Assessment and Resuscitation in Trauma Management

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KEYWORDS

• Trauma assessment • Resuscitation • Primary survey • Venous access
• Emergency airway • Cavitary triage

KEY POINTS

- Initial resuscitation should focus on rapid assessment and stabilization of life-threatening injuries with management of non–life-threatening injuries deferred until the patient is stabilized.
- Damage control resuscitation includes efficient intravenous access, avoidance of hypothermia, and a preference for colloid resuscitation rather than crystalloid.
- Providers should understand indications for both emergency intubation and discretionary intubation in the trauma setting as well as options when endotracheal intubation is not possible.
- Combining plain films, physical examination, and ultrasound allows for a complete cavitary triage to be performed and will identify nearly all hemodynamically significant sites of bleeding.
- Retrograde balloon occlusion of the aorta is likely beneficial in the profoundly hypotensive patient, but is not synonymous with resuscitative thoracotomy.

INTRODUCTION

The Golden Hour was first coined by R. Adams Cowley to emphasize the importance of prompt and efficient management of the acutely injured patient. Advances in both resuscitation and diagnosis have given providers a host of new procedural and imaging options and have resulted in improved trauma care at centers of all levels.

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BEYOND ADVANCED TRAUMA LIFE SUPPORT: INITIAL RESUSCITATION IN THE EMERGENCY DEPARTMENT

The Airway, Breathing, Circulation, Disability, Exposure management taught by Advanced Trauma Life Support (ATLS)[1] is an effective framework for initial evaluation and management of the injured patient and has been demonstrated to increase efficiency and quality of care.[2] As any experienced provider knows, in a well-staffed trauma center, these processes can be run in parallel and their order modified for certain exceptional cases. When performed in full, they represent a complete initial evaluation of the injured patient in an orderly and efficient manner (**Box 1**).

Airway/Access

Intravenous access

Although typically straightforward, intravenous (IV) access can be a frustrating problem in the care of the trauma patient. Standard resuscitation calls for the placement of 2 large-bore IVs, typically in the antecubital position, with ultrasound (US) assistance if necessary. Alternatives to peripheral cannulation should be performed if peripheral access is not completed quickly. There are several options for access that can be used in the trauma bay, with variability in the rate of fluid administration[3] (**Box 2**). Multiple other solutions to access have been described, including venous cutdown,[3] corpus cavernosum,[4] catheterization, direct right atrial catheterization, and umbilical vein catheterization in infants, but these are not of common utility in the trauma bay.

Central venous catheterization

Central venous catheterization (CVC) is an efficient mode of vascular access. Subclavian or femoral access is often preferred because of the ease of placement without US guidance. Caution should be maintained when using femoral access in the setting of severe trauma to the chest or abdomen, particularly penetrating injuries, because disruption or injury of the vena cava or iliac veins will prevent adequate delivery. In addition, in the case of accidental arterial access, these lines can be used in an emergency, but should be converted to venous access promptly.

Interosseous catheter

Interosseous (IO) catheter use has become widely accepted in trauma resuscitation and provides a fast alternative to CVCs. In the adult trauma patient, humeral and tibial access is preferred with success rates as high as 97%, although multiple other sites including the sternum, iliac crest, and femur have been described. Humeral IO

Box 1
The standard trauma

1. Patient arrival
2. Pulse check
   a. IV access established
   b. Manual blood pressure measurement
3. Primary survey
4. Report from Emergency Medical Services
5. Adjunctive imaging
6. Secondary survey
7. Disposition

Box 2
Maximal infusion rate of common catheters

Humeral IO	80 mL/min
Tibial IO	15 mL/min
32-mm 14 g IV	325 mL/min
30-mm 16 g IV	215 mL/min
30-mm 18 g IV	110 mL/min
30-mm 20 g IV	63 mL/min
9-Fr Mac distal port	508 mL/min
Proximal	200 mL/min
8.5-F Cordis	125 mL/min
7-F triple lumen distal port	38 mL/min
Medial	17 mL/min
Proximal	18 mL/min

Data from Young J, Gondek S, Kahn S, et al. Challenging IV access in the patient with septic shock. In: Diaz JJ, Efron DT, editors. Complications in acute care surgery: the management of difficult clinical scenarios. Cham (Switzerland): Springer International Publishing; 2017. p. 1–13.

catheters are preferred to tibial catheters because they provide greater flow rates but are inferior to both large-bore CVCs and IV catheters in this regard (see **Box 2**). In addition, resuscitation through a humeral IO drains into the subclavian vein, resulting in venous distention that facilities placement of a subclavian CVC when appropriate.

Airway

Indications for intubation During the initial assessment of the injured patient, a rapid decision must be made regarding control of the airway. To facilitate this, the Eastern Association for the Surgery of Trauma has produced revised guidelines for indications for emergency intubation[5] (**Box 3**).

Box 3
Indications for emergency intubation

Emergency intubation

Airway obstruction

Hypoventilation

Hypoxemia ≤90%

Severe cognitive impairment (GCS ≤ 8)

Severe hemorrhagic shock

Cardiac arrest

Major burn (≤40%) or inhalational injury

Discretionary intubation

Facial or neck trauma

Moderate cognitive impairment (GCS 9–12)

Persistent combativeness refractory to pharmacologic intervention

Respiratory distress

Expected operative course

Cervical spinal cord injury

Although patients with a Glasgow Coma Score (GCS) of 8 or less clearly require intubation, GCS of 9 to 12 has been associated with a 33% rate of traumatic brain injury (TBI), and combativeness has been associated with a 12.7% rate of TBI.[6] Reasonable attempts should be made to support noninvasive ventilation in suspected TBI patients, and reasonable pharmacologic attempts should be made to control agitation in these settings to avoid hemodynamic compromise as well as the risk of hypoxia associated with intubation. If these measures are unsuccessful, intubation may be required to expedite computed tomography (CT) scan and subsequent TBI management. Similarly, patients with cervical spine injury that are expected to progress to respiratory insufficiency appear to benefit from early intubation, and this should be considered in the trauma bay.[7–9]

Induction agents for emergency intubation Rapid sequence intubation should be used for nearly all emergency intubations in the trauma bay. No clear data have emerged to support a preference for one pharmacologic regimen over another. Succinylcholine is the preferred paralytic agent, although high-dose rocuronium may be used when succinylcholine is contraindicated due to significant burn, crush injury, prolonged down time, or renal failure. One suggested protocol is reviewed in **Box 4**. Practitioners should be familiar with both IV and intramuscular dosing regimens, or they should be displayed in clear view in the trauma bay. In this protocol, ketamine is the preferred induction medication for its favorable hemodynamic profile and ease of dosing. Although TBI was once considered a contraindication to the use of ketamine, these concerns have since been refuted.[10] All induction medications, including ketamine, may cause hemodynamic compromise because of offloading of the sympathetic response to trauma. Propofol, however, is the most commonly cited, and its use is generally avoided. In the setting of profound hypotension, patients may benefit from noninvasive ventilation until massive transfusion protocols are initiated to avoid complete hemodynamic collapse on induction.

Alternatives to direct laryngoscopy for difficult intubation Although direct laryngoscopy (DL) is the preferred mechanism of intubation, multiple alternatives have been developed and should be considered based on familiarity and experience. All resuscitation protocols must include alternatives to DL in the trauma bay because of multiple factors increasing the difficulty of emergency intubation, including limited view due

Box 4
Rapid sequence intubation medication options

Preferred induction agent
- Ketamine 1 to 3 mg/kg IV

Second-line agent
- Propofol 60 to 200 mg (6–20 cc)

Third-line agent
- Etomidate 10 to 20 mg IV (5–10 cc)

AND
- Succinylcholine 80 to 100 mg (4–5 cc)

If unable to obtain IV/IO access:
- Ketamine 5 mg/kg IM
- AND
- Succinylcholine 5 mg/kg IM

to maxillofacial or neck trauma, aspirated blood or vomitus, alterations in anatomy, difficulty in patient positioning, and other factors.

Video laryngoscopy

Video laryngoscopy (VL) offers several potential benefits over DL and should be considered an option for initial attempts at intubation. The clearest benefit is the ease of supervising inexperienced providers, although VL may be superior to DL in anatomically altered or obese patients and in patients with known or suspected cervical spine injury. VL may have improved first-attempt intubation rates when compared with DL, theoretically reducing the likelihood of hypoxic episodes in emergency intubation.[5] This may be theoretically beneficial to the spinal cord injury or TBI patient, but this has not been demonstrated clinically. Practitioners should, at a minimum, be familiar with the VL options at their centers.

Supraglottic devices

Supraglottic devices, including laryngeal mask airway, Combitube (Medtronic, Minneapolis MN, USA), and King (Ambu, Ballerup, Denmark) Airways (also known as esophageal/tracheal airways), are commonly used as rescue devices by both in-hospital and prehospital providers. No one device has been demonstrated to be superior to the others, and choice of device should be determined by availability and familiarity. These devices have limited utility in the trauma bay because critically injured patients should be assumed to have a high risk of emesis, and supraglottic devices do not offer any protection against aspiration. In addition, when endotracheal intubation is not possible because of airway or vocal cord edema, supraglottic devices will also fail. Supraglottic devices should not be considered a durable airway and should be converted to an endotracheal tube or surgical airway as early as is feasible. Patients receiving supraglottic devices in the field should be evaluated and converted in the trauma bay where possible, and although a reasonable option in the prehospital setting, their use should be avoided in the trauma bay.

Surgical airway

All patients in whom emergency endotracheal intubation fails should be prepared for a surgical airway with cricothyroidotomy as the preferred option for hypoxic patients or patients who cannot be ventilated with bag valve mask or a supraglottic device. Emergency tracheostomy should be reserved for patients who are well ventilated without intubation. Both cricothyroidotomy and tracheostomy may be performed, and both may be performed open or percutaneously depending on the experience of the proceduralist. Although some data have demonstrated that emergency cricothyroidotomy does not mandate conversion to tracheostomy for short-term management, patient characteristics must be accounted for. Anecdotally, cricothyroidotomy is more likely to be accidentally dislodged in patients who require multiple transfers for imaging, patients who require multiple procedures, or those who may be agitated and difficult to sedate. In these patients, tracheostomy may be a preferred, safer option if their hemodynamics allows conversion.

BREATHING

Ventilation

Few data exist to support initial ventilation strategies specific to the trauma population, although intubation in this group should follow accepted protocols for emergency intubation. Initiation of ventilator support with a lung protective strategy is probably superior where possible. A meta-analysis found that initiation of ventilation with tidal volumes of 6 to 8 cc/kg versus higher-volume ventilation in emergency room patients has been shown to reduce rates of acute lung injury, pulmonary infection, and mortality.[11] The transition of this data to the trauma population is limited, and it should be noted that protective ventilation is associated with increases in Pa_{CO_2} as well as need for higher positive end-expiratory pressure, both of which may be harmful to specific subgroups of the trauma population,[11] and may require additional sedation in order to facilitate a low-volume protective strategy.[12] Ongoing trials of ventilation strategies are currently accruing patients,[13] although no specific efforts have been made in the trauma population. Clinicians should exercise clinical judgment in determining a ventilator strategy for the intubated trauma patient.

Injuries to the Chest

Hemothorax

Although significant chest injury is reviewed separately in this issue, hemothorax becomes relevant to the primary survey in the setting of hypotensive patients. Chest tube drainage should be provided in the trauma bay to aid in cavitary triage. Hemothorax is often a harbinger of other significant injuries to the chest, and these patients should be evaluated for injuries to the great vessels, lungs, or heart. Because of the negative pressure in the chest, pericardial effusion is an insufficiently sensitive indicator of cardiac injuries in patients with hemothorax, and significant injuries to the heart may be missed on US, CT, or echocardiography.

Pneumothorax

Pneumothorax in itself does not mandate emergent management, but in the presence of tension physiology, intervention during the primary survey becomes mandatory. Three methods of emergency decompression are available to the proceduralist. Needle decompression is an acceptable option in the emergent setting, although more durable options are preferred if time allows. Needle decompression can be ineffective in many patients because of inappropriate positioning, occlusion, or displacement. Cadaver models have demonstrated that a midaxillary position may be superior to anterior placement because of differences in chest well thickness in an American population.[14] More durable options include finger thoracostomy and formal chest tube placement. Finger thoracostomy does mandate later conversion to chest tube, but is efficient in a time-sensitive situation. Choice of chest tube size has not been shown to be significant,[15] and percutaneous tube thoracotomy placement may be an acceptable treatment option, but neither have come into favor for the unstable patient because of concerns regarding occlusion of the tube and provider familiarity with traditional chest tubes.

CIRCULATION

Avoidance of Hypothermia

Hypothermia has long been recognized to have a negative impact on outcomes in traumatic injury, with actively rewarmed patients having significantly better outcomes from resuscitation.[16,17] Significant alterations in coagulation have been demonstrated to begin at temperatures of 35°C.[18] Multiple mechanisms for hypothermia-related coagulopathy have been identified, including direct inhibition of the coagulation cascade, morphologic changes to platelets, reduced platelet aggregation, and diffuse microvascular thrombosis.[18] In moderately hypothermic patients (>33°C), platelet effects are the dominant cause of coagulopathy, with effects in the severely hypothermic (<33°C) driven to a larger degree by delays in the coagulation cascade.[18] Heat loss in trauma patients has been shown to increase from a baseline 60 kcal/h to as much as 400 kcal/h after acute trauma.[19] The belief that hypothermia may be protective of certain complications in trauma has been disproven, and effort should be made throughout resuscitation to avoid or correct hypothermia. Recent review of the National Trauma Data Bank has clearly demonstrated worse infectious, thromboembolic, and coagulopathic complications for patients with demonstrated hypothermia.[20] Many strategies have been developed and instituted in the care of the acutely injured patient, and centers are encouraged to implement protocols to prevent hypothermia, incorporating both passive and active rewarming. With increasing severity of hypothermia, more aggressive interventions should be initiated, including fluid and forced air rewarming, heating pads, and humidified and heated ventilation.[21] Profound hypothermia will require even more drastic options, including heated body cavity lavage, extracorporeal warming via extracorporeal membrane oxygenation or hemodialysis circuits,[21] or active intravascular rewarming catheters.[22]

Permissive Hypotension

Although prehospital interventions are discussed elsewhere in this issue, the use of damage control resuscitation, or permissive hypotension, has been shown to be superior to older, more liberal resuscitation strategies. A goal systolic blood pressure of 90 mm Hg is sufficient for adequate organ perfusion in most injured patients[23] and crystalloid resuscitation should be limited as much as feasible. Fluid resuscitation in 250- to 500-mL aliquots can be used to maintain appropriate systolic blood pressure or the presence of a radial pulse.[24] Theoretically, the reduction in crystalloid utilization prevents worsening of coagulation via dilution of clotting factors, exacerbation of hypothermia and acidosis, and increased bleeding from hydrostatic pressure on forming clots. Exceptions to permissive hypotension include elderly patients, head injuries, pregnancy, and prolonged evacuation or transport times[17] due to clear harms from ongoing hypotension in these groups. This strategy should be implemented until definitive control of bleeding can be achieved,[25] or until an alternative cause for shock has been identified.

The use of permissive hypotension was shown to improve outcomes and reduce fluid resuscitation initially in penetrating injuries at an urban center.[23] There has been some difficulty in demonstrating a clear benefit when extrapolating these data to the general population or to other traumatic mechanisms.[24,26] Trauma centers outside of an urban center with long transport times or populations different from an urban population should consider these limitations before implementing a resuscitation strategy focused on permissive hypotension.

In addition, the use of permissive hypotension is contraindicated specifically in TBI, where hypotension is known to be associated with worse neurologic outcomes.[27] In this scenario, management should focus on the protection of injured but recoverable brain tissue, and some hypertension should be tolerated to avoid further neurologic injury. At very high systolic blood pressure, hydrostatic forces may worsen vasogenic cerebral edema and should be controlled with agents that do not increase the cerebral vasodilation, with preference given to beta-blockers over nitrates or calcium channel blockers[27–29]

Pulselessness

Resuscitative thoracotomy

Despite careful evaluation of resuscitative thoracotomy (RT) as a salvage maneuver, there remains significant controversy regarding its use. Current guidelines are focused primarily on mechanism and time since injury with clear consensus that the procedure is beneficial in penetrating injuries with a short transport time. This intervention is less clearly beneficial following blunt trauma because survival is dismal in this group and risk to both providers and resource utilization is high.[29,30] No specific recommendations exist regarding patient age, although pediatric thoracotomy appears to have similar survival rates to adult,[29] and geriatric thoracotomy is disfavored. In addition, new diagnostics, including US[31] and end tidal CO_2, are probably useful in the determination of candidacy. Use of these modalities has not yet appeared in major society guidelines,[32] although many trauma surgeons report using them to determine candidacy for RT.

Resuscitative endovascular balloon occlusion of the aorta

Resuscitative endovascular balloon occlusion of the aorta (REBOA) is gaining traction as a potential alternative to RT in select patients, with proponents citing similar time to aortic cross-clamping and significantly less morbidity,[33] whereas opponents argue that a lack of institutional experience and clear guidelines currently limit its use. REBOA is probably not an effective modality for control of hemorrhage in the chest, but its use for the profoundly hypotensive patient with abdominal or pelvic injuries may prove to be an effective alternative to RT.[34] Reduced catheter sizes and increasing experience are encouraging for this technology that is likely to find its role in the prearrest and periarrest trauma patient.[35]

Conceptually, REBOA is similar to open cross-clamping of the aorta. Arterial access is obtained at the femoral artery, preferably with the aid of US. Proceduralist preference and the availability of equipment will dictate sheath size, with some catheters usable with an initial 7-Fr sheath and others requiring upsizing to a larger catheter. In the acute trauma setting, proceduralists should be familiar with placement by external landmarks because imaging may not be available. REBOA placement is defined by zones (Fig. 1), with zone 1 extending from the left subclavian artery to the celiac artery, zone 2 extending from the celiac to the renal arteries, and zone 3 extending from the

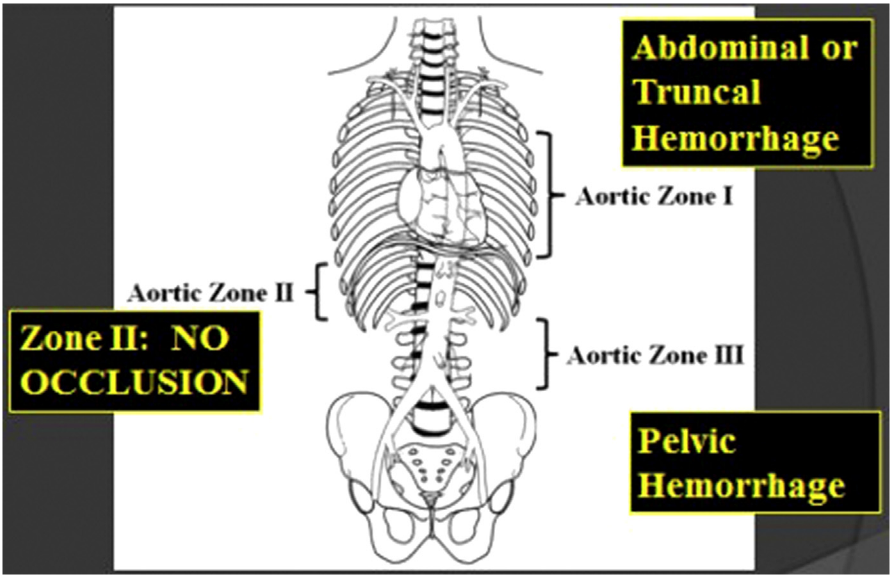

Fig. 1. Aortic zones for REBOA. For abdominal or truncal hemorrhage, the balloon is inflated in aortic zone I; for pelvic hemorrhage, the balloon is inflated in zone III. The balloon should not be used in zone II. (*Adapted from* Napolitano LM. Resuscitative endovascular balloon occlusion of the aorta: indications, outcomes, and training. Crit Care Clin 2017;33(1):57; with permission.)

renal arteries to the bifurcation of the aorta. In comparison with open cross-clamping, zone 1 should be considered similar to supraceliac cross-clamping and zone 3 considered similar to infrarenal cross-clamping. REBOA balloons are not typically placed in zone 2. When imaging is not available, the balloon can be placed just above the xiphoid process for zone 1 and just above the umbilicus for zone 3.[35]

Indications for REBOA have not been clearly defined. The patients most likely to benefit from its use are the profoundly hypotensive patients with injuries below the diaphragm. In these patients, placement will be determined by the likelihood of hemorrhage in the abdomen. In the setting of blunt trauma and transient or no response to resuscitation, REBOA should be placed in zone 1 for all patients with a positive focused assessment with sonography for trauma (FAST) and in zone 3 for patients with pelvic fractures and a negative FAST. Penetrating injuries to the abdomen are less clear, but REBOA may be helpful if placement is possible. It should be noted that REBOA is contraindicated in patients with potential injuries to the great vessels or above the balloon site or in patients with symptomatic blunt cardiac injury.[36]

REBOA should not be seen as synonymous with RT, because RT is most effective in patients that would be contraindicated to receive REBOA. It is these authors' opinion that pulseless patients who meet criteria should undergo RT. In patients who are profoundly hypotensive, REBOA is a helpful adjunct for resuscitation until hemorrhage can be controlled, such as severe blunt trauma. In addition, there may be a role for REBOA in patients who do not meet criteria for RT due to age or injury pattern but continue to have signs of life.

CAVITARY TRIAGE

With increased recognition of the harm of negative or surveillance operations, an important role in the initial assessment and resuscitation of the acutely injured patient is cavitary triage.[37] The provider should recognize not only which body cavities require intervention but also which ones may be at risk in the event of hemodynamic changes. Several adjunctive imaging studies are available to the clinician for cavitary triage and may be included in the trauma evaluation as part of the primary or secondary survey. The goal of cavitary triage is to identify all *hemodynamically significant* injuries, and ideal imaging and diagnostic modalities will have a high sensitivity for these. Less significant injuries can be identified with many other modalities once the patient's life-threatening injuries have been identified and managed. With increasing clinician comfort with US, initial triage of all major body cavities is now possible before leaving the trauma bay, and any major source of bleeding should be identifiable in the hemodynamically unstable patient. Imaging to identify hemodynamically significant injuries is reviewed in later discussion.

Chest Imaging

Chest Radiograph

Chest radiograph (CXR) should be obtained as primary triage of the chest, but is ineffective in demonstrating small hemothoraces and can often miss even substantial anterior pneumothoraces.[38] Although upright films may demonstrate blunting of the costophrenic angle with as little as 400 cc of hemothorax, supine films are substantially more limited and may require as much as 1 L before significant changes occur.[38,39] Often, however, the CXR may be the only efficiently available imaging modality in the acute setting, and even with these limitations, can effectively identify immediately life-threatening injuries.

Ultrasonography

Although limited in its ability to identify bony injuries to the chest, US has emerged as a reliable diagnostic test for both pneumothorax and hemothorax, with sensitivities ranging from 60% to greater than 90%, and is often superior to plain radiographs.[40] When compared with CT, US is significantly faster,[40] although slightly inferior to CT in the diagnosis of pneumothorax. Although not directly addressed in studies, the sensitivity of US for tension pneumothorax would be expected to be remarkably high, and diagnosis of this disorder is likely to be faster to obtain with US than with plain radiographs or CT.

Computed tomography

CT has a remarkable sensitivity for the acute injury to the chest, although some investigators have argued that this sensitivity may be too high,[41] with many nonclinically significant pulmonary contusions and occult pneumothoraces being identified. As such, it continues to be considered the gold standard for triage in the stable patient. Because of time constraints and need for transport to the radiology department, CT imaging should generally only be used for stable or fluid-responsive patients.

Abdominal Diagnostic Modalities

Focused abdominal sonography for trauma

FAST has become the standard of care for rapid diagnosis of intraabdominal hemorrhage and should be used for all unstable patients at risk for abdominal injury. With experience, as little as 200 cc of hemoperitoneum can be reliably identified within as little as 3 minutes without leaving the trauma bay.[42] Sensitivity for hemoperitoneum is 73% to 88%.[42] As a diagnostic modality for cavitary triage, injuries with less than 200 cc of bleeding are unlikely to be the cause of hemodynamic instability and can be identified easily on CT in the stable patient. FAST is known to be unreliable for hollow viscus injury and cannot grade solid organ injury,[42] and as such, is not beneficial to the stable trauma patient, although its use is often encouraged to improve operator speed and reliability. In addition, in the setting of penetrating injury, FAST will identify hemodynamically significant sources of hemorrhage, but will not identify trajectory or hollow viscus injury.

Computed tomography

Just as in chest trauma, CT remains the gold-standard imaging modality for the stable trauma patient and is increasingly being used in penetrating trauma to establish trajectory and rule out retroperitoneal injury.[42] Sensitivity for any intraabdominal injury is between 92% and 97.6%, with multicenter trial data demonstrating a negative predictive value as high as 99.6%.[37]

Diagnostic peritoneal lavage

Use of diagnostic peritoneal lavage (DPL) has dropped dramatically since the advent of FAST and increasing availability of CT. The negative predictive value of DPL is significantly higher than FAST alone, with accuracy as high as 92% to 98%,[42] and is more sensitive than CT for mesenteric injury.[43] However, DPL is limited by a known high rate of false positive results, especially in the setting of pelvic fracture. Some centers advocate continued use of DPL because of speed and convenience in the trauma bay, although it has largely been supplanted by a combination of CT, FAST, and selective use of observation as necessary.

Pelvic and Femur Fractures

Pelvic fractures representing hemodynamically significant injury are typically identifiable on plain radiograph. Cadaver studies have shown that 5-cm pubis diastasis results in a 20% increase in pelvic volume, whereas a 10-cm diastasis leads to 40% increase, indicating a large potential space for blood loss with associated injury to the pelvic veins. The use of pelvic binders has become commonplace in an attempt to quickly reduce pelvic volume and decrease transfusion needs.[44,45] FAST will identify some retroperitoneal injury, but should not be regarded as specific enough to rule out these injuries. In the hemodynamically unstable patient with pelvic fracture, DPL may be warranted to exclude intraabdominal hemorrhage as a source, whereas a stable patient may undergo CT scan with IV contrast to determine a source of ongoing bleeding.

Patients with contrast extravasation, regardless of pelvic fracture pattern, on CT scan should undergo angioembolization.[46] In addition, pelvic hematomas that are more that 500 cc are associated with an almost 5 times relative risk of having a concomitant arterial injury and should also be evaluated with angiography. Delay to angiography in hemodynamically unstable patients with pelvic fractures has been associated with increased mortality.

Retroperitoneal packing is often reserved for patients who require exploratory laparotomy in addition to intervention for ongoing retroperitoneal hemorrhage or for whom angiography cannot be accomplished expeditiously due to the need to mobilize resources.[47,48] Although some centers that use it preferentially for pelvic bleeding, common availability of angiography has largely replaced this procedure.

Femur fractures can also be a source of significant blood loss, with one retrospective study of isolated femur fractures estimating blood loss at an average of more than 1200 cc.[49] Physical examination coupled with plain radiograph of the thigh will be sufficient to rule out hemodynamically significant femur injury for the sake of cavitary triage. For patients who do not have other more life-threatening injuries, it is recommended that they undergo fixation within 24 hours to reduce ongoing blood loss as well as improve orthopedic outcomes.[50]

SUMMARY

The initial assessment of the trauma patient involves coordination of a multidisciplinary team with the goal of identifying life-threatening injuries, intervening on those deemed critical, and then prioritizing a care plan for the patient. It is an intense period of treatment and triage as the team initiates resuscitation and calls upon appropriate resources to reduce morbidity and mortality. In order to best care for the patient, the clinician must know what resources are available and be facile in mobilizing the care team in an efficient manner. This expeditious coordination of care requires training and practice with the ultimate goal of saving lives during the golden hour of resuscitation.

REFERENCES

1. American College of Surgeons. Advanced trauma life support: ATLS; student course manual. 9th edition. Chicago: American College of Surgeons; 2012.
2. Tsang B, McKee J, Engels PT, et al. Compliance to advanced trauma life support protocols in adult trauma patients in the acute setting. World J Emerg Surg 2013; 8(1):39.

3. Young J, Gondek S, Kahn S, et al. Challenging IV access in the patient with septic shock. In: Diaz JJ, Efron DT, editors. Complications in acute care surgery: the management of difficult clinical scenarios. 2017. Available at: http://lib.myilibrary.com?id=971614. Accessed March 14, 2017.
4. Bradley M. Brief report: systemic vascular access and resuscitation via corpus cavernosum. Mil Med 2016;181(11):e1491–4.
5. Mayglothling J, Duane TM, Gibbs M, et al. Emergency tracheal intubation immediately following traumatic injury: an Eastern Association for the Surgery of Trauma practice management guideline. J Trauma Acute Care Surg 2012;73(5 Suppl 4):S333–40.
6. Sise MJ, Shackford SR, Sise CB, et al. Early intubation in the management of trauma patients: indications and outcomes in 1,000 consecutive patients. J Trauma 2009;66(1):32–9, 40.
7. Como JJ, Sutton ERH, McCunn M, et al. Characterizing the need for mechanical ventilation following cervical spinal cord injury with neurologic deficit. J Trauma 2005;59(4):912–6 [discussion: 916].
8. Hassid VJ, Schinco MA, Tepas JJ, et al. Definitive establishment of airway control is critical for optimal outcome in lower cervical spinal cord injury. J Trauma 2008;65(6):1328–32.
9. Velmahos GC, Toutouzas K, Chan L, et al. Intubation after cervical spinal cord injury: to be done selectively or routinely? Am Surg 2003;69(10):891–4.
10. Zeiler FA, Teitelbaum J, West M, et al. The ketamine effect on ICP in traumatic brain injury. Neurocrit Care 2014;21(1):163–73.
11. Neto AS, Simonis FD, Barbas CSV, et al. Lung-protective ventilation with low tidal volumes and the occurrence of pulmonary complications in patients without acute respiratory distress syndrome: a systematic review and individual patient data analysis. Crit Care Med 2015;43(10):2155–63.
12. Ferguson ND. Low tidal volumes for all? JAMA 2012;308(16):1689–90.
13. Fuller BM, Ferguson IT, Mohr NM, et al. Lung-protective ventilation initiated in the emergency department (LOV-ED): a quasi-experimental, before-after trial. Ann Emerg Med 2017. [Epub ahead of print].
14. Schroeder E, Valdez C, Krauthamer A, et al. Average chest wall thickness at two anatomic locations in trauma patients. Injury 2013;44(9):1183–5.
15. Inaba K, Lustenberger T, Recinos G, et al. Does size matter? A prospective analysis of 28-32 versus 36-40 French chest tube size in trauma. J Trauma Acute Care Surg 2012;72(2):422–7.
16. Gentilello LM, Jurkovich GJ, Stark MS, et al. Is hypothermia in the victim of major trauma protective or harmful? A randomized, prospective study. Ann Surg 1997;226(4):439–47, 449.
17. Sharrock AE, Midwinter M. Damage control - trauma care in the first hour and beyond: a clinical review of relevant developments in the field of trauma care. Ann R Coll Surg Engl 2013;95(3):177–83.
18. Lier H, Krep H, Schroeder S, et al. Preconditions of hemostasis in trauma: a review. The influence of acidosis, hypocalcemia, anemia, and hypothermia on functional hemostasis in trauma. J Trauma 2008;65(4):951–60.
19. Peng RY, Bongard FS. Hypothermia in trauma patients. J Am Coll Surg 1999;188(6):685–96.
20. Shafi S, Elliott AC, Gentilello L. Is hypothermia simply a marker of shock and injury severity or an independent risk factor for mortality in trauma patients? Analysis of a large national trauma registry. J Trauma 2005;59(5):1081–5.

21. Perlman R, Callum J, Laflamme C, et al. A recommended early goal-directed management guideline for the prevention of hypothermia-related transfusion, morbidity, and mortality in severely injured trauma patients. Crit Care 2016;20(1):107.
22. Kiridume K, Hifumi T, Kawakita K, et al. Clinical experience with an active intravascular rewarming technique for near-severe hypothermia associated with traumatic injury. J Intensive Care 2014;2(1):11.
23. Bickell WH, Wall MJ, Pepe PE, et al. Immediate versus delayed fluid resuscitation for hypotensive patients with penetrating torso injuries. N Engl J Med 1994;331(17):1105–9.
24. Dutton RP, Mackenzie CF, Scalea TM. Hypotensive resuscitation during active hemorrhage: impact on in-hospital mortality. J Trauma 2002;52(6):1141–6.
25. Duchesne JC, McSwain NE, Cotton BA, et al. Damage control resuscitation: the new face of damage control. J Trauma 2010;69(4):976–90.
26. Stahel PF, Smith WR, Moore EE. Current trends in resuscitation strategy for the multiply injured patient. Injury 2009;40(Suppl 4):S27–35.
27. Chesnut RM, Marshall LF, Klauber MR, et al. The role of secondary brain injury in determining outcome from severe head injury. J Trauma 1993;34(2):216–22.
28. Helmy A, Vizcaychipi M, Gupta AK. Traumatic brain injury: intensive care management. Br J Anaesth 2007;99(1):32–42.
29. Burlew CC, Moore EE, Moore FA, et al. Western Trauma Association critical decisions in trauma: resuscitative thoracotomy. J Trauma Acute Care Surg 2012;73(6):1359–63.
30. Seamon MJ, Haut ER, Van Arendonk K, et al. An evidence-based approach to patient selection for emergency department thoracotomy: a practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg 2015;79(1):159–73.
31. Ferrada P, Wolfe L, Anand RJ, et al. Use of limited transthoracic echocardiography in patients with traumatic cardiac arrest decreases the rate of nontherapeutic thoracotomy and hospital costs. J Ultrasound Med 2014;33(10):1829–32.
32. Dennis BM, Medvecz AJ, Gunter OL, et al. Survey of trauma surgeon practice of emergency department thoracotomy. Am J Surg 2016;212(3):440–5.
33. Brenner ML, Moore LJ, DuBose JJ, et al. A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation. J Trauma Acute Care Surg 2013;75(3):506–11.
34. Biffl WL, Fox CJ, Moore EE. The role of REBOA in the control of exsanguinating torso hemorrhage. J Trauma Acute Care Surg 2015;78(5):1054–8.
35. DuBose JJ, Scalea TM, Brenner M, et al. The AAST prospective aortic occlusion for resuscitation in trauma and acute care surgery (AORTA) registry: data on contemporary utilization and outcomes of aortic occlusion and resuscitative balloon occlusion of the aorta (REBOA). J Trauma Acute Care Surg 2016;81(3):409–19.
36. Napolitano LM. Resuscitative endovascular balloon occlusion of the aorta: indications, outcomes, and training. Crit Care Clin 2017;33(1):55–70.
37. Livingston DH, Lavery RF, Passannante MR, et al. Admission or observation is not necessary after a negative abdominal computed tomographic scan in patients with suspected blunt abdominal trauma: results of a prospective, multi-institutional trial. J Trauma 1998;44(2):273–80, 282.
38. Velmahos GC, Demetriades D. Early thoracoscopy for the evacuation of undrained haemothorax. Eur J Surg 1999;165(10):924–9.

39. Mowery NT, Gunter OL, Collier BR, et al. Practice management guidelines for management of hemothorax and occult pneumothorax. J Trauma 2011;70(2): 510–8.
40. Soldati G, Testa A, Pignataro G, et al. The ultrasonographic deep sulcus sign in traumatic pneumothorax. Ultrasound Med Biol 2006;32(8):1157–63.
41. Kwon A, Sorrells DL, Kurkchubasche AG, et al. Isolated computed tomography diagnosis of pulmonary contusion does not correlate with increased morbidity. J Pediatr Surg 2006;41(1):78–82, 82.
42. Como JJ, Bokhari F, Chiu WC, et al. Practice management guidelines for selective nonoperative management of penetrating abdominal trauma. J Trauma 2010; 68(3):721–33.
43. Ceraldi CM, Waxman K. Computerized tomography as an indicator of isolated mesenteric injury. A comparison with peritoneal lavage. Am Surg 1990;56(12): 806–10.
44. Baqué P, Trojani C, Delotte J, et al. Anatomical consequences of “open-book” pelvic ring disruption: a cadaver experimental study. Surg Radiol Anat 2005; 27(6):487–90.
45. Krieg JC, Mohr M, Ellis TJ, et al. Emergent stabilization of pelvic ring injuries by controlled circumferential compression: a clinical trial. J Trauma 2005;59(3): 659–64.
46. Stephen DJ, Kreder HJ, Day AC, et al. Early detection of arterial bleeding in acute pelvic trauma. J Trauma 1999;47(4):638–42.
47. Evers BM, Cryer HM, Miller FB. Pelvic fracture hemorrhage. Priorities in management. Arch Surg 1989;124(4):422–4.
48. Cothren CC, Osborn PM, Moore EE, et al. Preperitonal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. J Trauma 2007;62(4): 834–9, 842.
49. Lieurance R, Benjamin JB, Rappaport WD. Blood loss and transfusion in patients with isolated femur fractures. J Orthop Trauma 1992;6(2):175–9.
50. Gandhi RR, Overton TL, Haut ER, et al. Optimal timing of femur fracture stabilization in polytrauma patients: a practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg 2014;77(5): 787–95.