Critical Trauma Skills and Procedures in the Emergency Department

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INITIAL EVALUATION OF TRAUMA PATIENTS

In the initial evaluation of trauma patients, it is crucial that adequate coordination between prehospital services and emergency medicine departments is established for proper management. The American College of Surgeons has designed the advanced trauma life support (ATLS) guidelines for management of trauma patients. The creation of the ABCDE mnemonic facilitates the identification of life-threatening injuries and creates a systematic approach following logical and sequential treatment priorities.

KEYWORDS

- Chest tube thoracotomy • Resuscitative thoracotomy • Cricothyrotomy
- Venous cutdown • Diagnostic peritoneal lavage • FAST • Compartment syndrome

KEY POINTS

- Emergency physicians (EP) must be familiar with trauma emergencies.
- EP must be dexterous while performing trauma-related procedures, such as chest tube thoracotomy, emergency department thoracotomy, surgical airway, early recognition of compartment syndrome, and venous cutdown.
- It is of paramount importance for the practitioner to be dexterous while performing these procedural skills to maintain function while avoiding complications and improving trauma patient outcomes.

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PREHOSPITAL MANAGEMENT

Coordination efforts should be established between the emergency medical services (EMS) network and the emergency medicine department to alert physicians of patients’ injuries, hemodynamic status, and estimated time of arrival. Efforts should be made to minimize the time on scene, facilitate preparation for arrival, and to direct patients to facilities with the required services. Prehospital management should focus on airway maintenance, bleeding control (avoidance of exsanguination), and immobilization. In unstable patients, transport to the closest facility is indicated. Whenever possible, immediate transfer to a trauma center should be done. Table 1 lists the transfer criteria to a level 1 trauma center.

EMERGENCY DEPARTMENT MANAGEMENT

The initial approach should be focused on immediate identification of life-threatening injuries. On arrival to the emergency department (ED), it is vital to gather useful information from EMS personnel regarding the mechanism of injury, hemodynamics on route, and prehospital management (medications administered, fluids given, needle decompression, intubation). Patients are evaluated based on the types and mechanism of their injuries in addition to vital signs.

PRIMARY SURVEY

The priority of the primary survey is to identify life-threatening injuries and to correct them as soon as possible. This systematic approach was designed to assess airway, breathing, circulation, disability, and expose patients to identify occult injuries. Box 1 describes the primary survey.

For continuous vital signs monitoring, patients should be connected to a cardiac monitor, a pulse oximeter, and a noninvasive blood pressure cuff. If not intubated, 100% oxygen delivered through a non-rebreather mask should be placed. If patients are able to communicate verbally, this may indicate airway patency. If patients are unconscious, intoxicated, or have suffered distracting injuries, the cervical spine should be immobilized. In unconscious patients, a definite airway should be established by rapid sequence intubation. The indications for intubation are listed in Table 1.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Transfer criteria to a level 1 trauma center</th>
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</thead>
<tbody>
<tr>
<td><strong>Physiologic Abnormalities</strong></td>
<td><strong>Type of Injury</strong></td>
</tr>
<tr>
<td>Systolic blood presume &lt;90 mm Hg</td>
<td>Penetrating trauma to head, neck, or torso</td>
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<tr>
<td>Glasgow Coma Scale &lt;14</td>
<td>Gunshot wound to proximal extremities</td>
</tr>
<tr>
<td>Need for immediate intubation or inadequate airway control</td>
<td>Extremity with neurovascular compromise</td>
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<tr>
<td></td>
<td>Amputation of extremity</td>
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<tr>
<td></td>
<td>Central nervous system injury of paralyzis</td>
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<td></td>
<td>Flail chest</td>
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<td></td>
<td>Suspected pelvic fracture</td>
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Abbreviation: MVC, motor vehicle collision.
**Box 1
Primary survey**

**Airway**
- Assessment of patency
- Bleeding (oral/laryngeal)
- Obstruction (from foreign body, facial fractures, trachea deviation)
- Jaw thrust/chin lift
- Suctioning
- Intubate
- Surgical airway

**Breathing**
- Assessment of lung ventilation
- Visual inspection (symmetric vs asymmetric chest wall movement)
- Palpation (chest wall defects, rib fractures, subcutaneous emphysema)
- Auscultation (breath sounds)
- Oxygenate with 100% oxygen ($O_2$)
- Monitor $O_2$ saturation
- Needle decompression for suspected tension pneumothorax

**Circulation**
- Control bleeding (manual direct pressure)
- Assess for blood volume status, check pulses
- Establish peripheral intravenous access and start warm crystalloid infusion
- Skin color (pale, pink, ash, blue)
- Assess heart rate
- Consider central venous access if peripheral access could not be established
- Perform focused abdominal sonography for trauma examination
- Consider pericardiocentesis if suspected pericardial tamponade

**Disability**
- Neurologic status:
  - Check pupil size and reactivity
  - Motor strength and movement
  - Glasgow Coma Scale
  - Orientation
  - Perform glucose scan by finger stick in patients with altered mental status

**Exposure**
- Remove all clothing and examine
- Prevent hypothermia
- Roll patients to both sides with cervical spine control
- Inspect spine, buttocks, flanks, and back

*Data from Ref.*1-3
Box 2. For intubation, the cervical collar may be removed and in-line stabilization of
the neck should be performed.1 If a tension pneumothorax is suspected, needle
decompression is indicated. Intravenous (IV) access should be established, preferably
in the superior extremities. Two large-bore (14–18 G) IV lines should be placed, and 2 L
of crystalloid solution should be infused.1,2 Draw blood work for typing, crossmatch,
and samples for the baseline blood count. After the initial fluid bolus, vitals signs
need to be reassessed. If unresponsive to isotonic infusion, blood transfusion of
type O negative group may be indicated.1 Early recognition for transfer to a level 1
trauma center is essential. Immediate efforts should be made for rapid transportation
to a trauma center in the case of patients who have fulfilled the criteria for transfer.

SECONDARY SURVEY

The secondary survey should not be started until the primary survey has been
completed, resuscitation has been initiated, and normalization of vital signs is
observed.1–3 This sequence of steps was designed to systematically perform
a more thorough head-to-toe examination for the identification of undiagnosed
injuries. A complete history should also be obtained. Periodic reassessment of vital
signs should be continuous. Box 3 mentions the different physical examination steps
for the rapid identification of injuries1,2

Whenever there are patients with facial fractures or suspected basilar skull fracture,
insert the nasogastric tube through the mouth.2 Limited bedside focused abdominal
sonography for trauma (FAST) examination should be performed to identify free intra-
peritoneal or pericardial fluid. This examination may be a useful tool, particularly in
hemodynamically unstable patients because it may be used to screen injuries that
can be triaged directly into the operating room without the need for a computed
tomography (CT) scan.5 In patients that have sustained blunt abdominal trauma, serial
abdominal examinations should be performed (preferably by the same examiner).1
Patients with blunt abdominal trauma can be a challenge, consultation with trauma
surgeon should be done in timely manner. In patients with penetrating abdominal
trauma who have tenderness, distention, and/or hypotension, emergent surgery is
indicated.2 If there is a high-riding or displaced prostate on digital rectal examination,
blood in the urethra in the genitalia examination, or if there is a suspected pelvic frac-
ture, a retrograde urethrography needs to be performed before placing a Foley cath-
eter.1,2 In patients with multisystem trauma, a tertiary survey is recommended before
the first 24 hours to decrease the likelihood of undiagnosed injuries. The most
common missed injuries are orthopedic.2 In stable patients, necessary imaging studies
should be ordered, including radiographs and CT scan. In the case of patients with
hemodynamic instability, they should never be transported to the CT scan until the
physiologic status improves. Fluid inputs and outputs should be measured and
charted. It is important to remember that most of these trauma patients are

<table>
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<th>Box 2</th>
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<tr>
<td><strong>Indications for endotracheal intubation</strong></td>
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<tr>
<td>Failure to maintain airway patency</td>
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<tr>
<td>Failure to ventilate</td>
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<tr>
<td>Failure to oxygenate</td>
</tr>
<tr>
<td>Decreased level of consciousness (Glasgow Coma Scale &lt;8)</td>
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<tr>
<td>Anticipation of deterioration of clinical course</td>
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</table>
## Box 3

### Physical examination steps for rapid identification of injuries

#### Head
- Identify and control bleeding from lacerations, abrasions (apply direct pressure, suture, place surgical clips)

#### Eyes, ears, nose, mouth
- Identify facial instability and anticipate potential airway deterioration
- Assess for hemotympanum
- Identify epistaxis, nasal septal hematoma, place nasal packing if bleeding is profuse
- Evaluate visual acuity
- Identify ocular injuries
- Evaluate ocular mobility
- Identify avulsed teeth

#### Neck
- Palpate assessing for subcutaneous emphysema
- Auscultate carotid arteries and listen for bruits
- Observe for expanding hematoma or distended neck veins

#### Chest
- Identify penetrating injuries
- Order a chest radiograph
- Palpate bony structures
- Auscultate
- Perform pleural ultrasound
- Place chest tube if necessary

#### Abdomen
- Inspect for distention, ecchymosis
- Evaluate for tenderness
- Perform focused abdominal sonography for trauma examination
- Identify penetrating injuries

#### Genitalia
- Inspect perineum for hematomas, lacerations
- Assess pelvic stability, place pelvic wrap if fracture is suspected
- Evaluate the urethral meatus for blood
- Inspect vagina for bleeding, perform digital and speculum examination to identify lacerations
- Perform rectal examination to assess for bleeding, high riding prostate, and evaluate sphincter tone

#### Extremities
- Check peripheral pulses
- Identify deformities
- Reduce limb-threatening dislocations, splint fractures
undergoing a substantial amount of pain. Management should be focused on initiating analgesia/anxiolysis judiciously and monitoring for hemodynamic compromise because some analgesics may have undesired adverse effects.¹

**DISPOSITION**

Most of these patients are going to be admitted to the hospital for the management and treatment of the injuries sustained.³ The patients who have hemodynamic instability should be transported to the operating room or should be transferred to a facility that can offer definitive treatment of their injuries.² In the case of transportation to a trauma center, a trained health professional capable of resuscitation should accompany the patients. When evaluating patients who have suffered major trauma without evidence of major injuries, the recommended time for observation is 4 hours. In the case of intoxicated patients, more time may be required. Serial physical examinations may be repeated for periodic assessments. Early consultation with the pertinent surgical services is essential for rapid management.

**CRICOTHYROTOMY**

Cricothyrotomy is an uncommon but life-saving procedure. It must be considered when other available techniques to oxygenate and ventilate have been unsuccessful. One 10-year study documented a significant decrease in cricothyrotomy rates because of possible emergency medicine residency, rapid sequence intubation techniques, and intubating trauma patients despite possible cervical spine injury. The rate was initially 1.8% and dropped to 0.2% over the decade.⁶ Although decreasing in rate, it is an essential skill for emergency physicians, particularly in trauma when most cases are likely to occur. In the same article, Chang and colleagues⁶ described that 32% of all cricothyrotomies involved facial fractures, 32% blood or vomitus in the airway, and 7% traumatic airway obstruction. Bair and colleagues⁷ also noted similar numbers in that 76% of the cricothyrotomies over 5 years at their institution were performed on trauma patients.

**CONTRAINDICATIONS**

Because a cricothyrotomy is a surgical emergent airway caused by failed attempts with other oxygenating or ventilating techniques, there are no absolute contraindications in adults. However, there are relative contraindications to at least consider as well as age considerations. A surgical cricothyrotomy is not recommended in a child younger than 10 to 12 years of age because of the anatomic variations in the pediatric airway leading to an increased risk of subglottic stenosis. Other patient populations to consider are coagulopathic patients, patients with previous neck surgery or radiation therapy, a transected trachea, or a fractured larynx. In the setting of transected trachea, and fractured pharynx, direct intubation of the proximal portion of the trachea or tracheostomy should be considered as an alternative management. In all cases, if the choice is a failed airway and ultimately death versus possible complications but a secured airway, the choice becomes simple Box 4.

**PROCEDURE**

There are several options for a cricothyrotomy: open technique, rapid 4–step technique (RFST), and the Seldinger technique. A bougie-assisted technique has also been described, although essentially it is RFST with bougie confirmation of position and aid of placement. The RFST is an open technique that has been modified to
decrease the instruments and steps needed. The best choice is made based on institutionally provided instruments, physician comfort level, and type of patient. All techniques suggest neck preparation, appropriate draping, and local anesthetic if time permits.

OPEN TECHNIQUE

Box 5.

OPEN CRICOTHYROTOMY TECHNIQUE STEPS

- Identify the cricothyroid membrane (Fig. 1).8
- Make a vertical incision through the skin, approximately 4-cm horizontal incision of the cricothyroid membrane (Fig. 2).
- Stabilize the larynx with a tracheal hook at the inferior aspect of the thyroid cartilage (Fig. 3 and 4).
- Dilate the ostomy with curved hemostats.
- Place the trousseau dilator in the incision, with dilatation of the ostomy.
- Place the tracheostomy tube in the trachea.

Box 5
Equipment

- No. 11 blade scalpel
- Trousseau dilator
- Tracheal hook
- Hemostats
- 10-mL syringe
- Tracheostomy tube (No. 4 or No. 6 cuffed) obturator
- Inner cannula
- Circumferential tie
- Bag-valve-mask and ventilator tubing suction

Identify the cricothyroid membrane. Place horizontal incision through the skin and membrane with a scalpel. Stabilize the larynx with a tracheal hook at the inferior aspect of the ostomy (on the cricoid cartilage) providing caudal traction. Place the tracheostomy tube in the trachea.

**SELDINGER TECHNIQUE**

- Identify landmarks and use the nondominate hand for larynx control as with all techniques.
- Use an 18-gauge introducer needle into the cricothyroid membrane at 45° caudally. Maintain negative pressure on the syringe until aspiration of air.
- Remove the syringe and use the guidewire through the needle, then remove the needle holding the guidewire in place.

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**Fig. 1.** Slide your index finger over the Adam’s apple to the soft cricothyroid membrane. (Courtesy of Operational medicine: health care in military settings, CAPT Michael John Hughey, MC, USNR, bureau of medicine and surgery, department of the navy, NAVMED P-5139, January 1, 2001.)

**Fig. 2.** Make a vertical incision through the skin, approximately 4-cm horizontal incision of the cricothyroid membrane. (Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy, NAVMED P-5139 January 1, 2001.)
Make a small skin incision to enable the airway and dilator to pass through the tissue more easily.

- Insert the tissue dilator-airway catheter over the guidewire and advance into the trachea.
- Remove the dilator and guidewire.
- Inflate the cuff and then confirm the airway and secure.

**Complications**

Complications (Box 6) do exist; but as stated previously, the option of a complication versus lack of a necessary airway makes a physician’s decision easy. The most important complication to avoid is failure to consider the cricothyrotomy early enough in a patient’s failed airway. Multiple attempts with failed intubation or alternative airway techniques for ventilation and oxygenation lead to severe hypoxic injury. The incidence of all complications is approximately 20%.9

![Fig. 3. Stabilize the larynx with a tracheal hook at the inferior aspect of the thyroid cartilage. (Courtesy of Operational medicine: health care in military settings, CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139 January 1, 2001.)](image)

![Fig. 4. Place tracheostomy tube in the trachea. (Photograph courtesy of Operational medicine: health care in military settings, CAPT Michael John Hughey, MC, USNR, bureau of medicine and surgery, department of the navy, NAVMED P-5139, January 1, 2001.)](image)
CHEST TUBE THORACOSTOMY

Chest trauma is a major cause of morbidity and mortality. Whether the mechanism was blunt or penetrating, many of the resultant injuries have the indication for chest tube insertion into the pleural cavity for evacuation of air, blood, or both. Once the indication for chest tube insertion (Box 7) is established, the necessary equipment (Box 8, Fig. 5) must be gathered, and the potential complications (Box 9) need to be anticipated for successful procedure performance.

There is only one absolute contraindication for chest tube thoracostomy, which is complete adherence of the lung to the chest wall.\textsuperscript{1,10} Relative contraindications include coagulopathy, pulmonary adhesions from preexisting pulmonary structural disease, or skin infection over the insertion site.

**Box 6**

**Complications of surgical airway management**

- Hemorrhage
- Pneumomediastinum
- Laryngeal/tracheal injury
- Cricoid ring laceration
- Barotrauma (TTJV [Trans-tracheal jet ventilation])
- Infection
- Voice change
- Subglottic stenosis


**Box 7**

**Indications for chest tube thoracostomy in trauma patients**

- Pneumothorax
  - Open: sucking chest wound
  - Closed
  - Simple
  - Tension: after needle decompression
  - In any mechanically ventilated patient
- Hemothorax
- Hemopneumothorax
- Hemodynamically unstable patients with a chest-wall penetrating injury
- Patients with penetrating chest trauma who are or could potentially be placed on mechanical ventilation
- Recommended for patients with chest trauma who are going to be air-lifted and can potentially develop a pneumothorax
PREPROCEDURAL EVALUATION AND RISK ASSESSMENT

A portable chest radiograph should always be ordered in the initial evaluation of stable trauma patients.\textsuperscript{1,10–13} Another useful tool is the bedside ultrasound, which can be reliably used to identify pneumothorax and pleural effusion. It is especially beneficial in unstable patients.\textsuperscript{10,11} In patients with a known history of coagulopathy, routine complete blood count and coagulation panel should be ordered. Preprocedure assessment of platelet count and prothrombin time should be evaluated. For elective chest tube thoracostomy, warfarin should be discontinued and time allowed for its

<table>
<thead>
<tr>
<th>Box 8 Equipment for chest tube thoracostomy</th>
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<tbody>
<tr>
<td>Face shield</td>
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<tr>
<td>Sterile gloves and gown</td>
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<tr>
<td>Antiseptic solution for skin cleansing (povidone-iodine or chlorhexidine)</td>
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<tr>
<td>Sterile drapes</td>
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<tr>
<td>Sterile gauze</td>
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<tr>
<td>Local anesthetic solution (lidocaine 1% or 2%)</td>
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<tr>
<td>Syringes and needles</td>
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<tr>
<td>Scalpel and blade</td>
</tr>
<tr>
<td>Suture (silk 1.0 or 2.0)</td>
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<tr>
<td>Instrument for blunt dissection (Kelly clamp or round-tip forceps)</td>
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<tr>
<td>Guidewire and dilator if Seldinger technique will be used (preferred for smaller tubes)</td>
</tr>
<tr>
<td>Chest tube</td>
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<tr>
<td>Connecting tubing</td>
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<tr>
<td>Closed drainage system</td>
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<tr>
<td>Sterile water if underwater seal system will be used</td>
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<tr>
<td>Dressing</td>
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**Fig. 5.** Chest tube tray. From left to right: silk suture 2.0, Webster needle holder, Allis towel clamps, Adson Tissue Forceps, Standard hemostat, Metzemaum Scissors curved, Hemostats curved, Scalpe.
effects to resolve. There is no reported evidence that abnormal blood clotting or platelet counts could increase the incidence of bleeding complications of chest tube insertion. However, if time permits, it is good practice to correct any coagulopathy or platelet defect before tube insertion. Chest tube insertion is an extremely painful procedure; analgesia/sedation should be given in addition to local anesthesia. The preferred sedatives include benzodiazepines and opioids. It is important to avoid the one-size-fits-all approach when preparing for chest tube selection. If there is an existing stab wound or soft tissue defect surrounding or adjacent to the site of insertion, the chest tube should not be inserted through. A new surgical incision must be performed to avoid potential complications.

### CHEST TUBE SIZE SELECTION

The following recommendations should be followed at the moment of chest tube selection:

- Pneumothorax: small-sized bore 10 to 18 F
- Pneumothorax in mechanical ventilated patients: medium-sized bore 20 to 24 F
- Hemothorax: large-sized bore greater than 24 F

### CHEST TUBE THORACOSTOMY BLUNT DISSECTION TECHNIQUE

Patients should be placed in the supine position or at 30° to 45°. Flex the arm ipsilateral to the lesion with the hand behind the head exposing the axilla. Identify the landmarks of the safe triangle, which is comprised of the anterior border of the latissimus dorsi, the lateral border of the pectoralis major, and a horizontal line from the nipple to the midaxillary line. The area is prepped with cleansing solution and sterile drapes are placed. Administer IV sedation/analgesia. Use a 25-gauge needle to infiltrate 5 to 10 mL of lidocaine in the incision site. Switch to an 18-gauge needle to infiltrate 10 to 20 mL of lidocaine into subcutaneous tissue, intercostal...
muscles, and periosteum. Apply negative pressure on the syringe; advance the needle over the superior border of the rib until fluid or air enters the chamber, which indicates that the pleural space is entered. Inject lidocaine into the pleural cavity. Perform a 2- to 3-cm incision parallel to the level of the fourth or fifth intercostal space midaxillary line (Fig. 6). Use the round-tip forceps or Kelly clamp to do a blunt dissection of the subcutaneous tissue and muscle and create a tract projecting one intercostal space above the incision site. Use the index finger to palpate the path and palpate the superior border of the rib. Advance the closed forceps or Kelly clamp over the superior border of the rib until the pleura is punctured, open, and spread the instrument to separate the pleura and intercostal muscle tissue (Fig. 7).

Use the index finger to palpate the pleural space to confirm proper positioning and to exclude the presence of adhesions. Small adhesions may be disrupted with a gentle sweep of the finger. Clamp the tube with the forceps or Kelly clamp in the proximal end, advance the tube into the pleural space and remove the instrument, and introduce the tube until all the holes are inside the pleural cavity. In the case of a pneumothorax, the chest tube should be directed anterior and apically; when drainage of fluid is desired, the chest drain should be directed posterior and basally. Use suture silk 1.0 or 2.0 to close the skin incision with the mattress technique and tie the loose ends around the tube to anchor it (Fig. 8). Connect the tube to an underwater seal; bubbles should be seen in the chamber in the case of a pneumothorax, and blood accumulation should be noted in the case of a hemothorax. A chest radiograph must be ordered to confirm the position of the chest tube. Once the chest tube position is confirmed, wrap sterile petroleum gauze around the incision site and secure the tube to the chest wall with adhesive material.

CHEST TUBE THORACOSTOMY GUIDEWIRE (SELDINGER) TECHNIQUE

The procedure is prepped as mentioned earlier. Inject local anesthesia intrapleurally. Use a large-bore needle, create negative pressure in the chamber of the syringe, and advance the needle over the superior border of the rib of the fourth or fifth intercostal space in the midaxillary line. Once air or fluid enters the chamber, the pleural cavity has been reached. Disconnect the syringe from the needle maintaining proximal control. A guidewire is advanced though the hub. Remove the needle with the guidewire in place. Perform a small superficial incision with a blade on the point of entry of the guidewire. Introduce a dilator over the wire to enlarge the incision site. Insert the chest

Fig. 6. A 2- to 3-cm incision parallel to the level of the fourth or fifth intercostal space midaxillary line is performed.
tube over the wire until all the holes are within the pleural cavity. Remove the guide-wire.\textsuperscript{13} Connect the tube to an underwater seal system. Suture the chest tube to the chest wall. Obtain a chest radiograph to confirm the position of the chest drain.\textsuperscript{10} Once confirmed, secure the tube, place sterile petroleum gauze around the point insertion site, and place adhesive material to secure the tube to the chest wall.\textsuperscript{10}

**CHEST TUBE MANAGEMENT**

All chest tubes should be connected to a single flow drainage system (eg, underwater seal or flutter valve).\textsuperscript{10} In the case of pneumothorax, condensation through the tube may confirm proper positioning.\textsuperscript{13} When hemothorax is drained, the respiratory swing of the blood in the chest tube may be used to evaluate tube patency and confirm the intrapleural position of the tube.\textsuperscript{10} A bubbling chest tube should never be clamped.\textsuperscript{10,16}

As a rule, surgical intervention is indicated if 1500 mL of blood are evacuated immediately through the chest tube, if drainage is more than 200 mL in 2 to 4 hours, or if

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**Fig. 7.** Advance the closed forceps or Kelly clamp over the superior border of the rib until the pleura is punctured; open and spread the instrument to separate pleura and intercostal muscle tissue.

**Fig. 8.** Use suture silk 1.0 or 2.0 to close the skin incision with mattress technique, and tie the loose ends around the tube to anchor it.
a blood transfusion is required. Controversies exist regarding the use of antibiotics in this setting. The recommendation is to treat with first-generation cephalosporins for the first 24 hours. Some studies showed a decrease in the risk for empyema, pneumonia, and pneumonitis. However, evidence is limited.

COMPLICATIONS

Multiple complications have been reported, which can generally be divided into insertional, positional, infectious, and technical involving the drainage system. The most common complications are recurrent pneumothorax and chest tube misplacement. Box 9 mentions common reported complications of chest tube thoracostomy. Other complications described are large primary leak, leak at the skin around the chest tube (suction on the tube is too strong), failure of lung expansion caused by a plugged bronchus, and allergic reaction to anesthesia or surgical preparation material. Uncommonly, nerve injuries have been reported as a result of chest tube malpositioning:

- Horner syndrome
- Phrenic nerve injury that has resulted in diaphragmatic paralysis
- Long thoracic nerve injury
- Ulnar neuropathy

Most of the mentioned nervous injuries improve after repositioning of the tube. Another rare but potentially fatal complication is re-expansion pulmonary edema. The cause is unknown. Risk factors include age less than 40 years, lung collapse for more than 3 days, large pneumothorax (>30%), rapid lung expansion, and application of negative pleural pressure suction. Treatment is supportive.

ED THORACOTOMY

Introduction

ED thoracotomy (EDT) can be lifesaving. Rehn first described emergency department thoracotomy (EDT) in 1894 while managing a right ventricle stab wound with associated pericardial tamponade. Ever since its first description, it has been a controversial procedure, complicated, and potentially harmful to the provider. Penetrating chest trauma is a major cause of morbidity and mortality. EDT has been described as the last resource to save the life of patients in extremis. Once the indications for EDT (Box 10) are established and contraindications (Box 11) considered, the necessary equipment (Box 12) must be gathered, and the potential complications (Box 13) need to be anticipated for successful procedure performance.

Technique

Place patients in the supine position. Once the left fifth intercostal space is detected, the area is prepped with cleansing solution and sterile drapes are placed. Perform

<table>
<thead>
<tr>
<th>Box 10</th>
<th>Indications</th>
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<tbody>
<tr>
<td>Penetrating chest trauma with loss of vitals signs during transport or in the ED</td>
<td></td>
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<tr>
<td>Penetrating chest trauma with rapid clinical deterioration without response to fluid resuscitation</td>
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<tr>
<td>Blunt trauma with loss of vital signs in the hospital</td>
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an incision laterally, extending from the left side of the sternum along the intercostal space to the midaxillary line. The incision must be done in the superior border of the sixth rib to avoid neurovascular injury. The incision should go through all layers in a single attempt. Use the Mayo scissors to cut the remaining intercostal muscles. Insert a rib retractor with the handle proximal to the bed; it will extend the laceration if needed. Once the pleura is visible, perform an incision with the scalpel and complete it with scissors. Open the retractor to expose the hemithorax and inspect the visible area for injury and act according to need. Remove blood and check for bleeding. If hemorrhage is present, apply pressure (use a staple or sutures). Inspect the pericardium and open it, grasp it with a nick in a cephalocaudal direction using scissors. It is important to identify the phrenic nerve to avoid damage. Once the pericardium is open, check the myocardium for wounds and clots. If a wound is found, the physician can occlude the wound using a finger. Another alternative is to use a Foley catheter to occlude the wound, inflate the balloon, and apply traction followed by a purse-string suture, then remove the catheter. Finally, any cardiac laceration can be sutured using the horizontal mattress technique with Teflon (DuPont, Wilmington, Delaware) pledgets.

If no injury is found in the left hemithorax, the chest incision may be extended across the sternum using a sternotomy knife or a Gigli saw to have a better evaluation of right atrium and ventricle. If intra-abdominal hemorrhage is suspected, aorta cross clamping is imperative.

<table>
<thead>
<tr>
<th>Box 11</th>
<th>Contraindications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thoracotomy contraindications</strong></td>
<td></td>
</tr>
<tr>
<td>Signs of death</td>
<td></td>
</tr>
<tr>
<td>Hemodynamically stable patients</td>
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</tr>
<tr>
<td>Chest blunt trauma with associated cardiopulmonary arrest in the scene</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Box 12</th>
<th>Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prep materials: iodine–povidone solution, towels</td>
<td></td>
</tr>
<tr>
<td>No. 10 scalpel</td>
<td></td>
</tr>
<tr>
<td>Rib spreader</td>
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<tr>
<td>Mayo scissors</td>
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<tr>
<td>Metzemann scissor</td>
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<tr>
<td>Tissue forceps</td>
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<tr>
<td>Hemostats</td>
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<tr>
<td>Vascular clamps</td>
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<tr>
<td>Lebshe knife with mallet</td>
<td></td>
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<tr>
<td>Sponges</td>
<td></td>
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<tr>
<td>3–0 cardiovascular suture</td>
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<tr>
<td>Jumbo applicators</td>
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</tbody>
</table>
Internal cardiac massage is indicated in the absence of cardiac activity while performing an open thoracotomy.

**Disposition**

Once vital signs are obtained after EDT, patients must be transferred to the operating room for definitive treatment. EDT will remain an indispensable tool in the treatment of severely injured trauma patients.24

**DIAGNOSTIC PERITONEAL LAVAGE VERSUS FAST**

Diagnostic peritoneal lavage (DPL) has been a mainstay in the evaluation of blunt abdominal trauma (BAT) for decades; it was first described in 1965.25 However, in recent years, DPL has fallen out of favor as the more noninvasive modalities of FAST (see Box 14 for comparison) and CT scanning have gained popularity and comfort. In fact, Rhodes and colleagues,26 in a 2011 12-year retrospective study at a level 1 trauma center recommended that with the substantial decrease in DPL occurrence, proposed that the American College of Surgeons consider changing DPL instruction to an optional component of ATLS. Therefore, DPL is no longer taught as a mandatory in ATLS course.27 However, DPL continues to have a place in trauma evaluation when FAST and CT scan are not an option because of facilities or patient hemodynamic instability. In that light, it is still a necessary skill to discuss, although as less surgeons and emergency physicians become comfortable with the procedure during training, it will continue to fall from favor.

<table>
<thead>
<tr>
<th>Box 13</th>
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</thead>
<tbody>
<tr>
<td><strong>Thoracotomy complications</strong></td>
</tr>
<tr>
<td>Infection</td>
</tr>
<tr>
<td>Dysrhythmias</td>
</tr>
<tr>
<td>Pericarditis</td>
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<tr>
<td>Postpericardectomy syndrome</td>
</tr>
<tr>
<td>Heart, coronary arteries, lung, esophageal, and phrenic injuries</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Box 14</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Comparison of DPL versus extended FAST</strong></td>
</tr>
<tr>
<td><strong>Ultrasound</strong></td>
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<tr>
<td>Rapid</td>
</tr>
<tr>
<td>Noninvasive</td>
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<tr>
<td>No complications</td>
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<tr>
<td>Portable</td>
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<tr>
<td>High specificity of intraperitoneal fluid</td>
</tr>
<tr>
<td>Can evaluate for pericardial fluid</td>
</tr>
<tr>
<td>No radiation or contrast exposure</td>
</tr>
<tr>
<td>Affordable</td>
</tr>
<tr>
<td>Repeatable</td>
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<tr>
<td>Easy to learn</td>
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<tr>
<td>Poor evaluation of retroperitoneal injury</td>
</tr>
</tbody>
</table>

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Critical Trauma Skills and Procedures 307
**Indications**

Abdominal evaluation is essential in any trauma patient, both blunt trauma and penetrating trauma. Both modalities have increased significance in patients with altered mental status or spinal cord injury. DPL is also indicated in anterior abdominal penetrating wounds when local wound exploration is positive, although there is no standard accepted red blood cell count in penetrating trauma and it does not detect retroperitoneal injuries. FAST evaluation in blunt trauma is accepted with little downside to evaluation. Ultrasound benefits use, in penetrating trauma is still controversial, but Udobi and colleagues found that there may be a role as an adjunct modality.

**Contraindications**

The FAST has no contraindications because it is noninvasive, rapid, and can be performed in concert with the trauma survey. Its utility will be decreased in obese patients and patients with subcutaneous air or ascites. The only absolute contraindication to DPL is obvious need for laparotomy. Relative contraindications include previous abdominal surgery, coagulopathy, advanced cirrhosis, morbid obesity, second- or third-trimester pregnancy, and pelvic fractures. The concern for previous abdominal surgery is that adhesions will increase the risk of iatrogenic injury. It could also compartmentalize the intraperitoneal fluid, resulting in a false-negative result. In pregnancy and patients with pelvic fractures, a supraumbilical open approach is the only possible option to avoid trauma to the uterus or destabilization of a pelvic hematoma.

**DPL PROCEDURE**

DPL has the option of a closed, semiopen, or open technique. Each is described later. The closed technique will be familiar to most physicians because it has the same basic principles already practiced with central lines.

- Place the patient in a supine position and decompress the bladder and stomach.
- Prep and drape the periumbilical area (Figs. 9 and 10).
- Use local anesthetic of 1% lidocaine with epinephrine to decrease cutaneous bleeding and consider conscious sedation if necessary.

**Semiopen**

- A vertical midline incision is made 2 cm below (or above in a supraumbilical DPL) the umbilicus.
- Identify the linea alba.
- Retract the skin and subcutaneous tissue bilaterally.
- Grasp the fascia bilaterally with hemostats.
- Insert an 18-gauge needle filled with saline at a 45° angle caudally
- Once the needle has transversed the peritoneum, the saline will flow freely into the peritoneal cavity.
- Pass a guidewire through the needle; if there is any resistance, remove the needle and wire.
- Remove the needle but maintain control of the wire.
- Pass a dilator over the wire.
- Remove the dilator and pass the DPL catheter into the peritoneal cavity.
- Remove the wire.
- Then aspirate, if 10 mL of blood are obtained the result is positive for intra-abdominal injury (Fig. 11).
If there is less than 10 mL, connect to warm lactic Ringer’s solution (LR) via IV tubing and allow it to flow in freely (Fig. 12).

Rock the patient back and forth, and then use gravity to allow at least 30% of the original amount to return (in a child infuse 10–15 mL/kg) (Fig. 13).

Once the effluent has been obtained, remove the catheter.

Place 4-0 nylon interrupted sutures or staples to the skin and dress the wound appropriately.

**OPEN TECHNIQUE**

- Make a vertical midline incision 2 cm below (or above) the umbilicus extending 5 to 6 cm; the vertical extension should be inferiorly if infraumbilical and superiorly extended if supraumbilical.
- Retract the skin and subcutaneous tissue.
- Incise the fascia (Fig. 14).
- Grasp and elevate the peritoneum with Allis clamps.
- Insert the lavage catheter into a small peritoneal incision (<5 mm) angled caudally (Fig. 15).

---

![Fig. 9. The insertion site is 1/3 the distance from the umbilicus to the symphysis, in the midline. (Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139 January 1, 2001.)](image)

![Fig. 10. Make a midline incision through the skin. (Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR Bureau of Medicine and Surgery, Department of the Navy NAVMED P-5139.)](image)
Continue as described earlier for evaluation of the effluent.

Once the effluent has been obtained, remove the catheter.

Close the fascia with a No. 0 monofilament polyglyconate synthetic absorbable suture, monofilament, nonabsorbable polypropylene, polyglactin 910 absorbable, or braided, monofilament synthetic absorbable suture in a running fashion; you do not need to close the peritoneum.

Close the skin with 4-0 nylon interrupted sutures or staples and dress the wound appropriately (Fig. 16).

CLOSED TECHNIQUE

- In the middle line of abdomen, 1 or 2 cm below the umbilicus, advance the introducer needle at a 45–angle caudally and use continuous negative pressure on the syringe.
Feel for the penetration (pops) of the skin, fascia, and peritoneum, and then advance another 2 mm.

If you get a blood return, this is a positive aspirate and you can stop.

If no blood returns, remove the syringe and advance the guidewire. You should not have resistance with this process.

Withdraw the needle and make a small incision adjacent to the guidewire.

Advance the lavage catheter over the guidewire until it is against the abdominal wall.

Hold the lavage catheter securely and remove the guidewire.

Attach the warmed LR or normal saline solution via IV tubing and proceed as described earlier.

After effluent is obtained, remove the lavage catheter and dress the wound appropriately.

**FLUID EVALUATION**

- Blunt abdominal trauma (BAT) red blood cell count (RBC) more than 100,000/\(\text{mm}^3\)

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Fig. 13. Place the fluid bag on the floor. *(Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139 January 1, 2001.)*

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Fig. 14. Incise the fascia. *(Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139.)*
For penetrating trauma, there is no consensus and depends on the area of trauma; in the anterior abdomen, more than 100,000/mm³ RBC is accepted. More than 500/mm³ white blood cell count. Presence of enteric or vegetable matter.

**FAST Examination**

- Place the patient in a supine position and evaluate using a 3.0- to 5.0-MHz transducer.
- Orient the ultrasound probe indicator toward the patient’s right side or head at all times to maintain proper orientation.
- Morrison pouch evaluation: Place the transducer at the costal margin in the anterior axillary line with the indicator pointed toward the patient’s head for the sagittal plane.
- Morrison pouch evaluation in the coronal plane: Place the transducer at the costal margin with the indicator toward the patient’s head, placed in the midaxillary line.

---

**Fig. 15.** Insert the lavage catheter into a small peritoneal incision (<5 mm) angled caudally. (Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139.)

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**Fig. 16.** After removing the tube, close the fascia, then the skin. (Courtesy of Operational medicine: health care in military settings CAPT Michael John Hughey, MC, USNR bureau of medicine and surgery, department of the navy NAVMED P-5139. January 1, 2001.)
- Splenorenal recess evaluation: The probe is placed at the posterior axillary line at the inferior costal margin with the indicator pointed toward the patient’s head.
- Subxiphoid anterior transverse plane: Place the transducer with the indicator toward the patient’s right side, placed in the midline abdomen and angled toward the right scapula using the liver as a window.
- Suprapubic evaluation (pouch of Douglas): The transducer probe should be pointed to the head and rotated to the patient’s right to obtain the transverse and sagittal views. The transducer is placed 2 cm superior to the pubic symphysis and angled inferiorly.
- (EFAST) extended FAST evaluation for pneumothorax: Place the transducer in the midclavicular line of the anterior chest wall. Look for the bat sign (rib shadowing) and look for the normal respiratory motion and artifact.
- EFAST: In M mode, orient the transducer parallel to the ribs in the intercostal spaces. The granular artifacts below the pleural line, also, called seashore, are indicating of normal respiratory movement.

**COMPLICATIONS**

Because ultrasound is rapid and quick, there are no direct complications from the procedure. However, with a sensitivity range of 65% to 95% depending on the study, false negatives are a definite possibility and could delay treatment. Ultrasound detection of fluid is also variable based on the amount of intraperitoneal fluid.31–34 Because DPL is an invasive procedure, certain complications are noted, although rare, and include infection; injury to the bowel, mesentery, or iliac vessels; bladder punctures; or abdominal wall infusions. Overall rate of complications ranges from 0.8% to 1.7%.27

**COMMON PITFALLS AND SUGGESTIONS**

- If the fluid does not flow freely into the peritoneal cavity but seems to drip slowly, consider placement erroneously in the abdominal wall and assess for repositioning.
- If the effluent does not readily return, consider blockage by the omentum. Use firm pressure on the abdomen or slight repositioning of the catheter for improved flow.
- If there is any difficulty advancing the wire through the peritoneal cavity or pain is reported remove the wire then the needle to avoid wire shearing into the peritoneal cavity.
- Stabilize the needle securely to avoid intra-abdominal organ lacerations.
- In pelvic fractures, there may be a false positive FAST (Figs. 17–25).
- Infuse fluid in the bladder catheter or place the catheter after evaluation of the pouch of Douglas to avoid a false negative from a poor sonographic window.
- The left kidney is more difficult to visualize because of its superior position. Directing the patient to take a deep breath in may help visualize the splenorenal angle better.
- A distended stomach can prevent visualization of the pericardium in the subxiphoid view; decompression with an nasogastric tube may be necessary.
- Move the probe around to visualize the entire area; rib shadows can hide a positive finding.
- Perirenal fat may appear hypoechoic.
- Use the Trendelenburg position to evaluate the paracolic gutters for free fluid and the reverse Trendelenburg position for pelvic evaluation.
ACUTE LIMB COMPARTMENT SYNDROME

Acute limb compartment syndrome (ALCS) is a surgical emergency and is caused by raised pressure within a closed fascial space (Box 15). An increase of the intra-compartmental pressure (ICP) reduces the capillary perfusion lower than a level necessary for tissue viability. The limbs are comprised of superficial and deep fascia that cover and divides the limbs into skeletal muscle groups, neurovascular bundles that accompany them into different compartments.

An increase in the ICP may reduce the capillary blood inflow if decompression is not performed promptly, leading to arteriolar compression, muscle and nerve ischemia, muscle infarction, and nerve damage.

The most important determinant of a poor outcome from ALCS after injury is delay in diagnosis. The complications are usually disabling and include infection, contractures, deformity, and amputation.

The normal pressure of the skeletal muscle compartment at rest is less than 10 mm Hg. One study demonstrated that when tissue pressure within a closed compartment increases to within 10 to 30 mm Hg of the patient’s diastolic blood pressure, inadequate perfusion ensues, resulting in relative ischemia of the involved limb.

Blood flow to tissues depends on the A-V gradient in capillary beds. If reduced less than a critical level, oxygen delivery is impaired and metabolism becomes anaerobic.
A drop in blood pressure, an increase in compartment pressure, or a combination of the two can reduce A-V gradients and lead to insufficient blood flow to tissues causing ischemia, leading to compartment syndrome.

Sensory changes, like paresthesia and hypesthesia, develop after 30 minutes of ischemia. The irreversibility of damage is directly related to the time of compartment syndrome onset. After 4 to 8 hours of compartment syndrome onset, irreversible functional changes in the muscle occur. Then, between 12 to 24 hours of onset, irreversible damage takes place.35,36

**INDICATIONS AND CONTRAINDICATIONS**

The diagnosis of compartment syndrome is primarily clinical, supplemented by direct measurement of compartment pressures. The history of substantial trauma and the presence of severe injuries should raise clinical suspicion. But, in patients in which clinical findings are inconclusive or subtle, such as: children, unresponsive, uncooperative patients or patients with distracting injury, or when it is particularly difficult to assess the history and physical examination, then high index of suspicion will grant a compartment pressure measure.

Severe and spontaneous pain is the earliest and most frequent sign of compartment syndrome among others (Box 16).38 Serial examinations are necessary to prevent complications and manage in a timely manner.38
There are not absolute contraindications for compartment pressure measure but if there is cellulitis or severe trauma to site of needle placement counts for contraindications.37

**PREPARATION FOR THE TECHNIQUE**

There are some ways for measure the compartment pressure depends on the devices available. Depends on the devices to be used the equipment will vary as technique needs. Therefore, the emergency physician should familiarize with the device that is available in the institution for which is work. For the purpose of this paper, three of the methods will be discussed: mercury manometer measure, Stryker and arterial line methods. Although, all of them are used there is agree that the mercury method is the less accurate in comparison with the other two.37

Obtain informed consent and explain procedure to patient. Local anesthesia as well as conscious sedation will be needed for most patients. The extremity being studied should be at the level of the heart and in a position that permits insertion of the needle perpendicular to the compartment being measured. This may require an assistant to hold an extremity above the stretcher. Any obstruction to needle entry and all structures that may put pressure on the compartment should be removed because them can raise falsely the compartment pressure. Use sterile technique at all times.37

![Fig. 21. FAST, right hemothorax. (Courtesy of Robert Park, MD).](image)

![Fig. 22. FAST, hepatorenal fluid. (Courtesy of Robert Park, MD.)](image)
PRESSURE MEASUREMENT SYSTEMS

Box 17.

PROCEDURE TECHNIQUE

Anesthetize and sterilize the puncture site. Connect an 18-gauge needle to one end of the plastic IV tubing (as shown in Fig. 26) and connect the 3-way stopcock to the other end. Connect a 20-mL syringe to the 3-way stopcock. Turn the stopcock lever to close to the remaining IV tube, and open the stopcock port. Pierce the vial with a needle and, using an 18-gauge syringe, withdraw fluid until it reaches halfway along the IV tubing. Annotate, or mark with a marker, the position of the meniscus in the IV tubing (Fig. 27). Turn the stopcock lever to close the IV tubing proximal to the skin, pull back on the plunger to fill the syringe with air, and connect one end of the IV tubing to the stopcock’s remaining port and fit the other to the rubber tubing of the manometer (see Fig. 26 B). If using a radial manometer with a connected balloon, turn the dial to close the balloon. Insert a needle at a 90° angle to the compartment and sufficiently deep to enter the selected compartment. Turn the stopcock lever to the bottom so that all ports are open. Slowly press the syringe plunger while observing the meniscus in the IV tube. When the meniscus in the IV tube begins to move toward the needle,
stop depressing the plunger and turn the stopcock lever to close the IV tube port, which will lock in the measurement reading (the value on the manometer is equal to the intracompartmental pressure). In some instances, 3 readings are recommended to achieve an agreement. Remove the needle and dress the puncture site.37

**STRYKER HANDHELD PRESSURE METHOD**

**Box 18**

**TECHNIQUE**

Anesthetize and sterilize the puncture site and attach the needle to the end of the diaphragm chamber. Draw up a 3-mL sterile saline in the syringe and connect the syringe to the diaphragm chamber. Raise the device cover, place the diaphragm chamber into the device, and close the cover. Aim the device at a 45° upward angle and depress the syringe plunger to clear the air and prime the needle with fluid. Turn on the device, hold the device at 90° to the compartment, press the button to ZERO. When the monitor reads 00, puncture the needle into the intended compartment; the pressure reading will be shown on the device. Later, remove the needle and dress the site as shown in **Fig. 27**.

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**Fig. 25.** Clinical decision-making algorithm when evaluating patients with suspected compartment syndrome. * pressure threshold.
Box 15
Common causes of ALCS

Orthopedic (fracture related)
- Tibial fracture
- Distal radial and ulna fractures: supracondylar fracture; femoral and calcaneal fractures

Vascular
- Arterial and/or venous injuries
- Revascularization procedures
- Phlegmasia caerulea dolens
- Intra-aortic balloon pumping
- Isolated limb perfusion

Iatrogenic
- IV/intra-arterial drug injection
- Tourniquet
- Pneumatic anti-shock garment
- Patients with hemophilia
- Anticoagulation
- Extravasation of fluid after an arthroscopic procedure
- Prolonged surgery

Soft tissue
- Crush injury without fractures
- Burn
- Edema or intramuscular hematoma
- Drug or alcohol overuse induced stupor snakebite


Box 16
Symptoms and signs of ALCS

- Pain (spontaneous and disproportionate)
- Pain on passive stretching of the involved muscles
- Swollen and tense compartment
- Rapid progression of signs over a short time
- Paresthesia (initially affecting 2-point discrimination)
- Pulselessness (usually in vascular injury)
- Paralysis (latest symptom)
ARTERIAL LINE SYSTEM

**Box 19**

**TECHNIQUE**

Anesthetize and sterilize the puncture site. Connect the transducer to the monitor and assemble the system as shown in Fig. 28. Fill the syringe with 15 mL of saline. Place one stopcock on the syringe. Open the stopcocks to allow filling of the transducer, high-pressure tubing, and needle. Once filled, close the stopcock to the high-pressure tubing. Open the top stopcock to air and place the transducer at the same level of the compartment being measured; calibrate the system to 0, and then close the top stopcock. Open the lower stopcock attached to the high-pressure tubing. Insert the needle into the compartment. Squeeze slightly the intended compartment or passive movement to the muscle in the compartment to provoke a spike on the monitoring. After a few seconds, measure the mean compartment pressure.

**TECHNIQUE FOR NEEDLE PLACEMENT**

The needle placement is an essential part of the compartment pressure measure technique. Accurate placement allows reliable measures. This section reviews the anatomy and placement of the needle.

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**Box 17**

**Mercury manometer system**

**Equipment**
- Two 18-gauge simple or spinal needles
- Two plastic extension tubes
- One 20-mL syringe
- One 3-way stopcock
- One vial of sterile normal saline
- One mercury manometer

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Fig. 26. Mercury monitor technique. (A) Connect the first IV tube to the stopcock in one end and 18-gauge needle to another, followed by connection of 20-mL syringe. (B) Connect the second IV tube to a manometer and open this remaining port to start with the measures.
The lower leg is the most common place for compartment syndrome to occur; the anterior compartment is the most common involved. The lower leg consists of 4 compartments: anterior tibial, deep posterior, posterior, and lateral. The anterior tibia compartment can reach 1 cm lateral to the anterior border of the tibia, and the needle should be placed 1 to 3 cm in depth (Fig. 29). The lateral compartment is in the lateral aspect of the fibula. Place the needle anterior to the posterior border of the fibula, about 1 cm in depth (Fig. 30A). The deep posterior compartment can be reached when the needle is placed posterior to the medial border of the tibia and directed to the posterior border of the fibula as shown in Fig. 30B. Then the posterior compartment is reached in the posterior aspect of the leg at the level of the calf. Insert the needle 2 to 4 cm in depth as shown in Fig. 30C.

Gluteal compartment syndrome is very uncommon. But in some instances, compartment syndrome may occur: prolonged immobilization and significant contusions to this area. Since the body habitus may vary, the compartment sites vary from patient to patient, then, insert 18-gauge spinal needle about 4 to 8 cm in depth, where the maximal point tenderness exists, as shown in the Fig. 31.

The foot compartment syndrome results from crush injuries. The number of compartments in the foot is still controversial, but for the purpose of the measure 3 different sites are identified as shown in the Fig. 32.

<table>
<thead>
<tr>
<th>Box 18 Stryker method equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sterile skin prep (povidone-iodine solution or chlorhexidine)</td>
</tr>
<tr>
<td>Local anesthetic with syringe and small-gauge needle for superficial infiltration</td>
</tr>
<tr>
<td>Stryker (Stryker Instruments, Kalamazoo, MI, USA) handheld intracompartmental pressure monitor</td>
</tr>
<tr>
<td>(1) 3-mL syringe</td>
</tr>
<tr>
<td>Sterile saline</td>
</tr>
<tr>
<td>(1) Device side-port needle</td>
</tr>
<tr>
<td>(1) Device diaphragm chamber</td>
</tr>
</tbody>
</table>
COMPLICATIONS

The late diagnosis of compartment syndrome results in muscle ischemia and loss of function and ultimate contractures (Volkmann contracture). Then the emergency physician should be able to perform the compartment pressure measure with proficiency and accuracy. Even though the procedure will be performed with proficiency, some complications may occur. Local and systemic infection is considered one of the complications of the measures methods.\(^{39,40}\) Using aseptic conditions and universal precautions should diminish this possibility. Pain associated with needle insertion and patient movement during measurement (proper analgesia should be given) can also complicate the procedure.\(^{39,40}\)

**Box 19**

**Equipment for arterial line system**

- Sterile skin prep (povidone-iodine solution or chlorhexidine)
- Local anesthetic with syringe and small-gauge needle
- (1) 18-gauge needle
- High-pressure tubing
- Pressure transducer with cable
- Pressure monitor
- Sterile saline
- Transducer stand
- (2) 3-way stopcocks
- (1) 20-mL syringe

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**Fig. 28.** The arterial line system for compartmental pressure measure.
TREATMENT OF ALCS

Patients should be immediately referred to a surgeon for urgent consideration of fasciotomy in the presence of ALCS (Box 20). A fasciotomy should be performed as soon as possible, preferably within 6 hours and definitely within 12 hours (if at all possible),
once the diagnosis of ALCS has been done. There are specific techniques depending on the compartment that is involved. Table 2 describes the different compartments and the proper approach to achieve successful decompression.

**VENOUS CUTDOWN**

One of the first steps during a trauma patient resuscitation is circulation achieved by vascular access. Vascular access takes first place in seriously ill patients, moderate to severe dehydrated patients, and hypovolemic shock patients. The challenge begins when vascular access is not achieved by conventional peripheral modality; then alternatives route should be explored, like venous cutdown.

Although venous cutdown is no longer taught in the ATLS course as mandatory skill, still as an alternative for vascular access when other less invasive modalities have failed. The venous cutdown modality have been displaced for the over-the-wire

---

**Fig. 31.** Gluteal compartment. Note the asterisk suggests the needle entrance place. (A) A, transverse cut of gluteal compartments. (B) Gluteal compartments.

**Fig. 32.** Foot compartments. Note the asterisk suggests the needle entrance place.
percutaneous catheters (known commonly as central lines), however, for infants and children, among others, still as an alternative vascular access route as shown in Box 21. In hypovolemic shock, the venous cutdown has advantages because of the rapid flow rate. When the large-bore catheter is inserted directly into the vein, the blood flow increases 15% to 30%. Thus, one blood unit can be transfused in 3 minutes; therefore, large-bore lines placed by venous cutdown are excellent mechanism to treat severe hypovolemia.

The saphenous vein is the most common vein used for venous cutdown. Its superficial location and usually predictable anatomy permit more rapid dissection. In addition, it is preferable in the setting of cardiac arrest because it is distant from chest compressions and resuscitative efforts. Other veins that are chosen for venous cutdown are the basilic and cephalic veins. Even though these sites are not commonly used, it is useful to know their anatomy in such cases as bilateral leg amputation or burned legs.

Venous cutdown is contraindicated when less invasive vascular access has been achieved. In addition, if the technique execution is prolonged, it is also contraindicated. Detailed knowledge of anatomy and the equipment to be used can reduce the time to perform the procedure as discussed in Table 3 and Box 22, respectively (Fig. 33).

**TECHNIQUE**

**Isolation of the Veins**

The venous cutdown technique is quite the same no matter what vein is to be cannulated. However, as expected, the isolation depends on the location and the vein to be catheterized. For the purpose of this section, the isolation is discussed as a different section but the technique per se is discussed as a whole.

The saphenous vein is the longest vein of the body and begins on the ankle and ends at level of the thigh when it joins the femoral vein. At ankle level, it is named the

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**Box 20**

**Indications for fasciotomy**

<table>
<thead>
<tr>
<th>Indication</th>
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<tbody>
<tr>
<td>Absolute pressure greater than 30 mm Hg</td>
</tr>
<tr>
<td>Perfusion pressure (diastolic blood pressure compartment pressure) less than 30 mm Hg</td>
</tr>
</tbody>
</table>

saphenous vein. It arises from the dorsal venous arch of the foot and then ascends cephalad 2 cm anterior to the malleolus. The leg should be extended and externally rotated to expose the medial malleolus. Then, apply counter-traction on the skin, and the 3-cm incision will be performed across the anterior tibial surface (not too deep). Separate the overlying tissue with a hemostat or mosquito. At the knee, the incision for isolation should be performed 1 to 4 cm below the knee and posterior to the tibia; beware of the proximity to saphenous branch of the genicular artery and the saphenous vein. This approach could fail when the knee is bent or flexed because the line could kink. The greater saphenous vein at the level of proximal thigh is another portion of the vein that can be used for cannulation. Actually, this site is the most recommended when treating hypovolemia because of the large caliber and easy access. This portion raises anteromedial in the proximal thigh. It could be found 4 cm inferior to palpable femoral pulse.

**Box 21**

**Clinical examples for venous cutdown**

- Infants and children
- Shock
- IV drug abusers
- Severely burned or scarred patients
- Skin or anatomy distorted
- Cardiac arrest without palpable femoral pulse

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**Table 3**

**Anatomy of great saphenous and saphenous, basilica, and cephalic veins**

<table>
<thead>
<tr>
<th>Vein</th>
<th>Anatomy</th>
<th>Incision Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saphenous</td>
<td>Begins at the ankle, crosses 1 cm anterior to medial malleolus and then up to the anteromedial aspect of the leg (preferable site for venous cutdown); in the knee, lies superficial on the medial aspect (less used because of the risk of injury of saphenous nerve and genicular artery)</td>
<td>Ankle: 1 cm anterior to medial malleolus (preferable site for children)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Knee: 1–4 cm below the knee and immediately posterior to the tibia</td>
</tr>
<tr>
<td>Great saphenous</td>
<td>Begins on medial aspect of the knee, then crosses anterolaterally, ascends until it joins the femoral vein</td>
<td>Anterior thigh: 3–4 cm below inguinal ligament and 3 cm lateral to pubic tubercle (preferable site for hypovolemia because of the large caliber)</td>
</tr>
<tr>
<td>Basilic</td>
<td>At level of midforearm, crosses anterolaterally; it is found at 1–2 cm lateral to the medial epicondyle</td>
<td>Antecubital fossa 2 cm above and 2–3 cm lateral to the medial epicondyle</td>
</tr>
<tr>
<td>Cephalic</td>
<td>Begins on radial aspect of the wrist and crosses anteromedially toward antecubital fossa</td>
<td>Most common site: antecubital fossa at the distal flexor crease</td>
</tr>
</tbody>
</table>
and 3 cm lateral to the pubic tubercle or approximately 2 cm inferior to the site of percutaneous femoral line placement. Another cited landmark is 4 cm below the inguinal ligament. A transverse 5- to 6-cm incision should be done distal to where labial/scrotal fold meets the thigh. With a hemostat blunt dissection should be done but if muscle or investing fascia is found the dissection is too deep. Then reassessment of the landmarks should be done.

The basilic vein can be cannulated, as an alternative, in the setting of leg amputation, leg trauma, or deformity. To find the basilic vein, the arm should be abducted 90°, flexed at 90°, and externally rotated. The incision should be done on the medial aspect of the arm 2 cm proximal and 2 to 3 cm lateral to the medial epicondyle. Superficial incision may be done until subcutaneous tissue is revealed. Blunt dissection is recommended to avoid injury to the brachial artery and median nerve.

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**Box 22**

**Equipment for venous cutdown**

<table>
<thead>
<tr>
<th>Equipment</th>
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<tbody>
<tr>
<td>Plastic dilator-lifter</td>
</tr>
<tr>
<td>Scalpel</td>
</tr>
<tr>
<td>Blade No. 10 or No. 11</td>
</tr>
<tr>
<td>Curved hemostat</td>
</tr>
<tr>
<td>0–0 silk sutures</td>
</tr>
<tr>
<td>Iris scissors</td>
</tr>
<tr>
<td>Plastic venous dilator</td>
</tr>
<tr>
<td>Large-bore IV catheter</td>
</tr>
<tr>
<td>IV tubing</td>
</tr>
<tr>
<td>Tape</td>
</tr>
</tbody>
</table>

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Fig. 33. Equipment for venous cutdown. Venous cutdown tray. Note the small plastic vein dilator-lifter (E), which is especially useful in children. Equipment: (A) scalpel No. 11 blade, (B) curved hemostat, (C) No. 0–0 silk suture, (D) iris scissors, (E) plastic venous dilator, (F) large-bore IV catheter, (G) IV tubing, and (H) tape for securing catheter. (From Custalow CB. Color atlas of emergency department procedures. Philadelphia: Elsevier Saunders; 2005. p. 163.)
The cephalic vein is subcutaneous in the antecubital fossa, overlying the lateral aspect of the biceps muscle. Careful incision should be done in the antecubital fossa in the lateral aspect. Although the cephalic vein ascends until deltoid muscle area, this site is very difficult to access and interferes with the resuscitative efforts.

**TECHNIQUE**

Once the vein is selected for the procedure, prepare and clean the chosen area with povidone-iodine or other antiseptic solution. Place a tourniquet proximal to the chosen site for venous cutdown. Anesthetize the place of venous cutdown if the patient is awake. With a No. 10 or No. 11 scalpel, incision in the site should be done perpendicular following the landmarks for vein isolation as described in the previous section (“Isolation of the Veins”) (see Fig. 33). Use the hemostat for blunt dissection of the vein, spreading the subcutaneous tissue until the vein is exposed. Use the hemostat to place distal and proximal silk ties. Then, tie the distal silk, but the proximal one should remain untied (the proximal tie will be used for maneuvering the vein, bleeding control, and/or tubing placing). Nick the vein with a No. 10 or 11 scalpel blade in 45° to transect one-third to one-half the diameter of the vein, not too large because the vein will be transected completely and not too small because false lumen may occur. To avoid false lumen insertion, a vein dilator can be used, especially in children. If a vein dilator is not available, a 20-gauge needle is bent at a 90° angle (to use it as a vein dilator or elevator).

In case the catheter does not have a tapered tip, make a bevel in the catheter at a 45° angle before introducing it. Introduce the catheter, but do not force it. If the catheter is large, grasp the proximal edge of the vessel with small forceps or a mosquito hemostat. After introducing the catheter, flush air from the cannula and then connect it to the IV tubing. The proximal ligature should be tied around the vein and the cannula. Then remove the tourniquet; once the catheter is tied, the IV infusion can begin. Fix the catheter to the skin and proceed to repair the incision wound. Topical antibiotic may be beneficial at the wound site. Do not delay the fluid infusion despite wound closure.

Mini-venous cutdown is an alternative modality of venous cutdown. With this method, the time-consuming part of the venous cutdown of placing the catheter is avoided. Instead of placing the tourniquet and tying the vein, the vein will be canalized under direct vision but with a percutaneous infusions catheter (Fig. 34 and 35). After identifying the vein, make an incision over it and with blunt dissection expose it. Then stab the skin with the percutaneous catheter below the incision for visualization. Remove the needle and a cannula will stay inside the vein. Then close the wound and fix it to the skin. This method is designed for chronically ill patients, obese patients, and children. Flow rates and infusions are the same as classic venous cutdown, as discussed previously.

**COMPLICATIONS**

The venous cutdown could be time-consuming in the step of venous catheterization that may result in patient deterioration. This complication can be overcome with a vein dilator or elevator. Detailed knowledge of anatomy is required to avoid secondary damage to surrounding structures, such as arteries or nerves. Other complications are local hematoma, infection, sepsis, phlebitis, embolization, and wound dehiscence. Using topical antibiotics can diminish the incidence of infection.
Fig. 34. Venous cutdown technique: procedural steps for venous cutdown. Step 1: Saphenous vein approach. The saphenous vein at the ankle can be found approximately 1 cm anterior to the medial malleolus. Place a tourniquet and use a topical antiseptic. Make a skin incision perpendicular to the course of the vein. Step 2: Bluntly dissect, isolate, and mobilize the vein. Step 3: Use a hemostat to isolate the vein and to pass the silk ties under the vein proximal and distal to the proposed cannulation site. Step 4: Tie the distal suture only. Step 5: Incise the vein while retracting the proximal ligature. Lift the proximal untied suture to control back bleeding. Step 6: Using the plastic venous dilator to lift the flap, advance the catheter into the vein. Attach IV tubing to the catheter. Step 7: Tie the proximal silk suture around the vein and catheter. Remove proximal suture and suture skin. (From Custalow CB. Color atlas of emergency department procedures. Philadelphia: Elsevier Saunders; 2005. p. 164.)
Step 4

Step 5

Step 6

Step 7

Fig. 34. (continued)
This procedure is not permanent and should be removed as soon as possible to avoid complications.

**SUMMARY**

Emergency physicians must be proficient in the acute management of trauma patients. Most injuries related to trauma are initially evaluated in the ED; this evaluation may be complex depending on the age of the patient, associated mechanism of injury, and comorbidities at the moment of trauma. Conditions, such as hemopneumothorax, hemorrhages, and surgical airway, require prompt intervention and proficiency in the execution of procedures to avoid complications and functional impairment while improving outcomes. It is of paramount importance for the practitioner to be dexterous while performing these procedural skills.
REFERENCES