hypertension. Unfortunately, the mortality from severe liver injury remains very high, and exsanguinations is the leading cause of death in these patients [30].

**Splenial injuries**

In patients with splenic injuries AAST grades III, IV and V, splenectomy is the procedure of choice for damage control. In lower grade injuries, simple hemostatic measures may be useful, such as topical hemostatic agents, suture or mesh wrapping [32].

**Pancreas injuries**

Major pancreas injuries are uncommon, but may result in considerable morbidity and mortality because of the magnitude of associated vascular and visceral injuries or underestimation of the extent of the pancreatic injury (Figure 4). The integrity of the main pancreatic duct is the crucial point in the management and outcome of patients with pancreatic trauma [33,34]. Pancreatic injuries that do not involve the duct require external drainage with closed suction systems. If the pancreas injury is to the left of the mesenteric vessels, distal pancreatectomy is indicated. In massive destruction of the pancreatic-duodenal complex, pancreaticoduodenectomy is indicated.

**Gastrointestinal tract**

If the sites of perforations are the stomach, duodenum, jejunum/ileum and colon, rapid control of contamination is an essential part of DCS [35]. Definitive repair with anastomosis to reestablish intestinal continuity are avoided at this time. Stomach injuries are sutured closed, with continuous stitch, running stitch and hemostasis. Smaller perforations of the small and large bowel

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**Table 2: Indications for perihepatic packing.**

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<thead>
<tr>
<th>Condition</th>
<th>Indications for Perihepatic Packing</th>
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<tr>
<td>Severe hemodynamic instability</td>
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<td>Lack of blood transfusion</td>
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<td>Coagulopathy induced by massive transfusion</td>
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<tr>
<td>Non-hemostatic efficacy of procedures</td>
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<tr>
<td>Severe liver injury</td>
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<td>Extensive subcapsular hematoma</td>
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<td>Prolonged hypothermia</td>
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<tr>
<td>Inexperience of surgeon+ transport to medical center</td>
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<tr>
<td>Other complex abdominal problems</td>
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<tr>
<td>Perihepatic packing</td>
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**Figure 3: Perihepatic packing.**

In centrally placed lacerations, after control of the major vessels, ooze may be managed by cavity packing with viable omentum [27]. In other situations tamponade may be the most expeditious DC technique. Tamponade can be achieved by perihepatic gauze packing (“perihepatic packing”), placing a balloon catheter within the tract where the inflated balloon acts as tamponade, or mobilizing the injured lobe and circumferentially wrapping it with absorbable mesh [27-31]. Also in a patient with limited retrohepatic caval injuries, perihepatic packing may initially control bleeding [27]. Perihepatic packing is a basic DC technique in establishing control of bleeding in liver injury. The process is based on the compression of the liver in superior and posterior directions. Abdominal compresses are placed around the liver, but not in the lesion itself, in order to compress the site of the injury and maintain pressure against the diaphragm (Figure 3). It is very important to avoid cutting the ligaments and liver mobilization, and also excessive compression between the liver and diaphragm. Adequately implemented, this maneuver successfully stops the bleeding, except in major arterial hemorrhage and severe injuries of juxtahepatic veins (AAST-VI). In such cases, there may be a repeated attempt at re-tamponade, or using some of the techniques of vascular control in terms of selective vascular occlusion (SVO) or total vascular occlusion (TVO) of the liver. Perihepatic tamponade is used as the main method of hemostasis in 5-6% of cases of severe liver trauma, where the application of conventional techniques to control bleeding has been unsuccessful, while in the additional 33% of patients it is necessary as a procedure, within the concept of DCS, to stop non-surgical bleeding. This method may be salutary in patients with acidosis, hypothermia and coagulopathy. In patients with minor retrohepatic vena cava injuries, tamponade may initially control the

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are closed with a running stitch, but bowels with multiple injuries or devascularized segments are resected. Staplers allow rapid and safe resection. Stoma formation and feeding ostomies are sometimes necessary at this point. The morbidity and mortality following abdominal trauma and bowel perforation are still high because of peritonitis and sepsis [35].

**Major abdominal vessels injuries**

Large abdominal, retroperitoneal and pelvic hematomas with pelvic fractures, should be carefully explored [36,37]. In patients who have developed coagulopathy and resultant diffuse nonsurgical bleeding, packing may be lifesaving. Injury of the major abdominal or pelvic veins should be managed by ligation. Injury to the abdominal aorta requires rapid repair using an arterial substitute for wall loss. The inferior mesenteric artery can be ligated safely in trauma patients. Injury of the superior inferior mesenteric artery and external iliac artery should be controlled by repair or placing an intraluminal shunt. Bleeding from the internal iliac artery deep in the pelvis is difficult to control and this may be achieved by ligation, packing and placing hemostatic agents. Injuries to the renal artery in unstable patients should be treated with ligation and nephrectomy, after confirming the presence of a normal contralateral kidney. Although the adoption of damage control has been associated with reduced mortality from abdominal vascular injuries due to coagulopathy, patients have continued to die of exsanguinations and represent a persistent challenge.

**Renal injuries, urinarily collecting system injuries and internal reproductive organ injuries**

Blunt renal trauma managed conservatively is associated with few complications in the hemodynamically stable patient [38]. Nephrectomy, after confirming the presence of the contralateral kidney, is the procedure of choice in patients who require damage control and have massive bleeding from an injured kidney [38]. In other cases, gauze packing and renal preservation may be possible. In the damage control situation, urethral repairs or complex procedures for urethral injuries are not indicated, temporary urinary diversion techniques are employed. Intraperitoneal bladder injuries should be managed with a running stitch. In major pelvic trauma, internal reproductive organs can be injured in association with pelvic fractures. In very rare situations, the fastest way to control bleeding would be a hysterectomy.

**Temporary abdominal closure**

Temporary Abdominal Closure (TAC) has increasingly been employed, as part of damage control surgery in severely injured patients, to reduce tension and avoid subsequent ACS during recovery in the restoration period in the ICU. Abdominal compartment syndrome is common in these patients who have undergone aggressive resuscitation. In the intensive care unit, continued attention to Intra-abdominal Hypertension (IAH) and abdominal compartment syndrome and measures to prevent or treat these conditions is imperative. Use of this dressing type reduces this risk, and is probably a major factor in the improvement in mortality seen in this patient population. TAC has many other useful properties. Besides being quick, it allows for rapid reentry into the abdominal cavity while preserving fascial integrity for latter definitive closure. The major goal of TAC techniques is no longer abdominal coverage alone, but also fluid control and facilitation of early fascial closure, including helping in septic source control with wide drainage as important aspects. Various methods of TAC are available, but negative pressure therapy seems to be best suited to achieve these goals. Fascial approximation techniques prevent lateral retraction of the abdominal muscles and can be combined with TAC techniques. Mesh mediated vacuum assisted wound closure is emerging as one of the most promising approaches. Vacuum assisted abdominal dressing (Barker technique abdominal dressings) is now used for a multitude of reasons [15]. The Barker style closure can be created from common material, but commercial kits have been developed which may improve effluent evacuation and control [39-41]. Given the versatility of this abdominal closure, it has generally replaced the other temporary closures, such as towel clip closures, ETHIZEP Temporary Abdominal Wound Closure Device or Bogota bag. The vacuum-pack technique (Figure 5) is the method of choice for patients requiring open abdomen management [41]. On completion of abdominal exploration, a perforated polyethylene sheet is placed over the intraperitoneal viscer and beneath the peritoneum of the anterior and lateral abdominal wall. Next, a layer consisting of compressible material, either sterile surgical towels or a sterile sponge, is placed over the polyethylene sheet. Two silicone drains are then placed above the towel/sponge and connected to a vacuum source at 100 to 150 mmHg continuous negative pressure. The skin surrounding the wound is dried and painted with tincture of benzoin and kept dry until covered with the final layer, a plastic polyester drape [41].

**Stage II**

**ICU resuscitation**

After the initial laparotomy, with surgical control of bleeding, the focus should be on aggressive resuscitation in the ICU. With more understanding of appropriate resuscitation by support of the patient’s physiology, the acidosis, hypothermia, and coagulopathy associated

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Figure 4a: Gunshot wound with lesion of the pancreas, portal vein and liver: left splenohemypo pancreatectomy.

Figure 4b: Gunshot wound with lesion of the pancreas, portal vein and liver: reconstruction of the portal vein.
with trauma should reverse. Currently, the goal should be as close to euvolemia as possible, with end organ perfusion, often with liberal use of blood products [17,19,21].

Secondly, since no single endpoint of resuscitation is capable of determining the resolution of the shock state, it should continue until multiple methods of evaluation indicate its resolution. Care should be taken during the resuscitation to support the patient’s core temperature, especially with the use of blood products to correct the patient’s coagulopathy and anemia. A host of products has been developed in the last two decades to help attain better resuscitation. These include a multitude of devices to monitor the patient’s volume status during resuscitation, like the volumetric pulmonary artery catheter and arterial pulse contour analysis, and to rewarm the patient, like both external and internal heat exchange devices. Additionally, a multitude of products has been developed for both localized hemostasis and the global reversal of coagulopathy to various levels of success. During this time period, a multitude of ventilator modes have been developed and commercialized to provide better lung protective capabilities in the ICU. Mechanical ventilation is an essential component of the care of patients with Acute Respiratory Distress Syndrome (ARDS), and a large number of randomized controlled clinical trials have now been conducted evaluating the efficacy and safety of various methods of mechanical ventilation for the treatment of ARDS [42]. Sedation and paralytic use has declined, to reduce the incidence of ICU polyneuropathy [43-45]. Glycemic control has become common place in the last decade, but even this concept has evolved since its inception [46]. Finally, monitoring for ACS development needs to be performed. Failure to recognize this clinical entity is often lethal. A better understanding of this clinical entity has grown in the last two decades, leading to improved survival of both trauma and septic patients receiving aggressive resuscitation [11,15,16].

Stage III

Planned reoperation, definitive repair, abdominal wall closure

After resuscitation in the ICU has allowed the patient to regain physiological reserves, generally in 24 to 48 hours, definitive repair can be undertaken. Since its initial presentation, a more regimented approach has been developed for guiding the subsequent laparotomy. In the severe abdominal trauma with septic abdomen, the planned reoperation focuses on definitive control of the septic source [47-53].

This phase involves the following procedures: careful removal of packs, inspection and identification of all injuries, control of remaining bleeding points, definitive gastrointestinal repair, nasoenteric feeding tube placement, closed suction drainage if needed, temporary or definitive abdominal wound closure, and tracheostomy if needed. One advantage of damage control surgery over the traditional approach is the possibility of regaining intestinal continuity in bowel injuries and avoiding stomas if possible [47].

Abdominal wall closure

Closure of the abdominal wall, which was initially considered part of the subsequent laparotomy, has evolved over the past two decades into part of damage control surgery for trauma patients with septic abdomen. In these patients there is always a question and the dilemma of whether to use temporary or definitive abdominal wound closure. This part of DCS needs to be developed since only 40-70% of patients can be closed immediately after definitive repair (skin closure only, silo placement/Bogota bag, vacuum assisted abdominal dressing). The optimal TAC should control the abdominal viscera while preventing additional contamination or visceral injury and control the effluent to preserve skin and soft tissue integrity. They should be simple to deploy without causing a radiographic artefact. Unnecessary tension should be avoided to prevent subsequent abdominal compartment syndrome. Additionally, fusion between the visceral block and abdominal wall should be prevented. They should not be costly and actively promote closure of the abdominal wall. Lastly, fascial integrity should be preserved for later use. In trauma patients, the majority of patients can achieve definitive closure; however, fascial closure rates may be lower in cases of septic abdomen [54]. Open abdominal wounds can be temporized utilizing skin-only closure, sterile silastic membrane coverage, absorbable or non-absorbable mesh materials, Negative Pressure Wound Therapy (NPWT), and the Velcro like Wittmann patch [6]. Immediate use of TAC’s have evolved over the last few decades from simple skin closures with suture or towel clips. Vacuum assisted abdominal wall dressings have become the predominant TAC, as they have the most characteristics of the optimal TAC to date. Additionally, prevention of fusion of the visceral block to the abdominal wall can be achieved using vacuum assisted closures, extending the time of primary fascial closure from 10 to 14 days to up to one month [55].

For patients that will have longer-term closure needs, interpositional mesh techniques have been developed. The meshes are attached to the fascial edges and can be tightened over time to help provide medial traction. Vacuum assisted abdominal wall dressings can be used in conjunction with interpositional meshes, though with more difficulty.

Definitive fascial closure should be pursued whenever possible [50]. Various wound care adjuncts may help facilitate fascial approximation/abdominal closure. While some authors suggest that the Wittmann Patch and NPWT may be associated with improved rates of fascial closure, others utilize the ”Planned Ventral Hernia” (PVH) as the default pathway in cases where prompt primary fascial closure is not possible. Additionally, the absorbable meshes can be left in place to fuse with the visceral block, to provide a bed for a split thickness skin graft and creation of a ”Planned Ventral Hernia” (PVH), if definitive closure cannot be achieved. Such PVHs are covered by split thickness skin grafts, with delayed fascial closure performed after the patient recovers from the acute illness [6]. This planned ventral hernia can be reversed in six to twelve months, once
the visceral block has separated from the surface tissues. Occasionally, large hernia defects require extensive abdominal wall reconstructions, utilizing abdominal component-separation techniques. Abdominal wall reconstruction is especially challenging in the presence of a fistula or stoma. For this reason, ostomy creation should be avoided in DCS patients, and enteral anastomosis should be attempted during definitive repair of DCS (stage III) [1].

Outcomes from DCS

Severe trauma is accompanied by significant morbidity and mortality. Damage control surgery attempts to identify those trauma patients incapable of undergoing definitive surgery due to loss of physiological reserves, and exchange an improvement in survival for increased morbidity. This approach has shown a survival rate of approximately 60%, compared to the 11% survival rate of conventionally treated patients in Rotondo and Schwab’s initial study [2,3]. In patients with lower energy mechanisms of trauma, such as stabbings, rates as high as 90% have been reported. Duchesne et al. [56] reported improved outcomes with the addition of damage control resuscitation to damage control surgery (74% vs. 55%). However, damage control surgery is not without its own morbidity and DCS-associated mortality. Intraabdominal Hypertension (IAH) and the ACS manifest clinically with tense, distended abdomen, progressive hypotension, oliguria, and increased airway pressures [16]. Early recognition of IAH and ACS is essential, by sustained or repeated elevation with intraabdominal pressure of >12 mmHg.

Abdominal compartment syndrome can be common place in traumatic injury patients, given the aggressive resuscitation receive. However, with the rise in its incidence, alternative treatment modalities have been developed to combat it. Additionally, actively seeking prevention by using open abdomen techniques such as vacuum assisted dressings is probably the main reason damage control surgery improves outcomes [15,16].

Surgical site infections and intraabdominal abscesses associated with DCS occur in as many as 83% of cases [1]. Major factors to consider include bile leak (incidence of 8-33%) and enterocutaneous fistula (incidence of 2-25%) [1]. Enterocutaneous fistulae are more common in patients treated by DCS, due to increased manipulation of the viscera. These fistulae tend to have prolonged spontaneous closure rates. Up to 15% of trauma patients may experience this complication [53,54,57].

Intraabdominal Abscess (IAA) rates vary considerably in the trauma literature (from 10 to 70%), and appear to largely correlate with the use of intraabdominal packing, especially when the duration of packing exceeds 72 hours. While more frequent washouts of the peritoneal cavity may decrease IAA rates, increased bowel manipulation leads to increased enterocutaneous fistula rates. In the septic abdomen patient, the development of tertiary peritonitis (a persistent or recurrent intraabdominal infection despite adequate initial surgical source control) appears to be approximately 20%; however, even this rate has considerable variability in the literature due to numerous definitions in use [58-60]. The advancement of interventional radiology allows for relatively easier control of this complication using percutaneous drains, compared to surgical drainage procedures. Surgical site infections and abdominal abscesses may also contribute to postoperative fascial dehiscence, reported in up to 25% of DCS patients [1].

Acute and subacute bowel obstruction in the setting of DCS with reported incidence, 2-21% is most likely related to surgical adhesions [41]. Regardless of the timing of post DCS bowel obstruction, the initial therapy consists of bowel rest, fluid resuscitation with electrolyte replacement, and nasogastric suctioning. However, when signs of clinical deterioration develop, operative intervention has to be undertaken regardless of the anticipated difficulty of adhesiolysis or the presence of “frozen abdomen”. Chronic ventral hernia is very common in patients undergoing DCS, with a wide incidence range (13%-80%) depending on patient-specific factors and institutional patterns of practice [6,55]. Large ventral hernias may be associated with prolonged recovery, due to physical discomfort or loss of function. Definitive abdominal wall closure is associated with recurrent herniation in 5-10% of cases, depending on the reconstructive method and patient factors [55]. DCS associated mortality rates are 17-31% [12,47]. Excluding the primary etiology that led to the DCS, common factors that cumulatively contribute to DCS associated mortality include Multi System Organ Failure (MSOF), Systemic Inflammatory Response Syndrome (SIRS), severe infection/sepisis from a variety of sources, enterocutaneous/enteroatmospheric fistulae, preexisting malnutrition, chronic comorbid conditions and advanced age [12,42,47].

Conclusion

Severe trauma with massive hemorrhage may lead to acidosis, coagulopathy, and hypothermia. The lethal nature of exsanguinations and profound shock, causing the “lethal triad” synergistically contributes to further physiological derangement and, if uncorrected, patient death. The concept of damage control surgery has evolved into a lifesaving strategy to improve outcome in selected patients with exsanguinating trauma and life threatening conditions incapable of tolerating traditional methods. Establishment of clearly defined indications is necessary for appropriate use of this approach by performing three basic stages of DCS. During the initial laparotomy, haemorrhage and abdominal contamination are controlled, and temporary abdominal closure is performed (Stage I). The patient then enters Stage II– physiological restoration in ICU. This is followed by planned re-operation and definitive management of injuries and abdominal closure (Stage III). Improved understandings of IAH and ACS have led to the development of DCS as a surgical decompressive strategy. Although DCS may be associated with specific morbidity, it has proven itself clinically as the most successful approach to severely injured patients, with a significant increase in survival.

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