Abdominal Trauma: Nonoperative Management and Postoperative Considerations

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INTRODUCTION

Multiply injured patients admitted to the intensive care unit (ICU) have an array of physiologic derangements that may include metabolic failure and cardiopulmonary embarrassment. The intensivist needs to understand the inherent differences in care of the postinjury patient. They should be familiar with the implications of specific injuries including guidelines for nonoperative management, postoperative care, and potential complications. This chapter will focus on the acute resuscitation and ICU management of the trauma patient, rather than the initial evaluation in the emergency department (ED). Initial therapy in the trauma bay, indications for emergent operation, and intraoperative decision making are beyond the scope of this chapter.

INITIAL EVALUATION IN THE INTENSIVE CARE UNIT

Although some patients may arrive in the ICU in extremis necessitating continued resuscitation without a thorough history and physical examination, the majority should undergo a complete assessment promptly, and it should not be assumed that the ED evaluation was comprehensive. Such an evaluation may be termed the tertiary survey (1). The evaluation is often more detailed than that performed in the ED, because all diagnostic results should be available, intraoperative findings known, further information is obtained from family members, and the physician has time for a more meticulous physical examination. Key elements include the patient’s past medical history, specifically any history of cardiopulmonary disease, past myocardial infarction, use of β-blockers or steroids, chronic hepatic or renal failure, and other elements that may acutely impact the patient’s care. Discovering minor injuries on the tertiary survey such as subtle extremity injuries overlooked during the ED evaluation is common (2,3). Documentation of this evaluation, particularly of final imaging results, can be done through a standardized form that facilitates communication among clinicians (Fig. 57.1).

The physical examination is important, even in intoxicated or head injured patients; in addition to external signs of trauma, the patient’s reported pain, particularly whether this is increasing or decreasing with time, is paramount. In the intubated patient with a depressed mental status, specific signs of injury such as ecchymosis, abdominal distention, and crepitus are critical to recognize. Similar to the ED, there are clear indications in the ICU for surgeon evaluation for possible laparotomy (Table 57.1).

Some patients will require imaging after ICU admission; patients with emergent operative indications may arrive in the ICU without any computed tomography (CT) scans. These patients, once hemodynamically stable, should undergo CT scanning to delineate additional injuries. Even in patients who undergo exploratory laparotomy, CT of the abdomen may be necessary to diagnose spine fractures and to evaluate the retroperitoneum. Routine postadmission studies include repeat chest radiograph and laboratory studies. A chest radiograph is important to determine central line catheter, tube thoracostomy, nasogastric tube, and endotracheal tube positions, as any of these could become dislodged with transport. The chest radiograph may also show interval change in a patient’s hemotorax, pneumotorax, or pulmonary contusion. Based upon physical findings in the tertiary survey, further imaging of extremities may also be indicated.

Once the patient has been fully evaluated by the treating ICU physicians and associated imaging and laboratory results obtained, the therapeutic plan is initiated to optimize the patient’s cardiopulmonary, metabolic, and coagulation status. In addition to the patient’s resuscitation, there is concurrent treatment of known injuries, ongoing evaluation for missed injuries, and monitoring for the sequelae of recognized injuries.

POSTINJURY RESUSCITATION

ICU management of the trauma patient, either with direct admission from the ED or following emergent operation, is considered in distinct phases with differing priorities. The period of acute resuscitation, typically lasting for the first 12 to 24 hours following injury, combines several principles: optimizing tissue perfusion, ensuring normothermia, and restoring coagulation. There are a multitude of management algorithms aimed at accomplishing these goals—most involve resuscitation with initial volume loading to attain adequate preload, followed by judicious use of inotropic agents or vasopressors (4). Although resuscitation endpoints continue to be debated, most agree that normalizing serum lactate or arterial base deficit within the first 24 hours is a reasonable target. Although the optimal hemoglobin (Hb) level remains debated, during shock resuscitation an Hb over 10 g/dL optimizes oxygen delivery and enhances hemostasis via platelet marginalization (4). A more judicious transfusion trigger of Hb below 7 g/dL in the euclidean patient after the first 24 hours of resuscitation limits...
Massive transfusion protocols, often initiated in the ED, may be continued in the ICU. Trauma-induced coagulopathy is now well recognized, and underscores the importance of preemptive blood component administration (12). The resurgent interest in viscoelastic hemostatic assays (TEG, ROTEM) has facilitated the appropriate and timely use of clotting adjuncts including the prompt recognition of fibrinolysis. The traditional thresholds for blood component replacement in the patient manifesting a coagulopathy have been INR over 1.5, PTT more than 1.5 normal, platelet count above 50,000/μL, and fibrinogen over 100 mg/dL. However, these guidelines have been replaced by TEG or ROTEM criteria in many trauma centers (Table 57.2). Such guidelines are designed to limit the transfusion of immunologically active blood components and adverse inflammatory effects and improves mortality (5,6). The resuscitation of the severely injured patient may require an inordinate amount of crystalloid. In fact, this is a challenging aspect of early care—balancing cardiac performance versus promoting an abdominal compartment syndrome (ACS) via tissue edema. Serial base deficit and lactate measurements are helpful; a persistent base deficit of more than 8 mmol/L or lactate over 5 implies ongoing cellular shock (7,8). Evolving technology, such as transesophageal echocardiography may facilitate resuscitation in the patient with cardiac dysfunction (9). During this initial treatment period, a low urine output is usually suggestive of hypovolemia and is not an indication for diuretics. Moreover, the use of diuretics during a patient’s initial ICU course should be carefully considered, even if the patient is chronically on such medications. In patients with a challenging resuscitation requiring multiple pressors, one should evaluate for adrenal insufficiency (10,11).
decrease the risk of transfusion-associated lung injury and multiple organ failure (12).

Adequate resuscitation is mandatory, and often determines when the surgeon can safely return the patient to the operating room (OR) after initial operative intervention. Specific goals of resuscitation include a core temperature higher than 35°C, base deficit less than –6, and normal coagulation indices. Hyperchloremia associated with normal saline administration and exogenous bicarbonate, occasionally given if the serum pH is below 7.2 to improve cardiovascular function and response to vasoactive agents, obfuscates the acid–base balance and lactate in general is considered a more reliable indicator of adequate tissue perfusion. Although correction of base deficit and lactate values is desirable, how quickly this should be accomplished requires careful consideration. Adverse sequelae of aggressive crystalloid resuscitation include increased intracranial pressure, worsening pulmonary edema, and intra-abdominal visceral and retroperitoneal edema resulting in secondary ACS as well as extremity compartment syndrome (13,14). Therefore, it should be the overall trend of the resuscitation rather than a rapid reduction of the base deficit that is the goal.

NONOPERATIVE MANAGEMENT OF TRAUMA

Blunt Liver and Spleen Injuries

The liver and spleen are the most commonly injured solid organs, occurring in 10% to 15% of all trauma patients (Fig. 57.2). The liver’s large size makes it the most susceptible organ injured in blunt trauma, and it is frequently involved in upper torso penetrating trauma. Blunt trauma to the left upper quadrant, often with associated rib fractures, should raise the concern for a splenic injury. Although the liver is more frequently injured, recurrent bleeding from splenic injuries is more common. Nonoperative management of solid-organ injuries is pursued in hemodynamically stable patients who do not have overt peritonitis or other indications for laparotomy (15–25). The clinician should consider the following elements when reviewing the CT scan: the American Association for the Surgery of Trauma (AAST) grade of injury (Table 57.3), the amount of free fluid within the abdomen, the presence of contrast extravasation indicating ongoing arterial bleeding, and
evidence of pseudoaneurysms (Fig. 57.3). High-grade injuries, a large amount of hemoperitoneum, contrast extravasation, and pseudoaneurysms are not absolute contraindications for nonoperative management; however, these patients are at high risk for failure and are more likely to need angioembolization (26–29). There is no age limit for consideration of nonoperative management for solid-organ injuries, but elderly patients do not tolerate secondary bleeding as well (30–32).

The AAST developed a grading scale to provide a uniform definition of solid-organ injuries based upon the magnitude of anatomic disruption (33–35). The grading of solid-organ injuries permits accurate relay of information between care providers, a predictive value on the incidence of nonoperative failure, and information for appropriate monitoring (Table 57.4). Most patients with liver or spleen injuries, regardless of grade, can be managed nonoperatively (16,23). A multidisciplinary approach including angiography with selective angioembolization and endoscopic retrograde cholangiopancreatography (ERCP) with stenting has resulted in higher rates of successful nonoperative management and improved survival in liver (26,27,36) and splenic injuries (28,29,37–40). Splenic angioembolization has been employed as an adjunct to nonoperative therapy, with reported salvage rates of 98% (40). Patients with contrast extravasation who are hemodynamically stable should likely undergo splenic embolization (28,29,38,39). Additionally, patients with splenic artery pseudoaneurysms or arteriovenous (AV) fistulae within the spleen are also candidates (41). If a patient is going to fail nonoperative management (Fig. 57.4), the time to failure is different for liver versus spleen injuries. Typically liver injuries rebleed within the first hours of admission, while splenic lacerations may have delayed rupture or bleeding weeks following the original injury. With high failure rates reported for grade V splenic injuries, empiric immunization for encapsulated organisms should be considered but may not be mandatory (42). Similarly, patients who undergo angioembolization of the spleen should also receive immunizations. Repeat imaging within 7 days is performed for high-grade injuries (43); hepatic injuries can be evaluated with ultrasound while splenic injuries undergo CT scanning. Patients with liver trauma and evidence of right upper quadrant fluid collections on ultrasound or clinical deterioration (increasing abdominal pain, worsening liver function tests, unexplained fever) should undergo CT scanning.

### Table 57.3 American Association for the Surgery of Trauma Solid-Organ Injury Grading Scales

<table>
<thead>
<tr>
<th>Grade</th>
<th>Liver Injury</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>&lt;10% surface area</td>
</tr>
<tr>
<td>II</td>
<td>10–50% surface area</td>
</tr>
<tr>
<td>III</td>
<td>&gt;50% or &gt;10 cm</td>
</tr>
<tr>
<td>IV</td>
<td>25–75% of a hepatic lobe</td>
</tr>
<tr>
<td>V</td>
<td>&gt;75% of a hepatic lobe</td>
</tr>
<tr>
<td>VI</td>
<td>Hepatic avulsion</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grade</th>
<th>Spleen Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>&lt;10% surface area</td>
</tr>
<tr>
<td>II</td>
<td>10–50% surface area</td>
</tr>
<tr>
<td>III</td>
<td>&gt;50% surface area</td>
</tr>
<tr>
<td>IV</td>
<td>&gt;25% devascularization</td>
</tr>
<tr>
<td>V</td>
<td>Shattered spleen</td>
</tr>
</tbody>
</table>

### Table 57.4 Appropriate Monitoring and Nonoperative Management Failure Rates for Solid-Organ Injuries by Grade

<table>
<thead>
<tr>
<th>Grade of Injury</th>
<th>Admission Monitoring</th>
</tr>
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<tbody>
<tr>
<td>I</td>
<td>Floor Exam/Hct every 12 hrs</td>
</tr>
<tr>
<td>II</td>
<td>Floor Exam/Hct every 12 hrs x 4</td>
</tr>
<tr>
<td>III</td>
<td>ICU Exam/Hct every 8 hrs x 6</td>
</tr>
<tr>
<td>IV</td>
<td>ICU Exam/Hct every 4 hrs x 6</td>
</tr>
<tr>
<td>V</td>
<td>ICU Exam/Hct every 4 hrs x 8</td>
</tr>
</tbody>
</table>

Hct, hematocrit; ICU, intensive care unit.

**FIGURE 57.3** Contrast blush noted on CT scan imaging of the liver (A) suggestive of active arterial bleeding; postinjury pseudoaneurysms of the spleen are likewise demonstrated with contrasted CT imaging (B).
Pancreatic Injuries
Historically, injuries to the pancreas were managed with operative intervention (44). With the recent evolution of nonoperative management for solid-organ injuries, a nonresectional management schema has been developed for most pancreatic injuries (45,46). Observation of pancreatic contusions, particularly those in the head of the pancreas that may involve ductal disruption, includes serial examinations and monitoring of serum amylase. Patients with pancreatic injuries involving the major ducts, originally a strict indication for operative intervention, may be managed with ERCP and stenting in selected patients; durability of this approach is currently under investigation (47).

Duodenal Hematomas
Following blunt trauma, patients may develop hematomas in the duodenal wall that obstruct the lumen. Clinical examination findings include epigastric pain associated with either emesis or high nasogastric tube (NGT) output; CT scan imaging with oral contrast failing to pass into the proximal jejunum is diagnostic (Fig. 57.5). Patients with suspected associated perforation, suggested by clinical deterioration or imaging with retroperitoneal free air or contrast extravasation, should be explored operatively. Nonoperative management includes continuous NGT decompression and nutritional support with total parenteral nutrition (TPN) (48,49). A marked drop in NGT output heralds resolution of the hematoma, which typically occurs within 2 weeks. Repeat imaging to document these clinical findings may be helpful before initiating an oral diet. If the patient does not improve clinically or radiographically within 2 to 3 weeks, operative evaluation is warranted.

Penetrating Wounds
Patients with abdominal gunshot wounds (GSWs) violating the peritoneum usually undergo emergent laparotomy due to an approximate 90% visceral injury rate. Selected patients with isolated low-energy GSWs to the right upper quadrant are observed (50); CT scan imaging must delineate the tract of the bullet, which should be confined to the parenchyma of the liver, and the patient must be hemodynamically stable with a benign clinical examination. Recently, several trauma centers have extended this policy to all abdominal GSWs without CT evidence of a hollow visceral injury (51,52). Patients with abdominal stab wounds to the back or flank with negative CT imaging or an isolated kidney injury are also managed nonoperatively (53). Similar to patients with right upper quadrant GSWs, individuals with stab wounds and a CT scan showing the tract of injury confined to the liver are usually observed (53). In some cases, laparoscopy will be done to assess the penetrating liver injury and ensure that hollow viscera are not violated. Regardless of the trauma surgeon’s decision for operative versus nonoperative management, it is essential that these patients undergo repeated abdominal examination. Observation for a missed bowel injury is critical; clinical findings in such patients include a rising white blood cell (WBC) count, fever, tachycardia, and increasing abdominal pain or diffuse abdominal tenderness. In patients with isolated liver injuries, complications are similar to those for patients with blunt injuries, namely, bleeding, bile leaks, or biliary sepsis.

COMPLICATIONS OF NONOPERATIVE INJURY MANAGEMENT
Following hepatic injuries, the most common complication is a bile leak or biloma, occurring in up to 20% of patients with major injuries (grade III or higher) (Fig. 57.6) (54,55). Clinical presentation includes abdominal distention, intolerance of enteral feeds, and elevated liver functions tests. CT scanning effectively diagnoses the underlying problem, and the vast majority is treated with percutaneous drainage and ERCP with sphincterotomy. Occasionally, laparoscopy or laparotomy with drainage of biliary ascites is indicated, particularly if the patient fails to resolve their ileus and fever (56). Hemobilia, manifested by the triad of right upper quadrant pain, jaundice, and upper gastrointestinal bleeding, is a rare complication indicative of a communication between a tributary of the hepatic artery and biliary system. Delayed rupture of a subcapsular hematoma with hemorrhage is another infrequent complication but the diagnosis is usually obvious. Patients undergoing angioembolization for liver trauma must be carefully monitored for hepatic necrosis, and
Duodenal hematomas are diagnosed radiographically by direct identification of a hematoma (A) or failure to pass oral contrast past the third portion of the duodenum on computed tomography scan (B) or upper gastrointestinal series (C).

may occasionally require delayed formal hepatic resection (Fig. 57.7).

The most common problem in patients with splenic injuries is delayed bleeding. Patients undergoing splenic embolization can experience rebleeding, with up to 15% of patients requiring splenectomy (57). Moreover, those undergoing successful angioembolization typically have significant ischemic pain, and some may develop splenic abscesses. In centers that advocate splenic autotransplantation to prevent overwhelming postsplenectomy sepsis (OPSS), recognition of CT scan findings of normal splenic implants versus infected splenic implants is critical in patients with clinical deterioration (58) (see Fig. 57.7).

ONGOING EVALUATION FOR INJURIES: HOW TO AVOID A MISSED INJURY

With the paradigm shift from operative to nonoperative management of trauma, the clinician must have a heightened sense of awareness to identify an occult injury.

Missed bowel injuries are the most commonly pursued injury, not due to their frequency (<5% of blunt trauma) but rather their associated morbidity. Diagnosing a hollow viscus injury is notoriously difficult (59), and even short delays in
FIGURE 57.6 Bilomas are the most common complication following hepatic trauma (A), while angioembolization for unremitting postinjury liver hemorrhage may result in partial hepatic necrosis (B).

FIGURE 57.7 A: Splenic implants are autotransplanted into the greater omentum to prevent overwhelming postsplenectomy sepsis. Follow-up computed tomography can differentiate between "normal" implants (B) and infected implants (C).
Section 6

The Surgical Patient

diagnoses result in increased morbidity (60,61). CT scan imaging is not 100% accurate; repeat CT scan imaging, diagnostic peritoneal lavage (DPL), ultrasound, and even laparotomy may be necessary for definitive evaluation. If a patient’s initial CT scan of the abdomen shows free fluid without evidence of a solid-organ injury to explain such fluid, patients are monitored closely for evolving signs of peritonitis suggestive of a bowel injury (62–64). If patients have a significant closed head injury or cannot be examined serially, DPL should be performed to exclude bowel injury. DPL should also be considered in a patient if there is increasing intra-abdominal fluid on bedside ultrasound in patients with a solid-organ injury but a stable hemoglobin, and/or in patients with unexplained clinical deterioration. When pursuing a diagnosis of bowel injury using DPL, particular attention should be paid to elevations in bilirubin, alkaline phosphatase, and amylase (65,66) (Table 57.5). The specific type of injury may be either bowel perforation due to ischemia from an avulsed mesentery, a direct antimesenteric blowout injury, or an extensive serosal injury (Fig. 57.8). One should not assume that drugs, alcohol, or their associated withdrawal syndromes are the primary source of a patient’s clinical deterioration.

Missing a rectal injury may be life threatening in patients with pelvic fractures. Although some patients have clear findings on physical examination, ranging from hematochezia to overt degloving of the perineum, others may have smaller injuries that are missed on initial evaluation in the trauma bay. In fact, the rectal examination may have been omitted in the trauma bay, so the intensivist should ensure that this has been done. Flexible sigmoidoscopy is the easiest diagnostic procedure for the clinician to perform at the bedside in the ICU; endoscopic evaluation should search for blood within the canal, ischemic mucosa, as well as intestinal perforation (67).

Pancreatic contusions, with or without associated ductal disruption, are difficult to diagnose in patients with blunt

TABLE 57.5 A Positive Diagnostic Peritoneal Lavage Following Blunt Trauma Defined by Specific Laboratory Values

<table>
<thead>
<tr>
<th>Laboratory Study</th>
<th>Positive Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>White blood cell</td>
<td>&gt;500 cells/μL</td>
</tr>
<tr>
<td>Red blood cell</td>
<td>&gt;100,000 cells/μL</td>
</tr>
<tr>
<td>Amylase</td>
<td>&gt;19 IU/L</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>&gt;2 IU/L</td>
</tr>
<tr>
<td>Bilirubin</td>
<td>&gt;0.1 mg/dL</td>
</tr>
</tbody>
</table>

FIGURE 57.8 Bowel injuries following blunt trauma include perforation due to ischemia from an avulsed mesentery (A), a direct antimesenteric blowout injury (B), and a blunt serosal injury (C).
abdominal trauma (68). Patients at risk include those with high-energy mechanisms suggested by a seatbelt sign on physical examination, or a direct blow to the epigastrium (69). The initial CT scan may show nonspecific stranding of the pancreas. Associated fluid around the pancreas should prompt further studies such as ERCP or magnetic resonance cholangiopancreatography (MRCP) to rule out a biliary or pancreatic duct injury. With a tentative diagnosis of a pancreatic contusion, one may consider following serial determinations of amylase/lipase; although these laboratory studies do not have a reliable sensitivity (70), increasing values over time combined with an alteration in clinical examination should prompt a repeat CT scan, a duodenal C-loop study, a DPL, or an ERCP depending upon the suspected lesion.

**POSTOPERATIVE MANAGEMENT OF SPECIFIC INJURIES**

In addition to resuscitation of the trauma patient, ICU care includes management of injuries found at operative exploration. Communication between the operating surgeon and the intensivist is critical, and should include intraoperative findings and procedures, any tenuous operative repairs, anticipated problems or complications, the need for repeat operative exploration, and location of drains. The intraoperative estimated blood loss (EBL) and associated blood product transfusion requirements are essential data to anticipate events in the postoperative period. The transfusion information should include whether a massive transfusion protocol was initiated, or if evidence of clinical coagulopathy was identified during operative treatment. Finally, all clinicians caring for the patient should remember that injuries can be missed even with prior operative intervention.

**Liver and Spleen Injuries**

Although the majority of patients with solid-organ injuries are successfully managed nonoperatively, hemodynamically unstable patients or those with associated injuries may require urgent operation. Life-threatening hepatic bleeding is most often controlled with perihpatic packing or sometimes with additional Foley catheter tamponade of deep lacerations (Fig. 57.9). The most immediate concern in the postoperative period is rebleeding; this is heralded by a falling hemoglobin, blood or blood clots accumulating under a temporary abdominal closure dressing, and bloody output from intra-abdominal drains. Substantial hemorrhage is reflected in hemodynamic instability and continued acidosis. Patients with recurrent hemorrhage may be treated with angioembolization or may necessitate repeat operative packing depending on the rate of bleeding (27). Postoperative hepatic ischemia is usually due to either a prolonged intraoperative Pringle maneuver or hepatic artery ligation or embolization; patients with the former should have an elevation but subsequent resolution of their transaminases while those with the latter may have frank hepatic necrosis. Patients are returned to the OR for pack removal 24 to 48 hours after initial injury. Other long-term sources of morbidity are similar to patients undergoing nonoperative management, and include intra-abdominal abscess, biloma, and hemobilia. Although patients should be evaluated for infectious complications, patients with severe liver trauma (grade IV or V) have intermittent “liver fever” for the first 5 postinjury days (71).

Operative intervention for splenic injuries includes splenectomy and splenorrhaphy. Postoperative hemorrhage may be due to the inadequate splenic hilar ligation, a missed short gastric artery, or recurrent bleeding from the spleen if splenic repair was attempted. An early postsplenectomy increase in platelets and WBCs is normal; however, beyond postoperative day 5 a WBC count above 15,000 should prompt a thorough search for underlying infection (72). The role of antplatelet therapy for thrombocytosis remains controversial; data are lacking on whether aspirin therapy yields a significant outcome benefit, and for which patient population. Therapy may be instituted when the platelet count exceeds 1,000,000/µL, if not contraindicated (e.g., cerebral trauma) due to evidence of platelet hyperactivity of more than 48 hours (73). Additional sources of morbidity include a concurrent but unrecognized iatrogenic injury to the pancreatic tail during splenectomy resulting in pancreatic ascites or fistula. Patients have an increased incidence of intra-abdominal abscesses in the left upper quadrant following splenectomy with concomitant gastrointestinal injury, but presumptive drainage does not prevent this complication. Routine care following splenectomy also includes immunizations for encapsulated organisms (Streptococcus pneumoniae, Haemophilus influenzae, and Meningococcus) usually just prior to discharge, optimally 2 to 3 weeks after splenectomy (74).

**Gastrointestinal Injuries**

Operative intervention for either penetrating or blunt gastrointestinal injuries entails primary repair, resection with primary anastomosis, or resection with a stoma diversion. Regardless of the type of operation or the type of anastomosis (stapled vs. sewn) (75), one should await resolution of the patient’s expected postoperative ileus before feeding. Return of bowel function is noted by a decrease in gastrostomy or NGT output and the passing of flatus. If an ileostomy or colostomy was required, one should inspect it daily to ensure it is pink without evidence of necrosis. Postoperative complications include anastomotic leak, prolonged ileus, and bowel obstruction. A leak with intra-abdominal contamination or sepsis presents with increasing abdominal pain, fevers, and respiratory compromise in the extubated patient, or persistent fevers and intolerance of enteral feeding in the intubated patient. CT scan is diagnostic and repeat operation is often required.

Important questions for the intensivist following operative intervention for pancreatic injuries include how much of the pancreas was resected, is there a pancreaticoenteric Anastomosis, was the pancreatic stump closed securely, was the spleen preserved, and where were drains placed (76). Closed suction drains should remain in place until the patient is tolerating an oral diet or enteral nutrition, with the associated drain output being less than 30 mL/day. Postoperative complications include pancreatic fistula, pseudocyst, abscess, pancreaticoenteric leak, and pancreatitis. The most common of these is a pancreatic fistula, occurring in up to 20% of patients with isolated pancreatic trauma including the major duct, and in up to 35% of patients with combined pancreatic and duodenal injuries. Diagnosis in patients with drains in place is defined as output greater than 30 mL/day with an amylase level three
times greater than serum value after postoperative day 5 (77). In patients without drains in place who have persistent abdominal pain, fevers, or intolerance of oral intake, CT scan imaging should be performed to evaluate for an intra-abdominal fluid collection. Drainage by interventional radiology (IR) is performed for fistula diagnosis and control. Pancreatic fistulae following trauma are managed in an identical fashion to those occurring following elective pancreatic resection (77).

Abdominal Vascular Injuries

Vascular injuries can produce rapid exsanguination and threaten extremities, or may be a clinically silent time bomb due to temporary retroperitoneal tamponade. Few result in a delayed diagnosis, particularly with CT scanning, and hence the focus of the intensivist is postoperative management. In general, outcome following vascular injuries is related to the technical success of the operation; the main causes of patient morbidity and mortality are associated soft tissue and nerve injuries once the vascular repair has been accomplished. Therefore, optimizing the patient’s hemodynamic status, maintaining euvolemia, and correcting coagulopathy are critical points of resuscitation. Prosthetic graft infections are rare complications (78) but preventing bacteremia is imperative; administration of perioperative antibiotics and treatment of secondary infections are indicated. Long-term arterial graft complications such as stenosis or pseudoaneurysms are uncommon, and routine graft surveillance is rarely performed. Consequently, long-term antiplatelet agents or antithrombotics are not routine.

There are specific injuries that require additional care. Abdominal aortic injuries are repaired using either a polytetrafluoroethylene (PTFE) patch or interposition graft; the patient’s systolic blood pressure should not exceed 120 mm Hg for at least the first 72 hours postoperatively. Patients requiring ligation of an inferior vena cava injury often develop
marked bilateral lower extremity edema; to limit the associated morbidity the patient’s legs should be wrapped with ACE bandages from the toes to the hips and elevated at a 45- to 60-degree angle. For superior mesenteric vein injuries, either ligation or thrombosis following venorrhaphy results in marked bowel edema; fluid resuscitation should be aggressive and abdominal pressure monitoring routine in these patients. In complex hepatic trauma, the right or left hepatic artery, or in urgent situations, the portal vein may be selectively ligated; persistent elevation in liver transaminases indicates secondary liver parenchymal necrosis and may necessitate delayed resection. Of note, if the right hepatic artery is ligated intraoperatively, cholecystectomy is performed concurrently.

Abdominal Wounds

In general, wounds sustained from trauma should be examined daily for progression of healing and signs of infection. Complex soft tissue wounds of the abdomen, such as degloving injuries following blunt trauma (termed Morel–Lavallée lesions), shotgun wounds, and other destructive blast injuries, can be particularly difficult to manage. Following initial debridement of devitalized tissue, wound care includes wet-to-dry dressing changes twice daily, or application of the wound vacuum-assisted closure (VAC). One should carefully watch for infection, development of necrotizing fasciitis, subcutaneous abscess, or associated undrained hematoma. Repeated operative debridements may be necessary, and early involvement of the reconstructive surgery service for possible flap coverage is advised for extensive tissue loss.

Midline laparotomy wounds are inspected 48 hours postoperatively by removing the sterile surgical dressing. If the patient develops high-grade fevers, inspection of the wound should be done sooner to exclude an early necrotizing infection. If a wound infection is identified—evidenced by erythema, pain along the wound, or purulent drainage—the wound should be widely opened by removing skin staples. After ensuring that the midline fascia is intact with digital palpation, the wound is managed with wet-to-dry dressing changes.

### DAMAGE CONTROL SURGERY

Damage control surgery (DCS) is an abbreviated operation whose goals are to control hemorrhage, limit contamination from enteric sources, and enable rapid transport to the ICU for correction of adverse physiology (79,80). There are standard indications for performing the DCS-abbreviated laparotomy in patients with unresolved metabolic failure (Table 57.6). Intraoperative techniques of DCS include perihedral packing, balloon tamponade of deep liver lacerations, segmental stapled bowel resection left in discontinuity, ligation of abdominal venous injuries, shunting of abdominal arterial injuries, and external drainage of biliary or urologic injuries.

Following DCS, the surgeon will “close” the abdomen with a temporary closure device. Options for temporary closure include Bogotá bag closure (a 3-L urology irrigation bag), 1010 Steri-Drape (3M Health Care, St. Paul, MN) and Ioban closure, and wound VAC dressing (Fig. 57.10). In most cases, the patient’s abdomen is closed with the 1010 Steri-Drape and Ioban closure after the first operation and with the VAC following additional operative explorations. The temporary abdominal closure allows egress of abdominal contents and contains the edematous bowel while providing excellent decompression. Jackson–Pratt (JP) drains are placed under the Ioban covering to control the effluent from third spacing during fluid resuscitation.

Upon transfer to the ICU, aggressive resuscitation of the patient is performed to reverse metabolic failure (81). This includes vigorous rewarming through heating the room, infusion of fluids and blood products through a warming device, and use of a warming device such as the Bair Hugger (Augustine Medical, Inc., Eden Prairie, MN). Invasive rewarming may be warranted for refractory temperatures below 34°C. Restoration of a normal cardiovascular state is attained by infusion of fluids and blood products, as well as judicious use of vasopressor agents. Finally, the patient’s coagulopathy must be reversed with appropriate blood products including fresh-frozen plasma, cryoprecipitate, and platelets now usually guided by serial TEG or ROTEM assessments. Ideally, physiologic correction should occur within 24 hours of admission to the ICU, with planned return to the OR for definitive repair by 48 hours. Planned return to the OR includes pack removal, definitive bowel repair, and placement of vascular grafts as indicated.

There are several specific management points of the patient with an open abdomen that deserve mention. Despite a widely open abdomen, patients can develop ACS (82); therefore, bladder pressures should be monitored every 4 hours, with significant increases in pressures alerting the clinician to the possible need for repeat operative intervention and abdominal decompression. Patients with an open abdomen lose between 500 and 2,500 mL/day of abdominal effluent. Appropriate volume compensation for this albumin-rich fluid remains controversial, both in the amount administered (replacement based on clinical indices vs. routine 0.5-mL replacement for every milliliter lost) as well as the type of replacement (crystalloid vs. colloid/blood products). Patients with abdominal packing in place, particularly for liver lacerations, may rebled from such injuries. In these situations, the patient may begin to exsanguinate from the abdomen through the JP drains placed under the Ioban covering. Rapid blood product resuscitation may provide enough intra-abdominal pressure and subsequent tamponade to stabilize the patient for reoperation. Alternatively, bedside laparotomy with repacking of the liver is an option.

Following physiologic restoration, a systematic approach to abdominal closure must be initiated; this aggressive process may include direct peritoneal resuscitation (83), early institution of enteral nutrition (84), careful diuresis, and sequential closure techniques (85).

| TABLE 57.6 Intraoperative Indications to Perform Damage Control Surgery |
|-----------------------------|-----------------------------|
| **Factor**     | **Level**                      |
| Body temperature    | Temperature <35°C            |
| Acid-base status    | pH <7.2                      |
| Base deficit (BD)  | BD < -15 mmol/L in patient <55 yrs |
|                    | BD < -8 mmol/L in patient >55 yrs |
| Serum lactate      | Lactate >5 mmol/L            |
| Coagulopathy       | PT or PTT >50% of normal     |

**Table Notes:**
- PT: prothrombin time; PTT: partial thromboplastin time; BD: base deficit.
FIGURE 57.10 Methods of temporary abdominal closure following damage control surgery or operative decompression for abdominal compartment syndrome: Bogotá bag closure (A), 1010 Steri-Drape and ioban closure (B), and vacuum-assisted closure dressing (C).

ABDOMINAL COMPARTMENT SYNDROME

The ACS represents intra-abdominal hypertension due to either intra-abdominal injury (primary) or following massive resuscitation (secondary) (14,86–88). The large volumes of crystalloid required to manage multiply injured patients results in resuscitation-associated bowel edema, retroperitoneal edema, or large quantities of ascitic fluid. A diagnosis of intra-abdominal hypertension cannot be definitively made by physical examination, but is obtained by measuring bladder pressures (89). Conditions in which the bladder pressure may be unreliable include bladder rupture, external compression from pelvic packing, neurogenic bladder, and adhesive disease.

Increased abdominal pressure affects multiple organ systems (Fig. 57.11). The ACS, however, is defined by intra-abdominal hypertension (bladder pressure higher than 12 mmHg; Table 57.7) causing end-organ sequelae: decreased urine output, increased peak airway pressures, decreased preload, elevated intracranial pressure (ICP), and extremity venous obstruction (86). With morbidity and mortality rates exceeding 50% (82,90), patients at risk for the development of ACS, particularly those receiving large amounts of crystalloid and blood products during shock resuscitation, should be evaluated closely. Development of secondary ACS can be an indolent process. Some clinicians have queried aggressive intervention to prevent the development of ACS. Although perhaps counterintuitive in the acute resuscitation of patients,
early administration of vasoactive agents to reduce the volume of crystalloid administered might be a therapeutic alternative in these patients at risk for ACS. In patients with acute renal failure, with minimal to no urine output, judicious fluid administration, early use of pressors, and institution of renal replacement therapy prior to fluid overload may also be warranted.

Organ failure can occur over a wide range of recorded bladder pressures, and, thus, there is not a single measurement of bladder pressure that mandates therapeutic intervention, except >35 cm H₂O. Rather, emergent decompression is warranted in the patient with intra-abdominal hypertension and end-organ dysfunction. Mortality is directly affected by a delay in decompression, with 64% mortality in patients undergoing presumptive decompression, 70% mortality in patients with a delay in decompression, and 89% mortality in those without decompression (91). Decompression for postinjury ACS is usually performed operatively either at the bedside in the ICU if the patient is hemodynamically unstable, or in the operating room. Bedside laparotomy is easily accomplished, eliminates transport in hemodynamically compromised patients, and requires minimal equipment (scalpel, suction, cautery, and abdominal temporary closure dressings).

Patients with significant intra-abdominal fluid as the primary component of their ACS, rather than bowel or retroperitoneal edema, may be candidates for decompression via a percutaneous drain (92,93). Differentiation of those amenable to such drainage is determined by bedside ultrasound, hence obviating a trip to the OR for a critically ill patient.

DCS and the recognition of the ACS have improved patient outcomes but at the cost of an open abdomen. Over 20% of patients with a persistent open abdomen suffer complications that prolong their hospital course. Complications include intra-abdominal abscess, bile leaks, enteric fistula, and anastomotic leaks (Fig. 57.12) (94). Management includes operative or percutaneous drainage of abscesses, ERCP and drainage of bilomas, and control of fistulae and nutritional support for bowel complications. Current research is under way to develop techniques to minimize complications and reduce morbidity in patients with these devastating injuries. All clinicians caring for patients with an open abdomen should understand the potential morbidity and the importance of fascial closure to help mitigate these complications (87).

**ANCILLARY CARE ISSUES**

**Tubes and Drains**

Following operative or nonoperative management of abdominal injuries, patients may have a variety of tubes and drains. Intra-abdominal drains are typically closed suction drains such as JP or Blake drains; the amount from the drain should be quantified every 8-hour shift, and the character of the output (bilious, succus, bloody, etc.) from the drains should

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**TABLE 57.7 Abdominal Compartment Syndrome Grading System Based Upon Bladder Pressure Measurements**

<table>
<thead>
<tr>
<th>ACS Grade</th>
<th>Bladder Pressure (cm H₂O)</th>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>10–15</td>
</tr>
<tr>
<td>II</td>
<td>16–25</td>
</tr>
<tr>
<td>III</td>
<td>26–35</td>
</tr>
<tr>
<td>IV</td>
<td>&gt;35</td>
</tr>
</tbody>
</table>

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**FIGURE 57.12** Complications of the open abdomen include intra-abdominal abscess, bile leaks, enteric fistula (A), and bowel perforations (B).
be monitored daily. Although general guidelines for drain removal are less than 30 to 50 mL/day, one should consult with the surgeon prior to removal because these drains may be difficult to replace. Patients with rectal injuries may have presacral drains placed, which consist of Penrose drains exiting next to the rectum; these are passive drains, and should be covered with ABD pads for appropriate coverage. Patients with open abdomens and temporary abdominal closure will often have drains of some type; again, quantity and quality of the effluent may guide treatment options such as intravenous fluid replacement and need for return to the operating room.

Enteral access for nutrition is acquired through multiple techniques. NGTs, placed for gastric decompression, can be used for enteral nutrition once NGT output decreases. Gastrostomy tubes, either percutaneously or operatively placed, exit the abdominal cavity in the left upper quadrant. These should be placed to gravity for 12 to 24 hours after initial insertion. Dobhoff tubes provide postpyloric access for nutrition, and can be advantageous in patients who have a gastric ileus. Jejunal feeding tubes are usually placed operatively; surgeons may choose to use needle catheter jejunostomy (NCJ) tubes or red rubber catheters. The primary issues with jejunal feeding tubes are those encountered with NCJs. Due to the small caliber of the feeding tube, there is the propensity for clogging. The NCJ should be flushed every 6 hours with saline, and only NCJ compatible enteral formulas should be used. Additionally, no medications should be placed down the NCJ. Nasojunal tubes, often called nasobiliary feeding tubes, may be placed in the ICU using upper endoscopy for prolonged gastric ileus.

Nutrition

Although the topic of nutrition could encompass an entire textbook, a few issues warrant mention (95). Multiple studies have illustrated the importance of early total enteral nutrition (TEN) in the trauma population, particularly its impact in reducing septic complications (96–99). The route of enteral feedings, stomach versus small bowel, tends to be less important as gut tolerance appears equivalent unless there is upper gastrointestinal pathology (100,101). Although early enteral nutrition is the goal, one should be cognizant of any bowel anastomoses; typically, evidence of bowel function should be present before advancing to goal tube feeds. Overzealous jejunal feeding can lead to small bowel necrosis, a devastating complication (102). Patients undergoing monitoring for nonoperative management of solid-organ injuries should remain NPO in the first 24 to 48 hours in case they require an operation. There is some residual concern about starting TEN in patients with an open abdomen. A recent multicenter trial demonstrated TEN in the postinjury open abdomen is both feasible and advantageous (84); TEN was associated with higher fascial closure rates, decreased complications, and decreased mortality. Once resuscitation is complete, initiation of TEN, even at trophic levels (15 mL/hr), should be considered in all injured patients with an open abdomen unless the bowel remains in discontinuity.

Prophylaxis

A critical component of the ICU care of the multiply injured patient includes prevention of deep venous thrombosis (DVT) and stress gastritis. Administration of heparinoids for the prevention of DVT following trauma or surgical intervention is the current standard of care (103), although the addition of antiplatelet agents appears justified in high-risk patients (73). Issues following abdominal trauma include timing of such administration in patients with either active bleeding from traumatic injury or those with solid-organ injuries. Typically, heparin products are held until patients have resolved their hemorrhagic diathesis or until 24 hours after their hemoglobin has stabilized. Carafate is the current drug of choice for the prevention of stress gastritis (104,105) until enteral feeding is established. In patients who have had specific gastric surgery, H2 blockers may be used as an alternative.

Key Points

- Systematic management of the multiply injured patient consists of the primary survey, resuscitation, the secondary survey, and definitive care.
- Although some patients may arrive in the ICU in extremis necessitating immediate resuscitation without a thorough history and physical examination, the majority should undergo a complete assessment promptly; it should not be assumed that the evaluation in the ED was comprehensive.
- There are clear indications in the ICU for surgeon evaluation for possible laparotomy: progressive decline in hemoglobin, unexplained leukocytosis and fever, diffuse abdominal tenderness, hypotension and associated abdominal distension or free fluid on bedside ultrasound, CT scan with evidence of free air or gastrointestinal contrast extravasation, CT scan with free fluid without associated solid-organ injury, and intra-abdominal hypertension.
- Even in patients who undergo exploratory laparotomy, CT of the abdomen may be necessary to diagnose spine fractures and to evaluate the retroperitoneum.
- Trauma-induced coagulopathy is now well recognized, and underscores the importance of preemptive blood component administration; the resurgent interest in viscoelastic hemostatic assays (TEG, ROTEM) has facilitated the appropriate and timely use of clotting adjuncts including the prompt recognition of fibrinolysis.
- Adequate resuscitation is mandatory, and often determines when the surgeon can safely return the patient to the OR after initial operative intervention. Specific goals of resuscitation include a core temperature >35°C, base deficit less negative than 6, and normal coagulation indices.
- Nonoperative management of solid-organ injuries is pursued in hemodynamically stable patients who do not have overt peritonitis or other indications for laparotomy. The clinician should consider the following elements when reviewing the CT scan: the AAST grade of injury, the amount of free fluid within the abdomen, the presence of contrast extravasation indicating ongoing arterial bleeding, and evidence of pseudoneurosms.
- Following hepatic injuries, the most common complication is a biliary leak or biloma, occurring in up to 20% of patients with major injuries (grade III or higher). The most common problem in patients with splenic injuries is delayed bleeding.
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