Chapter 13
General Surgical Problems in the Critically Injured Patient

David N. Naumann and Mark Midwinter

Abstract Critically injured patients requiring surgical management often require complex multi-organ support in the intensive care unit. In order to achieve best possible patient outcomes a multidisciplinary approach is required between surgical and critical care specialists in order to optimise the care of the patients from arrival to discharge. Familiarity with the patient pathway, their injury severity, surgical management, and possible complications are paramount in the overall care of these patients. Trauma to the abdomen may result in solid organ, hollow viscus or major vascular injury,

D.N. Naumann, MA, MB, BChir, DMCC, MRCS (✉)
• M. Midwinter, BMedSci, Dip App Stats MD, FRCS
NIHR Surgical Reconstruction and Microbiology Research Centre, Queen Elizabeth Hospital, Birmingham B15 2TH, UK

Academic Department of Military Surgery and Trauma, Royal Centre for Defence Medicine, Queen Elizabeth Hospital, Birmingham B15 2TH, UK
e-mail: david.naumann@nhs.net

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most commonly the liver, spleen, kidneys, pancreas, as well as the large and small bowel and vascular structures including major retroperitoneal vessels. These injures are graded in severity according to the American Association of Surgery for Trauma (AAST) which relates to both management strategies and outcomes. Damage control surgery (DCS) is now routine for battlefield abdominal trauma, and this philosophy has heavily influence current civilian practice. The five-stage sequence of DCS includes (i) patient selection, (ii) intra-operative, (iii) critical care, (iv) return to theatre; and (v) formal closure. This has been incorporated in to a broader philosophy of Damage Control Resuscitation. An understanding of the decision making and sequence of surgical management, as well as that of the abdominal compartment syndrome and open abdomen are important features of the management of the surgical patient in critical care, and are discussed in this chapter.

Keywords Organ injury • Damage control surgery • Abdominal compartment syndrome • Abdominal closure • Selective non-operative management

How Should Intra Abdominal Injuries Be Classified?

Intra-abdominal injuries may be sustained either in isolation or as part of a polytraumatic pattern of injury. Since the abdomen contains both solid and hollow viscus organs, each must be considered individually and in concert with the rest during the diagnosis of and subsequent management of injuries. Major vascular structures within the abdomen may also be injured in blunt and penetrating trauma. Since appropriate management may include surgery, interventional radiology and/or selective non-operative management, accurate diagnosis is paramount, and may utilise scoring systems for risk stratification and guidance of treatment. Modern ultrasound and cross-sectional imaging techniques allow the anatomical delineation of injuries in order to aid this diagnostic and decision making process. Indeed, availability of radiological adjuncts such as Focussed Assessment with Sonography in Trauma (FAST) and Computed Tomography (CT) can improve outcomes [1], and prevent unnecessary surgery even following battlefield injury [2]. The former is useful in the overall assessment of patients and decision making, whereas the latter may enable delineation of anatomical injuries.

Solid Organ Injury

The most commonly injured solid organs include the liver, spleen, and kidneys [3]. Specific Organ Injury Scales (OIS) relating to each of these organs have been assigned by the American Association for the Surgery of Trauma (AAST) [4, 5]. These facilitate the reporting and comparison of management strategies and outcomes but do not directly relate to specific management of individual patients, which is more dictated by haemodynamic parameters and stability over time. These OIS are illustrated in Table 13.1 (Liver), Table 13.2 (Spleen), Table 13.3 (Kidney), and Table 13.4 (Pancreas). Blunt splenic trauma (even higher grades of injury) may be treated selectively by non-operative strategies [6]. Although this may be suitable for some penetrating splenic injuries, the vast majority are still managed surgically [7]. Both blunt [8, 9] and penetrating [10] hepatic injuries may also be managed non-operatively with the caveat that certain associated risk factors, such as other injuries, peritoneal signs, and high injury severity scores increase the risk of the requirement for surgery [8]. Kidney trauma is most commonly managed non-operatively, with the exception that Grade V injuries are likely to require surgery [11]. Pancreatic injury management may also be managed selectively non-operatively but this needs to tempered by the high incidence of associated duodenal and vascular injury and complications from major pancreatic duct disruption.

Table 13.1 AAST liver injury scale

Grade*	Type	Description of injury
I	Hematoma	Subcapsular <10 % surface area
	Laceration	Capsular tear <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10–50 % surface area intraparenchymal <10 cm in diameter
	Laceration	Capsular tear 1–3 parenchymal depth <10 cm in length
III	Hematoma	Subcapsular, >50 % surface area of ruptured subcapsular or parenchymal hematoma; intraparenchymal hematoma >10 cm or expanding
	Laceration	>3 cm parenchymal depth
IV	Laceration	Parenchymal disruption involving 25–75 % hepatic lobe or 1–3 segments
V	Laceration	Parenchymal disruption involving >75 % of hepatic lobe or >3 segments within a single lobe
	Vascular	Juxtahepatic venous injuries; i.e., retrohepatic vena cava/central major hepatic veins
VI	Vascular	Hepatic avulsion

*Advance one grade for multiple injuries up to grade III

Hollow Viscus Injury

A high index of suspicion is warranted for hollow viscus injury following abdominal trauma, including following blunt trauma [12]. The presence of a solid organ injury is predictive of hollow viscus injury [13], and therefore it is important to consider all contents of the abdomen rather than the most obviously injured organ. Classification of small bowel and colonic injuries according to AAST [14] are illustrated in Table 13.5. Hollow viscus injury with

Table 13.2 AAST spleen injury scale

Grade*	Type	Description of injury
I	Hematoma	Subcapsular <10 % surface area
	Laceration	Capsular tear <1 cm parenchymal depth
II	Hematoma	Subcapsular, 10–50 % surface area intraparenchymal <5 cm in diameter
	Laceration	Capsular tear, 1–3 cm parenchymal depth that does not involve a trabecular vessel
III	Hematoma	Subcapsular, >50 % surface area or expanding; ruptured subcapsular or parecymal hematoma; intraparenchymal hematoma ≥5 cm or expanding
	Laceration	>3 cm parenchymal depth or involving trabecular vessels
IV	Laceration	Laceration involving segmental or hilar vessels producing major devascularization (>25 % of spleen)
V	Laceration	Completely shattered spleen
	Vascular	Hilar vascular injury with devascularizes spleen

*Advance one grade for multiple injuries up to grade III

peritoneal leakage of bowel contents following trauma must be treated surgically in order to prevent sepsis and multi-organ failure. Very early CT scan may show the solid organ injury but miss associated hollow viscus injury as radiological signs for this take time to develop (bowel thickening, changes in perfusion, associated fluid collection etc.). Therefore a high index of suspicion for associated hollow viscus injury in patients with solid organ injury managed non-operatively must be maintained and rescanning considered if there is any doubt.

TABLE 13.3 AAST kidney injury scale

Grade*	Type	Description of injury
I	Contusion	Microscopic or gross hematuria, urologic studies normal
	Hematoma	Subcapsular, nonexpanding without parenchymal laceration
II	Hematoma	Nonexpanding perirenal hematoma confirmed to renal retroperitoneum
	Laceration	<1.0 cm parenchymal depth of renal cortex without urinary extravagation
III	Laceration	<1.0 cm parenchymal depth of renal cortex without collecting system rupture or urinary extravagation
IV	Laceration	Parenchymal laceration extending through renal cortex, medulla, and collecting system
	Vascular	Main renal artery or vein injury with contained hemorrhage
V	Laceration	Completely shattered kidney
	Vascular	Avulsion of renal hilum which devascularizes kidney

*Advance one grade for bilateral injuries up to grade III

Retroperitoneal Vascular Injury

Retroperitoneal trauma may cause vascular injury, bleeding, and formation of haematoma that may further injure the retroperitoneal anatomical structures. Such haematomas can be divided into three zones in terms of the anatomical relationships. The decision to manage retroperitoneal injuries with surgery or conservative treatment depends on the likely structures that may have been injured, and the mechanism of injury:

(a) ***Zone 1*** (central and medial; may lead to pancreaticoduodenal injury and/or major abdominal vascular injury). If

Table 13.4 AAST pancreas injury scale

Grade*	Type	Description of injury
I	Hematoma	Minor contusion without duct injury
	Laceration	Superficial laceration without duct injury
II	Hematoma	Major contusion without duct injury or tissue loss
	Laceration	Major laceration without duct injury or tissue loss
III	Laceration	Distal transection or parenchymal injury with duct injury
IV	Laceration	Proximal? transection or parenchymal injury involving ampulla
V	Laceration	Massive disruption of pancreatic head
I	Hematoma	Minor contusion without duct injury
	Laceration	Superficial laceration without duct injury

*Advance one grade for multiple injuries up to grade III

Table 13.5 AAST small bowel and colon injury score

Grade*	Type	Description of injury
I	Hematoma	Contusion or hematoma without devascularization
	Laceration	Partial thickness, no perforation
II	Laceration	Laceration <50 % of circumference
III	Laceration	Laceration ≥50 % of circumference without transection
IV	Laceration	Transection of the bowel
V	Laceration	Transection of the bowel with segmental tissue loss
	Vascular	Devascularized segment

*Advance one grade for multiple injuries up to grade III the mechanism of injury is penetrating, then Zone 1 injuries must be explored surgically due to risk of injury to the aorta, vena cava, coeliac trunk, and superior mesenteric artery. Blunt trauma may be managed conservatively, but with a high index of suspicion.

(b) ***Zone 2*** (lateral/perinephric area; may cause injury to the colon and/or genitourinary system). Penetrating injuries to this zone should also be explored in order to check for injuries to the ipsilateral kidney, adrenal gland, ureter, and renal vasculature. It is important to note that even blunt trauma may cause secondary penetrating trauma from fractured ribs. Blunt trauma may safely be managed conservatively. However, if a Zone 2 haematoma is diagnosed during laparotomy, the surgeon must note whether it is expanding or pulsating, and explore if this is the case.

(c) ***Zone 3*** (pelvic, usually due to pelvic fracture and/or iliofemoral vascular injury). Blunt trauma to this zone requires an external fixation device to compress the haematoma. Selective angio-embolization of bleeding vessels may be required if the patient remains haemodynamically unstable. Surgical exploration is only indicated following penetrating injury.

What Is Damage Control Surgery?

The concept of *damage control* in naval warfare refers to the well-rehearsed, efficient and timely efforts of a crew to keep a damaged ship afloat in order to maintain mission integrity and return to port for more definitive repairs. Along similar lines, damage control surgery (DCS) is a surgical strategy to directly address the physiological stresses of major trauma without the need for definitive restoration of anatomy; to keep the injured soldier alive long enough—like the damaged ship—to return home for definitive 'repairs'. The DCS operative strategy sacrifices the completeness of the immediate surgical repair in order to address the physiological consequences of the combined trauma of injury and subsequent surgery.

Major trauma is characterised by a sudden, severe anatomical insult leading to catastrophic haemorrhage and major imbalance of physiological parameters. Loss of blood volume and subsequent hypothermia stimulate widespread adrenergic vasoconstriction. Clotting factors are depleted, leading to coagulopathy and further bleeding. The resulting haemodynamic compromise and hypoperfusion of organs with tissue injury leads to anaerobic respiration of tissues and metabolic acidosis. This process has been called the 'trauma triad', 'lethal triad' or 'triad of death' of hypothermia, acidosis and coagulopathy [15–17]. It is this physiological cascade that must be mitigated in order for the casualty to remain alive long enough to achieve future definitive care.

Damage Control Versus Primary Surgery

Before the philosophy and practice of DCS, conventional wisdom dictated that a casualty would undergo initial resuscitative measures in the emergency department of a hospital, and when 'stabilised' would be transferred to the operating theatre for definitive repair of their injuries (i.e., primary surgery). The patient may then be transferred to the intensive care unit (ICU) post-operatively for further resuscitation and physiological monitoring.

Such a logical sequence would supposedly negate the requirement for a return to theatre – indeed in such a model the requirement for further surgery might be considered to be an adverse event or complication. The DCS philosophy is different to this traditional model in the respect that surgery is only one part of the overall resuscitation, and that restoration of physiology (rather than anatomy) is the priority. DCS is one part of the overall process of Damage Control Resuscitation (DCR) that focuses on early correction of physiological derangement [18–20]. The introduction of DCR has influenced to practice of DCS as aggressive physiological correction extends surgical options.

Damage Control Sequence

When the term *damage control surgery* was first coined in 1993 by Rotondo and Schwab, the authors first described a classical three-stage approach, which mainly concerned abdominal trauma [21, 22]. Although the general concepts of DCS have remained fairly consistent since this original description, its practice has now evolved, and can be considered in 5 distinct stages [23, 24]. These stages are (i) Patient selection, (ii) Intra-operative, (iii) Critical Care, (iv) Return to theatre; and (v) Formal closure.

I. ***Patient selection***

Regardless of physiological and situational parameters used in decision-making, a timely and considered decision is important, and must involve accurate communication between surgical, critical care and anaesthetic teams. This may occur either pre-operatively (before the patient has arrived in the operating room), or within the first minutes of surgical intervention. One formalised approach has been described by Rotondo and Zonies [25], and uses the patient selection factors of *conditions*, *complexes* and *critical factors* (Table 13.6). Additionally some physiological criteria that may indicate that a DCS approach is indicated have been suggested as: Injury severity score >25, systolic blood pressure <70 mmHg, core temperature < 34 °C and pH <7.1.

II. ***Intra-operative stage***

The start of the intra-operative stage should be as soon as possible, and the time of surgery should be carefully monitored and kept to a minimum. The surgical team should be mindful of the dynamic changes in the patient's physiology (including acid-base status, coagulation, temperature, blood product requirements). The basic philosophy is that the minimum must be done to stop haemorrhage, limit contamination, and provide temporary closure or cover of abdominal contents before the patient is rapidly transferred to critical

Table 13.6 Selection of patients in whom application of damage control principles is likely to be of benefit

Conditions
High energy blunt trauma
Multiple torso penetration
Haemodynamic instability
Presenting coagulopathy and/or hypothermia
Complexes
Major abdominal vascular injury with multiple visceral injuries
Multifocal or multi-cavity exsanguinations with concomitant visceral injuries
Multiregional injury with competing priorities
Critical Factors
Severe metabolic acidosis (pH 7.30)
Hypothermia (temperature <35 °C)
Resuscitation and operative time > 90 min
Coagulopathy as evidenced by the development of non-mechanical bleeding
Massive transfusion (>10 units of PRBC).

Adapted from Rotondo and Zonies [25]

care. Active warming is important and a theatre temperature of 26 °C is normal practice [19].

(a) *Haemorrhage/vascular control*
Although the application of proximal pressure and haemostatic dressings are useful in the initial control of bleeding, only surgical control is considered definitive [26]. The first priority during this operative stage is therefore the control of bleeding. Haemorrhage control may

be achieved by ligation, suture, or tamponade (by packing or balloon). Large vascular injuries may also be treated with temporary shunting in order to facilitate subsequent vascular repair in order to preserve a limb. Definitive vascular repair by grafting or anastomosis during this stage is not appropriate, but may be considered in the later stages.

(b) *Limit contamination*
Contamination control is often achieved by stapled or tape closure of the ends of the injured hollow viscus. Anastomoses and stomas are not usually fashioned in DCS. A thorough washout with copious normal saline is also performed to minimize contamination.

(c) *Temporary closure*
Pre-emptive strategies to prevent compartment syndromes such as fasciotomies and laparostomy are employed. Temporary closure or cover is established in order to protect the abdominal contents whilst the patient is moved to a critical care environment. There are various temporary closure techniques used, which are described later in this chapter.

III. ***Critical Care Stage***

In the critical care environment attempts continue at correcting the physiological consequences of injury and its associated metabolic failure. These concepts are discussed at length in Chaps. 5, 6, 7 and 8. Early return to the operating theatre is indicated if there is obvious ongoing surgical bleeding or a compartment syndrome develops.

IV. ***Return to the operating theatre***

This is dictated by improvement in the patient's physiological status. The following indices are often used to guide reoperation; base deficit >-4 mmol/l, lactate <2.5 mmol/l, core temperature >35 °C and an International Normalised Ratio <1.25 [24]. Before the decision to return to the operating theatre is made, plans to assemble the appropriate surgical team must be put in place to ensure that the optimum repairs of the injuries are performed in the optimum surgical environment. This may require more than one surgical specialty, but with a clearly identified leader to orchestrate the procedures and take a global view of the patient's condition. At this stage anastomoses are fashioned, stomas raised and vascular repairs performed. However, surgical judgment on restoring gastrointestinal continuity should be exercised and in particular the requirements for on going inotropic support.

V. ***Formal closure***

This may not be possible at stage IV as there may still be significant oedema or clinical risk of developing a compartment syndrome (abdominal or extremity). Therefore a planned further operative phase for closing or covering the site is made. The balance of risks between leaving the abdomen open as a laparostomy or delayed closure will depend on the injuries sustained and the overall condition of the patient and their abdominal viscera. Component separation or mesh repair may be considered, and are discussed further later in this chapter [27]. If fascial closure has not been possible by day 10 it may be safer to allow the laparostomy to mature and plan a delayed closure many months later rather than risk making an inadvertent enterotomy to get closure earlier.

Vascular Damage Control

Major vascular injuries must be dealt with quickly and urgently in order to stop haemorrhage and potentially enable limb salvage, but cannot wait until transfer to vascular specialist units. Damage control techniques may be utilised during surgery that do not necessarily require vascular specialists to perform. Although most distal vascular injuries can be ligated, an injured proximal portion of an extremity vessel may threaten the viability of that limb. The damage control surgery technique of placing a temporary vascular shunt may make limb salvage possible, and has long-term limb preservation results similar to those where initial revascularisation was attempted [28]. This technique is relatively straightforward, quick, and does not necessarily require specialist vascular support. It enables the preservation of circulatory flow to the threatened limb so that subsequent definitive vascular reconstruction may be performed by an appropriately trained and skilled surgeon. This technique is performed by gaining proximal and distal control of the area of bleeding, followed by proximal and distal thrombectomy (using an appropriately sized Fogarty catheter). The temporary shunt is then placed into the vessel lumens creating a 'bridging' temporary pathway for circulatory flow. Where the injuries are so severe that this is technically impossible, or the limb is unsalvageable, amputation is indicated at a level at which viable and vascularised tissue may be preserved.

Military Experience

Damage control surgery is now in routine use for battlefield trauma. Its practice has recently been shown to reduce mortality and faecal diversion for abdominal injuries [29], and good limb salvage results following vascular injury [30]. In recent years the experiences of DCS from the deployed military has had influence on civilian practice [31, 32] but more investigational research is required to demonstrate true translatability. A Cochrane Review found no published or pending randomised evidence that compared DCS with immediate and definitive repair in patients with major abdominal trauma [33], and further evidence-informed consensus is required to address this uncertainty [34].

Which Patients Require Acute Operative Intervention Following Abdominal Trauma?

Before the advent of interventional radiology for trauma and detailed cross sectional imaging techniques such as computed tomography (CT), laparotomy was considered mandatory for penetrating trauma and serious blunt trauma with physiological compromise. This was associated with a risk of non-therapeutic laparotomy in some studies ranging from to 9–37 % [35], which can cause potentially preventable complications and morbidity. More recently, non-therapeutic laparotomy has been reported as low as 3.9 % even following battlefield injuries due to the sensitive and specific nature of comprehensive CT imaging and reporting [2]. The management of trauma patients can therefore be divided into (a) surgical; (b) selective non-operative management; and (c) interventional radiology.

Selective Non-operative Management

Selective non-operative management (SNOM) is a management strategy where patients are observed without surgery, by careful and regular examination and clinical assessment. It is preferable that the same examiner or team should regularly assess the patient to detect any deterioration in clinical status that would indicate intervention is required. Such an approach must be tailored to the individual patients' needs on a case-by-case basis. Injuries that may be managed using SNOM include solid organ injuries such as splenic and hepatic lacerations. Indeed SNOM for splenic injury is used as a quality indicator for surgical units that treat children [36]. The subsequent requirement for surgery may increase with the AAST grading of the solid organ injuries, and therefore a higher index of suspicion is warranted the higher the injury grade. Even penetrating injuries to the abdomen do not necessarily require surgery, and can be managed by SNOM. The Eastern Association for the Surgery of Trauma recently published clinical practice guidelines, recommending that "*A routine laparotomy is not indicated in hemodynamically stable patients with abdominal stab wounds without signs of peritonitis or diffuse abdominal tenderness*" [37].

Interventional Radiology

Some solid organ injuries may be suitable for interventional radiological management rather than surgery. Selective angioembolisation following blunt trauma can reduce the non-therapeutic laparotomy rate, and can be used for injury grades IV and V [38]. Inter-disciplinary discussion between radiology and surgical specialists and appropriate imaging techniques are vital for the success of this approach.

Surgical Intervention

Despite advances in diagnostic techniques, there are still some injuries for which laparotomy is mandatory. Hollow viscus injury following trauma with leakage of abdominal contents may only be treated with surgical intervention. Uncontrolled haemorrhage and clinical deterioration are also indications for emergency surgery, and damage control surgery if deemed appropriate. Solid organ injuries which have deteriorated despite SNOM and/or interventional radiology may also require surgical intervention for definitive management.

What Is Abdominal Compartment Syndrome?

Abdominal compartment syndrome is a dangerous complication that may lead to organ failure, diaphragm splinting, compression of the inferior vena cava, and reduction of cardiac return.

Definition

Abdominal Compartment Syndrome (ACS) has been defined by the World Society of the Abdominal Compartment

Syndrome (WSACS) as a sustained intra-abdominal pressure (>20 mmHg) with or without an abdominal perfusion pressure of <60 mmHg that is associated with new organ dysfunction or failure [39].

Diagnosis

Early diagnosis is important, since treatment is urgent. Intra-abdominal pressure is commonly monitored by measuring the intraluminal bladder pressure via urinary catheter. A small volume of water is instilled into the bladder, and the tubing is clamped. A manometer is attached proximal to the clamp, and the pressure reading is given as the number of centimetres above the symphysis pubis (units cmH_2O) (Fig. 13.1). However, management decisions should be made on the clinical picture and not solely based on pressure measurements.

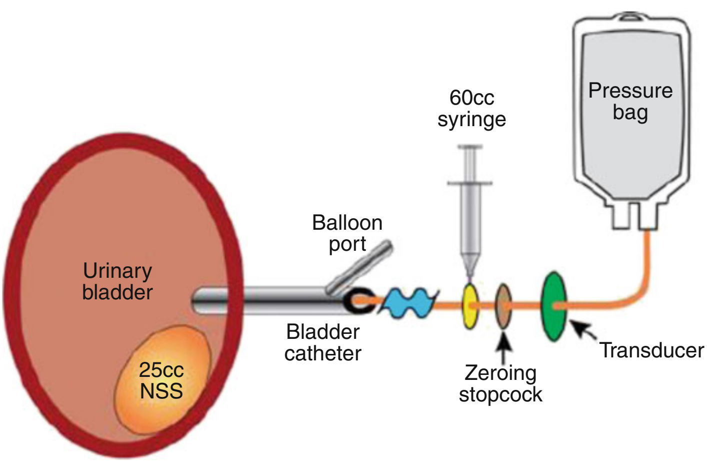

FIGURE 13.1 Intravesicular manometry device (From Gavrilovska-Brzanov et al. [49])

Pathophysiology

ACS can arise for three main reasons: (i) increase in size/volume of intra-abdominal organs; (ii) diminished abdominal wall compliance; and (iii) increase in intra-abdominal fluid through capillary leak or fluid resuscitation. The abdominal organs may increase in size and volume due to inflammation (such as liver dysfunction and acute pancreatitis [40]), ileus and distension, bowel obstruction, malignancy, intra-abdominal collection, or infection. The abdominal wall musculature can decrease in compliance due to the position of the patient (for example if prone), major abdominal wall burns, trauma, and surgical intervention. Fluid leakage into the abdominal cavity can occur during massive fluid resuscitation [41, 42], in particular crystalloid fluid resuscitation [43].

How Should Abdominal Compartment Syndrome Be Managed?

Prevention

The WSACS have recommended that intra-abdominal pressure should be monitored when there are any risk factors for intra-abdominal hypertension or ACS, and that the trans-bladder technique should be the gold standard [39]. Primary prevention of ACS is preferable to management once it arises. Laparostomy (i.e., leaving an open abdomen) following emergency laparotomy may be indicated if ACS is thought to be likely. Delayed closure may be performed once the oedema and fluid balance have been corrected sufficiently to allow closure.

Treatment

Once ACS is confirmed, urgent decompressive laparotomy is required in order to relieve the pressure [44], and this should be followed with temporary abdominal closure. This may become necessary if the intra-abdominal pressure remains 20–25 mmHg and is causing a deterioration of organ failure. Onward management should include a combination of careful fluid management (to decrease the overall fluid balance), and appropriate utilisation of vasoactive medications.

How Should Critically Injured Patients with Open Abdomens Be Managed?

The primary aims of the management of the open abdomen are to provide temporary cover until a time at which it is appropriate to perform formal closure. Closure should be achieved as soon as feasible (and without causing ACS), since it may lead to fluid and electrolyte imbalance, septic complications (e.g., abscess, systemic infection), formation of fistulae and adhesions, catabolic state, and systemic inflammatory response [45]. The management of the open abdomen therefore has three main priorities: (i) providing cover to the contents, to prevent injury (e.g., bowel) and preventing the introduction of contamination; (ii) control the intra-abdominal fluid volumes (i.e., from ascites and resuscitative fluid leakage); and (iii) to enable future wound closure by preventing the formation of adhesions and lateral recession of the abdominal musculature [46]. Concurrent attention should be paid to nutrition [44] and fluid maintenance to ensure the patient has appropriate nutritional supplementation via the best route, and electrolyte balance. Antibiotic coverage (both antibacterial and antifungal) should be considered in close collaboration with microbiology specialists.

Temporary Covering of the Open Abdomen

Before fascial closure is performed, the open abdomen requires temporary closure to minimise the complications listed above. Adequate temporary closure of the abdomen must take into account the fact that there will be considerable amounts of fluid accumulated in the abdomen, which requires either frequent dressings changes or a system that can adequately collect and drain the fluid. The simplest version of temporary closure may be in the form of simple packing, such as non-adherent wet gauze. Although such an approach may be suitable for severe sepsis, it is not commonly performed for trauma. Skin may be closed without closure of the fascia, but this also carries a high risk of dehiscence and loss of skin. More common techniques in usage include the Bogotoa bag, mesh, and vacuum assisted (negative pressure) drainage. The necessity of siting stomas and minimising potential contamination is an important consideration.

(a) *Bogota bag* (Fig. 13.2)

A large IV bag may be fashioned into a shape suitable for coverage of the abdominal defect, and sutured or stapled to the skin edges [47]. This can then be covered by antibiotic-covered dressings and drapes. The whole dressing may be replaced at the bedside without requirement for further trips to theatre.

(b) *Mesh*

Non-absorbable mesh may be loosely fixed by suture to fascia on either side of the abdominal defect. As the swelling reduces, the central portion of mesh can be excised and the two edges re-sutured, or the central portion can be plicated (Fig. 13.3). This process can be repeated until the point at which the fascial edges can be brought together for definitive closure.

Figure 13.2 Bogota bag temorpary closure of the abdomen (von Ruden et al. [50])

(c) *Negative pressure dressings* (Fig. 13.4)

Negative pressure therapy has the advantage of being suitable for fluid drainage (reducing the risk of intra-abdominal sepsis), as well as promoting angiogenesis, tissue perfusion, granulation, and bringing the skin edges closer together [48]. This is the approach recommended by the WSACS for the management of open abdomens [39]. The most common negative pressure dressings are the VAC Abdominal Dressing and ABThera Systems. Both of these systems are designed with individual layers: first a layer to protect the viscera, then a sponge fashioned into the shape of the defect, which is then covered with an adhesive occlusive (airtight) dressing. A vacuum is then created by connecting the perforated centre of the dressing to a negative pressure system. Such systems may allow definitive closure to be delayed.

Definitive Closure of the Abdomen

Fascial closure must be tension-free in order to prevent increased abdominal pressure, dehiscence, and ventral herni-

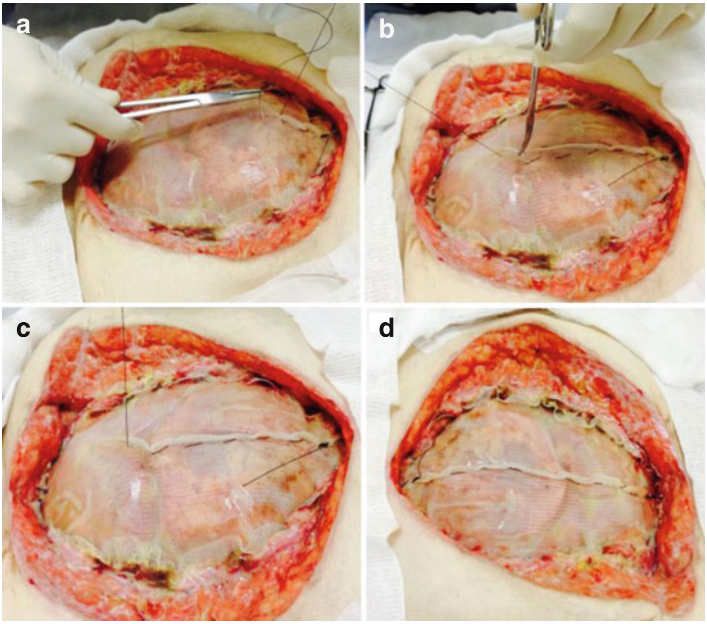

FIGURE 13.3 Mesh temporary closure of the open abdomen: plication of the central part at the bedside. (**a**) A suture is tied at one end of the mesh. (**b**) The mesh is pinched in the central portion, and plicated with a running suture. (**c**) The suture continues to the opposite end of the wound. (**d**) The suture is now tied so that it has been plicated along its entire length (From Correa et al. [51])

ation. If the fascial edges do not come together without tension, then the options for closure include: intentional ventral hernia, component separation, or utilisation of bridging mesh between the fascial edges. The exact timing and technique for definitive abdominal closure should be decided on a case-by-case basis depending on the clinical status of the patient in terms of their anatomical and physiological suitability for further surgery.

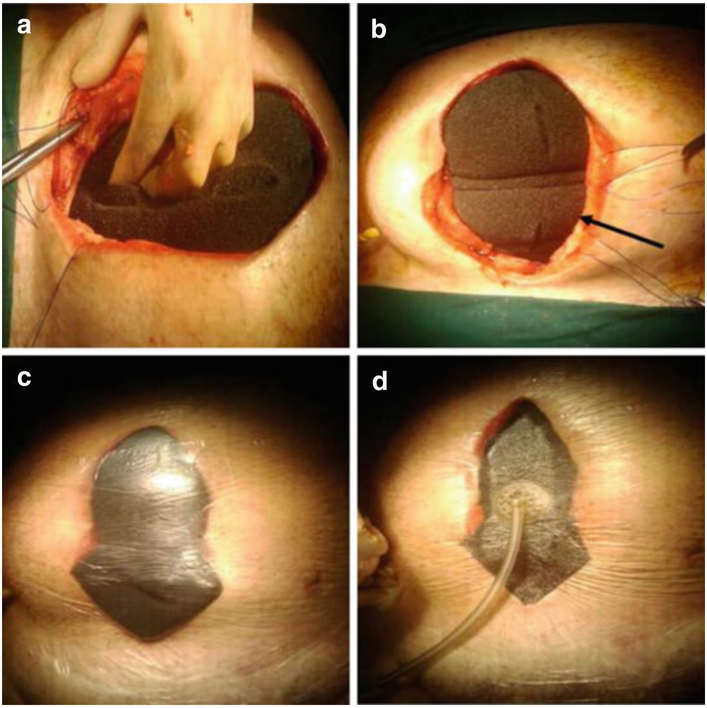

FIGURE 13.4 Negative pressure dressing for management of the open abdomen. (**a**) The edges of the fascia are placed under tension using interrupted sutures. (**b**) Sutures are spaced approximately 5 cm apart circumferentially. (**c**) A second sponge is positioned and sealed with an airtight plastic sheet. (**d**) The sponge is connected to a suction system (pressure between 50 and 150 mm Hg) (From Pliakos et al. [52] with permission)

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