CHAPTER 55

Initial Management of the Critically Ill Trauma Patient

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INTRODUCTION

Throughout the years, trauma has consistently been a leading cause of mortality worldwide. According to the World Health Organization (WHO), over 5 million deaths are attributed to traumatic injury annually accounting for 9% of global mortality (1). The largest contributors to these deaths are road traffic injuries, with an estimated 3,500 lives claimed per day. The latest WHO reports cite road traffic injuries as the eighth leading cause of death in all ages and the number one cause of death among those aged 15 to 29 years (2). In the United States, the most deaths occur among those 70 years and older and are primarily due to chronic diseases such as cardiovascular disease, cancer, stroke, COPD, and diabetes (3). However, unintentional injury still remains the fourth leading cause of death for all age groups in the United States and trauma is the leading cause of death in the United States among children, adolescents, and young adults ages 1 to 44 (4). Unlike the above-mentioned chronic diseases, a larger proportion of the overall deaths due to unintentional injury are represented in the younger populations (3).

Not only does trauma account for a large number of deaths, high medical costs and loss of productivity from permanent disability carry further impact on society. When injury is regarded as a category of disease, the economic impact of injury is substantial, with hundreds of billions of dollars in estimated lost wages, medical expenses, property damage, and administrative costs. One estimate by Centers for Disease Control and Prevention (CDC) place the total cost of injuries and violence in the United States in 2013 at $671 billion (5). This estimate is staggering in itself, but one can only imagine the impact on society in terms of lost human potential and the tremendous loss of life-years which is far more difficult to quantify and may be inherently underestimated. This makes trauma a particularly unique and tragic cause of mortality and morbidity.

The fact that trauma and trauma patients have such a significant impact on global society is not surprising. Nobody is immune to trauma and all have been affected directly or indirectly by a traumatic event. The trauma victim can present with a wide range of backgrounds and medical problems that may significantly influence the resiliency of the patient physiology and response to specific therapies. Certain populations require special considerations, including children, pregnant women, the elderly, and the obese. The latter two populations are increasingly prevalent. The baby boomer generation has reached retirement age and now contributes to the general geriatric population. The prevalence of those considered clinically obese is also increasing, recently estimated as one-third of adults and 17% of youth in the United States (6). Furthermore, injuries can involve any area of the body and not uncommonly affect multiple organ systems simultaneously. Adding to this complexity are the multitude of possible mechanisms of injury, each with varying degrees of severity. As will be discussed, it is helpful in the management of trauma to initially categorize these by mechanism: blunt versus penetrating.

Given such a diversity of scenarios and types of victims, major decisions in patient care are often made through a collaboration of various different surgical, medical, and radiologic specialists. Trauma patients first encountered in the field by first responders and the Emergency Medical Services (EMS) are then handed off to the emergency medicine physicians, trauma surgeons, and nurses in the emergency department upon arrival. Depending on the structure of the receiving Trauma Center, the prehospital information received, and the available resources, further members of the team that may be called early on include anesthesiologists, pharmacists, respiratory therapists, social workers, radiology technicians, and radiologists. More serious traumas may require further involvement of those in the blood bank, operating room, interventional radiology suite, intensive care unit, and surgical subspecialties such as neurosurgery, cardiothoracic surgery, and orthopedics. As the complexity of the trauma patient rises, the number of involved care providers also grows, and therefore the potential for miscommunication and error increases. All these variables and pitfalls challenge the provider even further when factoring in the time-sensitive nature of many major injuries. The more rapidly the injuries are identified and treated appropriately, the more likely the preventable death rate from trauma is reduced (7,8).

ADVANCED TRAUMA LIFE SUPPORT

Since the inception of Advanced Trauma Life Support (ATLS) in 1978, the course has become increasingly more widespread and now represents the mainstay of treatment of the acutely injured patient. The course was founded on the assumption that appropriate and timely care could significantly improve outcomes in trauma patients (9). Since then, data exists to demonstrate a positive impact from this approach (10,11). Studies show that ATLS training for doctors in developing countries have resulted in decreased injury mortality (12).

Central to ATLS is the premise of treating the greatest threat to life first, even before the exact diagnosis of the problem is identified, thus forming the basis for the initial assessment and management of the trauma patient. The mnemonic “ABCDE” is not only intentionally simple to remember, it emphasizes that certain patterns of injury kill in systematic time frames and therefore creates an inherent order. Loss of the airway, “A,” regardless of mechanism, kills more readily
than the loss in ability to breathe, “B.” Likewise, loss of the ability to breathe kills more readily than loss of circulating blood volume, “C” (9). The basis for this can be understood at the molecular and cellular level as it relates to preservation of cellular respiration. “D” stands for disability signaling the identification of injuries to the central nervous system (CNS) of which prognosis is generally dependent on good oxygenation and circulation. Finally, “E” represents exposure and environment as a reminder to expose the entire body for general inspection followed by protecting the body from environmental threats, namely hypothermia.

Cells in the human body can survive only a relatively short amount of time without a steady supply of oxygen; resiliency to hypoxia is dependent upon the cell type. Oxygen, the final destination for electrons on the electron transport chain, is the driving force in cellular respiration. Without oxygen, the ATP-generating mitochondria will cease to function and the cell has an abrupt lack of energy to maintain adequate cellular function. Furthermore, the initial insult of hypoxia or associated hypoperfusion triggers a complex physiologic cascade which predisposes tissues to reperfusion injury exacerbating local vasocostriction, thrombosis, free radical formation, and direct cellular damage. The brain especially has a very limited ability to store energy and therefore is particularly vulnerable to any lapse in supply of oxygen. Cellular injury and death may result from less than 5 minutes of anoxia. Assessing and managing the ABCs can therefore be thought of as prioritizing actions to best facilitate preservation of this vital pathway.

A compromised airway, inadequacies of breathing, and deficient effective circulating volume all further contribute to both metabolic and respiratory acidosis. With hypoxemia, cells resort to anaerobic metabolism in which lactic acid is a byproduct that builds up in the circulation. With hypoventilation, carbon dioxide is not removed from the blood and accumulates to dangerous levels. Hypotension and hypoperfusion to the kidney will result in impaired ability to remove acid from the body. Acidosis in itself will contribute to coagulopathy and multiple organ dysfunction. Severe acidosis will affect heart function and circulation is further impaired.

A major injury affecting the ABCs can thus lead the trauma victim to enter what has traditionally been termed the “lethal triad,” consisting of hypothermia, acidosis, and coagulopathy. To successfully resuscitate the critically ill trauma patient, one must understand how elements of the lethal triad propagate one another, as well as how to halt the progression to avoid irreversibility and ultimately death.

**PRIMARY SURVEY**

The main objective of the primary survey is to identify and manage immediately life-threatening injuries in the most expeditious manner. It is within this critical stage that a heightened awareness and appropriate action can easily make the difference between life and death. Patient outcome is directly related to the time between injury and definitive care. The time-sensitive nature of this critical juncture has been emphasized by past studies demonstrating high mortality attributed to inadequate assessment and resuscitation in the initial phases (7,8).

ATLS advocates simultaneous evaluation and treatment because of the rapidity in which surviving these injuries demand. Having a general algorithm as a guide creates order in situations that are unpredictable and highly stressful and may give a sense of security to the situation. It is helpful to remember in the moment, that there are a limited number of rapidly lethal injury types that may present. Many of these have a rapidly corrective action to take for the best chance at survival. Also important to remember, the primary survey may need to be repeated at any time as trauma is often a dynamic clinical situation. As a general rule, if the patient becomes unstable at any time regardless of prior stability, one should go back and reassess the ABCs.

### Airway

Ensuring a stable airway is the initial priority when managing a trauma patient. Regardless of the specific circumstances of the injury, the mechanism of cellular respiration is totally dependent on a secure access to an oxygen supply. When an airway is obstructed, the overall process by which oxygen is delivered to all the tissues of the body halts at the first step and the patient deteriorates quickly. Therefore, the unstable airway must be addressed before continuing on to assessment and treatment of breathing and circulation.

The first step in determining the status of the airway is by eliciting a verbal response from the patient. Patients that are conscious and respond by talking with a normal voice most likely do not have an immediate airway issue. Next, it is important to further assess for an impending airway obstruction or an airway that is at high risk for compromise. In the trauma setting, common examples include massive facial trauma where the airway is at risk for blockage with blood, broken teeth, or edematous soft tissues. Other injuries that threaten the airway are less obvious yet very important to identify early if present. Certain injuries to the neck may risk compromising the airway at the pharyngeal or tracheal level. Examples include penetrating injuries to the neck causing an expanding hematoma or direct tracheal laceration with intraluminal bleeding. Patients that suffer a significant burn must be assessed carefully for signs of an inhalation injury such as singed nasal hairs, soot around the mouth, oral mucosal swelling, anterior neck burn, or dysphonia. The most common situation where an airway may be at risk is in a patient with altered mental status due to severe head injury. Regardless of its etiology, the initial concern comes from the patient’s inability to guard against dangers such as obstruction from the tongue, nasopharyngeal bleeding, or aspiration.

In the event that the patient is judged to have an unstable airway, immediate actions need to be taken to obtain a definitive airway; a definitive airway being a cuffed tube within the trachea. Rapid-sequence orotracheal intubation is the preferred method of ensuring airway stability. Although time is limited and tensions are high, it is worthwhile to ensure that equipment, appropriate medications, and ancillary resources are available prior to initiating the act of intubation. It has been demonstrated that the risk of adverse events increases with the number of intubation attempts, therefore it is important to adequately prepare for the intervention (13). Everyone on the team should be aware that the decision has been made to intubate the patient. In this way, one is best able to maintain order and minimize miscommunication. Failure to do so and the “easy” airway can become a “difficult” airway. If adequate oxygenation and ventilation is achieved with Bag-Valve-Mask (BVM), there should be enough time for preparation.
However, it is important to remember that with each assisted ventilation, the stomach becomes more distended with air, and vomiting and aspiration become more likely complications. The coordination of multiple support services is the key to maintaining control over the situation, namely the pharmacist, respiratory therapist, and the involved nurses. Medications for induction and neuromuscular paralysis (typically Etomidate for induction and Succinylcholine for rapid onset transient paralysis) should be drawn and confirmed prior to initiating laryngoscopy and endotracheal intubation.

Simultaneously, the equipment for intubation should be retrieved, checked, and made ready for use. One should assume that a cervical spine injury has not been ruled out prior to the decision to intubate; therefore in-line stabilization must continue throughout the procedure. This is ensured by dedicating one person to manually stabilize the cervical spine while the collar is removed and continue monitoring until the patient is successfully intubated, endotracheal tube (ETT) secured, and collar replaced. The patient should be suctioned and preoxygenated with a high-flow mask or BVM prior to intubation. Often an oropharyngeal airway (OPA) is useful because tongue obstruction is common in the unconscious patient which may only occur after induction and paralysis. Preoxygenation should be attempted; however, times that the instability of the airway is dire or attempts at preoxygenation may only occur after induction and paralysis. One should not prolong the situation by waiting for the SaO₂ to rise. Hypotensive patients may not have adequate perfusion such that a pulse oximetry reading is unavailable or inaccurate. In these cases, intubation should proceed without hesitation.

It is advisable to have a second method for intubation immediately available, typically special equipment in the event of a difficult airway. Video laryngoscopy is being more frequently used and has superior visualization to direct laryngoscopy when performed appropriately (14). Confirmation of successful endotracheal intubation is made by direct visualization of the tube passing the vocal cords, capnography, auscultation of bilateral breath sounds, absence of sounds over the epigastrium, and ultimately with a chest radiograph. One should also be prepared for the hemodynamic effects of induction and positive pressure ventilation as hypotension may occur due to increased intrathoracic pressure and subsequent decreased venous return. Volume resuscitation is often needed and it is imperative to obtain a chest x-ray (CXR) soon after intubation to assess for proper tube position and absence of pneumothorax (15).

In less frequent cases, a surgical airway is indicated and appropriate preparation for this contingency should also be made. Situations that may require a surgical airway include massive facial trauma which obscures visualization, repeated failed intubation attempts which may exacerbate vocal cord edema, or direct laryngeal trauma that distorts the anatomy. It is important to have a low threshold to perform a surgical airway when repeated attempts to intubate are failing. A surgical airway may be started while attempts at intubation are ongoing. A generous vertical incision should be made over the cricothyroid membrane to avoid the laterally approaching blood supply and if the need arises to extend the incision superiorly or inferiorly. The thyroid is avoided at this level and there is minimal soft tissue to hinder access to the cricothyroid space. The cricothyroid membrane should then be incised with the scalpel and the opening dilated with a Kelly clamp or scalpel handle. If an appropriately sized tracheostomy tube is available this should be placed; otherwise, using a 6F or larger ETT is acceptable in emergent situations.

**Breathing**

A stable airway implies a secure and unobstructed path by which oxygenated air can access the lungs. However, this does not necessarily imply that breathing is adequate. Effective breathing involves proper functioning of the mechanical, physiologic, and cellular mechanisms responsible for delivering air through the airway to an alveolar surface for gas exchange. Injuries that may compromise this process to varying degrees of severity include rib fractures, flail chest, pulmonary contusion, pneumothorax, hemothorax, diaphragmatic rupture, and paralysis.

Assessment for effective oxygenation and ventilation begins by looking at the patient even as they are rolling into the trauma bay. All trauma patients that present should be provided supplemental oxygen via nasal cannula and placed on pulse oximetry monitoring. The patient may be awake and talking thereby demonstrating an open airway and the ability to move air. However, the patient may still not be oxygenating and ventilating adequately. Does the patient appear to be short of breath, struggling against restraints to sit up, using accessory muscles, or outright declaring a difficult time breathing?

First, one must globally assess for signs of impending acute respiratory failure including tachycardia, tachypnea, retractions, and diaphoresis. Focus on visually inspecting the neck and chest wall for signs of injury such as contusions, lacerations, chest asymmetry, or splinting. Auscultate the chest over the anterior and lateral lung fields especially taking note of any difference between the breath sounds bilaterally. Finally, palpate over the clavicles, sternum, and rib cage for crepitus, tenderness, chest wall deformity, or flail segment. Unfortunately, the most severely compromised patients are those that are not awake, talking coherently, or moving air at all, making assessment much more difficult.

Two major interventions need to be considered during the breathing assessment of the primary survey prior to moving forward: pleural space decompression with tube thoracostomy and intubation with mechanical ventilatory support.

A tube thoracostomy is the initial management for acute respiratory failure due to pneumothorax or hemothorax. A tension pneumothorax is an extremely dangerous situation which develops when the lung collapses from pleural space violation with reversal of its normal negative pressure state to positive pressure through a one-way valve mechanism. Air enters the pleural space through an injury to the tracheobronchial tree, lung parenchyma, or directly through the chest wall, and becomes trapped in the pleural space. With each breath, the air pressure in the pleural space increases, resulting in further collapse and compression of the lung, affecting both respiratory function and hemodynamics simultaneously and therefore rapidly lethal. A tube thoracostomy should not be delayed to confirm this diagnosis by radiography if suspected. The problem may be temporized by decompressive needle thoracostomy using a large bore angiocath prior to placing the chest tube. This can be performed at the second intercostal space at the midclavicular line. Alternatively, this can be performed at the fifth intercostal space at the midaxillary line, especially in those with a large amount of soft tissue overlying...
the anterior chest (16). A large hemothorax has a pathophysiology similar to tension pneumothorax but may further be complicated by hemorrhagic shock given the extent of concurrent blood loss. Treatment also starts with placing a chest tube which will relieve the tamponade effect and allow expansion of the lung, but also allows further blood loss and possible worsening hemorrhagic shock.

An open pneumothorax, also termed a sucking chest wound, is also rapidly lethal and occurs when the chest wall is violated from the skin to the level of the pleural space. If the chest wall defect is of comparable size to the tracheal lumen, the negative pressure generated by attempted breathing may cause air to traverse the wound rather than inflate the lungs via the trachea. It often presents with audible air movement and bubbling over a large chest wound. Treatment for this involves immediately covering the defect, preferentially with an occlusive dressing or a gloved hand followed by a chest tube. Definitive closure in the operating room will also be needed.

Other major injuries causing acute respiratory failure that may need to be addressed with intubation and mechanical ventilation include rib fractures, flail chest, pulmonary contusion, and paralysis of the diaphragm or chest wall. Assisted ventilation can be attained manually via face mask, laryngeal mask airway, King tube, or ETT. Once stabilized and a definitive airway is placed, the patient can then be placed on a mechanical ventilator. Arterial blood gas (ABG) analysis should be obtained early and adjustments made accordingly.

**Circulation**

After addressing the airway and breathing status of the patient, assessment and management of circulation becomes the next priority in the primary survey. Simply, the immediate goal is to ensure delivery of a steady supply of oxygenated blood from the lungs to the rest of the cells in the body. Failure of the body to accomplish this means that the patient is in shock. Shock is defined as the inadequate perfusion of oxygenated blood to the end-organs resulting in tissue death or injury at the cellular level.

Evaluation of circulation begins with palpation of peripheral pulses. Important information gained from this simple act include determining the presence or absence of a pulse, estimating the heart rate and regularity, as well as judging the quality of the pulse, be it bounding or thready. A quick estimate of systolic blood pressure (SBP) based on a pulse examination can be useful at times, especially as an exact blood pressure reading by cuff measurement takes a significantly longer time to attain. Furthermore, a pneumatic cuff will fail to read when a blood pressure is extremely low. Generally, a palpable radial pulse correlates to an SBP of at least 80 mmHg. Likewise, a palpable femoral pulse correlates to SBP of 70 mmHg and a carotid pulse correlates to an SBP of at least 60 mmHg. One should not wait for a cuff pressure reading prior to taking action if a pulse examination suggests blood pressure is low. One must assume that the patient is in shock and proceed with aggressive resuscitation.

Simultaneously with circulation assessment, appropriate intravenous (IV) access should be attained. This is a critical and often underappreciated priority during the primary survey. At times, lack of intravenous access can become the rate-limiting step to providing the needed resuscitation in forms of volume, medications, and blood products. The most frustrating trauma resuscitation situations are those limited by the inability to deliver IV therapy simply because of lack of access. Two large bore angiocaths should be placed, preferably on each of the upper extremities. Two separate access points ensures that blood volume can be delivered twice as fast and that there is a redundancy in place in case an IV becomes dislodged or stops working. Unfortunately, the higher the severity of hemorrhagic shock, the more difficult it is to place IVs as the veins are collapsed and autonomic peripheral vasoconstriction decreases extremity blood flow. In these situations, attention may need to be directed toward attaining more advanced IV access such as a large bore central venous line (CVL), intraosseous (IO) catheter, or a saphenous vein cut down. Intraosseous catheter placement is being used more often in adult patients in shock and can be performed within seconds (17). Once access to the circulation is attained, isotonic fluids infusion should be initiated.

The heart should be auscultated for irregularity, murmurs, or muffled heart sounds, although the noise of the trauma bay makes this difficult at times. A blood pressure cuff should be placed and serial measurements obtained. A useful parameter to note and monitor is the pulse pressure. The pulse pressure will decrease with increasing amounts of blood loss. The loss of effective blood volume causes both a decrease in the SBP and a reflex peripheral vasoconstriction which raises the diastolic blood pressure (DBP). If the automated blood pressure cuff cycles and is unable to provide a measurement, one should be aware that this very well may be due to extreme blood loss with hypotension resulting in equipment error. Hypotension should be assumed until a more accurate reading can be obtained, possibly by obtaining a manual pressure and shifting more reliance on other measurable parameters such as heart rate and pulse character to gauge hemodynamic stability until an accurate measurement can be attained.

There are various types of shock that one may encounter in the critically ill trauma patient including cardiogenic, neurogenic, and septic. However, the most important to rule out early in the setting of trauma is hemorrhagic shock. Hemorrhage is the leading cause of preventable death in the injured patient (7,8). Therefore, identifying bleeding and taking actions to halt it should be the main priority during this stage of the primary survey. Managing the patient in hemorrhagic shock is often, and rightfully so, a stressful situation for the entire team. To maintain a clear focus on the problem, it is helpful to systematically and rapidly consider life-threatening blood loss as coming from five possible sources: the external environment, long bone fractures, the pelvis/retroperitoneum, the thoracic cavity, and the abdominal cavity.

The source of external blood loss is often obvious, such as a large laceration with active bleeding that can be identified readily on physical examination or indicated by the patient’s pain. Quickly scan for any sign of a large wound or bloody surfaces on the patient’s body and gain immediate control by exposing the area and applying directed point pressure if significant bleeding is detected. At other times, the external bleeding source is less obvious. Significant laceration on the back or perineum may not be initially appreciated until the patient has been logrolled and thoroughly examined. At times, an external injury may already be hemostatic, but starts to bleed again with the onset of resuscitation. The extent of blood loss from an injury may also not be fully appreciated as the blood is “on the floor,” meaning it has already been lost in the field.
or literally on the floor of the trauma bay. A scalp laceration should not be underestimated; a person can fully exsanguinate from an isolated scalp laceration and these injuries may not be easily controlled. Massive bleeding from an extremity may not be adequately controlled with pressure alone and in this situation, a tourniquet would be appropriate to utilize. Recent studies have shown a survival benefit without increase in rates of adverse outcomes or amputations associated with the use of a tourniquet for hemorrhage control in major trauma (18,19).

Long bone fractures that account for life-threatening bleeding as well should be detectable on physical examination as a significant deformity. A person can lose up to 2 L of blood per thigh from a severe associated femur fracture. Thus, bilateral femoral fractures can account for more than half of a patient’s total blood volume. Control of bleeding from long bone fractures can be aided by fracture reduction with or without traction splinting. Early consultation with orthopedics can be helpful as they can greatly aid in managing this source of bleeding, especially in the multisystem trauma patients.

The remaining three sources of potentially life-threatening bleeding—thoracic cavity, pelvis/retroperitoneum, and abdominal cavity—are less readily ruled out by physical examination. Therefore the role of adjunctive imaging immediately available in the trauma bay greatly facilitates rapid identification of these bleeding sources.

The thoracic cavity is normally well protected by the sternum, rib cage, and spinal column. However, once violated by either blunt or penetrating trauma, major injury to the residing structures is often fatal. Physical examination of the chest may reveal a penetrating wound, deformity, absence of breath sounds, tenderness, or bony crepitus. An underlying hemothorax can be rapidly fatal as each pleural cavity can hold up to 2 L of blood. A portable CXR is thus an invaluable adjunct to identifying a thoracic source of bleeding. Placing a thoracostomy tube will both confirm suspicion of a hemothorax and act as an immediate treatment by allowing for lung expansion. The hemodynamic response from a chest tube may vary. Relieving tension physiology may allow the component of cardiogenic shock to be relieved. However, allowing an outlet for the bleeding which was somewhat controlled by the confined space of the thorax may exacerbate further bleeding and hypotension and one should pay close attention to the physiologic response to this intervention. Once in place, the thoracostomy tube then provides use as a measuring tool to aid in determining if the patient needs more extensive operative exploration with surgical bleeding control. One should note the initial volume of blood evacuated from the chest, as well as the rate at which blood loss is occurring. Guidelines proposed by ATLS state that an initial output of greater than 1,500 mL of blood or more than 250 mL blood loss per hour should prompt anterolateral thoracotomy and surgical control of bleeding (9). Other important findings on CXR to suggest a thoracic source of bleeding may include a widened mediastinum, spinal fractures, or lung field opacity.

A major pelvic fracture is often a source of bleeding that can be difficult to manage for a variety of reasons. One reason is that the pelvis has three sources of potential bleeding: arterial, venous, and osseous. Another complicating factor is that a pelvic fracture does not necessarily bleed into a discreet cavity, but rather can expand and track along the retroperitoneum, an often underappreciated but considerably large reservoir for blood loss. Many fractures do violate the abdominal cavity where even more bleeding can spill into. Furthermore, 30% of major pelvic fractures are associated with a concomitant intra-abdominal injury (9). When bleeding is suspected to be from either or both the pelvis and abdomen, it may be difficult to determine where to proceed next. During the primary survey, start by scanning the area around the pelvis for signs of a significant injury including deformity and ecchymosis. The pelvis should be handled by palpating the iliac crests bilaterally and then gently adducting to assess for stability, noting if the patient describes pain or if there is any induced movement from this action. The normal pelvis is a strong bony ring and should have no laxity. Care must be taken to avoid applying excessive outward pressure or “rocking the pelvis” as this may exacerbate further bleeding if a fracture is indeed present. More information may be gained by obtaining a pelvic x-ray at this time especially if the patient remains hemodynamically unstable in the trauma bay. Depending on the fracture pattern, temporary pelvic reduction may be helpful in controlling blood loss by using a pelvic binder or wrapping the pelvis with a sheet. Note that certain fracture patterns may actually be worsened by applying a binder and therefore this should not be employed in pelvic fractures indiscriminately. Early consultation with orthopedics is often helpful.

Difficult situations occur when a patient is hypotensive and has an identified pelvic fracture on x-ray. Initial management includes volume resuscitation with or without pelvic reduction. Most pelvic bleeding will be stemmed by these early conservative measures as the tamponade effect of the hematoma and pelvic volume reduction overcomes bleeding from the bone and venous plexus. The question of what to do next arises if the patient remains hypotensive. Approximately 10% of severe pelvic fractures will have bleeding from an arterial source which does not tamponade to a halt readily. Although a CT can often elucidate the source more accurately than an x-ray, it is not appropriate to transport the patient for imaging if the patient is hemodynamically unstable. It is also not necessarily appropriate to venture to the OR in these cases because surgical control of bleeding is extremely difficult considering the inaccessibility of a narrow pelvis, the complex sacral venous plexus, and the retroperitoneal reservoir of blood loss that is not well controlled with simply packing the pelvis intraperitoneally. There is evidence for significant reduction in blood transfusion requirement and trend toward reduction in mortality with preperitoneal pelvic packing in selected high-risk patients (20).

The mainstay of source control for suspected pelvic arterial bleeding in the persistently hypotensive patient is angiography and angioembolization. Several challenges arise when pursuing this avenue of treatment. First and foremost, this modality may not be readily available to the patient. Also, precious time is diverted to notifying and mobilizing the Interventional Radiology team, after which the equipment must then be prepared and the patient needs to be transported to the radiology suite. This location is often separate from the OR and may be a difficult decision if other sources of bleeding are being simultaneously considered. Because of this, some centers are implementing use of hybrid OR/IR suites such that these contingencies can be partially accounted for (21).

The fifth potential source of major bleeding is the abdomen, classically considered the “black box,” as it is often the most difficult to rule out. During the primary survey, examination of the abdomen consists of looking for signs such as open
wounds, ecchymosis, distention, and abdominal pain. There are many specific sources of bleeding within the abdominal cavity that can account for hemorrhagic shock. Spending valuable time trying to guess which organ is responsible can easily be overwhelming and pointless. Regardless of the specific organ or vessel involved, if the source is deemed intra-abdominal, the next step is to proceed to the operating room for abdominal exploration. Therefore, the crucial step in the algorithm is determining if the bleeding and hemorrhagic shock originates in the abdominal cavity. Two modalities can be employed in the trauma bay for this step: the focused abdominal sonography for trauma (FAST) examination and diagnostic peritoneal lavage (DPL).

With increased utilization of ultrasound technology, FAST examination has largely supplanted DPL as it is rapid, noninvasive, and accurate. The FAST examination includes obtaining four views or windows: the pericardial, perihilar, perisplenic, and pelvic. For the pericardial window, the probe is placed in the epigastrium and directed cephalad to assess for fluid in the pericardial space that may be indicative of cardiac tamponade. The perihilar, perisplenic, and pelvic windows are assessed to determine the presence of intra-abdominal fluid, which in a hypotensive trauma patient should be considered blood until otherwise ruled out. Avoid wasting an excessive amount of time reviewing the FAST when a patient is hypotensive. It is either positive for tamponade or not, positive for abdominal fluid or not. Simplifying the assessment and management process in this way is helpful for rapidly proceeding to the next step to resolve the shock state. It is also noteworthy to understand that the window in which the FAST examination is positive does not necessarily correlate with the organ injured (22). Another advantage of the FAST examination being rapid and noninvasive is that it can easily be repeated in cases of refractory or recurrent hypotension.

If the FAST is positive and the patient is hemodynamically unstable, the patient should immediately be taken for an exploratory laparotomy. However, if the FAST is positive and the patient is hemodynamically stable, the patient should be evaluated with a CT abdomen pelvis with contrast to assess for the source of intra-abdominal free fluid.

If the FAST is negative, other sources for hemorrhage should be assessed and the FAST examination should be repeated as sufficient blood volume may not have accumulated. In this situation, another option would be to perform a diagnostic peritoneal lavage (DPL) or a diagnostic peritoneal aspirate (DPA). The DPL involves entering the abdomen via a percutaneous incision and inserting a catheter to aspirate for blood or intestinal contents and infuse a liter of saline. The saline is then allowed to return to the bag and the fluid can be analyzed with specific criteria indicating positivity. As one can imagine, the disadvantages of this technique is that it is invasive, time-consuming, and susceptible to problems with infusion or fluid return. More often it is more expeditious and practical to perform a related procedure, the DPA. This involves accessing the abdominal cavity in the same manner, but relying on the results of simply aspirating for gross blood to determine positivity. If these adjuncts to the primary survey lead one to believe that the source of hemorrhagic shock is the abdominal cavity, the next step is abdominal exploration for control of the bleeding source.

If the reason for shock is indeed hemorrhagic, then halting blood loss is the most crucial step to affect survival. Although often the initial thought is how and when to control this bleeding surgically, it is important to remember the nonsurgical adjuncts that may be employed simultaneously. Tranexamic acid (TXA) is an antifibrinolytic agent that has gained recognition in acute trauma by demonstrating improved survival if given within 3 hours of injury in those with severe blood loss (23, 24). Other situations where facilitating hemostasis nonsurgically may be indicated are in patients on antiplatelet medications, such as Aspirin or Plavix, or anticoagulation such as Warfarin. In such cases, platelet transfusion, vitamin K, fresh frozen plasma (FFP), and prothrombin complex concentrate (PCC) may be utilized. Recently, there has been popularity of newer anticoagulant agents for cardiac and thromboembolic disease in the form of direct thrombin inhibitors (e.g., Dabigatran) and direct factor Xa inhibitors (e.g., Rivaroxaban, Apixaban). Unfortunately, no approved reversal agents for these medications have demonstrated efficacy.

Although the identification and control of bleeding is the most important factor determining survival in the setting of hemorrhagic shock, morbidity and mortality can be curtailed by repleting blood volume loss with blood transfusion therapy as well. ATLS continues to promote volume resuscitation in shock with up to 2 L of isotonic IV fluid prior to starting blood transfusion (9). In the event of massive hemorrhage, evidence supports a survival benefit in patients that undergo what is termed the massive transfusion protocol (MTP). MTP involves complementing each packed red blood cell (PRBC) unit transfused with addition of FFP and platelets. Initial studies have utilized a 1:1:1 (PRBC/FFP/platelet) ratio to demonstrate benefit; however, the exact ratio of these components has not been definitively determined. Massive transfusion is defined as needing to receive more than 10 units of PRBC within the first 24 hours (25, 26).

Much of the focus in circulation assessment of the primary survey is centered on hemorrhage. However, other causes of shock in the setting of trauma need to be considered, especially if one is unable to determine a source of bleeding. Furthermore, a more severely injured patient may have multiple affected organ systems, and therefore multiple reasons to be in shock. Cardiogenic shock may result from cardiac tamponade, blunt cardiac injury, or acute myocardial infarction. Cardiac tamponade may be suspected in penetrating injury to an area termed the “box,” defined by the clavicles superiorly, the nipple lines laterally, and the costal margin inferiorly. Although tamponade may be diagnosed through classic signs described as Beck triad (hypotension, jugular venous distention, and muffled heart sounds), more likely the diagnosis is established during FAST examination. Definitive treatment for this may involve sternotomy or thoracotomy with pericardiostomy and control of bleeding. Blunt cardiac injury may also contribute to shock, though is rarely the sole cause. A more likely scenario for cardiac injury is secondary to myocardial ischemia or infarction secondary to rapid and large volume blood loss. Neurogenic shock is also a consideration when dealing with a major trauma victim. This occurs secondary to a spinal cord injury and concurrent loss of sympathetic tone to the peripheral vessels.

When a trauma patient arrives without a palpable pulse, an emergency department thoracotomy (EDT) may be beneficial in rare cases (27). It is most effective in victims of penetrating trauma that present with recent loss of pulses or signs of life if performed within 15 minutes onset of prehospital CPR (28). However, thoracotomy is rarely of benefit to victims of blunt trauma and overwhelmingly so, with meaningful survival benefits in less than 5% of blunt trauma patients that present in
Disability
The disability portion of the primary survey involves assessing the neurologic status of the patient once the immediate problems regarding airway, breathing, and circulation have been addressed. This assessment involves determining the Glasgow Coma Score (GCS) of the patient, examining the pupillary size, reactivity to light, and symmetry when compared to each other, as well as noting any obvious sensorimotor deficits and/or lateralizing signs. The key concern with an abnormal neurologic examination is CNS injury, namely traumatic brain injury (TBI) or spinal cord injury. Although nothing can be done to reverse the initial insult or primary CNS injury, avoiding secondary injury to the brain and spinal cord is vital to obtaining the best possible outcome from this type of trauma. The acutely injured brain is especially sensitive to both hypoxia and hypotension. Mortality rates of those patients with severe TBI with hypotension on admission are more than twice that of patients without hypotension. A single hypoxic event documented in TBI patients with concurrent hypotension increases mortality even further (30). Therefore prioritizing the ABCs is the best course of treatment in this population. After hemodynamic stabilization, other important factors to control include minimizing elevations in intracranial pressure (ICP), maintaining normothermia, and decreasing the incidence of posttraumatic seizures. Early consultation with neurosurgical colleagues is advised to help guide medical supportive care in TBI patients, as well as determining which patients are candidates for emergent surgical decompression.

Exposure/Environment
After assuring hemodynamic stability and addressing the neurologic status, the next step in the primary survey is denoted by the letter “E.” This should prompt one to think of exposure and environment. The entire patient is exposed by removing all clothing such that one lessens the chance of missing a significant injury that needs to be treated early (31). Although removing layers of clothing contributes to hypothermia somewhat, ongoing blood loss or a large wound from a missed injury is a larger heat sink and a threat to adequate circulation as well. Therefore, full examination should be performed expeditiously and thoroughly prior to covering the patient with warm blankets and obtaining a check of body temperature. Hypothermia contributes to coagulopathy and multiple organ dysfunction syndrome (MODS). In fact, hypothermia is a component of the classically taught Lethal Triad of Trauma: Hypothermia, Coagulopathy, and Acidosis. If hypothermia is severe, one should divert more attention to a variety of methods to counteract this. Options in this arena include using warmed IV fluids or blood, warming the air given through the ventilator, or at the most extreme level, active internal rewarming which may involve irrigating body spaces (e.g., pleura) with warmed fluids or even rewarming through ECMO.

Assessment for Transfer
By the end of the primary survey, the patient should have reached a certain level of stability such that one can take a moment to decide on the best course of definitive management for the patient. If the sustained injuries require definitive management beyond the capacity of the hospital, interhospital consultation with the nearest facility where the patient can receive that care is indicated. Delaying this process is associated with increased mortality (32,33). The facility that can provide the higher level of care should be contacted and physician-to-physician communication detailing the injuries identified and management performed thus far should take place. It is important to remember that the workup does not have to be fully completed prior to transfer as this may delay the patient from receiving definitive care. If a CT scan is necessary to elucidate injuries, this should be deferred as it can be performed at the tertiary care center under the guidance of the accepting physician. Energy and focus should be diverted to arranging appropriate transport, compiling the relevant information to send with the patient, and assessing for any additional interventions needed to guard against clinical deterioration en route. The patient may need intubation for airway protection, a chest tube placement for pneumothorax prior to air transport, or fracture reduction and stabilization to curb bleeding. If there is time while awaiting arrival of transport, then a more thorough history and quick secondary survey may be performed as long as it does not cause further delay to definitive care.

SECONDARY SURVEY
Although the primary survey serves to identify and treat rapidly lethal injuries and ensure that oxygenated blood is delivered to the peripheral tissues, the secondary survey involves a more meticulous and comprehensive review to identify and possibly treat all of the injuries that the patient presents with. Additionally, the background history of the event and prior medical issues come to light at this time. It is worth emphasizing that if the patient clinically deteriorates or becomes hemodynamically unstable at this time, the secondary survey should be aborted and the ABCs reassessed. For example, the patient may have a delayed presentation of intra-abdominal bleeding and need an urgent laparotomy and would therefore be managed in the OR until stability is reassured. The secondary survey may need to be completed after this event.

The secondary survey resembles the more structured H&P that one performs with any new patient but generally more expedient and injury-focused. It is important to acknowledge that other issues seemingly unrelated to the trauma may impact the treatment course for the patient, such as chronic medical problems, past surgeries, social habits, or daily medications.

History
In the acute trauma setting, the history is often pieced together from multiple sources due to the level of distress or impairment the patient is experiencing. The prehospital provider often has the advantage of witnessing the scene of the accident. For example, they may have gained a sense of how much blood was on the ground, how much damage was done to the vehicle, how high the victim fell, or the position the patient was found in. They may have gained information from witnesses of the event, obtained history from the patient prior to deterioration, or observed changes in the
patient status from the time of contact to the time of presentation to the ED. Therefore one should consider carefully and deliberately the report given by the prehospital caretaker as it may provide invaluable information. If the clinical status of the patient is such that one cannot receive the initial sign out, the information should be obtained by another member of the team, or the EMS provider may be asked to stay until this can be done.

To aid one in expeditiously obtaining the most relevant information for the situation from the patient, it is helpful to obtain an “AMPLE” history. Each letter correspond the following: “A” for allergies, “M” for medications, “P” for past medical history/past surgical history/pregnancy, “L” for last meal, “E” for events surrounding the trauma (9). Obtaining a list of current medications may be especially relevant and often dictates further management. Beta-blockers are a common medication prescribed and may inhibit a patient from mounting a tachycardic response to traumatic bleeding. Antiplatelet agents are also very commonly encountered and may necessitate actively reversing the effects through platelet transfusion (34). Anticoagulants like warfarin are extremely important to note, especially in those with suspected TBI. Rapid correction of coagulopathy in these case have demonstrated improvement in long-term outcome (35,36).

Physical Examination

Although the physical examination should be performed quickly, it also needs to be meticulous and comprehensive. A head-to-toe assessment is therefore carried out in a standardized manner. By this point, the patient has had all clothing removed during the primary survey and most of the body can be readily examined without delay or disruption in focus. After this is done, it is important to check the back and perineum, which can be areas that hide significant injuries. A dedicated person at the head maintains C-spine precautions and is in charge of verbally directing the log roll. The patient should not assist in moving during this time. At least two additional people are needed to roll the patient in a manner to maintain full spinal precautions. Often a third person assisting with maneuvering the legs is necessary especially with a known lower extremity fracture. Finally, an experienced provider checks the back for any signs of injury from top to bottom, palpates each spinal level for midline tenderness, deformity, or step-offs, and then does a check of the perineum, including a rectal examination if indicated. Findings should be clearly verbalized to the nurse documenting the examination.

Head Trauma and Traumatic Brain Injury

The scalp is checked for lacerations, hematomas, or skull deformities. A thorough palpation of the entire head often finds injuries missed on visual inspection. The posterior aspect of the head is difficult to fully examine and may need to be better assessed when the patient is log-rolled. Large scalp lacerations can bleed significantly and may need to be addressed immediately with staples, suture ligation, or Raney clips. Any sign of injury to the head should increase suspicion for TBI. All patients with altered mental status, loss of consciousness, or significant mechanism should receive a CT scan of the head. This may be deferred only if the patient is neurologically intact with no evidence of posttraumatic amnesia, confusion, or impaired alertness (37).

Facial Trauma

Facial trauma may be obvious upon initial presentation, but in many cases can be subtle and prone to missed detection. It is particularly important to check certain areas that can be occult but very relevant to management. Any abnormality should prompt one to obtain a dedicated CT scan of the face. Aside from the pupillary examination, the eyes are checked more thoroughly for signs of globe injury, extraocular movement abnormality, or visual impairment. An orbital fracture is among the most commonly missed injuries and may be missed on physical examination. The nares should be inspected for deformity, CSF drainage, bleeding, and septal hematoma. The maxilla should be checked for tenderness to movement or instability that may be present in a LeFort fracture. Asking the patient to voluntarily open and close the jaw to assess for abnormal alignment may reveal injury to the maxilla or mandible. The oropharynx should be inspected for tongue lacerations, broken teeth, soft tissue swelling, or signs of inhalation injury. A basilar skull fracture may be detected by noticing periorbital or retroauricular ecchymosis, hemotympanum, or clear fluid from the nose or auditory canal.

Neck Injuries

The neck is a very important area to spend additional attention on during the secondary survey. Injuries to the neck are often missed initially, but have the potential for great morbidity and mortality considering the major vital structures in such a compact space. A cervical collar placed in the field may further hinder a good examination. It is important to stress that the c-spine collar must be removed to perform a thorough examination and that c-spine precautions should be maintained while the collar is removed. It is not acceptable to solely examine the neck through the holes in the collar. If an occult injury is identified, quickly reconsiders if the airway needs to be secured as some neck injuries can progress rapidly even if they initially seem minor. Examination of the neck starts with the classification of trauma as penetrating or blunt mechanism.

With penetrating injuries, the examination focuses on if the platysma is violated and where the injury is in regards to the three zones of the neck. Assessment for “hard signs” or “soft signs” will dictate whether to operate immediately or to obtain further investigation. Examples of “hard signs” of neck trauma include pulsatile or expansile masses, active bleeding, stigmata of airway compromise or involvement, hematemesis and neurologic deficits. “Soft signs” of neck trauma include subcutaneous emphysema, difficulty breathing or swallowing, nonexpansile nonpulsatile hematoma, paresthesias. Both Zone I and Zone III injuries in the stable patient need further evaluation of the vascular structures and the aerodigestive tract. This may be with the aid of CT angiography (CTA), laryngoscopy, bronchoscopy, esophagoscopy, and contrast esophagram. In the past, all zone II injuries past the platysma were surgically explored. Nowadays, elective nonoperative management is acceptable for asymptomatic and hemodynamically stable patients in this neck region (38).

Blunt injuries to the neck tend to be even less obvious, but can be equally morbid. The airway may be a concern if a significant hematoma causing airway compression or direct damage to the larynx or trachea is suspected. Blunt esophageal injuries are rare. The neurovascular examination is especially important considering the potential for a cervical spine injury.
or a blunt cerebrovascular injury (BCVI). Although a somewhat rare occurrence, blunt injury to the carotid or vertebral arteries can have devastating outcomes if not identified and treated early. Risk factors that necessitate screening according to the Western Trauma Association guidelines include: high cervical spine fractures, cervical spine fractures involving the vertebral foramina, basilar skull fractures, LeFort II and III fractures, closed head injury with diffuse axonal injury or GCS less than 6, and hanging injuries. Screening can be performed using CTA (16-slice or greater) which may need a conventional 4-vessel angiogram if findings are equivocal (39). Intervention varies with grade of injury and more severe injuries may need operative or endovascular intervention. Less severe injuries may be managed with antplatelet agents or anticoagulation. Recent data have demonstrated equal efficacy when retrospectively comparing antplatelet therapy and therapeutic heparin (40). Typically, treatment decisions are influenced by concurrent injuries and risks of bleeding.

**Thoracic Trauma**

Much discussion regarding trauma to the chest has been discussed earlier in this chapter while describing the primary survey. This underscores the importance of examining this body region more thoroughly during the secondary survey. Visually inspect for lacerations, gunshot wounds, bruising, deformities, and asymmetry while the patient breathes. Palpate and auscultate each region of the thorax as more subtle injuries may have been missed in the primary survey. The CXR is particularly useful in identifying pneumothoraces, hemothoraces, or rib fractures. It is less useful for more occult injuries and further investigation is often needed with a CT scan. An aortic injury may be suspected if the CXR demonstrates a widened mediastinum, blunting of the aortic knob, or deviation of the NGT. This should be followed up with a CTA of the chest and if found, should be directed to cardiothoracic surgery. Initial management is heart rate and blood pressure control. Definitive surgical treatment may be deferred if other injuries necessitate alternative management such as TBI necessitating emergent operative evacuation or intra-abdominal bleeding needing operative control (41).

Blunt cardiac injury should be suspected in those with significant mechanism to the chest especially those that are found to have a sternal fracture, multiple left-sided or bilateral rib fractures, or chest tenderness. Screening should be performed initially with a 12-lead electrocardiogram (EKG). With a normal EKG, no further evaluation is warranted. Otherwise, the patient may need to be admitted and monitored on telemetry for up to 24 hours. Obtaining serial cardiac enzymes has limited utility in evaluation and management of the patient with a chest injury, distracting injuries, and drug or alcohol intoxication.

Any suspicion of esophageal injury necessitates esophagoscopy and contrast esophagram to rule out.

**Abdominal Trauma**

The abdominal examination is an extremely important part of the trauma evaluation mainly because it may at times be very difficult to ascertain if any significant injury is present therein. Although the abdomen is briefly addressed during the primary survey in regards to a possible bleeding source, the examination in the secondary survey should be more complete and deliberate. One should inspect the abdomen carefully for any external sign of injury such as a laceration, contusion, or a seatbelt sign (44). Palpate for tenderness or signs of peritonitis and document this examination carefully. Injuries to the abdomen are classically indolent and one should be prepared for the abdominal examination to change over time. A patient may have minimal tenderness during the initial period and develop frank peritonitis hours later. Other complicating factors often confound the abdominal examination include head injury, distracting injuries, and drug or alcohol intoxication. The mechanism of injury is among the first steps in the management algorithm. Penetrating injuries to the abdomen most often encountered are stab wounds and gunshot wounds. In regards to anterior abdominal stab wounds, operative intervention is generally advocated if the secondary survey reveals one of three conditions: hemodynamic instability, evisceration, or peritonitis. Selective nonoperative management can be pursued otherwise with admission and serial abdominal examinations (45). Please note, however, that thoracoabdominal stab wounds require special consideration if present due to the chance of an occult diaphragmatic injury. If the injury is below the level of the nipple on the left side, the patient should have a diagnostic laparoscopy or thoracoscopy (46). A CT scan is not adequate to rule this out. Gunshot wounds to the abdomen are given much more consideration due to the high-velocity nature. The statistically high likelihood of injury to the abdominal viscera necessitating surgical repair allows one to readily decide in favor of surgical exploration, although there are a few notable exceptions. For instance, there are recent reports of a single gunshot wound to the right upper quadrant in a hemodynamically stable patient being managed successfully nonoperatively (47). Blunt abdominal trauma is less straightforward in regards to decision for laparotomy. Assessment of hemodynamic stability and the presence of peritonitis in conjunction with available imaging, either FAST or CT, are considered carefully during the decision making process.

The FAST examination has an obvious role in the primary survey, as previously discussed. However, the role of FAST after the primary survey, as well as in the secondary survey and beyond the secondary survey remains as an excellent bedside tool to assess the intra-abdominal compartment, especially in the context of a previously stable patient who has become hemodynamically unstable. If the patient has become hemodynamically unstable, it is worth repeating the primary survey. As in the primary survey, if the FAST is positive and the patient is stable, a CT of the abdomen and pelvis with contrast is recommended. However, if the FAST is positive and the patient is hemodynamically unstable, the patient warrants immediate exploratory laparotomy, as in the initial primary survey. And again, in the hemodynamically stable patient with a positive FAST examination, the patient should proceed to have a CT scan of the abdomen and pelvis with contrast. Free fluid in
the setting of solid-organ injury may be managed nonoperatively and monitored depending on the extent of injury or may be amenable to control by interventional radiology. Free fluid without solid-organ injury is concerning for bowel injury and would warrant a lower threshold for operative exploration.

Cases which require abdominal exploration for trauma can vary significantly in regards to indication and urgency. Although certain cases are amenable to definitive repair of injuries and abdominal closure, more recently the standard of care in severe abdominal trauma has evolved toward a damage-control mentality and approach. Once the life-threatening bleeding has been halted and enteric contamination controlled, the patient may be served best globally by temporarily closing the abdomen using a negative-pressure abdominal closure device (e.g., ABThera) or similar contraption. Central to providing the best chance of survival and favorable long-term outcome is to avoid the “lethal triad” mentioned earlier: coagulopathy, acidosis, and hypothermia. The sooner the patient can be transferred to the ICU for resuscitation, warming, and other measures to restore physiologic normalcy, the better the chance for survival. The patient can then be brought back for reexploration and possible fascial closure when more physiologically stable.

Related to the topic of damage-control laparotomy and temporary abdominal closure is the recognition and management of abdominal compartment syndrome (ACS). ACS is characterized by intra-abdominal hypertension (>20 mmHg) as determined by bladder pressure measurements with concurrent end-organ dysfunction (48). Causes of ACS in the setting of trauma most commonly include ischemia and reperfusion of abdominal viscera leading to increased abdominal pressure, massive third spacing of fluids due to the acute response to injury and large volume resuscitation, or ongoing uncontrolled intra-abdominal bleeding occupying space in the peritoneum. Regardless of the cause, the effect of the intra-abdominal hypertension is the compression of inferior vena cava, decrease in venous return, loss of effective cardiac output, and inadequate perfusion to the end-organs. Most commonly affected are the renal system leading to oliguria and the pulmonary system due to impaired tidal volumes. Bladder pressures should be measured serially and conservative measures may be attempted including bowel decompression, sedation, and paralysis; however, ACS that is inadequately treated and progresses to multiorgan failure has a high mortality rate. Therefore one should have a low threshold to proceed to definitive treatment being decompressive laparotomy and temporary abdominal closure.

Pelvic Trauma

The pelvis may be examined physically by looking for any external signs of trauma and then assessing the stability of the pelvic ring. The assessor should attempt to adduct the iliac wings while noting any atypical mobility and to check for patient tenderness. Care must be taken not to be too forceful and to minimize the number of manipulations as this can exacerbate bleeding in an unstable pelvis. A pelvic x-ray can be a useful adjunct to determine the fracture pattern and may be the only opportunity to image the patient if hemodynamically unstable and therefore unable to obtain a CT scan. An open book pelvic fracture should initially be managed by placing a pelvic binder as this help to tamponade venous hemorrhage, decrease pelvic volume, and stem bleeding from the fractured ends of bone. Hemodynamically stable patients should have a CT scan with IV contrast to assess for active extravasation. If an arterial blush is noted, angioembolization is often indicated as this is unlikely to halt spontaneously. In the hemodynamically unstable patient in the setting of significant pelvic fracture, management can be a challenging affair. Often there is significant mechanism to suspect a concurrent abdominal source of hemorrhage as well. With a positive FAST, abdominal exploration should be undertaken; however, pelvic bleeding is notoriously difficult to control intraoperatively. Preperitoneal packing has recently been receiving growing attention in the trauma literature and can be a useful adjunct to aid in hemostasis while arranging for angioembolization (20,21). Packs are placed through a suprapubic extraperitoneal incision in the paravesical space bilaterally. External pelvic stabilization can also be utilized for hemorrhage control. Early involvement of the orthopedic team is often helpful in this decision as well as for long-term definitive care. Aside from bleeding control and definitive fixation, the key issue in management of an unstable pelvic fracture is to assess the surrounding structures for an associated injury such as to the bladder, rectum, perineum, or genitai.

Extremity and Peripheral Vascular Trauma

As life-threatening situations are addressed during the primary survey, less attention is typically spent on examining the extremities unless they are a source of major hemorrhage. Often this can be managed with direct pressure and a pressure dressing, but may require a tourniquet and operative exploration if initially uncontrollable. During the secondary survey, a more comprehensive examination of the extremities needs to be undertaken. Lacerations, contusions, deformities should be further evaluated radiologically with careful attention to the joints. Any laceration overlying a fracture should be considered an open fracture and prophylactic antibiotics early on should be administered to reduce long-term morbidity. Each extremity should have a sensory motor examination, range of motion evaluation, and pulse checks. Pulses should be compared with the opposite extremity for any discrepancies and if suspected, an Ankle-Brachial Index should be performed. Extremity compartment syndrome is caused by increased pressure within the fascial compartment leading to venous occlusion which eventually leads to limitation in arterial inflow. If untreated, irreversible nerve and muscle damage may ensue. This should be a consideration in certain injuries such as vascular injuries, crush injuries, tibial-fibular fractures, and cases of ischemia-reperfusion. The treatment for this is decompression via fasciotomy (49).

Back, Spinal Column, and Perineum

The secondary survey physical examination is completed by logrolling while adhering to full spinal precautions as described earlier and taking note of any lacerations, contusions, or deformities. Any midline spinal tenderness should be noted and followed up with the appropriate imaging studies. The perineum is classically neglected during examination and often presents later as a missed injury. The mechanism and associated injuries are important to consider such as a concurrent pelvic fracture. In opposition to traditional teachings, the digital rectal examination (DRE) is not always necessary and should no longer be considered a routine part of the examination (50). It is warranted in selected cases and should always
be included in the setting of a pelvic fracture due to a higher risk of associated rectal and urethral injury. When performed, one should note any presence of gross blood, palpable defects in the rectal wall or pelvic bone fragments, a high riding and mobile prostate gland, and abnormal sphincter tone.

**Adjuncts to the Secondary Survey**

After a complete history and physical examination, often the trauma patient requires additional imaging and laboratory tests to further delineate injuries and conditions. Plain x-rays continue to have value in the evaluation of extremities for fractures and dislocation, evaluation of the thoracic and lumbar spine, and localization of foreign bodies. Multidetector computed tomography (CT) has largely become the imaging modality of choice for trauma patients due to its continually improving speed and resolution. Preferably, the addition of IV contrast is useful in assessing the abdomen and pelvis for bleeding and should be standard. In certain situations, IV contrast with CT angiography protocol is indicated for the head, neck, chest, and extremities if injury to the vasculature is a concern. Although contrast-induced nephropathy is a risk factor, IV contrast should not be withheld in a severely injured trauma patient when hemorrhage is suspected (51). MRI does not have a significant role in acute trauma management and may be utilized in the workup for spinal cord injuries, diffuse axonal injury, and ligamentous injuries. Mostly this can be deferred until after the initial assessment and hemodynamic stability is established.

**REASSESSMENT, MISSED INJURIES, AND THE TERTIARY SURVEY**

After the secondary survey has been performed and the necessary imaging obtained, it is important to have a planned reevaluation of the patient's condition to assess response to therapy and decide upon appropriate disposition. It is important to stress that if there is a change for the worse noted during reassessment, the primary survey can and should be repeated. If the patient needs to be monitored in the intensive care unit (ICU), plans should be made as early as possible so that the transition of care can be performed in a smooth, safe, and efficient manner. Direct physician-to-physician communication between the trauma team and the ICU providers needs to be performed. As well, one should become familiar with the hospital's system for bed flow and with the key nursing and administrative contacts to optimize this process. Ideally, trauma patients should be move in a unidirectional manner such as from the ED to the Radiology Department to the ICU without diversion back to the ED.

Ideally all injuries should be identified within the context of the primary and secondary survey. However, this is not realistically possible in every situation, especially with the more severe multi trauma patients with complicating factors such as altered mental status due to TBI, distracting injuries, or alcohol intoxication.

Patients that present requiring emergent intubation and perhaps an exploratory laparotomy to control bleeding may end up in the ICU without having completed the remainder of the primary and secondary survey. It is important to implement a system in which ongoing active reassessment once the patient is stabilized becomes the norm to seek out additional injuries. Musculoskeletal injuries, retroperitoneal injuries, and perineal injuries are among the more commonly described missed injuries (31). Many centers have instituted a formal tertiary survey in their trauma systems which have greatly facilitated the decrease in missed injury rates. A tertiary survey should be performed once within 24 hours of admission and additionally in patients who have resolved altered mental status and have become ambulatory.

An additional issue to check for within the initial 24 hours is the existence of “trauma lines,” invasive central venous, arterial, or urethral catheters that were placed in the emergent setting. As these devices are often placed under suboptimal conditions due to the urgency of the situation, sterile technique cannot be assumed. This detail is often missed during transition of care from one facility to the next or even between the trauma team and the ICU providers and may contribute to higher rates of avoidable catheter-related infections (52).

Also to be taken into consideration in the trauma population is the very high risk of developing a deep venous thrombosis (DVT). Trauma patients have more than a 50% chance of acquiring a DVT when not receiving prophylaxis. Independent risk factors associated with DVT in trauma patients include lower extremity fractures, pelvic fractures, spinal cord injuries, venous injury requiring repair, femoral CVL, and any major operative intervention. Low-molecular-weight heparin is the preferred agent for prophylaxis and should be considered as early as possible (53). Dosing is based on ideal body weight but may need to be adjusted for reasons which may include obesity and renal failure. Anti-Xa levels are more commonly being used to guide therapy. Many trauma patients present with injuries that are contraindications to DVT prophylaxis, such as intracranial hemorrhage, spinal cord injury, solid-organ injury, coagulopathy, and ongoing hemorrhage. Coordination with consulting services regarding timing of prophylactic low-molecular-weight heparin and the consideration for inferior vena cava filter placement should be a daily discussion.

**DOCUMENTATION**

The most urgent of trauma cases are fast-paced, dynamic, and often with a degree of diagnostic uncertainty at times. As discussed earlier, management of trauma places more emphasis on identifying and treating the greatest threat to life first, even when the definitive diagnosis remains unclear. As this is the case, there may be a natural tendency for the practitioner to place medical record documentation low on the list of priorities. However, it is also for these very reasons that accurate and timely documentation is critical in providing good patient care. Emphasis should be placed on calling out findings to the recording nurse during the primary and secondary survey to help identify trends and changes as the patient progresses through the hospitalization. An oral discussion between care providers is critical in effective and efficient patient care. However, this should also be supplemented by a written record in the chart. With each instance of a transfer of care, there is a higher chance for miscommunication or inaccuracies to propagate.

Finally, the medical record and documentation is central to the review process after trauma and is a large part of
performance improvement. We must never forget that good documentation is a responsibility and essential characteristic of a good physician.

Key Points

- Traumatic injury continues to occupy a large proportion of annual global mortality, which in addition to claiming thousands of lives per day, causes significant long-term morbidity further impacting society in regards to loss of productivity and high medical costs.
- The premise of ATLS is to expediently identify and treat the greatest threat to life first even before obtaining a definitive diagnosis or detailed history.
- The primary survey inherently prioritizes the assessment and treatment of a secure airway, intact breathing, and adequate circulation and thus addresses any rapidly lethal injuries prior to performing a more detailed examination, and should be repeated readily with any change in patient status.
- IO access should be considered in the hemodynamically unstable trauma patient that presents with difficult or inadequate intravenous access and can be placed within seconds by a trained practitioner.
- CT has become the imaging modality of choice in trauma patients requiring surgery.
- MTP, the immediate transfusion of blood products in a 1:1:1 ratio of packed red blood cells (PRBCs), FFP, and platelets, should be activated and administered immediately on recognition of ongoing severe traumatic hemorrhage likely to exceed 10 units of PRBC transfusion in the initial 24 hours.
- The mainstay of treatment for severe TBI focusses on decreasing incidence of secondary injury by maintaining adequate oxygenation and perfusion.
- The lethal triad of trauma includes hypothermia, coagulopathy, and acidosis; the severity of which being manifested in trauma patients requiring surgery should guide one to favor a damage-control approach with temporary abdominal closure and planned reexploration over definitive surgery.

References


