Trauma Resuscitation

29

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Epidemiology of Trauma

Throughout history, injury, both intentional and unintentional, has been among the leading causes of premature death and disability. Today trauma continues to be the primary cause of death and disability in the first four decades of life. The impact of injury continues to rise with the increasing motorization in developing countries. The World Health Organization (WHO) estimates that injury is responsible for 10% of annual deaths worldwide, with youth and young adults being the predominant victims (WHO) [1]. Road traffic crashes, suicide, and homicide are each expected to increase in rank among the global causes of death. The number of victims suffering disability following trauma increases the injury burden. The global macroeconomic costs of road injuries alone from both direct healthcare costs and indirect loss of productivity are estimated to be over 100 billion dollars annually [2].

Recognition of the impact of trauma has resulted in significant strides in injury control. Over time, the combined work of both the public and private sectors, including the efforts of healthcare workers, public health professionals, police forces, the automotive industry, traffic and road engineers, insurance companies, and government ministries, have, and continue to, significantly reduced the burden of injury. The introduction of formal trauma systems has been dramatic, with successful examples in developed nations demonstrating significant reductions of years of life lost due to injury nearing 50% [3]. The four Es of injury control: engineering, enforcement, education, and economics are a powerful combination [4]. Healthcare practitioners providing daily care for the injured can increase their impact by partnering with and advocating for injury control organizations.

Death Due to Injury

Historically, death following injury follows a tri-modal distribution. Catastrophic injury including aortic disruption, cardiac rupture, massive hemorrhage, brain injury with herniation, atlanto-occipital dislocation, brainstem injury, and complete airway disruption/obstruction are major causes of non-preventable death at the scene [5]. These fatalities can only be avoided through primary prevention measures such as eliminating impaired and distracted driving, seatbelt laws, and motor vehicle safety. Patients who survive the initial trauma can be salvaged through prompt attention to maintaining or establishing the airway, restoration of inadequate ventilation and oxygenation, and early hemorrhage control. Patients who survive beyond the first day may still succumb to severe traumatic brain injury and sepsis/multi-organ failure. However, effective initial resuscitation and management including minimizing delayed diagnosis and treatment of injuries enhances survival. Current literature suggests that mature trauma systems have minimized the third peak of "late" trauma deaths leading to a bimodal distribution of injury deaths as a more common current trend [6, 7]. Coordinated multidisciplinary trauma teams, proficient critical care, and established trauma systems are the foundations for maximizing survival in these patients. Modern trauma systems have reduced late deaths and disability due to early recognition and management of injury and hemorrhage control.

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Mechanisms

Injury may be intentional or unintentional, and due to blunt, penetrating, and/or blast mechanisms. Knowledge of the circumstances leading to the injury can serve as important clues to occult trauma at presentation. Secondary factors, such as alcohol, drug, and toxin ingestion, are also essential considerations in the initial management of the trauma patient. Environmental exposure is an important concern and determinant of risk at presentation. Hypothermia should be suspected with prolonged pre-hospital times, particularly in cold climates. Burns, smoke inhalation, and carbon monoxide poisoning are often present when patients present following extraction from enclosed settings during fires.

Blunt mechanisms have characteristic injury patterns. Falls from a height of 5 m or more are often associated with extremity, spine, and solid organ injury. Falls down greater than several stairs are associated with upper extremity, face, head, and neck trauma. Auto-pedestrian collisions have a high risk of head and neck injuries. Young children frequently present with isolated head injury following pedestrian motor vehicle crashes [8]. Elderly patients frequently present with intracranial hemorrhage, torso, and extremity injury and have a significant increase in morbidity and mortality [9]. Side impact collisions are usually associated with solid organ injury as well as extremity and rib fractures, and chest trauma on the affected side [10–12].

Injuries sustained from penetrating trauma vary considerably with the speed of the projectile. Knives and low-velocity handguns tend to cause injury along the missile's trajectory. Higher-velocity weapons such as hunting and assault rifles additionally cause significant cavitation due to the associated pressure wave. This can disrupt tissue many centimeters away from the missile's trajectory and significantly increase the severity of injury [13].

Blast injuries can cause overpressure injuries affecting the middle ear, lungs, and hollow viscous, penetrating injuries due to shrapnel, and blunt force trauma as the victim is struck by large objects or thrown due to the force of the blast [14].

Host factors are equally important when considering potential injuries. Children and toddlers have a wide range of normal age-specific physiology. They often harbor significant internal injury with less apparent external trauma. Based on size alone, they are more susceptible to multisystem injury [15]. Their physiologic reserve tends to be greater but can dramatically and rapidly deteriorate once exhausted.

The elderly often present with significant occult injury despite experiencing relatively low energy. A frequent example is the ground-level fall. Furthermore, injury response may be masked, due to both a lack of extreme physiologic reaction and underlying co-morbidity, such as atrial fibrillation or the presence of a pacemaker. Cirrhosis, congenital coagulopathy, chronic obstructive pulmonary disease, ischemic heart disease, and diabetes mellitus in particular increase the mortality of the geriatric trauma patient. Medication effects may also be significant (e.g., beta blockers, anticoagulants) and must be considered. Non-reversible anticoagulants, now popular in the management of atrial fibrillation, pose significant challenges in managing trauma related hemorrhage in the elderly [16]. Further elaboration on this topic can be found in Chap. 42.

Trauma Teams and Preparation

Physicians, nurses, and other health care providers may encounter injured patients in a variety of settings ranging from the pre-hospital environment, rural hospitals with teams consisting of a doctor, nurse, and X-ray technician, to tertiary care facilities with dedicated trauma teams and all specialties immediately available. Regardless of the setting, preparation is critical to success. Poor planning and execution can delay effective assessment, resuscitation, and definitive care of the injured.

Because of local and regional variations, it is imperative that trauma practitioners understand the workings and agreements of their own trauma systems. Practitioners should be able to easily answer the following questions: Which patients can be definitively managed in your institution? What are the pre-hospital triage and bypass criteria? What happens when a case is mistriaged? What happens when a multi- or mass casualty event occurs? What are the criteria for activating the trauma team in your hospital? What is the composition of the team ?[17, 18].

In jurisdictions with formalized trauma systems, a tremendous amount of work has occurred to effectively coordinate a response that maximizes the survival of the injured. While many of these systems seem intuitive, they require continued support, organization, and advocacy. Within a facility, trauma team individual practitioners should be clear on their role. They should inform themselves of the resuscitation setup and the location of all essential equipment in the area prior to patient arrival. Where is the difficult airway cart? What is in it?—including special intravenous (IV) equipment, central line trays, and intra-osseous equipment. Pediatric resuscitation kits, the Breslow tape? Chest tubes, insertion trays, and pleural drains? Where is the ultrasound unit for performing focused assessment with sonography in trauma (FAST) or eFAST? Does it work and where is the on switch? How are stat radiographs, operating room (OR) access, and patient transport arranged? These are simple questions that a brief walk through of the resuscitation bay can answer. Being prepared lays the stage for a smooth coordinated resuscitation with effective team leadership and a minimum of chaos and conflict [19–22].

Assessment and Priorities: xABCDE

The ATLS® course fundamentally changed the initial assessment and management of trauma [23]. The course was introduced in North America in 1980 by the American College of Surgeons following development of the prototype in Nebraska. It standardized a single safe approach to trauma care and introduced a common language. The course along with ACLS® (Advanced Cardiac Life Support) also introduced large-scale simulation to medical training. A parallel curriculum and certification program for course instructors promoted quality and consistency. By 2006 the program trained over a million physicians and currently has expanded to over 80 countries. Programs such as PHTLS® (Prehospital Trauma Life Support) and ATCN® (Advanced Trauma Care for Nurses) also expanded the audience for the ABCDE approach to trauma care. The principles of ATLS® are relevant to both practitioners who infrequently manage the severely injured and trauma teams in large urban trauma centers where the initial priorities are applied simultaneously. The goal is to manage the greatest threat to life first and to do no further harm to the patient.

The priorities, making up the primary survey, are as follows: (and have recently change to xABCDE in the 11th edition of ATLS)

- Control of eXanguinating external hemorrhage (recently added to the 11th Edition of ATLS)
- Airway assessment and management with attention to cervical immobilization (when relevant)
- Breathing (Assessment and management of oxygenation and ventilation)
- Circulation (Assessment and management of shock states)
- Disability (Assessment and management of neurologic injury)
- Exposure (Assessment and management of the back and extremities)

The patient should be approached from the head of the bed by whoever is responsible for performing the initial assessment. The findings should be clearly communicated to the team. This assessment and the initiation of resuscitation should take one to two minutes to complete [24–26].

A typical sequence in approaching a suspected major trauma patient would be as follows:

1. Ask the patient his or her name, apply oxygen, and if no response proceed to more definitive airway maneuvers while simultaneously ensuring that the cervical spine is immobilized where appropriate.
2. Inspect and auscultate the chest, palpate and percuss where findings warrant.
3. Palpate a pulse to establish rate and caliber. Ask for a set of vital signs including heart rate, blood pressure, temperature, and respiratory rate. Ask for initiation of two large bore IVs (18 gauge minimum) and initiate warmed intravenous fluids or, if a patient is hypotensive and in shock, early blood products where appropriate.
4. Check the patient's pupils. Estimate the Glasgow coma scale (GCS).
5. Expose the patient. This is a great time to log roll, remove the backboard, and perform a rectal examination when indicated.

The key findings requiring intervention during the initial assessment are as follows:

1. Identifying airway obstruction, either anatomic, mechanical, or due to coma, that requires an airway maintenance technique.
2. Identification of large or tension pneumothoraces requiring needle decompression or finger thoracostomy, and chest tube insertion.
3. Identification of shock and consideration of the etiology.
4. Identification of coma and especially impending herniation evidenced by a dilated pupil requiring urgent neurosurgical assessment and temporizing medical decompression.
5. Identification of life- or limb-threatening extremity injuries.

The most useful investigations that should be performed immediately are the chest X-ray, which identifies hemopneumothoraces, an EFAST (Extended Focused Assessment with Sonography for Trauma) (as discussed later in Chaps. 44 and 45) for identifying potential sources of hemorrhage and cardiac tamponade for patients in shock, as well as screening for pneumothoraces and hemothoraces, and a blood gas, which provides an immediate estimate of adequacy of oxygenation and ventilation, the level of base deficit and serum lactate, and an early hemoglobin (Hgb). In the case of major blunt force mechanisms, the inclusion of a pelvic X-ray is also very useful to screen for open book and vertical sheer pelvic fractures (important sources of hemorrhage) [27]. A trauma lab panel including a type and screen and/or cross match should also be drawn during this process. Serum alcohol (ETOH) levels are often routinely performed to assist in assessment of depressed level of consciousness and to aid with future trauma prevention initiatives. Drug and toxin screening may also be very useful at this stage.

The primary survey and resuscitation including all of these investigations should be completed within 15 minutes or less. Clear communication of actions and findings will speed the process and allow earlier intervention when required. Agreeing on the sequence of these steps by team members before the resuscitation is very advantageous. Remember that the *greatest threat to life should be treated first*. A patient who presents with obvious major hemorrhage from a scalp or extremity wound should have direct pressure applied to arrest the bleeding while approaching the airway assessment. Immediate application of a tourniquet in the field for blast or high-velocity extremity wounds in the combat arena has proven life-saving. As in all aspects of medicine, clinical judgment and experience are important.

Once the initial assessment is complete and initial resuscitation has commenced, a quick repeat of the ABCs is very useful. At this point, unless immediate surgical intervention is required, the team can proceed to a complete head-to-toe examination (the secondary survey) and more definitive investigations. Early transfer should be considered at this point if this initial patient management is occurring at a site that is not resource intensive (blood products, surgical specialties, necessary imaging, personnel). CT imaging should not delay transport to tertiary care unless it will impact the transfer decision.

Airway: Assessment and Management

Following control of exanguinating hemorrhage, the airway is the priority in assessment and management. Patients with airway obstruction have moments to live. The obstruction may be mechanical due to soft tissue injury or swelling or may be functional, associated with depressed levels of consciousness including coma. Airway obstruction may be obvious or subtle, especially in the case of impending obstruction, which can occur following an inhalation injury in a closed space during fires [28].

In all cases where cervical spine injury is suspected or possible, the cervical spine must be immobilized during airway assessment and management. Theis includes virtually all blunt force trauma patients with a significant mechanism of injury. It also includes penetrating trauma with a trajectory that may involve the cervical spine, penetrating trauma that may be associated with unwitnessed blunt trauma, blast injuries where multiple mechanisms are evident, and patients presenting with coma where trauma is within the differential.

The best initial approach to the airway is simply to introduce yourself to the patient and ask the patient their name. The ability to respond indicates a patent airway, reasonable ventilation, circulation adequate to perfuse the brain, and the absence of major traumatic brain injury. For patients able to speak, the most useful follow-up questions are asking them their Allergies, Medications, Past medical history, Last meal, and what happened (Events) (AMPLE history). Oxygen should be applied in all suspected cases of major trauma until a thorough assessment of the magnitude of injury is complete.

In patients where airway obstruction may be impending, consider the following rules. GCS < 8 = intubate. If patients have a potential impending airway obstruction with intermediate levels of GCS 9–12, inhalation injury, or neck hematoma, then ask yourself the following. What is my experience? What assistance and backup are available? Where will the patient be monitored? In cases of transport, who is travelling with the patient? What equipment do they have and how long will it take? All of these factors should be considered when planning a definitive or temporizing airway.

Once a decision has been made that the patient requires an airway, then assess for difficulty. If the patient is dying from airway obstruction and you are the only help available, then attempt intubation and/or proceed directly to a surgical airway. In other cases, airway maintenance techniques including jaw thrust, chin lift, insertion of an oral or nasal airway, and bag mask ventilation should be performed next.

In all other cases, assess the difficulty of intubation. Remember that cervical spine immobilization will shift the spectrum of airway control towards more difficult. This may increase the need for airway adjuncts such as intubating video laryngoscopes. Forming an opinion of the difficulty of airway capture is important. An easy airway typically would be recognized by a wide mouth, normal-sized and placed dentition, a large chin and jaw, and a lack of facial and neck soft tissue trauma or swelling. Clues to a difficult airway include small mouth, chin, jaw, significant overbite, and facial/neck trauma. The LEMON pneumonic is a useful reminder.

- Look
- Evaluate
- Mallampatti Score
- Observe
- Neck

In cases of an easy airway with fairly straightforward anatomy, proceeding to drug-assisted intubation, after preoxygenation with an appropriately sized cuffed tube is recommended for all practitioners who have had adequate training [29]. Appropriate equipment including suction, oxygen, oropharyngeal airways, nasopharyngeal airways, bag-mask, laryngoscope, bougie, supra-glottic devices, endotracheal tubes, pulse oximetry, CO2 detections devices, and a surgical airway kit should all be close at hand.

Where a difficult airway is suspected, temporizing with bag mask ventilation and oxygen is the next step. In regional or urban institutions, asking for experienced help should be next. In rural and remote locations, bag mask ventilation until the arrival of an experienced aero medical transport crew may be appropriate [30].

In difficult airway cases, the application of a variety of airway tools and devices to assist intubation is critical to success. A variety of approaches and devices have been described by various specialty organizations. The best approach is the one which your center and team are most familiar and comfortable with. A simple and inexpensive device, which often allows capture of a more difficult airway, is the gum elastic bougie. It is a long slender rod with a hook or hockey stick at the end. Simply visualize the epiglottis, hook it underneath, and advance. Correct tracheal positioning is confirmed by feeling the bougie bounce along the tracheal rings. When advanced, gentle resistance will be encountered when it reaches the secondary and tertiary bronchi. The absence of resistance and tracheal ring sensation suggests esophageal intubation.

The laryngeal mask airway (LMA) can provide reasonable ventilation and oxygenation when this is difficult to achieve using bag mask ventilation. In experienced hands, the intubating LMA can be very useful. However, the LMA does not protect the airway in cases of aspiration and may be easy to dislodge.

Recently, the introduction of the video laryngoscope has revolutionized the management of the difficult airway and greatly facilitated capture on these patients. Intubation over a fiberoptic bronchoscope remains an option in the right hands.

Regardless of approach, if the airway is not captured and the patient is desaturating, proceed immediately to a surgical airway. Surgical airways will be discussed further in Chap. 33.

Once an airway is placed, always confirm correct position using these five techniques:

1. Look for symmetrical chest wall expansion.
2. Listen and auscultate for breath sounds.
3. Feel—palpate the chest wall for symmetrical expansion.
4. Oxymetry—confirm adequacy of oxygenation.
5. Capnometry—confirm adequacy of ventilation.

Remember that an AP chest X-ray (CXR) cannot confirm the correct positioning in the trachea vis-a-vis the esophagus. Look for evidence of right mainstem bronchus intubation, due to the lesser angulation and more direct descent compared to the left. Typical endotracheal tube sizes would be 7 mm for females and 8 for males. Average distance from the teeth would be 22 cm for females and 24 cm for males for correct tracheal positioning 3–4 cm above the carina. Confirm this position on the chest X-ray.

Breathing: Oxygenation and Ventilation

Assessment of the chest initially by inspection and auscultation is performed early in the primary survey. The goal is to confirm the presence of bilateral breath sounds. Simultaneous oxymetry and, in the case of airway capture, capnometry are very useful. If breath sounds are absent, check the vitals and pulse oxymeter—if both are adequate take the time to complete the remainder of the primary survey and obtain a CXR. EFAST (see Chap. 22) in experienced hands can be a useful aid in detecting large hemo–pneumothoraces. If the patient is desaturating or hypotensive, then immediate decompression is required. While large pneumothoraces can develop in spontaneously breathing patients leading to air hunger and desaturation, pneumothoraces with mediastinal displacement and tension physiology leading to hypotension are most likely in patients who have had positive pressure ventilation of any means.

If the patient has already been intubated and breath sounds are absent on the left, always confirm that this is not due to right main stem intubation. Simply check the endotracheal-tube (ETT) position, and if it seems well-advanced, try pulling it back 1–3 cm and repeat the auscultation. When absent breath sounds are confirmed and persistent and the patient is desaturating or hypotensive, perform needle decompression with a large over-the-needle catheter in the 5th intercostal space just anterior mid axillary line. In an overweight or obese patient, perform needle decompression in the 2nd intercostal space in the midclavicular line [31]. If the needle fails due to chest wall thickness or kinking, consider performing a finger thoracostomy followed with a chest tube (28–32 French). The chest tube should be placed in the mid-anterior axillary line, above the rib to avoid the neurovascular bundle. Useful landmarks are to remain above the nipple in males and above the inframammary fold in females. This should avoid inadvertent injury to the diaphragm and intra-abdominal organs. A sharp trochar should not be used for chest tube placement. Good sterile technique with complete barrier precautions should be used whenever possible to mitigate the risk of empyema and its associated morbidity. The chest tube should be connected to 20 cm underwater suction, and outputs closely measured.

Hemorrhage of >1500 cc, or >200 cc/hour for four consecutive hours or more are indications for thoracotomy. If the chest tube drainage stops, beware, it may simply be clotted. Persistent evidence of shock with a large hemothorax on EFAST/CXR are also indications for surgery.

At the completion of the primary survey, a CXR should be obtained and a more thorough exam performed. Simple pneumothoraces, particularly those that occupy 2 cm or less from the chest wall or apex, or occult pneumothoraces (pneumothoraces seen only on computerized tomography (CT) occupying less than 1/3rd of the pleural cavity) may be observed in stable patients. Repeat CXR should be performed within approximately 6 hours. In patients requiring transport, placement of a chest tube is advised.

Additional injuries should be identified on the CXR including rib, clavicle, scapular, and vertebral fractures, wide mediastinum, pneumo-mediastinum, pulmonary contusion or aspiration, elevated or obvious ruptured hemidiaphragms, and subcutaneous emphysema. The presence of these abnormalities provides important clues to the severity of injury, necessary additional investigations, and treatment plans.

CT of the cervical spine is increasingly being performed for cervical spine clearance in major mechanisms of injury. CT of the abdomen and pelvis is likewise routinely performed to identify occult intra-abdominal injury. Together these tests will also identify all cases of occult pneumothorax. CT of the chest should be added to these investigations where the mechanism is high impact/rapid deceleration and could be associated with blunt traumatic aortic injury. CT of the chest combined with CT of the C Spine and CT of the abdomen and pelvis allows complete reformatting and inspection of the cervical, thoracic, and lumbar spine improving both the accuracy and timeliness of spinal clearance. This is important for early mobilization, initiation of physiotherapy, and prevention of respiratory failure in patients with blunt chest trauma. In patients with multiple rib fractures and significant chest pain, mobilization and pain control should be a priority.

At the completion of the secondary survey, an electrocardiogram (ECG) should be performed. Significant cardiac contusion leading to pathologic arrhythmias and heart failure or hypotension typically occurs in patients with severe polytrauma and abnormal vital signs on presentation. Patients may present following an acute myocardial infarction or arrhythmia as the initiating event that led to syncope that in turn resulted in a traumatic event causing injury. This should be screened for by obtaining the ECG. Wide QT and QRS may be seen in patients with co-existent toxic ingestion. Troponins are of little value in acute chest trauma. In the absence of a suspected acute coronary syndrome, they are not predictive of outcomes in trauma [32].

Circulation: Recognition of Shock and Control of Hemorrhage

Once airway and breathing have been attended to and obvious sources of external hemorrhage are compressed, the vital signs should be reviewed. Quick palpation of a pulse for caliber and rate and assessment of skin temperature provide valuable information. The most common cause of patients in shock following trauma is hemorrhage. Other potential causes of shock to consider include obstructive shock due to tension pneumothorax or cardiac tamponade, distributive shock due to spinal injury (or sepsis when presentation is delayed), and cardiogenic shock due to an underlying acute coronary event/myocardial infarction. The history of the event, combined with pulse, blood pressure, skin temperature, and examination of the neck veins, will usually help identify the cause of shock (Table 29.1).

Two large bore IVs, 18 gauge or larger, should be initiated. If they cannot be inserted and the patient is in profound hypovolemic shock, then one should move onto a different form of access and consider an intraosseous line, central venous access, or a venous cutdown based on the expertise of the clinician. Options for venous access and considerations for choice will be elaborated on in Chap. 33. Warm intravenous fluid, such as crystalloid or blood products, should be initiated, but the primary goal is to find and stop the bleeding or correct the underlying cause of shock. An initial crystalloid bolus of up to 1 liter may be necessary, but aggressive fluid resuscitation has been shown to increase mortality and therefore should be used judiciously. In patients with traumatic brain injuries, hypotension should be avoided as it worsens outcomes. In penetrating trauma with ongoing hemorrhage, aggressive resuscitation prior to surgical control of bleeding may in fact further exacerbate hemorrhage, increase coagulopathy, and worsen outcomes. Damage Control Resuscitation will be considered in Chap. 30.

If a patient is hypotensive and in suspected hemorrhagic shock, a massive transfusion protocol should be activated. These protocols have streamlined resuscitation and help avoid coagulaopathy and thrombocytopenia through the early administration of packed red blood cells, plasma, and platelets in predefined low ratios [33]. This will be discussed further in Chap. 30. Tranexamic acid is also now an accepted adjunct. It is an antifibrinolytic which is cheap, safe, and potentially effective if used within the first 3 hours of injury.

Always remember that hypotension is a late sign of shock and, in the case of hemorrhage, typically does not occur until the loss of one third or more of the blood volume. Early signs are anxiety, confusion, tachycardia, and narrowed pulse pressure. Repeat the vital signs to follow trends and monitor resuscitation. Useful ways to evaluate the adequacy of resuscitation include the cardiac rhythm, GCS, and urine output.

Ultimately, the goal is to find and correct the cause of shock. In the case of hemorrhage, identifying the source and rapidly stopping the bleeding is the key. ATLS® teaches "blood on the floor and four more." In addition to external hemorrhage from lacerations, principal sites of blood loss are the chest, pelvis, abdomen, and long bones. A CXR,

Table 29.1 Shock, physical findings

Etiology of shock	Pulse	BP	Skin	Jugular venous pressure
Hemorrhagic	Rapid, thready	Low with reduced pulse pressure	Cool	Low
Tension pneumothorax	Rapid, thready	Low with reduced pulse pressure	Cool	Elevated
Tamponade	Rapid, thready	Low with reduced pulse pressure	Cool	Elevated
Spinal	Normal, slow, full	Low with wide pulse pressure	Warm	Low
Cardiogenic	Rapid, thready	Low with reduced pulse pressure	Cool	Elevated

Pelvic X-ray, EFAST exam, and palpation of the extremities will review the potential sources of blood loss. EFAST can also demonstrate cardiac tamponade and identify pneumothoraces, both potential sources of obstructive shock.

A patient in shock due to hemorrhage or tamponade requires immediate definitive management. With external hemorrhage, direct pressure, compressive dressings, hemostatic agents, extremity tourniquets, and junctional tourniquets are among the tools to be considered [34]. In the case of pleural hemorrhage or cardiac tamponade, a thoracotomy should be performed. In cases of positive abdominal FAST exam, the treatment is immediate laparotomy. With long bone fractures, splinting and resuscitation should be definitive [35].

Pelvic fractures represent a special challenge. The three patterns of pelvic trauma are lateral compression with pubic rami fractures, open book fractures, and vertical sheer injury. Lateral compression fractures are associated with pubic rami and acetabular fractures but usually do not present with massive hemorrhage. These patients often can have urethral or extraperitoneal bladder injury. Open book fractures frequently have major bleeding. Compression with a binder or sheet to temporize is useful. Vertical shear fractures usually present in hemorrhagic shock. Pelvic binders are less practical and often have to be combined with axial traction. Early orthopedic consultation is very helpful. In cases where shock is present, a decision is required on whether the next step is surgery with packing and pelvic stabilization followed by angio-emolization, immediate embolization, or CT first to plan therapy followed by either surgery and or angio-embolization. This can be difficult as angiography, while particularly useful for retroperitoneal or solid organ arterial hemorrhage, does not stop venous bleeding and can miss low flow bleeding. In profound shock, patients should go directly to the operating room. Patients who respond to initial resuscitation may be reasonable candidates to be taken by the team to CT. Patients with partial or transient response can be divided into FAST positive or negative groups. FAST positive should have laparotomy first, FAST negative can be managed initially with angio-embolization. Pelvic fractures may be associated with intra-abdominal hemorrhage in which case initial management should be in the OR [36–38]. These challenging scenarios will be further highlighted in Chaps. 32 and 33.

Patients in neurogenic shock should receive initial 1–2 L boluses of crystalloid but then frequently require pressor therapy and ICU monitoring. Patients with co-existent cardiac pathology due to an MI or severe contusion will need to be supported in an ICU with close cardiac monitoring and physiological adjuncts such as inotropes.

It is important to not get fixated on a single body cavity or single cause of shock. Trauma patients can have multiple causes of shock and multiple sources of hemorrhage. Traumatic brain injury does not cause shock. In addition, a wide mediastinum with a suspected blunt aortic injury is also almost never the source of hemorrhagic shock as frank aortic rupture usually leads to immediate death. In these situations, look elsewhere for a source of hemorrhage. Patients who are relatively stable during resuscitation are candidates for truncal CT to help with definitive diagnosis and to exclude occult injury. Abdominal examination is unreliable in patients following major trauma especially when associated with multiple extremity or spine injuries. FAST is not sensitive for solid or hollow viscous injury. It simply identifies free fluid, which may indicate bleeding.

Neurologic Injury

The goal during the disability portion of the primary survey is to recognize life-threatening neurologic injury, particularly severe traumatic brain injury. Pupils and GCS should be inspected and estimated during the initial assessment. Severe traumatic brain injury is characterized by GCS less than or equal to 8. Asymmetric pupils may indicate mass effect with impending transtentorial herniation. The presence of either mandates prompt neurosurgical consultation. The most effective initial management is to ensure that viable brain is preserved by maintaining oxygenation and perfusion. In these patients, vigorous resuscitation to avoid or correct hypotension is a priority. Systolic blood pressure target should be greater than 110 mmHg as this may decrease mortality and improve outcomes. Resuscitation for patients with hemorrhagic shock should employ a massive transfusion protocol. Mannitol 0.–1 g/kg may be an effective temporizing maneuver in order to control ICP and avoid arterial hypotension and, as a result, transiently minimize brain swelling and herniation. The same is true of temporary hyperventilation when used in moderation for as short a period as possible. Prolonged hyperventilation, with a PCO2 < 25mmHG, should be avoided. In most cases, normal PaCO2 levels are desirable to avoid cerebral vasoconstriction, but in the case of impending herniation, this can be life-saving.

CT of the head should be performed as soon as possible. However, treatment of hemorrhage in order to maintain cerebral perfusion still takes precedence. Patients presenting with hemorrhagic shock still need to have the bleeding stopped first, before brain imaging, in most cases. Patients who respond to resuscitation and who in the judgment of the trauma team leader will maintain perfusion while undergoing CT may have an expedited CT performed first [39].

Traumatic brain injury (TBI) may be characterized as severe (GCS </= 8), moderate (GCS 9–12), and mild (GCS 13–15) including concussion. Patients with moderate traumatic brain injury should undergo CT. Patients with mild TBI should be assessed in accordance with the Canadian CT

head rule to determine whether CT vs. simple observation and follow-up is required. See Chaps. 46 and 47 for an evidence-based discussion of imaging in stable patients. CT is required for patients with evidence of open, depressed, or basal skull fracture, persistent GCS < 15 beyond 2 hours, age >65 with loss of consciousness, amnesia, or disorientation, and/or vomiting two or more times. Consideration should be given to imaging those with dangerous mechanisms or amnesia for events >30 minutes [40, 41].

Musculoskeletal Trauma Including Spine

The priority during the exposure portion of the primary survey is to identify long bone fractures. Patients are initially exposed, log rolled, and extremities are inspected and rapidly palpated. Management of fractures is by immobilization and splinting. During the secondary survey, all extremities and joints should be examined, in detail, including sensory, motor, and neurovascular examination.

The entire spine, cervical, thoracic, and lumbar should be immobilized until spinal column injury has been ruled out. In most cases of major blunt mechanisms or penetrating injury with trajectory near the spine, X-rays are required. CT is not required for all injured patients but has proven invaluable for major blunt trauma patients, particularly those that also require truncal CT. If CT of the chest and abdomen/pelvis are not being performed, then plain radiographs should be obtained. For patients who did not have major mechanism, the Canadian C Spine rule [42] provides guidelines on when to request C spine x rays and when clinical exam is sufficient. If clinical exam is being relied upon, patients must have a GCS of 15, be stable, be younger than 65, must not have been exposed to a dangerous mechanism, and must not have any extremity paresthesias. They should be alert, and cooperative, have no midline pain, and be able to actively rotate to 45 degrees in both directions, extend, and flex the neck comfortably [43].

Patients who present with spinal cord or peripheral nerve injury should have initial findings carefully documented, and the injured part should be protected through immobilization. The primary management of these injuries in early trauma care is preservation of oxygenation, ventilation, and perfusion while taking care to do no further harm [44].

Management of extremity fracture is by splinting and immobilization. As already noted, direct compression of bleeding and/or application of a pelvic binder should already have been performed as part of the circulation portion of the primary survey. Open fractures should receive antibiotic and tetanus prophylaxis as well as prompt orthopedic consultation. Dislocated joints should be recognized and reduced emergently, ideally in the trauma resuscitation room. If operative reduction is required, this should be performed emergently [45, 46].

Musculoskeletal injuries in major trauma patients are frequently not recognized during initial trauma assessment. A thorough secondary assessment when appropriate, as well as routine performance and documentation of a tertiary survey within 24–36 hours, is important to identify these injuries. Reassessment, particularly when level of consciousness improves if initially compromised, will enhance detection rates and prevent morbidity due to delayed recognition.

Conclusions

An organized, consistent approach by trauma practitioners and trauma teams will allow effective and safe management of the severely injured. Early identification and management of shock is critical. In cases of hemorrhage, the priority is to stop the bleeding. Rapid performance of an xABCDE assessment accompanied by a CXR, Pelvic XR, and EFAST exam simplifies decision-making in blunt trauma. Operative control, angio-embolization, and musculoskeletal stabilization, when required, should occur immediately in tertiary care trauma centers. In referring centers, well-organized trauma systems will focus on early injury identification, efficient but thorough communication, and prompt arrangement of transport.

Repeating the ABCs serially, as well as point-of-care testing with ABGs initially and as required, will allow all patients with evolving shock to be readily identified and appropriately resuscitated. Massive transfusion protocols and attention to avoidance of hypothermia, acidosis, and coagulopathy are keys to success [47, 48].

Patients who suffer trauma through a significant mechanism and in whom major injury is obvious or suspected require a thorough head to toe assessment, full head, neck, thoracic, abdominal, and pelvic CT, when hemodynamically stable, to rule out truncal and spine injury and the liberal use of plain radiographs for all extremities and joints with pain or abnormal physical findings [49].

Trauma systems and teams are designed to ensure that resources and infrastructure are available to support safe care. Trauma is not a solo sport; early engagement of the system and team saves lives [49–51]. Trauma care continues to evolve and adapt to changing technology, medical advances, and systems and team dynamics [52].

Key Points

- Organized trauma systems and trauma care significantly reduce injury death and morbidity.
- The ATLS® system provides a common global approach to trauma resuscitation. It allows teams and centers to speak a common language.
- The ABCDE principles of trauma resuscitation are equally valid when practiced sequentially or simultaneously by a trauma team.
- Trauma teams function optimally when members are prepared, leadership is clear, and communication is encouraged.
- Trauma resuscitation continues to improve with the adoption of balanced resuscitation, massive transfusion protocols, and adjuncts for rapid and definitive control of hemorrhage.

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