Objectives

- Prioritize and initiate a timely assessment of the traumatized patient.
- Initiate treatment of life-threatening traumatic injury.
- Utilize radiography in identifying significant traumatic injury.
- Identify and respond to significant changes in the patient’s status after traumatic injury.
- Initiate early burn management.
- Review indications for initiating surgical consultation and/or transferring the patient to a higher level of care.

Case Study

A middle-aged man has been brought to the emergency department after his car collided with a large truck. He was not wearing a seat belt and was ejected. He is making incoherent sounds and is unable to clear his oral secretions. He has an open femur fracture with hemorrhage, and contusions are present over the left chest wall and upper quadrant of the abdomen. Vital signs include a blood pressure of 90/60 mm Hg, pulse rate of 125 beats/min, and respiratory rate of 35 breaths/min.

The patient is lethargic but moves all extremities voluntarily. His skin is cool and clammy.

- What does the primary survey indicate?
- What are the most urgent initial interventions?
I. INTRODUCTION

It is not the intention of the FCCS program to replace the Advanced Trauma Life Support (ATLS) course provided by the American College of Surgeons. The material presented here is intended to highlight evaluation and treatment issues for the provider confronted with a deteriorating patient in the setting of injury. Care providers who regularly encounter patients with traumatic injuries are encouraged to enroll in an ATLS course or obtain other similar training.

A. Death Following Injury

In the United States, traumatic injuries remain the leading cause of death in individuals aged 1 to 44 years. Death due to injury occurs in one of three periods. The first period is within seconds to minutes of injury, when deaths generally result from severe brain or high spinal cord injury, loss of the airway, or rupture of the heart, aorta, or other large blood vessels. Few of these patients can be salvaged because of the severity of injury, and prevention is the only way to reduce such trauma-related deaths. The second period occurs within minutes to hours following injury; these deaths are usually due to subdural and epidural hematomas, hemopneumothorax, solid organ rupture (spleen or liver), pelvic fractures, or other injuries associated with blood loss. The “golden hour” after trauma is characterized by the need for rapid assessment and resolution of these injuries. The third period occurs days to weeks after the initial injury and is most often due to sepsis with associated multiple organ failure.

Three principles guide the approach to injury. The most important is that the greatest threat to life must be treated first. The second premise is that it is not necessary to establish a definitive diagnosis before beginning lifesaving treatment. The third is that a detailed history is not essential to begin care in the setting of acute injury.

II. TRAUMA MANAGEMENT

Early management of the seriously injured patient requires simultaneous evaluation and treatment. The first goal is to ensure adequate oxygen delivery to vital organs by following an established sequence of priorities that allows identification and treatment of injuries causing immediate threats to life (primary assessment). Patient management should begin with the rapid primary evaluation and simultaneous resuscitation of vital functions, followed by a more detailed secondary assessment (head-to-toe examination), and finally, the initiation of definitive care. This process begins with the ABCDE of trauma care, which guides the identification of life-threatening conditions through the initial assessment sequence of airway, breathing, circulation, disability, and exposure (Table 9-1).

A surgeon skilled in trauma management should be consulted early in the course of all serious trauma cases. Routing trauma patients to a center with trauma surgeons is crucial in the survival of the victims. When a surgeon is not immediately available or when the patient is awaiting transfer, evaluation (tertiary assessment) and intervention should continue.
### A. Primary Assessment: Initial Evaluation and Resuscitation

#### 1. Airway and Breathing

If the patient is able to communicate verbally, the airway is unlikely to be in immediate jeopardy; however, repeated assessment of airway patency is essential. Patients with severe head injury (Glasgow Coma Scale [GCS] score of 8 or less) usually require placement of a definitive, protective airway. Nonpurposeful motor responses support the need for immediate airway management.

The airway should first be assessed for patency. Assessment for signs of airway obstruction includes inspection for foreign bodies and facial, mandibular, or tracheal/laryngeal fractures that may result in airway obstruction. Patients can develop signs of airway obstruction after benign initial presentation. Profuse bleeding from an oropharyngeal injury may warrant a definitive airway placement.

After blunt trauma, airway control should proceed on the assumption that an unstable fracture or ligamentous injury of the cervical spine (C-spine) exists. Airway patency must be established, supplemental oxygen provided, and adequacy of ventilation ensured, as discussed in Chapter 2. If active airway intervention is needed before evaluation for possible C-spine fracture, the technique chosen for airway control (intubation, adjunctive device, or surgical airway) should take into account the expertise of available personnel, type of equipment available, patient factors, and injuries. If the patient is apneic or deteriorating rapidly, effective bag-mask ventilation can be lifesaving. Standard orotracheal intubation should be attempted with the use of in-line manual stabilization of the head and neck. Proper in-line stabilization may be accomplished from the front or the side of the patient. One care provider supports the occiput and mandible with both hands to maintain neck alignment without applying traction or distraction. With secure stabilization, the anterior portion of the cervical collar may be removed to allow airway interventions. In-line stabilization is continued until the cervical collar is replaced and the endotracheal tube or other airway device is secured. If an airway cannot otherwise be secured, a laryngeal mask airway, esophageal-tracheal double lumen airway device, or surgical cricothyrotomy is indicated.
a. Key Issues in Airway Control

Facial fractures are not an immediate priority unless heavy bleeding or uncontrollable secretions are present. Similarly, facial fractures usually do not require that the patient be intubated. Mandibular fractures, however, are more likely to be associated with soft-tissue injury that may compromise the airway. Care should be taken to avoid nasotracheal intubation in patients with suspected midface and basal skull fractures.

Further details regarding advanced airway management can be found in Chapter 2.

b. Key Injuries

While many injuries can eventually affect the ability to ventilate and oxygenate, several important injuries need to be urgently identified and managed.

Pneumothorax is frequently associated with rib fractures and can require chest tube placement. Any patient who has a pneumothorax on plain chest films and is receiving general anesthesia should have a chest tube in place. Tension pneumothorax should be evaluated and treated (Chapter 5). Open pneumothorax is generally associated with soft-tissue loss requiring dressing closure and chest-tube placement. Massive hemothorax is suggested by physical examination and chest radiograph. Immediate evacuation of more than 1500 mL of blood after placement of a chest tube or ongoing blood loss of >200 mL per hour for 2 to 4 hours is an indication for thoracotomy.

Rib fractures are often missed on a chest radiograph; however, a fracture may be suspected and documented when tenderness over the fracture is identified during physical examination. Pain control may be required to ensure adequate spontaneous ventilation. Flail chest resulting from segmental rib fractures is manifested by paradoxical movement of the involved portion of the chest wall (ie, inward movement of the segment during inhalation). Flail chest is also associated with contusion of the underlying lung, pain, and hypoxemia.

2. Circulation

Case Study

A young man arrives in the emergency department with an epigastric stab wound, but the character of the weapon is unknown. Presenting systolic blood pressure is 90 mm Hg and the patient is tachycardic. His systolic blood pressure improves (>100 mm Hg) with administration of intravenous fluids but deteriorates when bolus fluids are stopped. Extremities are cool and the patient is anxious.
– Is this patient in shock?
– What is the primary concern?
– What therapy is recommended?

The leading cause of shock in a trauma patient is hemorrhage. Initial empiric treatment in adults consists of isotonic crystalloid infusion (2 L of warmed lactated Ringer or normal saline solution) via two large-bore peripheral intravenous catheters and control of external hemorrhage by means of manual compression. Targets for empiric fluid therapy are normalization of blood pressure, reversal of tachycardia, and maintenance of adequate organ perfusion (Chapter 7). Patients with no traumatic brain injury, but extensive hemorrhage that may require operative intervention, are better managed by resuscitation with permissive hypotension to a systolic blood pressure of 90 to 100 mm Hg until operative control of the hemorrhage can be accomplished. This supports control of vessels that may have thrombosed and are not presently bleeding, but that may re-bleed if the blood pressure is normalized. When hypoperfusion and vascular compensation limit peripheral access, cannulation of a central vein (ideally with a 7F, 8.5F, or 9F introducer) is an alternative, as is intraosseous access. Concomitant diagnostic studies for the source of bleeding can include chest radiographs (hemothorax), pelvic radiograph (pelvic fracture, open-book or vertical pelvic shear injury), focused assessment sonography in trauma (FAST), or diagnostic peritoneal lavage (DPL) [intraperitoneal hemorrhage]. If the patient is hemodynamically stable, a computed tomography (CT) scan of the abdomen and pelvis may be performed to better delineate the injuries unless a definitive indication to operate is present. A hemodynamically unstable patient should not be moved for CT scanning. Immediate control of external hemorrhage should proceed simultaneously with rapid resuscitation. In trauma to an extremity, direct pressure is recommended. Blind clamping at bleeding vessels is discouraged to avoid potential injury to adjacent structures.

As shown in Table 9-2, a patient’s systolic blood pressure, heart rate, respiratory rate, and mental status can be used to assess blood loss. The American College of Surgeons also validates a decrease in pulse pressure as a sign of occult hypoperfusion. Circulating blood volume corresponds to 7% of normal body weight (70 mL/kg) in an adult and 8% to 9% of normal body weight (80-90 mL/kg) in children. Blood loss up to 1,200 mL may occur in a normotensive adult (70 kg) with minimal tachycardia. Class II hemorrhage is uncomplicated shock, but crystalloid resuscitation may be sufficient. Class III hemorrhage requires crystalloid resuscitation and often blood replacement. Class IV hemorrhage can be considered preterminal and requires aggressive measures to restore intravascular volume and red blood cell mass and to control bleeding. Treatment should be directed by the initial response to therapy rather than by a classification scheme. Patients will respond to fluid resuscitation in one of three ways. One group of patients will regain normal vital signs with small volumes of fluid. A second group of patients will initially respond to the fluid resuscitation, but then demonstrate signs of hemodynamic deterioration with time or a decrease in the fluid resuscitation; they
will require additional fluids and focused evaluation of the etiology and treatment of the injuries. This transient response is suggestive of ongoing hemorrhage. The third group of patients will not show signs of physiologic improvement despite volume resuscitation; these patients often need immediate operative intervention. They likely have ongoing major hemorrhage. Without rapid and aggressive intervention, their mortality will be high.

### Table 9-2 Hemorrhage Classification

<table>
<thead>
<tr>
<th>Shock Class</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood loss (mL)</td>
<td>Up to 750</td>
<td>750-1500</td>
<td>1500-2000</td>
<td>&gt;2000</td>
</tr>
<tr>
<td>Blood loss (% blood volume)</td>
<td>Up to 15%</td>
<td>15%-30%</td>
<td>30%-40%</td>
<td>&gt;40%</td>
</tr>
<tr>
<td>Pulse (beats/min)</td>
<td>&lt;100</td>
<td>100-120</td>
<td>120-140</td>
<td>&gt;140</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>Normal</td>
<td>Normal</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Pulse pressure</td>
<td>Normal or increased</td>
<td>Decreased</td>
<td>Decreased</td>
<td>Decreased</td>
</tr>
<tr>
<td>Respiratory rate (breaths/min)</td>
<td>14-20</td>
<td>20-30</td>
<td>30-40</td>
<td>&gt;35</td>
</tr>
<tr>
<td>Urine output (mL/h)</td>
<td>&gt;30</td>
<td>20-30</td>
<td>5-15</td>
<td>Negligible</td>
</tr>
<tr>
<td>Mental status</td>
<td>Slightly anxious</td>
<td>Mildly anxious</td>
<td>Anxious, confused</td>
<td>Confused, lethargic</td>
</tr>
<tr>
<td>Resuscitation fluid</td>
<td>Oral or crystalloid</td>
<td>Crystalloid</td>
<td>Crystalloid and blood</td>
<td>Blood and crystalloids</td>
</tr>
</tbody>
</table>

Adapted with permission from the American College of Surgeons. American College of Surgeons Committee on Trauma. Advanced Trauma Life Support for Doctors (ATLS): Student Course Manual, 9th ed. Chicago, IL: American College of Surgeons; 2012.

For 70-kg man.

When beginning resuscitation for patients in shock, isotonic crystalloid can be used. However, the volume should be controlled and minimized to no more than 1 or 2 L. If there is an inadequate physiologic response, this should be followed by the early administration of packed red blood cells (PRBCs). Fully crossmatched blood is rarely available for emergency trauma resuscitation. Uncrossmatched type-specific blood can be safely administered and is available in many hospitals within 15 to 20 minutes after a request is received. If type-specific blood is not available and the patient is unstable, O-negative PRBCs should be used. In most trauma centers, uncrossmatched blood is almost immediately available in the trauma resuscitation area for use in the unstable trauma patient.

In situations where massive transfusion is anticipated or probably likely, the early use of a balanced resuscitation using a combination of PRBCs, fresh frozen plasma, platelets, and cryoprecipitate should be strongly considered. In these situations, the most urgent priority is control of ongoing hemorrhage. Typically this involves operative intervention; however, with certain injuries—especially severe pelvic fractures with active bleeding into a

Citrate in PRBCs may chelate calcium, promoting a coagulation defect in patients receiving massive transfusion.
pelvic hematoma—other interventions, such as angiography with embolization, can be lifesaving. Many trauma centers have a massive transfusion protocol in place to allow the rapid procurement of blood products for administration in the critically injured, unstable, massively bleeding patient. Developing evidence suggests that the administration of crystalloid solutions should be minimized, especially in this population. There is also increasing evidence that the use of ratio-based blood product resuscitation (PRBCs, fresh frozen plasma, and platelets close to a 1:1:1 ratio) improves outcomes and may decrease the physiologic insult to these critically ill patients. Ratio-based resuscitation likely provides some of the same benefits as the use of fresh whole blood and may be helpful in minimizing the coagulopathy that can develop in the massively injured.

3. Disability/Exposure

Rapid neurologic evaluation is performed in the emergency department and includes determination of level of consciousness, pupillary size and reaction, lateralizing signs, and level of spinal cord injury. The GCS score is a quick, simple method for determining the level of consciousness and is predictive of outcome (particularly the best motor response). A decrease in the level of consciousness may reflect decreased cerebral perfusion or may be due to direct brain injury. Hypoglycemia, ethanol, narcotics, and other drugs may also be involved. An altered level of consciousness indicates the need for immediate reevaluation of oxygenation, ventilation, and tissue perfusion. Changes in consciousness should be assumed to be due to intracerebral conditions until proven otherwise. If the patient’s condition permits, a good exam prior to sedation and intubation is essential to determine the presence of any localizing intracranial or spinal cord injury.

Throughout the initial resuscitation period, efforts should be made to control and prevent hypothermia. Patients are often hypothermic after environmental exposure, and the body temperature may fall further after administration of room temperature resuscitation fluids and cold blood, removal of clothing for examination purposes, loss of normal temperature-regulating reflexes in shock, or the use of some medications. Hypothermia contributes to coagulation abnormalities, cardiovascular collapse, and poor outcome, and so should be avoided and treated. Warm intravenous fluids, heated respiratory gases in mechanical ventilation, warm rooms, insulating covers, and heat lamps can be used.

4. Monitoring

Improvements in parameters such as heart rate, blood pressure, pulse pressure, respiratory rate, acid-base status, body temperature, and urinary output are the best guides to adequacy of resuscitation. Evaluation begins during the initial survey and should be repeated frequently. Pulse oximetry is a valuable adjunct for monitoring hemoglobin saturation with oxygen in injured patients, but it is not useful for evaluating the adequacy of ventilation. Blood pressure, as the sole marker of resuscitation, may be a poor measure of actual tissue perfusion. Additional metabolic markers, such as serum lactate, base deficit, and pH, will assist in the determination of the adequacy of resuscitation. Perfusion of extremities may be evaluated by examining capillary refill and hematoma formation, as well as the presence of the peripheral pulses.
A urinary catheter should be inserted as soon as is practical to monitor urine output as a gauge of renal perfusion, although it must be used with caution in male patients when urethral injury is suspected (e.g., blood at the urethral meatus, scrotal hematoma, or abnormal prostate on rectal exam). In these cases, a retrograde urethrogram can be used to rapidly evaluate for urethral injury.

5. Hemorrhagic Shock

As resuscitation proceeds, it is crucial to identify potential causes of hypotension. A search for occult blood loss should be undertaken after any external hemorrhage is controlled. The most frequent sites for such blood loss are the chest, abdomen, pelvis, and the soft tissues adjacent to long bone fractures.

a. Hemothorax

A chest radiograph (ideally with the patient in upright or reverse Trendelenburg position if hemodynamically stable) is a reliable screen for intrathoracic bleeding. Ultrasonography of the chest also may reliably detect hemothorax or pericardial fluid.

Hemothorax should be drained promptly by chest tube placement, with a subsequent radiograph to verify the location of the chest tube, blood evacuation, and lung expansion. As noted earlier, rapid loss of 1500 mL of blood upon chest tube insertion or continued losses of >200 mL/h for 2 to 4 hours may necessitate thoracotomy. If available, autotransfusion devices should be attached to any chest tube drainage canister placed for massive hemothorax.

b. Intra-abdominal Hemorrhage

Abdominal examination is often misleading in the detection of acute bleeding, especially in patients with lower chest trauma, rib fractures, spinal cord injury, intoxication, or altered level of consciousness. Any patient who has sustained significant blunt torso injury from a direct blow or deceleration, or a penetrating torso injury must be considered to have an abdominal visceral or vascular injury. Focused ultrasound for trauma and DPL are the most expeditious and reliable methods of identifying significant intraperitoneal hemorrhage, although the FAST exam has largely replaced the use of DPL in most institutions. When readily available and used by trained individuals, FAST has the sensitivity, specificity, and accuracy of DPL in detecting hemoperitoneum, an injury that requires immediate surgical evaluation to determine the need for an operative intervention. In stable cases with a positive FAST result, abdominal CT scan may be appropriate to identify the source of bleeding and determine the need for any further intervention. Abdominal hemorrhage frequently comes from splenic or liver laceration, other visceral injury, or retroperitoneal hematoma. Patients with unstable or abnormal vital signs are usually not candidates for CT scanning and require surgery to control bleeding.
c. Pelvic Hemorrhage

Assessment of bony stability by means of physical examination and plain radiographs of the pelvis is crucial for early identification of major pelvic fractures. Patients with pelvic fractures (open-book or vertical shear) are at high risk for major bleeding, which is usually venous. Initial management includes vigorous blood volume replacement and, possibly, mechanical tamponade with a pelvic binder or bedsheet wrapped tightly around the pelvis to produce circumferential compression. External skeletal fixation may be helpful if the fracture anatomy is appropriate, and an orthopedic surgeon should be consulted early in the course of treatment. In patients with arterial bleeding associated with pelvic injury, CT scanning will reveal a blush of contrast. Pelvic angiography for embolization should be considered in the persistently hypotensive patient due to an increased likelihood for arterial bleeding. Angiography may be required in approximately 10% of patients with pelvic fractures. Recently, angiography has become the treatment of choice for control of bleeding from pelvic fractures and hematomas, even in the unstable patient.

d. Long Bone Fractures

Patients with long bone fractures will likely have associated hemorrhage in the surrounding injured tissue. Humerus and femur fractures may result in 1 to 3 units of blood loss, which can be problematic in the patient with multiple long bone fractures. Repeated physical examination for soft tissue swelling and changes in the diameter of the extremity will assist in the management of these patients.

e. External Hemorrhage

External hemorrhage can be very dramatic, as with a lacerated major arterial or venous blood vessel where direct pressure will decrease blood loss. Other cases, such as scalp lacerations, may go unrecognized as a possible source of significant blood loss. Rapid application of direct pressure, temporizing suture repair, or application of a tourniquet to a bleeding extremity may be lifesaving. One technique employs a blood pressure cuff inflated to a pressure higher than the patient’s systolic blood pressure. Tourniquet use should be followed by surgical consultation as the tourniquet places the extremity in jeopardy of ischemic injury. In some situations, including military conflict and intentional mass casualty events, the early control of hemorrhage along with the liberal use of tourniquets can be lifesaving and may take priority in the initial evaluation and management.

6. Nonhemorrhagic Shock

The differential diagnosis of nonhemorrhagic shock in the trauma patient includes obstructive shock (tension pneumothorax, cardiac tamponade), blunt cardiac injury, air embolism, and neurogenic shock with acute spinal cord injury. Head injury is a rare cause of hypotension, but when it occurs, it is usually a preterminal event.
a. Tension Pneumothorax

Tension pneumothorax causes hemodynamic compromise and pulmonary dysfunction due to acute compression of the lung parenchyma and a shift of the mediastinum away from the hemithorax with the increased pressure. Do not wait for a chest radiograph to make this diagnosis. Breath sounds will be diminished, lung expansion will be asynchronous, and patients may develop respiratory distress, acute desaturation, bradycardia, and occasionally, distended neck veins. Classic venous distension may be absent in the setting of pneumothorax complicated by hypovolemia. All but gross changes in breath sounds may be difficult to detect in the resuscitation room. Tracheal shift is a late sign and may not be a presenting finding. In adults, needle chest decompression is performed via the midclavicular line in the second intercostal space; this is a lifesaving intervention that is followed by placement of a chest tube.

b. Cardiac Tamponade

The classic signs of cardiac tamponade — hypotension, distant heart sounds, jugular venous distension, and pulsus paradoxus — may be obscured due to noise and hypovolemia (decreasing jugular distention). Ultrasound (FAST) is a sensitive test for fluid in the pericardial sac. Pericardiocentesis via a surgical pericardial window should be considered for the patient with refractory shock, persistent central venous hypertension, and a high-risk penetrating wound (between the nipples, above the costal margin, below the clavicles). When surgical expertise is not available, a needle/catheter pericardiocentesis may be performed as a temporizing measure. Occasionally, major blunt chest trauma ruptures the cardiac surface. Most cases involve atrial tears and can be repaired if diagnosed early.

c. Blunt Cardiac Injury

The diagnosis of blunt cardiac injury should be suspected in a patient involved in a high-speed, frontal impact accident who has unexplained hypotension or arrhythmia or, less commonly, cardiogenic shock. Changes in the electrocardiograms (ECGs) are usually nonspecific and can include premature ventricular contractions, bundle branch block, atrial fibrillation, unexplained sinus tachycardia, and ST-segment changes. If blunt cardiac injury is a possibility, a screening ECG should be obtained in the emergency department. Abnormalities other than tachycardia warrant 24 hours of monitoring for arrhythmias. Hemodynamically stable individuals with no ECG abnormalities need no further cardiac evaluation or observation. Echocardiography may be indicated in hypotensive patients to evaluate cardiac function. Use of cardiac troponins in diagnosing blunt cardiac injury is sometimes helpful. Treatment includes correction of acidosis, hypoxia, and electrolyte abnormalities; judicious administration of fluid; and pharmacologic treatment of life-threatening arrhythmias.
Inotropes may be indicated to support hemodynamic function. It is important to ensure that refractory hypotension is not due to ongoing blood loss. Patients may present with acute myocardial infarction secondary to cardiac injury, or an acute myocardial infarction may have led to trauma (ie, fall, motor vehicle crash).

d. Neurogenic Shock

Neurogenic shock occurs when a cervical or high thoracic spinal cord injury (above T6 level) causes sympathectomy. It is characterized by hypotension, frequently associated with relative or absolute bradycardia. Flaccid paralysis, loss of extremity reflexes, and priapism may be associated neurologic findings. Treatment for hypotension includes volume resuscitation and vasopressors (phenylephrine or norepinephrine) if volume loading does not reverse the hypotension. Atropine or dopamine may be considered in the presence of bradycardia associated with hemodynamic instability.

B. Secondary Assessment: Diagnosis and Treatment of Other Injuries

Most patients with acute injuries can be resuscitated to a hemodynamically stable state. The primary survey should immediately identify acute life-threatening injuries. The next goal is to complete a secondary assessment to identify and treat other injuries. This assessment is crucial to allow proper triage to the operating room, radiology suite, or ICU.

1. History

Essential components of a patient’s history include details of the mechanism of injury, previous medical illness, current medications, allergies, and tetanus immunization.

2. Physical Examination

The patient should be examined from head to toe. The skull is carefully inspected to identify occult injuries. Signs of basilar skull fracture include hemotympanum, rhinorrhea, or otorrhea; Battle sign (ecchymosis of the skin over the mastoid); and raccoon eyes. Facial bones, mandible, and neck are palpated for tenderness and crepitus. The GCS score and limited neurologic examination from the initial assessment are used to evaluate for head trauma (Chapter 8). Extraocular eye movements are checked to exclude muscle or nerve entrapment. The neck is inspected for distended neck veins, the position of the trachea, or subcutaneous emphysema. Neck pain or tenderness over the cervical spine warrants additional radiographs (see later section), CT, or magnetic resonance imaging. The chest is auscultated and palpated for tenderness and crepitus. The patient is log-rolled so that the thoracic and lumbar spine can be palpated for tenderness and other injuries can be detected. In penetrating trauma, exclude occult entrance or exit wounds in the axillary, cervical, or inguinal regions. The abdomen is likewise inspected, auscultated, and palpated. The

The right ventricle is most frequently involved in blunt cardiac injury, and volume challenge is the initial therapy for hypotension in the absence of pulmonary edema.
pelvic bones are assessed for stability with lateral compression, anterior-posterior compression, and a gentle rocking motion; lack of pain with these motions in an awake patient without competing pain issues is usually sufficient to rule out significant pelvic bone fractures. The rectum is evaluated for tone and the presence or absence of blood and to ensure that the prostate gland is not displaced or difficult to palpate. The presence of perineal/scrotal hematoma and blood at the urethral meatus implies potential urogenital injury, which is a risk for urinary catheter insertion. The extremities are inspected, palpated, and evaluated for range of motion and neurovascular integrity.

3. Laboratory Studies

Minimal testing includes complete blood count, electrolyte measurements, blood glucose level, blood alcohol level, and toxicology screening. In any patient with evidence of hypovolemia, blood-group typing and a coagulation profile should be performed. Arterial blood gas measurements should be analyzed in selected patients to confirm adequate ventilation and perfusion (presence of acidosis). An elevated serum amylase level may be an indicator of pancreatic or bowel injury in the patient with blunt abdominal trauma. Creatinine phosphokinase should be checked if rhabdomyolysis is suspected. The hematocrit may not reflect the patient’s acute volume status; without ongoing resuscitation equilibration by transcapillary fluid shifts can take hours to be reflected as a decrease in hematocrit. In general, a fall of 3% in the hematocrit is equivalent to 1 unit of blood loss. Serum lactate level measurements and follow-up to monitor clearance can help management and prognosis.

4. Radiologic Evaluation

a. General

In the evaluation of blunt multiple-system trauma, a supine chest radiograph and supine view of the pelvis are obtained as the primary survey is performed. This allows for interpretation of completed radiographs as the secondary survey begins. Plain films of the pelvis are crucial for early identification of major fractures and may allow for early placement of a pelvic binder to help reduce ongoing blood loss.

b. Head

CT scanning is essential for initial evaluation of a head-injured patient or in any patient with a decreased or altered level of consciousness. Many centers will also obtain a CT scan of the cervical spine when the head scan is obtained.

c. Spine

The initial lateral C-spine radiograph has been largely abandoned for the diagnosis of cervical spine injury. Given the common issues in obtaining adequate cervical spine images, including inadequate visualization of the spine between C7 and T1 and poor definition of the occiput, most centers now obtain a CT evaluation of any areas that
cannot be clinically cleared or have concerning results on physical exam. In the patient with increased risk of C-spine injury, cervical immobilization is crucial until these studies are reviewed and correlated with a reliable physical examination for evidence of tenderness. However, patients should be removed from a rigid spine board expeditiously due to the risk of skin pressure injury with extended immobilization. Magnetic resonance imaging is helpful for disc, spinal cord, and ligament injuries. If a C-spine fracture is found, radiographic screening of the entire spine is indicated because ~10% of these patients will have a second, noncontiguous vertebral column fracture. CT scans of chest and abdomen often can be reformatted to provide information on spine injury without the need for additional plain radiographs or additional radiation exposure.

Neurologic examination alone does not exclude a C-spine injury. The following considerations apply to patients at risk for C-spine injury:

- Patients who are alert, awake, and have no changes in neurologic status or neck pain may be considered to have a stable C-spine and need no radiologic studies. Beware of injuries that could distract the patient with C-spine injury.

- Early CT scans may facilitate evaluation of the C-spine in any head-injured or intubated patient. Adding CT evaluation of the C-spine to the initial CT scan of the head is an appropriate strategy after injury.

- The presence of paraplegia or quadriplegia is presumptive evidence of spinal instability.

- Patients with neurologic deficits potentially due to a C-spine injury require spine surgery consultation.

- Exclusion of any bony injury does not eliminate the possibility of ligamentous disruption. Magnetic resonance imaging can facilitate clearance of ligamentous injury if the examination is not reliable.

d. Chest

Once the spine is cleared for fractures, an upright (or reverse Trendelenburg) chest radiograph is indicated to better define or identify pneumothorax, hemothorax, mediastinal widening or irregularity (concern for aortic transection), or fractures, as well as to confirm the position of various tubes. Chest radiographs are inadequate to rule out aortic injury when a significant lateral impact or deceleration injury exists. Suspect this lethal injury where the mediastinum is widened on chest radiographs and an appropriate mechanism is involved. CT angiography provides an excellent method to screen for aortic injury and define other thoracic injuries. Its use has largely replaced traditional angiography in the initial diagnosis of thoracic aortic injuries.
e. Abdomen

Plain abdominal radiographs are not usually helpful. In the hemodynamically stable patient, a CT scan of the abdomen and pelvis and the FAST examination are the mainstays of abdominal evaluation in a trauma patient. FAST can be followed up with a CT scan of the abdomen if free peritoneal fluid is identified in the stable patient. DPL may still be used in certain circumstances, but has generally been replaced by the CT imaging and the FAST exam.

f. Genitourinary Tract

Hematuria may be evaluated with a CT scan or other contrast studies. It provides anatomic detail about abdominal and retroperitoneal structures and any direct injury to the kidney(s). If physical examination suggests that a urethral injury is present, a urethrogram should be obtained before urinary catheterization. A cystogram may be indicated if bladder injury is suspected. Intravenous pyelograms are not commonly performed.

g. Skeletal Fractures

Films of the extremities (anterior posterior and lateral views) should be obtained on the basis of physical examination or patient complaint. Films should include the joint above and below the site of injury.

5. Other Issues

A nasogastric tube serves to decompress the stomach and may reduce the risk of pulmonary aspiration; however, it should be placed orally in patients with midfacial fractures or possible basilar skull fractures. Blood in the gastric aspirate may be the only sign of an otherwise occult injury to the stomach or duodenum, and further investigation may be indicated. Tetanus prophylaxis is routine (Table 9-3). Systemic antibiotics should usually be withheld until a specific indication is determined, but they are employed in three situations: (1) patients undergoing intracranial pressure monitoring or chest tube placement frequently receive gram-positive coverage when the device is inserted; (2) patients with penetrating abdominal trauma may be given coverage for gram-negative aerobic and anaerobic organisms for the first 24 hours after injury; and (3) patients with open fractures are given gram-positive coverage for 24 hours as orthopedic evaluation is arranged.

Remember to consult specialty services early so that they can offer input into treatment decisions.
Female patients of childbearing age should be questioned about the possibility of pregnancy or be checked with a β-human chorionic gonadotropin test before extensive radiographic evaluation is performed unless significant hemodynamic instability is present. The priority with the unstable pregnant patient always has to be maternal resuscitation and stabilization. Anyone in her second or third trimester should be positioned with a wedge under her back to elevate the right side, avoiding compression of the vena cava. This is done only after examination of the spine and pelvis does not reveal any pain or tenderness, which may indicate a fracture. Remember that the optimal care of the mother yields optimal care for the fetus. Obstetrical consultation should be considered (Chapter 14).

Another important issue is the need for adequate tetanus prophylaxis in patients with open wounds. The patient’s current vaccination status must be verified and updated if needed. In those who have an unclear immunization status or with especially contaminated tetanus-prone wounds, the use of tetanus immune globulin should be considered (Table 9-3).

**Table 9-3 Guide to Tetanus Prophylaxis in Routine Wound Management**

<table>
<thead>
<tr>
<th>History of Absorbed Tetanus Toxoid</th>
<th>Clean Minor Wounds (Not prone to tetanus)</th>
<th>All Other Wounds (Tetanus-prone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unknown or &lt;3 doses</td>
<td>Tdap or Td</td>
<td>TIG</td>
</tr>
<tr>
<td>≥3 doses</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Abbreviations: Tdap, tetanus toxoid, reduced diphtheria toxoid, acellular pertussis vaccine; Td, tetanus toxoid and reduced diphtheria toxoid — for adult use (dose = 0.5 mL); TIG, tetanus immune globulin — human (dose = 250 IU).

aPatients who have completed a three-dose primary tetanus vaccination series and have received a tetanus toxoid-containing vaccine <5 years before the injury do not require a tetanus toxoid-containing vaccine for wound management.

bChildren <7 years = Tdap is recommended; if pertussis vaccine is contraindicated, Td is given. Children 7-9 years or adults >65 years = Td is recommended. Children and adults 10-64 years = Tdap is preferred to Td if the patient has never received Tdap and has no contraindication to pertussis vaccine. For patients >7 years of age, if Tdap is not available or not indicated because of age, Td is preferred to tetanus toxoid.

cSuch as (but not limited to) wounds contaminated with dirt, feces, soil, and saliva; puncture wounds; avulsions; and wounds resulting from missiles, crushing, burns, and frostbite.

dEquine tetanus antitoxin should be used when TIG is not available.

eIf only three doses of fluid toxoid have been received, a fourth dose – preferably an adsorbed toxoid – should be given. Although licensed, fluid tetanus toxoid is rarely used.

fYes, if ≥10 years since the last tetanus toxoid-containing dose.

gYes, if ≥5 years since the last tetanus toxoid-containing dose; more frequent boosters are not needed and can accentuate side effects.
C. Tertiary Assessment: Ongoing Evaluation

Case Study

A middle-aged man sustained multiple liver lacerations in a motor vehicle crash. He also had mesenteric lacerations and bowel resection was performed. The ends of the bowel were stapled, and the abdomen was filled with packs to control venous bleeding from the liver. He continues to require fluid resuscitation and administration of blood products due to coagulopathy. Several hours after admission to the ICU, increased airway pressures and falling urine output are noted.

- What are possible causes of increased airway pressures?
- Why has the urine output fallen?

After life- and limb-threatening injuries have been addressed and metabolic derangements have been corrected, periodic systematic assessment is performed to identify occult injuries not evident at presentation.

1. Head Injury

Evaluation of the head-injured patient is an ongoing process requiring early neurosurgical consultation. Serial assessment of the GCS scores, pupil size and response, and presence or absence of lateralizing neurologic signs is crucial. Any changes in examination results are noted and acted upon as they are discovered.

Serial CT scans of the head may offer clinically useful information, but the key to patient management is detection of changes in physical examination. Continued resuscitation is imperative to avoid secondary brain injury, which typically occurs when a patient becomes hypoxic or hypotensive during acute care. These secondary insults increase the likelihood of poor outcome (Chapter 8).

2. Pulmonary Injury

Trauma patients often have a full stomach at the time of injury and experience aspiration. Aspiration of the acidic gastric contents may cause a chemical pneumonitis initially and predispose patients to an infective pneumonitis or acute respiratory distress syndrome later. Antibiotics are not indicated in initial management. Bronchoscopy may be needed for removal of large particulate matter.

Delayed onset of pneumothorax or hemothorax may follow chest trauma. Additionally, pulmonary contusions and resulting acute respiratory distress syndrome may not become obvious until later (12-48 hours). Continued assessment includes physical examination, oximetry and/or arterial
blood gas measurements, chest radiographs, and ventilatory mechanics.

3. Cardiac Injury

Continuous ECG monitoring and frequent measurements of blood pressure are mandatory in the emergency department and ICU. Continuous arterial blood pressure monitoring may be indicated (Chapter 6). Electrolyte disturbances may lead to cardiac contractile dysfunction or arrhythmias in the aggressively resuscitated trauma patient. Common electrolyte disturbances include hyperchloremia, hypokalemia and hyperkalemia, hypomagnesemia, and hypocalcemia.

4. Abdominal Injury

Substance abuse or neurologic injury may not allow reliable initial abdominal examination. Perforation of a hollow viscus in blunt trauma is sometimes difficult to diagnose. Free air under the diaphragm on an upright chest radiograph, over the liver on a left lateral decubitus radiograph, or on an abdominal CT indicates the need for operative exploration. CT scanning also provides information about the retroperitoneum. In the head-injured patient who is undergoing a head CT scan and has a nonoperative neurologic injury, abdominal scanning should be considered, as physical examination may be unreliable. However, caution must be used in the clinical interpretation of CT imaging for hollow viscus injury - a negative scan does not absolutely rule out the possibility of an occult injury.

A frequently missed condition is abdominal compartment syndrome. This condition occurs when intra-abdominal pressure increases due to intraperitoneal or retroperitoneal hemorrhage, ascitic fluid accumulation, edema secondary to massive fluid resuscitation, or intraoperative surgical closure of the abdomen under tension. Increased intra-abdominal pressure decreases cardiac output and compresses the vascular bed and kidneys. The diaphragm is displaced upward by increased intra-abdominal pressure, which results in decreased thoracic volume and compliance. Decreased volume within the pleural cavity predisposes to atelectasis, and ventilated patients with intra-abdominal hypertension require increased airway pressure to deliver a fixed tidal volume. Vascular compression can decrease blood flow to the liver and kidneys with resultant dysfunction. Finally, intra-abdominal hypertension significantly increases intracranial pressure (Chapter 13).

5. Musculoskeletal Injury

The neurologic and vascular evaluation of the extremities is an ongoing process. A swollen and tense extremity should be watched closely for the development of a compartment syndrome, particularly in patients with decreased responsiveness. In alert patients, serial physical examination is the best monitoring method. Classical signs include pain, pallor, pulselessness, paresthesia, and/or paralysis. Loss of pulse is a very late finding. The most helpful early signs are complaints of pain out of proportion to physical findings and severe pain on passive stretch of the involved muscle groups. In the unconscious patient or when the examination is unreliable, compartment pressure may be monitored using a needle with a standard gauge. Pressures >30 mm Hg warrant consideration of fasciotomy.
Musculoskeletal examination should be repeated, either as patients recover from other injuries or as their mental status clears, to identify new pain or tenderness. Plain radiographs should then be obtained to identify occult fractures. Commonly missed orthopedic injuries include fractures of the scapula, thoracic and lumbar spine, pelvis, ankle, and wrist.

Crush syndrome should be considered when patients have been trapped, injury to large muscle mass is involved, prolonged compression has occurred with protracted immobilization, or vascular compromise is present (such as tourniquet use or compartment syndrome). Crush syndrome develops when damaged myocytes lyse, releasing myoglobin, potassium, phosphorus, and calcium. Manifestations of this syndrome include cardiac dysrhythmias, renal failure, metabolic acidosis, and hypovolemia. Preemptive hydration before reperfusion of crushed muscle mass usually is accomplished before arrival at the hospital. Revascularization of ischemic extremities, fasciotomy for compartment syndrome, or release of tourniquets can mimic this situation. Before reperfusion, normal saline should be administered (1- to 2-L bolus or 10-15 mL/kg/h). Careful monitoring for cardiac signs of hyperkalemia should be instituted. After reperfusion, aggressive hydration to maintain urine output above 3 to 4 mL/kg/h helps prevent heme pigment-associated renal injury. Adjuvants such as bicarbonate and mannitol may be used.

6. Other Considerations

Resuscitation is an ongoing process. Traditional end points such as normalization of blood pressure, heart rate, and urine output may not always reflect complete correction of the shock state. The attainment of normal vital signs can occur even in the setting of tissue hypoperfusion resulting in a compensated state of shock. Lactate concentration and resolution of metabolic acidosis may provide more definitive end points for adequacy of resuscitation. Because the time to normalization of these parameters is predictive of survival, additional resuscitation in the form of volume replacement, red cell transfusion, or support with vasoactive agents may be indicated within the first 24 hours following injury despite normal or near-normal vital signs. Persistence of a metabolic acidosis or elevated lactate concentration may be an early indicator of complications, including ongoing hemorrhage or abdominal compartment syndrome.

Damage control surgery (initially limited to control of bleeding and decontamination of hollow organ ruptures with spillage) may be needed in the first 24 to 48 hours, before definitive surgery is performed. Many trauma patients benefit from delayed definitive surgery, particularly the repair of fractures, during this period of ongoing stabilization. Decisions to proceed with surgery should be made after appropriate consultation with the primary surgical service, a critical care physician, and other consultants as indicated.

In the immediate resuscitation period, periodic reassessments are important. Once a patient is stabilized, all intravenous access sites should be reassessed. Because full sterile precautions to prevent line-related infections may not be feasible during emergency vascular access, many lines will need to be replaced. If central venous access is no longer indicated, it should be discontinued.
III. BURN INJURY: INITIAL EVALUATION AND STABILIZATION

Case Study

A young man is brought in after a gasoline can exploded as he was burning brush. The patient sustained a full-thickness burn injury to both forearms and showed signs of flash-burn injury to his face. He is in no respiratory distress and has received no fluids since his injury. Although he has no abdominal burns, he complains of abdominal pain. Family members recall that the patient was thrown into a tree stump by the explosion. You are asked to see the patient in the emergency department to assist during his initial wound care.

– What are the initial evaluation priorities?
– What is the greatest risk to this patient?

A. General

Burn injuries represent a significant cause of morbidity and mortality. Deaths from burn injury occur with greatest frequency as a result of residential fires with smoke inhalation. Like other forms of injury, burns tend to be frequent in the young and the elderly. Scalds are the most common form of childhood injury, whereas electrical and chemical injuries affect adults in the workplace. Factors that affect burn mortality include size of cutaneous injury, patient age, and presence or absence of inhalation injury. Burn injuries should not distract providers from seeking other potential traumatic injuries. The initial evaluation and treatment of a serious burn injury follows the same pathway as trauma, including the primary and secondary surveys.

B. Airway/Breathing

The initial evaluation of the airway is directed, in part, by the history of the injury. Patients who are at the greatest risk of smoke inhalation injury typically have a history of being in a closed space with flame and smoke. With increased exposure time, the likelihood of injury increases. Smoke inhalation injury can be described by three mechanisms. These include particulate injury, toxic byproducts of combustion injury, and direct thermal injury. Particulates found in the soot and smoke of the fire are responsible for a reactive airway injury that may result in bronchospasm. Toxic exposure may have direct cytotoxic effect on alveolar tissue or affect energy-generating pathways, or bind hemoglobin and reduce the availability of oxygen for intracellular use. Direct thermal injury can result in oral, nasal, and upper respiratory injury with airway swelling.
Inhalation injury is generally diagnosed by a combination of clinical signs and symptoms confirmed by bronchoscopy. Clinical findings include facial burns, parched oral mucosa, nasal singeing, soot in the oral and nasal passages, and symptoms of reactive airway exacerbation. Bronchoscopic findings include mucosal edema, ulceration, sloughing, and mucous plugging. Chest radiographs are frequently normal at admission, and hypoxemia often is not appreciated.

Three stages of inhalation injury have been identified:

1. Acute hypoxia with asphyxia typically occurs at the scene of the fire.
2. Upper airway and pulmonary edema may evolve during the first hours to days after injury.
3. Infectious complications that stem from exposure to heat and chemical irritants may appear later (eg, pneumonia).

Treatment of inhalation injury is largely supportive. If exposure to carbon monoxide is suspected, 100% oxygen should be provided. Early intubation is advocated, especially if the patient will be transferred, because pulmonary and laryngeal injury may quickly evolve even though the initial airway assessment is satisfactory. Caution should be exercised in the use of succinylcholine due to the possibility of clinically significant hyperkalemia. Intravascular resuscitation should not be delayed or withheld because inhalation injury increases resuscitation fluid requirements. Humidification of inhaled gases helps in secretion control and reduces desiccation injury to the airway.

C. Circulation

Patients sustaining small burns (<20% total body surface area [TBSA]) typically will have normal vital signs. Those with larger burns (>20% TBSA) may develop burn shock. This is due to a diffuse capillary leak syndrome resulting from the release of cytokines, interleukins, and vasoactive amines and causing third spacing of fluid. The combined loss of fluid from the burned surface area and the interstitial edema may result in the loss of circulating volume. Systemic hypotension may ensue. Resuscitation following the American Burn Association recommendations (discussed later) should be followed as it permits large volumes of fluid to be administered over an extended period. Large-bore peripheral intravenous catheters should be placed (through the burn, if necessary). The preferred resuscitation fluid is lactated Ringer solution.

D. Assessment of Injury

The approach to the initial assessment is the same as in trauma. An initial primary survey (ABCDE) is performed, followed by a head-to-toe examination. All clothes must be removed to determine burn size, and the patient must be covered with blankets because heat is lost quickly. Depending upon the history, the patient may have other injuries and should be assessed for trauma in accordance with the guidelines outlined.
1. **Depth of Burns**

There are three burn depths:

1. First-degree (superficial): erythematous, painful
2. Second-degree (partial thickness): red, swollen, blistered, weeping, very painful
3. Third-degree (full thickness): white, leathery, painless

Third-degree or full-thickness injuries involve all layers of the epidermis and dermis and require surgical reconstruction. Burns that involve deep structures, such as tendon, muscle, and bone, have been called fourth-degree burns.

2. **Burn Area (Rule of Nines)**

The rule of nines is commonly used to estimate the surface area that has been burned (Figure 9-1). The head and upper extremities each represent 9% of the TBSA. The anterior and posterior trunk and the lower extremities each represent 18%, and the perineum represents 1% of the TBSA. In children, the head is proportionally larger, leading to a relative decrease in the area of other body segments. Alternatively, the patient’s hand, which equals roughly 1% of TBSA, may be used to estimate the size of a small or irregular burn. An often used tool to estimate the total body surface area in children younger than 15 years is the Lund-Browder Chart (Figure 9-2).

Figure 9-1. Rule of Nines

Most appropriate for adults and children over 15 years of age.
Burn shock presents with profound hypovolemia, which has both interstitial and intracellular components. Increased capillary permeability is one of the key components of the burn shock response. In small burns, maximal edema is seen 8 to 12 hours after injury; larger burns at 12 to 24 hours. Plasma volume loss coincides with edema formation and increased extracellular fluid. Edema is affected by fluid administration during resuscitation. Fluid and electrolytes should be replaced as dictated by organ perfusion indicators and electrolyte imbalance. Because fluid and electrolyte losses in burns are primarily insensible, fluid lost cannot be quantified adequately. Venous access should be obtained and a urinary catheter placed. The American Burn Association recommends the consensus formula of 2 to 4 mL/kg/% TBSA as an estimation of the fluid requirements in the initial 24 hours after serious burn injuries. Beginning at the low end of this range may reduce edema and extravascular complications such as abdominal compartment syndrome. The TBSA is calculated only for second- or third-degree burns. Resuscitation is carried out with Ringer lactate solution. Half of the crystalloid resuscitation should be administered in the first 8 hours, the remaining over the next 16 hours. Surrogate markers of adequate resuscitation include normalization of blood pressure, heart rate, and urine output. Appropriate urine output in adults is 0.5 to 1 mL/kg/h and 1 to 1.5 mL/kg/h in children. An arterial blood gas measurement...
to monitor the pH and base deficit and serum lactate levels are also good markers of adequate resuscitation. While appropriate resuscitation is critical to maintain physiology, care must be taken to avoid over-resuscitation as this can lead to significant increases in edema and result in progression of the burn injury.

A circumferential burn to an extremity may develop significant edema that the underlying tissue cannot accommodate due to the constrictive nature of the burn wound. Impaired limb and tissue perfusion may ensue that can only be managed by performing an escharotomy to the extremity and/or digits. In larger burns of the abdomen and chest wall, a compartment syndrome may develop whereby cardiovascular and respiratory compromise may mandate torso escharotomies or abdominal decompression. Surgical consultation should be sought immediately for any of these problems.

**F. Carbon Monoxide Exposure**

A fire in an enclosed space mandates consideration of carbon monoxide poisoning in addition to the worry for inhalation injury. The typical oxygen saturation monitor will not detect carbon monoxide and can give artificially elevated oxygen saturation levels; therefore, if carbon monoxide poisoning is suspected, an arterial blood gas with a carboxyhemoglobin level will clarify the clinical picture. High-flow 100% oxygen will reduce the half-life of carbon monoxide in the plasma and is the primary treatment. Early use of hyperbaric oxygen for patients with high carboxyhemoglobin levels (>25%) or evidence of significant neurologic or cardiovascular toxicity has been recommended, but data supporting this recommendation are limited.

**G. Burn Wound**

Local wound care begins with serial debridement of nonviable tissue and blisters by appropriate surgical consultants. Little care is required for the burn wound before transfer to the burn center or surgical consultation. If gross contamination is present, a gentle washing and coverage with clean linen may be appropriate. If the patient cannot be rapidly transferred to a burn center, it may be necessary to apply silver sulfadiazine (or appropriate antibiotic ointment) and occlusive dressings to help prevent evaporative heat loss.

**H. Other Considerations**

Placement of a nasogastric tube is indicated if the patient vomits, requires intubation, or has a burn >20% of TBSA. This may also prove beneficial to provide nutritional support for large burns, given the high nutritional requirements. Intravenous opiates should be given for pain. Rings and bracelets should be removed as they may cause constriction early in resuscitation. Burns are tetanus-prone injuries, and tetanus prophylaxis should be reviewed (Table 9-3).
I. Special Considerations

1. Chemical Burns

Chemical burns may be caused by acid (eg, cleaning products, industrial applications), alkali (eg, hydrides of sodium, potassium, and sodas of ammonia), or organic compounds (eg, petroleum products). Severity of injury relates to the agent involved, its concentration, and the duration of contact. Initial care requires removing the patient from the source of chemical injury immediately. In general, removal of clothing is essential. Dry substances should be brushed off and the area irrigated copiously with water. Do not use neutralizing agents as they may increase the severity of burn.

Contact with petroleum products (such as spilled gasoline at the scene of a motor vehicle crash) is associated with rapid skin penetration and late multiple-organ failure. Again, rapid removal of the patient from the source and vigorous irrigation of exposed surfaces are warranted. Advice regarding chemical burns is available from regional burn centers.

2. Electrical Injury

Electrical injury is a syndrome with a variety of presentations. Exposure to an electrical source <1,000 volts produces a low voltage injury similar to other cutaneous burns. When exposure exceeds 1,000 volts, a greater potential for deep as well as cutaneous injury exists.

Three types of skin injury can occur with electrocution:

1. Entrance and exit wounds, typically circumscribed, deep lesions, occur at points of contact with the electrical source or ground (usually hands and feet).
2. Cutaneous burns may be caused by arc injury from the primary site to the patient, a flash injury, or an actual flame injury if clothing catches fire.
3. Deep soft tissue injuries involve muscle, nerve, or the vascular bed as current passes through the tissue.

Beware of pneumothorax, airway compromise, cardiac arrest, and blunt injury secondary to falls and violent muscle contraction. Muscle compartment pressures may increase, necessitating fasciotomy, not just escharotomy. If myoglobin is present in the urine or creatine kinase concentrations are elevated, provide adequate intravascular fluid to increase the urine output to 3 to 4 mL/kg/h until resolution of the rhabdomyolysis. Patients may develop ileus after electrocution. The ECG should be reviewed in electrical injury.

The initial priority in the management of electrocution is removal of necrotic tissue and decompression of compromised deep tissue compartments, particularly muscle. Resuscitation is begun at 4 mL/kg/% TBSA cutaneous injury and titrated to maintain urine output of 0.5 to 1 mL/kg/h unless rhabdomyolysis is present and higher urine output is desirable. Aggressive fluid resuscitation potentiates filtering of pigment and dilution of iron (nephrotoxic). Alkalinization of the urine may be considered to decrease the nephrotoxic potential despite lack of supportive evidence. If large areas of soft-tissue injury are present, surgical consultation should be requested.
As with other burns, infection is the chief risk, but other potential problems are myocardial and vascular injury, encephalopathy, cataracts, and gut perforation.

Lightning injury may be thought of as massive exposure to direct current. Most injury is topical because exposure times are extremely brief. Mortality rates associated with lightning relate to early cardiac and respiratory arrest. Aggressive basic and advanced life support may be lifesaving for these patients.

IV. REFERRAL AND TRANSFER CONSIDERATIONS

Early involvement of surgical expertise is important in the care of the injured patient. A surgeon should be summoned as soon as it is known that a seriously injured patient is arriving. Early neurosurgical consultation is advised for patients with head injury.

General guidelines for field triage and interfacility transfer have used physiologic, anatomic, and high-risk mechanistic criteria to suggest triggers for triage and transfer. One may extrapolate that these parameters can be used to initiate involvement of a trauma surgeon as well. Some triggers are suggested in Table 9-4 and Table 9-5.

<table>
<thead>
<tr>
<th>Table 9-4 American Burn Association Criteria for Patient Transfer to a Burn Center*</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Partial-thickness burns greater than 10% of total body surface area</td>
</tr>
<tr>
<td>• Third-degree burns in any age group</td>
</tr>
<tr>
<td>• Burns involving the face, hands, feet, genitalia, perineum, or major joints</td>
</tr>
<tr>
<td>• Patients at the extremes of age or those with significant comorbid disease</td>
</tr>
<tr>
<td>• Electric burns and chemical burns</td>
</tr>
<tr>
<td>• Smoke inhalation injury</td>
</tr>
<tr>
<td>• Patients with combined trauma and significant burn injury</td>
</tr>
<tr>
<td>• Children at hospitals with no expertise in caring for pediatric burn patients</td>
</tr>
<tr>
<td>• Burns suspected to be due to child or elder abuse</td>
</tr>
<tr>
<td>• Burn patients with a delayed presentation or evidence of burn wound infection</td>
</tr>
</tbody>
</table>

*Adapted with permission from the American College of Surgeons. American College of Surgeons Committee on Trauma. Guidelines for the operation of burn centers. In: Resources for Optimal Care of the Injured Patient. Chicago, IL: American College of Surgeons; 2006:79-86.
If appropriate surgical services are unavailable, early transfer to the closest trauma or burn center should be initiated. This should not be delayed for additional radiologic studies if surgical resources are unavailable, unless those studies are requested by the accepting physician. The trauma center should be contacted for advice and to discuss potential problems or concerns with transport personnel.

Table 9-5  Indications for Field Triage and Interfacility Transfer

Physiologic Criteria
- Glasgow Coma Scale score of <13
- Systolic blood pressure <90 mm Hg
- Respiratory rate <10 breaths/min or >29 breaths/min (<20 breaths/min in infant <1 year)

Anatomic/Injury Triggers
- Penetrating injuries to head, neck, torso, and extremities proximal elbow or knee
- Chest wall instability or deformity
- Amputation proximal to the wrist or ankle
- Two or more proximal long bone fractures
- Crushed, degloved, mangled, or pulseless extremity
- Pelvic fracture
- Open or depressed skull fracture
- Paralysis

Mechanism of Injury Triggers
- Adult: falls >20 feet
- Children: falls >10 feet
- High-risk automobile crash
  - Intrusion: >12 inches occupant side; >18 inches any side (including roof)
  - Ejection (partial or complete) from automobile
  - Death in same passenger compartment
  - Vehicle telemetry data consistent with high risk of injury
- Auto vs. pedestrian/bicyclist: thrown, run over, or with significant (>20 mph) impact
- Motorcycle crash >20 mph

Patient Triggers
- Age >55 years
- Systolic blood pressure <110 mm Hg in persons aged >65 years
- Falls in older adults (including ground level falls)
- Pediatric trauma transport
- Anticoagulant use or bleeding disorders
- Burns
- Pregnancy >20 weeks
- Judgment of emergency medical services provider

Common pitfalls in the transfer of seriously ill patients include failure to intubate before transfer, failure to recognize the need for transfer to a higher level of care, and a general failure to stabilize the patient adequately before transport. Unrecognized ongoing hemorrhage, delayed onset of tension pneumothorax, and reversible/preventable causes of secondary brain injury must be considered.

**Basic Trauma and Burn Support**

- The first goal in trauma management is to identify and treat immediately life-threatening injuries by following the ABCDE sequence of priorities.

- After blunt trauma, airway control should proceed on the assumption that an unstable cervical spine injury exists.

- A diagnosis of tension pneumothorax should be based on clinical criteria and not on a chest radiograph.

- Hemorrhage is the most likely cause of shock after injury, and initial empiric treatment consists of crystalloid infusion to normalize blood pressure, reverse tachycardia, and maintain adequate organ perfusion.

- In general, blood should be added to resuscitation early if the response is inadequate or if continued ongoing hemorrhage is suspected. Uncrossmatched, type-specific blood can be administered safely.

- A secondary assessment includes a head-to-toe examination to identify and treat potentially life-threatening injuries.

- Computed tomographic scanning is essential for the initial evaluation of head-injured patients with a depressed level of consciousness.

- Burn resuscitation is proportional to the area sustaining second- and third-degree burns and is titrated to signs of perfusion. Adequate urine output is one of the key indicators of adequate resuscitation.

- Closed-space smoke inhalation injury places the patient at high risk for upper airway and inhalation injury that may not be obvious at the initial presentation.

- Surgical expertise should be secured early and transfer considered for those patients who require a higher level of care.

- Transfer to a specialized care setting should not be delayed for additional radiologic studies unless the accepting physician requests the studies.
Suggested Readings

Current and updated resources for this chapter may be accessed by visiting http://www.sccm.me/fccs6.


**Suggested Websites**


4. American Association for the Surgery of Trauma. www.aast.org


6. Eastern Association for the Surgery of Trauma. www.east.org

7. Trauma.org. www.trauma.org

