SECTION 1

CENTRAL VENOUS ACCESS

P5: ULTRASOUND-GUIDED CENTRAL LINES – IJ, SUBCLAVIAN

P8: BLIND CENTRAL LINES

P14: TRANSVENOUS PACER
VASCULAR ACCESS

CENTRAL VENOUS ACCESS

INTRODUCTION

The ability to access the central veins of the body is imperative for immediate resuscitation via rapid high-volume fluid administration, associated hemodynamic monitoring, medication administration (including medications that have to be given through central access only), and blood sampling that can assist with therapy (mixed venous sampling). The central venous system is accessible both above and below the diaphragm and this variability can be beneficial as sites can be chosen depending on injury patterns and body surface availability. The most common sites used for accessing the central venous system include the femoral vein in the groin region, the internal jugular (IJ) vein in the neck, subclavian vein accessed infraclavicularly, and the confluence of the IJ and subclavian veins via the supraclavicular approach.

KEY POINTS

• Central venous system accessible both above and below diaphragm
• Most common sites are femoral, IJ, subclavian veins

INDICATIONS

• Inability to obtain peripheral IV access
• Need for specific IV medications that may be damaging to peripheral veins (high concentration dextrose solutions, pressors, hypertonic saline, TPN electrolytes)
• Access for cardiac devices (i.e., transvenous pacing)

• Central venous pressure (CVP) monitoring
• Need for emergent dialysis without previous access

CONTRAINDICATIONS

• Cellulitis at puncture site
• Uncooperative patient
• Distorted anatomy
• Cervical spine injury
• Severe carotid stenosis
• Coagulopathy if placement in noncompressible sites

ANATOMICAL POINTS

• Internal jugular vein
  1. Emerges from base of skull just anteromedial to the mastoid process (Fig. 2.6).
  2. The IJ diameter is widest below the level of the cricoid cartilage, making cannulation easiest at this point.
  3. The IJ runs lateral and anterolateral to the common carotid; however, variation does exist.
  4. Cannulation of the right IJ is preferred over that of the left IJ because of the straight line into the right atrium, and the presence of a higher pleural dome and thoracic duct on the left side.

• Subclavian vein
  1. The axillary vein becomes the subclavian vein as it crosses the first rib, then joins the IJ vein behind the sternoclavicular joint to become the brachiocephalic vein (Fig. 2.7). The fibrous connective tissue joins the subclavian vein to the clavicle and first rib, preventing collapse of the vessel in low flow states.
  2. The vein courses in close proximity to the undersurface of the medial third of the clavicle, and cannulation should take place at this point.

• Femoral vein
  1. The femoral artery lies at the midpoint of a line connecting the symphysis pubis and the anterior superior iliac spine. The femoral vein lies 1 cm medial to the arterial pulse (Fig. 2.8). This is approximately the junction of the middle and medial third of the distance from the symphysis pubis and the anterior superior iliac spine.
2. Puncture of the femoral vein must occur 1 to 2 cm below the inguinal ligament.

CAUTION

Inadvertent puncture of the femoral vein above the inguinal ligament may lead to bowel perforation or the needle can enter the external iliac and cause retroperitoneal bleeding.

NOTE

For identification of the femoral vein, the operator may approximate this by spreading the thumb and index finger and placing them on the pubic symphysis and anterior superior iliac spine respectively. The base of the “V” of the hand approximates the path of the femoral vein just below the inguinal canal. This can be especially useful in patients who do not have a pulse.
**Figure 2.7** Anatomy of the subclavian vein.

**Figure 2.8** Femoral vein cannulation. The skin puncture site is 1 cm medial to the femoral artery pulse and 2 to 4 cm inferior to the inguinal ligament. Direct the introducer needle posteriorly at a 45- to 60-degree angle while aspirating.
EQUIPMENT

Multiple standard central line kits are available. Most include the following:

- Povidone-iodine solutions
- Sterile drape
- Local anesthetic
- 25-gauge needle
- 5-mL syringes
- 22-gauge finder needle
- Introducer needle
- Guidewire
- 4 × 4 gauze pads
- Central venous line
- Dilator
- No. 11 blade
- Suture (three or four size 0, nylon or silk on a straight needle)
- Dressing material
- Sterile gloves and gown should be used

TECHNIQUE: SELDINGER

The Selinger technique is most commonly used for placement of a central venous line. The following steps are common to all sites of central line placement and will subsequently be referred to.

- Assume failure with line placement and prepare enough area so that another area can be attempted without breaking the sterile field (i.e., having a sterile field from angle of jaw to nipples will allow for attempted placement of IJ, subclavian, and supraclavicular line in one preparation).

1. Anesthetize the area of skin puncture (for subclavian lines, anesthetize the clavicular periosteum must occur as well).
2. Using the large-bore introducer needle on a 5-mL syringe, locate the vein aspirating for venous blood (for IJ vein, a 22-gauge seeker needle may be used to locate the vein first; Fig. 2.9)

- It is useful to align the bevel of the needle with the numbers on the syringe to always be cognizant to allow fine guidewire control.

3. Disconnect the syringe and occlude the needle hub to avoid air being drawn in via the negative intrathoracic pressure.
4. Insert the guidewire through the introducer needle into the vein.
5. Remove the introducer needle.
6. Use a no. 11 blade to slightly enlarge the puncture site via a stab incision along the tract.
7. Thread the dilator over the guidewire until the guidewire protrudes out of the dilator.
8. Hold the guidewire while inserting and withdrawing the dilator.

NOTE

Central line catheters come in a variety of infusion ports, lengths, and internal diameters. In general, shorter lines with larger internal diameters have the highest flow rates.

Percutaneous sheaths are intended for introduction of pacemakers and pulmonary artery catheters and for rapid infusion of blood or crystalloid during resuscitation of the hypotensive patient.

Multiport catheters have lower flow rates but can allow for simultaneous infusion, blood sampling, and CVP monitoring.

PREPARATORY STEPS

1. Properly position the patient according to the site of insertion. For IJ, place the patient in 20 degrees of Trendelenburg position.
2. Prepare the insertion site. When performing IJ or subclavian, prepare both sites so that if unsuccessful at one site, the other can be used.
3. Wear gown and gloves for the procedure.
4. Anesthetize site of insertion with lidocaine.
5. It is imperative to observe absolute sterile procedure for each step of the insertion of the central line. Emergent placement of central lines has a historically high infection rate, which is unacceptable.
9. Thread the catheter over the guidewire, withdrawing the guidewire until it protrudes from the infusion port of the catheter. (In a triple-lumen catheter, this is commonly the shortest port and is brown in color.)

10. Grasp the guidewire and insert the catheter to the desired depth. Insert introducer sheaths completely.

11. Hold the catheter in place and remove the guidewire.

**CAUTION**

NEVER let go of the guidewire. The negative pressure of the venous system can pull the catheter into the body, making the wire an embolus that will lodge in the right side of the heart or pulmonary vascular system, requiring radiological removal.

**CAUTION**

If there is any resistance to removal of the wire through the catheter, remove both as one unit to prevent inadvertent wire shear, similar to previous discussion with needle shear.
15. Place a small dab of antibacterial ointment where the catheter enters the skin.
16. Apply dressing with adherent transparent material (i.e., Tegaderm).
17. Verify placement with a chest radiograph.

PROCEDURAL STEPS

Internal Jugular Vein

- Central approach (preferred): Locate the triangle formed by the sternal and clavicular heads of the sternocleidomastoid muscle superiorly and the clavicle inferiorly (Fig. 2.10). The point of insertion is at the apex of this triangle (Fig. 2.11). Insert the needle at a 30- to 40-degree angle to the skin. Direct the needle toward the ipsilateral nipple. The vein should be entered within 1.5 to 3 cm.

**CAUTION**

The operator must resist the desire to continue to allow the needle to go past the 3-cm point for IJ placement. Serious complications can occur with deeper insertion, including pneumothorax and vascular catastrophes.

Figure 2.10 • An important triangle (in which the internal jugular vein passes) is formed by the medial and lateral heads of the sternocleidomastoid on two sides and the clavicle on the third side. In attempting an internal jugular vein insertion by the central approach, place the finger in the apex of the triangle as shown. See text for discussion.

12. Aspirate blood into a syringe from the catheter port.
13. Flush all ports with saline.
14. Suture the line in place and/or staple with included staplers in kit.
• **Anterior approach:** Insert the needle at the anterior border of the sternal head of the sternocleidomastoid muscle, just lateral to the carotid artery at an angle of 45 to 60 degrees (Fig. 2.12). The introducer needle is directed toward the ipsilateral nipple. The internal jugular vein should be encountered in an adult within 3-5 cm. The remainder of the process is similar to the central approach.

*CAUTION* Because of the proximity to the carotid artery and the depth of needle penetration, this approach is not recommended.

• **Posterior approach:** Insert the needle at the posterior border of the clavicular head of the sternocleidomastoid, just cephalad to where the external jugular vein crosses the border. Alternatively, when the external jugular vein cannot be visualized, insert the needle along that border at the junction of the middle and lower third. Aim the needle at the sternal notch at a 30- to 45-degree angle to the skin. The vessel should be entered within 5 cm (Fig. 2.13).

*Subclavian Vein*

• **Infraclavicular approach** (Fig. 2.14): Multiple needle insertion sites are described: 1 cm inferior to junction of medial and middle third of clavicle or just lateral to the midclavicular line along the inferior surface of the clavicle, or on the inferior surface of the bony protrusion of the clavicle approximately ½ to ⅔ the length of the clavicle (Simon’s tubercle) from the sternoclavicular joint. By sliding the operator’s thumb down the “S” shaped clavicle, the thumb rests at this tubercle and this approximates where needle placement should occur. With all approaches, the needle should be kept parallel to the frontal plane (the back of the patient) while aiming at the suprasternal notch and hugging the undersurface of the clavicle. The vessel should be entered within 4 cm.
**Figure 2.13** Posterior approach to cannulation of the internal jugular vein. Insert the needle along the posterior border of the sternocleidomastoid muscle just above the site where the external jugular vein crosses that border. Alternatively, when one cannot see the external jugular vein, introduce the catheter at the junction of the medial and lower third of the posterior margin of the sternocleidomastoid muscle. The vein should be entered in 5 to 7 cm. See text for discussion.

**Figure 2.14** To locate the subclavian vein using the infraclavicular approach, place the index finger in the sternal notch and the thumb at the point of insertion of the needle, as discussed in the text. After inserting the needle under the clavicle, aim the syringe and needle at the suprasternal notch, which should be at the tip of the index finger, while holding the syringe and needle parallel to the table.
Supraclavicular approach (Fig. 2.15): Skin entry site is more accessible during cardiopulmonary resuscitation and with the patient sitting upright. Indicated when infraclavicular approach cannot be performed, or if experienced as a primary technique. The needle is inserted at a point 1 cm lateral to the lateral border of the clavicular head of the sternocleidomastoid and 1 cm superior to the clavicle. The needle should be aimed at the contralateral nipple, aiming parallel to the table or slightly "upwards", bisecting the angle formed by the clavicle and the sternocleidomastoid. The vein should be entered within approximately 3 cm.

**NOTE**

The bevel of the needle should be oriented caudally, as should the "J" in the guidewire, so that the wire will enter the brachiocephalic vein and the superior vena cava rather than the carotid.

**CAUTION**

One must resist the temptation to have the needle pointing downwards as this could lead to pneumothorax or catastrophic vascular complications.

**Figure 2.15** • In supraclavicular subclavian vein insertion, note the angle at which the syringe is directed to the contralateral nipple is parallel or actually aiming “upwards” from the axis of the table. This is different from the other central venous access approaches. See text for discussion.

**Figure 2.16** • Supraclavicular subclavian with needle aimed at contralateral nipple.
Femoral Vein

- Insert the needle far enough distal (usually about 2 to 4 cm inferior) to the inguinal ligament to allow penetration of the femoral vein to occur at the midpoint between the pubic tubercle and the anterior superior iliac spine and 1 cm medial to the femoral artery pulse (Fig. 2.16). The needle should be aimed cephalad at a 45- to 60-degree angle to the skin.

AFTERCARE
1. Suture or staple the line in place
2. Monitor puncture site for infection
3. Monitor catheter for correct depth. Lines may migrate several centimeters despite suturing.
4. Remove line as soon as it is no longer necessary. Femoral lines should be used for less than 3 days.

PEDiatric CONsiderations
- The femoral vein is the preferred site for emergent central venous access in the infant or child.
- The anterior or central approach to the IJ vein and the infraclavicular approach to the subclavian vein should be performed only by practitioners with significant experience and only on immobilized or sedated children.
- IO access is usually easier and more rapidly achieved.
- Umbilical vessel catheterization can be used to obtain rapid vascular access for the newborn in shock when other methods fail.
  - Umbilical vein catheterization is easier to perform than umbilical artery catheterization and is the procedure of choice (Fig. 2.17).
  - A strict sterile technique must be used.
  - Place the neonate under a warmer in the supine frog leg position.
  - Scrub the umbilicus with a povidone-iodine solution.
  - Tie a piece of umbilical tape around the base of umbilicus.
  - Place a purse-string suture around the umbilicus and about 1 cm above the tape. Leave the suture untied as it will later be used to secure the umbilical catheter (Fig. 2.18).
  - Using a scalpel (no. 10 blade) and forceps, cut the cord transversely across the top of the forceps 1 to 2 cm from the base of the cord.
  - Identify the single large, thin-walled umbilical vein.
  - Prepare an umbilical catheter (5.0 French for full term infant, 3.5 French for a preterm infant).
In emergent situations, insert the catheter 4 to 5 cm into the umbilical vein until there is free flow of blood in the catheter to avoid potential placement of the tip into the portal system. A more permanent catheter can be placed to a depth at the junction of the inferior vena cava and right atrium once the child is stabilized. Tighten the umbilical tape to secure the catheter.

**COMPLICATIONS**

- **Pneumothorax**: more common with subclavian vein cannulation versus IJ vein. Prevent by avoiding multiple attempts and using proper positioning and technique.
- **Air embolism**: occurs more often in the hypovolemic patient. Avoid by occluding the needle hub with a finger. Also, cover wound and track with Vaseline gauze when catheter is removed.
- **Catheter or wire embolism**: avoid by holding wire securely at all times. Never forcefully remove wire through the catheter. If necessary, remove wire and catheter together and recanulate the vessel.
- **Infection**: most common with femoral vein cannulation. Incidence increases with increased duration of line use.
- **Venous thrombosis**: most common with femoral vein and more common with infected lines. Avoid by removing lines as soon as possible.
- **Arrhythmias**: most common with subclavian and IJ vein with intracardiac positioning of the catheter.
- **Chylothorax, hemothorax**: perform IJ and subclavian on the right side to avoid the thoracic duct.
- **Arterial puncture**: compress site for 10 minutes. Monitor for hematoma formation. Assess chest radiograph for hemothorax.

![Figure 2.18 • Securing the umbilical cord stump.](image)
SECTION 2

CHEST TUBE THORACOSTOMY

P10: TUBE THORACOSTOMY
TUBE THORACOSTOMY

INTRODUCTION

Tube thoracostomy involves transthoracic placement of a chest tube into the pleural space. It is placed for evacuation of air, blood, pus, or any other fluid that collects within the pleural space. The most common indications for emergent placement of a chest tube are spontaneous pneumothorax, traumatic pneumothorax or traumatic hemothorax, and iatrogenic complications from invasive procedures.
KEY POINTS

- The primary purpose of emergency tube placement is to restore the mechanical function of the lung that may currently, or in the future, restrict optimal pulmonary function.
- Adhesions of the lung to the chest wall may preclude insertion of a chest tube at a particular site.
- Insertion of a chest tube at the site of a previous thoracostomy carries a danger of puncturing the lung parenchyma with chest tube insertion.
- Tube thoracostomy is not a treatment for large blebs.
- Simple and small nontraumatic pneumothoraces do not need a chest tube.

INDICATIONS

- Tension pneumothorax

CAUTION

In patients with asthma or chronic obstructive pulmonary disease, the lung may be hyperinflated under pressure from auto-PEEP (positive end-expiratory pressure; see previous discussion of needle decompression of tension pneumothorax).

- Hemothorax
- Hemopneumothorax
- Simple pneumothorax greater than 25%
- Hydrothorax
- Chylothorax
- Empyema
- Pleural effusion (symptomatic or unstable vital signs)
- Chest trauma (penetrating) without evidence of a pneumothorax when the patient will be undergoing positive pressure ventilation. Explain the procedure and its necessity if the patient is stable. Make sure the necessary equipment is present to have a smooth procedure.
- Considered for those who are at risk for developing pneumothorax and who will undergo air transport

CONTRAINDICATIONS

- Pulmonary bullae
- Pulmonary, pleural, or thoracic adhesions

- Loculated pleural effusion
- Skin infection over the chest tube insertion site

ANATOMICAL POINTS

POSTEROLATERAL CHEST TUBE
(MOST COMMON CHEST TUBE SITE)

- Identify the fifth intercostal space and the midaxillary line. This can be approximated by using the nipple and moving laterally to the midaxillary line.

CAUTION

The diaphragm rises to the nipple level during normal expiration. Placement of a chest tube below this level risks inadvertent puncture of the diaphragm or abdominal cavity contents.

- The skin incision is made in between the midaxillary and anterior axillary lines over a rib that is below the intercostal level selected for chest tube insertion. This will allow tunneling of the chest tube through the subcutaneous tissue and allow a more indirect and air-sealed tract into the pleural space.

ANTERIOR CHEST TUBE

- Identify the second and third intercostal space in the midclavicular line.
- The skin incision is made over a rib that is below the intercostal level selected for chest tube insertion.

NOTE

This is limited to pneumothoraces only.
EQUIPMENT

- Antiseptic solution
- Drapes and towel clips
- 1% lidocaine with or without epinephrine, 10 to 20 mL
- 25-gauge needle
- 22-gauge needle
- 10-mL syringe
- No. 10 scalpel blade with handle
- Kelly clamps (two)
- Forceps
- Thoracostomy tube:
  - Pneumothorax/hemothorax: 36–40
  - Nontraumatic pneumothorax: 24–32
  - Child: 12–28 (guided by Broselow tape)
  - Infant: 12–18 (guided by Broselow tape)
- Pleurivac system (collection bottle, underwater seal, suction control). Use only high-volume suction, such as wall suction, delivering at least 60 cm of water pressure with a flow of at least 15 to 20 L/min. Low-volume systems, such as Gomco, are not to be used.
- Connecting tubing
- Gauze pads
- Adhesive tape
- 4 X 4-inch pads
- Xeroform gauze dressing
- Antibacterial ointment
- 2, 1, or 0 suture (not 2-0 or 1-0), needle driver, and suture scissors

TECHNIQUE

The described technique is called “open” because of direct penetration of the pleural space by the operator.

NOTE

Trocar-introduced chest tubes are no longer acceptable because of their excessive complication rates from events such as inadvertent plunging into the thorax causing damage to the heart and other important organs.

PREPARATORY STEPS

1. Place patient on cardiac monitor and oxygen; apply pulse oximetry.
2. For resuscitative measures, place two large-bore intravenous lines.

NOTE

This is an extremely painful procedure that requires adequate anesthesia. Patients should ideally receive both procedural sedation as well as local anesthesia to make the procedure as tolerable as possible.

CAUTION

Beware when placing the chest tube that with massive hemoperitoneum, the blood may push the diaphragm as high as the third intercostal space, but commonly into the fifth intercostal space. Insertion here may result in perforation of the liver or spleen.

3. Avoid old scars from a previous site or thoracotomy because underlying adhesions to the lung may have formed in proximity to these old scars.
4. Six important points to ensure a smooth procedure:
   a. The positioning of the patient: If the patient is in extremis with hypotension, then perform the procedure with the patient supine. If the patient is more stable, position the patient at least at a 30-degree angle, head up. In both instances, with a posterolateral approach, the patient will have the upper extremity held above the head, allowing excellent exposure.
   b. Adequate anesthesia: It is difficult to place a thoracostomy tube into a moving patient. Giving adequate anesthesia is the key to a successful and smooth placement.
   c. All instruments should be laid out in the sequence of use: Groping for instruments, suture materials, scalpels, and needles is time-consuming, and with respect to infection control, can be dangerous. Have the needed items placed in sequence of use, and rid the area of the unnecessary clutter of rarely-to-be-used items.
d. **Measure the chest tube against the chest wall prior to placement.** This is to determine how deep the chest tube will need to be inserted. Apply a Kelly clamp to the tip to allow easy guidance and insertion into the chest.

**CAUTION**

Be sure when placing a Kelly clamp on the end of the tube that the metal tip of the instrument does not go past the end of the chest tube. The softer, more pliable chest tube will be safer when leading the insertion into the thorax.

5. Dissect bluntly with the Kelly clamp the top of the rib at the chest tube insertion site (Fig. 4.15). Remain on the upper border of the rib and clear the area with the Kelly clamp with blunt dissection.

**CAUTION**

The neurovascular bundle runs along the inferior margin of the rib. This can cause significant bleeding if inadvertently lacerated. Staying above the rib for this procedure will avoid this complication.

6. With one or two spreads of the intercostal muscles, close the Kelly clamp and use the tip to puncture the pleura in a controlled fashion.
With the tip of the Kelly clamp near the pleural plane, open the clamp and stretch the tissue to slightly larger than tube size.

**CAUTION**

*It requires significant force to penetrate into the pleural space. One must have an extremely tight grip on the Kelly clamp, ideally with fingers of the noninstrument hand acting as a guide to prevent inadvertent “plunging” into the chest cavity.*

7. Insert an index finger into the hole and perform a “finger sweep” (a sweep of the finger in the hole at the chest tube insertion site) with the objective to note any adhesions or diaphragm and to confirm the presence of the intrathoracic space (and not the intraperitoneal space noted by palpable liver or spleen) (Fig. 4.16). Pleural adhesions that cannot be easily separated by the finger should alert the operator that another site of insertion should be attempted. If a tear in the diaphragm is noted, then an operative repair is mandated and the patient should be prepared for the operating room. Chest tube placement should still occur prior to intubation.

**NOTE**

*Always keep a finger in the thoracostomy tube hole until the tube has advanced into the pleural space. This will prevent losing the tract and inadvertent placement of the chest tube in the thoracic wall.*

8. While leaving your finger in the thoracostomy hole, advance the chest tube with the Kelly clamped around the distal end into the chest wall tract and into the chest cavity. It is usually necessary to keep the puncture site open

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**Figure 4.16** • Perform finger thoracotomy before insertion of the thoracostomy tube. (From Feliciano DV. Tube thoracostomy. In: Benumof JL, ed. *Clinical Procedures in Anesthesia and Intensive Care*. Philadelphia: Lippincott; 1992. Fig. 15.3, with permission.)
before advancing the tube. This can be done by inserting the Kelly clamp and spreading it apart. Direct it posteriorly and apically (Fig. 4.17). All the holes in the chest tube should be within the pleural space. For anterior tube thoracostomy: in passing the tube, aim it anteriorly toward the apex of the lung.

**CAUTION**

Always keep your finger in the hole until the thoracostomy tube is in position in the chest cavity, otherwise the tract into the thorax will be lost and placement of the tube may be in an incorrect location.

9. Connect the tube immediately to the Pleurivac or suction apparatus under a water seal of negative 20 cm of H₂O to evacuate the pleural cavity and re-expand the lung.

10. Once proper functioning of the tube setup is assessed, remove any existing needles or catheters from needle decompression of a tension pneumothorax to prevent laceration of the lung.

11. Secure the tube with sutures. Bring the sutures through both sides of the wound edge near the tube and tie. Wrap the two remaining ends multiple times around the tube, with each end wrapped in the opposite direction of the other. After multiple layers of the suture are wrapped, bunch them up at the entrance to the wound and tie tightly. Make a kink in the tube so that it will not slide in or out of the chest wall. Sutures superior and inferior to the tube along the wound will create a seal with the subcutaneous tissue. (Purse-string sutures may be used, but may cause wound ischemia around the tube and possible necrosis at the entrance site if tied too tightly.)

12. Close the remainder of the incision with simple interrupted sutures.

### AFTERCARE

1. Apply antibacterial ointment to the incision site followed by an occlusive dressing of vaseline gauze over the wound to prevent inadvertent loss of seal. After this, apply two sterile 4 × 4-inch dressings with a slit cut halfway across the center of the dressing, and advance the pads around the chest tube via the slit so that two dressings encircle the chest tube.

2. Secure the dressing in place with adhesive tape followed by an Elastoplast dressing. It is our preference to attach adhesive tape between the dressing and the chest tube, and spiral additional strips of 1-inch adhesive tape around the chest tube before application of the Elastoplast dressing to provide additional security against pulling out the tube.

3. Tape the area with the tube enveloped in the tape for a few centimeters to prevent excessive movement at the skin/tube juncture, thus decreasing the pain experienced by the patient.

4. Listen for bilateral breath sounds.

5. Obtain chest radiograph immediately after the tube placement to make sure there is lung re-expansion and proper positioning of the chest tube.

6. Check for leaks in the system.

7. Leaks are indicated by persistent bubbling or failure to reexpand the lung. When a leak
is found, this indicates one of the following causes:

• Tubing connection is not tight: make sure all connections are tight and there is no hole in the tubing.
• One of the holes in the chest tube is not in the chest itself but in the subcutaneous tissue, and thus air is leaking out of the chest tube.
• Air is continuing to leak through a bronchiole with a bronchopleural fistula formed. If this continues, suspect a ruptured bronchus. When an air leak is massive and neither (a) nor (b) is the cause, then a rupture of the mainstem bronchus or other larger bronchi should be suspected. Occasionally a small bronchopleural fistula may be “overpowered” and reduced by the insertion of two or three chest tubes.
• Rupture of the esophagus, although rare, is another possible cause of continuing air leak in the chest tube. With a ruptured esophagus, air dissects into the mediastinum and pleural spaces and is drained by the chest tube, causing a persistent air leak.

### PEDiatric CONSIDERATIONS

• Mediastinum of children is more mobile
• Large pneumothoraces or hemothoraces can cause dramatic mediastinal shift resulting in more respiratory or vascular compromise than adults
• Children tend to develop hypoxemia faster secondary to higher metabolic demands and decreased pulmonary function residual capacity
• Because of the decreased space between the ribs in the pediatric population, the finger sweep may be impossible, so extreme caution should be undertaken while placing the chest tube in the thorax. The operator should use the “feel” of the tube when placing to make sure that no resistance is felt during introduction. Guidelines for pediatric chest tube size are listed in Table 4.1.

### COMPLICATIONS

• Re-expansion pulmonary edema
• Injury of the lung

<table>
<thead>
<tr>
<th>TABLE 4.1. Guide for Pediatric Chest Tube Size</th>
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<tbody>
<tr>
<td>Age (weight)</td>
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<tr>
<td>-----------------</td>
</tr>
<tr>
<td>Neonate (≤5 kg)</td>
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<tr>
<td>0–1 year (5–10 kg)</td>
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<tr>
<td>1–2 years (10–15 kg)</td>
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<td>2–5 years (15–20 kg)</td>
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<td>5–10 years (20–30 kg)</td>
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<tr>
<td>&gt;10 years (30–50 kg)</td>
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<td>Adult (&gt;50 kg)</td>
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• Bleeding from the chest wall
• Continuing air leak
• Occlusion of the chest tube
• Persistent pneumothorax
• Subcutaneous emphysema
• Lung puncture with resultant hemothorax
• Diaphragmatic laceration with intraperitoneal placement
• Cardiac dysrhythmias from tube placement against the heart
• Extrapleural positioning of the tube
• Infection
• Erosion of the tip into extrapleural structures
• Tension pneumothorax after clamping the tube, which should never be done; just leave connected to the underwater seal
• Loss of tidal volume while on high suction because of a significant pulmonary air leak
SECTION 3

CRICOTHYROTOMY
DEMONSTRATION OF BOTH
OPEN AND CLOSE TECHNIQUE

P15: OPEN & NEEDLE CRICOTHYROTOMY
INTRODUCTION

The emergency physician has many tools in his or her armamentarium for the “cannot intubate, cannot ventilate” patient. However, when all noninvasive methods are not possible the surgical airway is the best approach. Surgical airways compose up to 4% of all airways and are one of the skills that will literally save someone’s life if performed properly. For emergent surgical airway access, cricothyrotomy is the preferred procedure by most physicians.

KEY POINTS

- This procedure is also referred to as cricothyroidotomy, cricothyrotomy, or laryngotomy.
- Cricothyrotomy has a 5 fold lower complication rate relative to tracheostomy.

INDICATIONS

- Inability to intubate and/or ventilate using noninvasive methods in a hypoxic patient.

CONTRAINDICATIONS

- The only absolute contraindication is that the patient can be intubated by less invasive methods or that the patients has a partial tracheal transection for which performance of cricothyrotomy will cause it to extend and become a complete transection.
- The following are relative contraindications:
  - Laryngeal fracture or trauma
  - Cricoid cartilage injury
  - Distal tracheal obstruction
  - Neonate, infant, or small child
**ANATOMICAL POINTS**

- The cricothyroid membrane is located in the midline of the anterior neck bordered by
  - Thyroid cartilage or “Adam’s apple,” superiorly
  - Cricoid cartilage, inferiorly
- The esophagus lies immediately posterior to the larynx and trachea.
- For the right-handed operator, stand on the patient’s right side and, with the palm of the left hand placed against the chin, use the thumb and middle finger to palpate the hyoid bone (Fig. 1.32). Left-handed operators, simply do the reverse.
- With the index finger, palpate the thyrohyoid membrane and then the thyroid cartilage.
- Remove the middle finger and thumb to a position on either side of the thyroid cartilage to stabilize this structure (Fig. 1.33) while the index finger advances distally toward the cricoid cartilage until an indentation is felt between the cricoid and thyroid cartilages (Fig. 1.34). This indentation is the cricothyroid membrane.

**EQUIPMENT**

- Scalpel with no. 11 blade
- Trousseau dilator or curved hemostat
- Cuffed ETT 1 size less than standard orotracheal intubation (usually size 6 ETT can be used for most adult patients) or one may use a three-part plastic tracheostomy tube (Silex or Portex tracheostomy tubes)
- Outer cannula with neck plate to secure the tube
- Inner cannula with adaptor to connect to bag-valve apparatus
- Central obturator for ease of insertion
- Tracheal hook
- Chlorhexidine or povidone iodine

**Figure 1.32**  
Grasp the thyroid cartilage with the thumb and long finger, and use the index finger to walk down the midline, locating the cricothyroid membrane. See text for discussion.

**Figure 1.33**  
The larynx stabilized between the left thumb and middle finger. Insert the tip of the index finger over the cricothyroid membrane. To puncture the membrane, direct a no. 11 scalpel and blade along the nail of the index finger and through the membrane in one step.

**Figure 1.34**  
Hold the larynx as shown, with the index finger placed over the cricothyroid membrane.
- 1 dozen 4 x 4-inch gauze pads
- Scissors
- 10-mL syringe
- Tracheal suction catheter
- Suture or tying material
- Bag-valve apparatus
- Lidocaine 1% or 2% with epinephrine in a syringe with 21- to 25-gauge needle attached
- 18-gauge needle attached to 10-mL syringe filled with 6 mL of water
- Sterile towel or drape

**TECHNIQUE**

**PREPARATORY STEPS**
1. Inflate the tracheostomy or ETT cuff with 10 mL of air to check for leaks
2. Apply preparation solution to the anterior aspect of the patient's neck
3. The operator must have a completely sterile gown, mask with facial shield, hair shield, and appropriately sized sterile gloves
4. Time permitting, drape the patient's neck with sterile towel or drape, leaving the length of the trachea exposed
5. Locate the patient's cricothyroid membrane. A methodical approach will be detailed in the "Techniques" section.
6. In the conscious patient, infiltrate the area over the cricothyroid membrane using lidocaine with epinephrine.

**PROCEDURAL STEPS**
1. Right-handed operators should stand to the patient's right side and left-handed operators vice versa.
2. With the palm of the nondominant hand, push superiorly on the symphysis of the jaw to extend the atlanto-occipital joint which open exposure of the neck Figure 1.32.
3. With the nondominant hand, make a “pincher grasp” with the thumb and long fingers to stabilize the tracheal cartilage. The operator should be able to grasp the entire laryngeal apparatus and stabilize it (Fig. 1.33).
4. Using the index finger to slide down inferiorly, identify the thyroid cartilage, cricothyroid membrane, cricoid cartilage, and tracheal rings. Then slide back up again, reidentifying these structures. Finally, slide back down past the thyroid cartilage to identify the cricothyroid membrane and have the index finger remain in this area (Fig. 1.34).

**NOTE**

**Horizontal Approach (Preferred)**

1. Identify the cricothyroid membrane with careful palpation by the index finger of the nondominant hand.
2. Leave the tip of the finger directly on the membrane (Fig. 1.33)
3. Use a no. 11 blade and slide horizontally along the index finger into the cricothyroid membrane at the midline (Figs. 1.35 and 1.36).

**CAUTION**

The incision should be no greater than 3 cm, which is the size of the cricothyroid membrane. Wider incision could lead to inadvertent major vessel laceration and catastrophic bleeding.
Alternative Vertical Approach

If a vertical approach is utilized please use the following guide:

1. Place scalpel in the dominant hand.
2. Make a vertical skin incision in the midline of the anterior neck from the thyroid cartilage to the cricoid cartilage.
3. Identify the cricothyroid membrane. If there is any difficulty visualizing, the following technique may be attempted:
   a. Use an 18-gauge needle attached to a 10-mL water-filled syringe and enter the trachea at the cricothyroid membrane. If there is any resistance to the needle you are probably in an incorrect place. Reposition and reattempt.
   b. Aspirate air, confirmed by bubbles in the syringe, to establish endotracheal entry.
   c. Disconnect the syringe, leaving the needle in place to guide the remainder of the procedure.

CAUTION

Failure to leave the blade or needle in the cricothyroid membrane will lead to loss of integrity of the tract and inability to place the subsequent airway. This point cannot be emphasized strongly enough.

5. Whether or not a horizontal or vertical incision was used, once the cricothyroid membrane has been identified, the following steps can be followed: Make a horizontal stab incision less than 1 cm deep and parallel to the axis through the cricothyroid membrane with the blade (Fig. 1.37) and extend the opening laterally.
6. With a cutting motion, cut away from the midline about 1 cm, then turn the blade 180 degrees with the cutting edge away from the still-applied index finger and cut across the midline about 1 cm to the other side (Fig. 1.37).
7. If a needle had been used as a guide, remove it now.

CAUTION

Airway pressure differentiation will cause a “whoosh” of air and blood to be exuded from the incision. The operator must have full-body substance precautions to avoid exposure.

8. Insert a tracheal hook parallel to the incision into the membrane and, once in the trachea, turn the hook so the handle is superior and
then allow it to seed on the inferior margin of the thyroid cartilage (Fig. 1.38).

9. Pull with the nondominant hand superiorly and retract the larynx upwards, which will allow opening of the incised cricothyroid membrane (see Fig. 1.45).

10. You may now remove the scalpel blade from the trachea.

11. Insert the tips of the Trousseau dilator or a curved hemostat into the incision with the dominant hand and open the membrane vertically and horizontally with firm opening of the instrument tips.

12. Insert the ETT into the opening with the dominant hand.

**Figure 1.37** - After inserting the blade (A), carry the incision laterally (B), and then rotate the blade 180 degrees with the sharp edge interiorly, and then continue the incision in the opposite direction (C). Do not remove the no. 11 blade until a tracheal hook has been inserted through the incision to grasp the thyroid cartilage (D). This is a critical point, in that if the no. 11 blade is removed before this, one may lose the tract created into the trachea and a false passage may be found when attempting to put in the tracheal hook.

**NOTE**

Once the tracheal hook is in place, the airway has been accessed and stabilized. Never let go of the tracheal hook until the ETT/shiley tube has been confirmed as correctly placed. Premature removal will lead to loss of the tract and subsequent failure of definitive airway placement.

**Figure 1.38** - The tracheal hook stabilizes the airway and prevents mobility while the trachecostomy tube is being inserted. See text for discussion.

*Usually a 6.0-mm tube suffices in an adult.*
13. Insert the ETT to a depth of 2 to 3 cm.
14. Remove the tracheal hook after inserting the tube only after verification of correct tube placement (Figure 1.38).
15. If using a shiley tube, hold the cannula in place with the nondominant hand, remove the obturator, and inflate the cuff with 10 ml of air using a syringe.
   a. If using an ETT, inflate the cuff with 10 mL of air using a syringe.
   b. Cut the ETT to the appropriate size with scissors
16. Attach the bag-valve adaptor to the tube.
17. Ventilate the patient with a bag-valve apparatus (Figs. 1.39 and 1.40).
18. Secure the tube with suture or ties.
   c. Do not secure the tube so tightly around the neck as to cause vessel compression.

**AFTERCARE**

1. Chest radiography to confirm placement of the tracheostomy tube
2. Initiate mechanical ventilation as indicated
3. Emergent tracheostomy tube may be used for up to 72 hours
4. Obtain surgical or otolaryngology consults for definitive tracheostomy, if needed

**PEDIATRIC CONSIDERATIONS**

- There is considerable variation in the literature regarding the minimum age requirement for surgical cricothyrotomy; 5 years, 10 years, and 12 years have been cited by various texts.
- Normal excess subcutaneous adipose, along with a hyoid and cricoid cartilage that are more prominent than the thyroid cartilage in infants, makes identification of the normal anatomical landmarks difficult.
- Because of the relatively small anatomy of infants and small children, there is potential for difficulty passing even the smallest ETT through the cricothyroid membrane, with potentially higher rates of failure and complications.
- Percutaneous needle cricothyrotomy or tracheostomy is the preferred procedure in infants and small children.
- The procedure for older children is the same as that outlined for adults.

**COMPLICATIONS**

- Improper identification of the cricothyroid membrane
- Posterior tracheal wall injury
- Esophageal perforation
- Esophageal intubation
- Subcutaneous intubation
- Subcutaneous emphysema
- Bleeding or hemorrhage

**Figure 1.39** Patient with shotgun blast to the mouth and face, with anatomy distorted, making a cricothyroidotomy the best option for securing an airway. (Courtesy of Robert Simon, MD.)

**Figure 1.40** Cricothyroidotomy in place using the technique described in the text. (Courtesy of Robert Simon, MD.)
SECTION 4

PERICARDIOCENTESIS

P6: ULTRASOUND-GUIDED ECHOCARDIOGRAPHY/PERICARDIOCENTESIS
PERICARDIOCENTESIS

For ultrasound-guided pericardiocentesis see Chapter, the ultrasound chapter, pages 486–489.

KEY POINTS

- Removal of as little as 30 mL of fluid may be sufficient to relieve pericardial tamponade causing pulseless electrical activity (PEA) and restore spontaneous circulation
- Bedside ultrasonography facilitates optimal aspiration insertion while minimizing complications
- Anticipate the need for pericardial window if unable to aspirate or as definitive therapy after successful aspirate
- Clotted blood aspirate indicates ventricular aspirate; nonclotting indicates aspirate of pericardial origin

INDICATIONS

- Diagnostic procedure during PEA for a cardiac arrest
- Therapeutic procedure during PEA for cardiac arrest
- Temporizing procedure for the decompensating patient with pericardial tamponade awaiting emergent pericardial window

CONTRAINDICATIONS

- No contraindications exist if the patient is in PEA or extremis with tamponade, as the procedure may be life-saving
- Coagulopathy

ANATOMICAL POINTS

- The pericardial sac is located posterior to the sternum and extends from the second to sixth rib
- The pericardium itself consists of two layers; the outer layer, called the fibrous pericardium, and the inner, double-layered sac called the serous pericardium
- The pericardium extends 1.5 cm to the right of the sternum and 5.0 to 7.5 cm to the left of the sternum in the medial plane of the fifth intercostal space
- The fibrous pericardium is tethered to the diaphragm

NOTE

Because of the pericardial insertion into the diaphragm, its location is influenced by movements of both the heart and the diaphragm.

EQUIPMENT

- Iodinated preparation solution
- Defibrillator
- Continuous cardiac monitoring
- Local anesthetic (1% lidocaine [Xylocaine], 10 mL)
- 10-mL syringe and 60-mL syringe with Luer lock
- Three-way stopcock
- 9- to 15-cm, 18-gauge spinal needle
- Sterile double-ended alligator clip (sterile)
- Sterile field with towels and clips
- Sterile 4 × 4-inch sponges
- 1-inch adhesive tape
- Electrocardiogram (ECG) machine (well grounded)
- Ultrasound machine
Figure 4.1 • Path of pericardiocentesis needle. Sagittal view of the sub-costal margin in the region of the pericardial needle entry point, indicating that the introduction of the needle well below the left costal margin permits further insertion of the needle at the appropriate angle to the skin. (From Feliciano DV. Tube thoracostomy. In: Benumof JL, ed. Clinical Procedures in Anesthesia and Intensive Care. Philadelphia: Lippincott; 1992. Fig. 27-4, with permission.)
TECHNIQUE

PREPARATORY STEPS
1. Place the patient in the supine position.
2. The patient should be placed on cardiac monitor with resuscitation cart and defibrillator at bedside.

NOTE

Intravenous crystalloid should be infused to optimize the preload to maintain cardiac output, especially in the hypotensive presentation of pericardial effusion.

3. The xiphoid process and left costal margin should be palpated to identify an insertion site 1 cm below and 1 cm to the left of midline for subxyphoid insertion (Fig. 4.1)
4. Patient’s epigastric and left chest area should be prepared and draped in sterile fashion
5. If using ultrasound to facilitate insertion, obtain subxiphoid and parasternal views to find area of maximal pericardial fluid (see pages 486–489, ultrasound section)
6. Anesthetize predetermined area of insertion with 1% lidocaine without epinephrine

PROCEDURAL STEPS
1. Attach the syringe to the stopcock and then connect this assembly to the needle.
2. Attach the alligator clip to the base of the needle and the other end to lead V1 of a running ECG machine.

NOTE

Although ideally attaching the alligator clip to the base of the needle should occur, patients in cardiac arrest or in extremis when pericardiocentesis could be life-saving should not have the procedure delayed by such preparation. Ideally, ultrasonic identification of needle placement is much more accurate and safer than the alligator clip. Identify your area of insertion anatomically or more ideally by echocardiographic guidance (see pages 486–489, ultrasound section).

3. Using the subxiphoid approach, insert the needle 1 cm inferior to the costal margin and 1 cm left of midline at a 30- to 45-degree angle aiming for the left scapular tip (Figs. 4.2 and 4.3). If using ultrasound, insert at subxiphoid point of maximal effusion.
4. Using the parasternal approach, insert the needle in the left fifth intercostal space just above the sixth rib and within 1 cm of the sternal border. If using ultrasound, look for intercostal site of maximal effusion (see pages 486–489, ultrasound section).
5. Advance needle with suction applied until aspiration of fluid or identification of a current of injury pattern (sudden ST-segment elevation via the lead on the alligator clip) is seen on the monitor, which is indicative of epicardial injury.
6. If dysrhythmia ensues, withdraw needle with constant aspiration until dysrhythmia stops.

CAUTION

If unable to aspirate, remove needle to the skin and redirect. Do not move inserted needle laterally as this can cause direct cardiac injury or injury to the coronary arteries due to shearing forces with the sharp, beveled edge.

7. If anticipating a large amount of fluid removal, insert a catheter to continue drainage. After aspiration from pericardium, insert a guidewire and remove needle. The catheter is then inserted via the Seldinger technique.

NOTE

The needle should never be used to completely drain pericardial fluid as this can cause cardiac injury from the swinging myocardium of the normal cardiac cycle.

NOTE

To verify origin of bloody aspirate, consider a stat venous blood gas. Ventricular blood will have same hematocrit as peripheral blood; higher $O_2$ and lower $PCO_2$ than pericardial blood.
AFTERCARE
1. After needle is withdrawn, apply sterile dressing and adhesive tape to site.
2. Order chest radiograph to exclude pneumothorax or hemothorax.
3. If catheter is inserted, secure catheter tip to chest wall with 4.0 silk sutures and apply dressing to area.
4. Cardiothoracic surgery personnel should be consulted for transfer of care.

PEDIATRIC CONSIDERATIONS
- Echocardiographically guided pericardiocentesis has proven to be superior to blind insertion in children

COMPLICATIONS
- Laceration of the heart, coronary arteries, or internal mammary artery
  - Left anterior descending artery is especially vulnerable because of its anterior location on the myocardium. Always watch cardiac monitor for any current of injury pattern with constant aspiration during insertion. Most punctures of myocardium have no morbidity when the needle is withdrawn.
- Pneumothorax, hemothorax, hydrothorax
  - Postprocedure radiograph is mandatory. Treat with chest tube versus observation depending on the size of the pneumothorax.
- Liver laceration
- Diaphragmatic tear
- Bowel puncture
- Hemopericardium tamponade
- Dysrhythmia

Figure 4.2 • Sagittal view of the thorax indicating the orientation of the pericardial needle, introduced via the subxiphoid approach, relative to the surface of the pericardium. Note that the needle enters the skin to the left of the xiphoid (see Fig. 4.3), and that the needle enters the pericardial space at right angles to the pericardium when inserted with this approach. (From Feliciano DV. Tube thoracostomy. In: Benumof JL, ed. Clinical Procedures in Anesthesia and Intensive Care. Philadelphia: Lippincott; 1992. Fig. 27-2, with permission.)

Most pediatric pericardial effusions can be definitively treated with needle insertion and catheter drainage.
Asystole, atrial fibrillation, ventricular fibrillation, and vasovagal arrest have all been reported. Withdraw needle if arrhythmia occurs. Continuous cardiac monitoring is mandatory.

Figure 4.3 • Anterior view of the xiphoid indicating the optimal entry point for the pericardiocentesis needle. Note that the optimal entry point is approximately 1 cm below the costal margin and 1 cm to the left of the midline. (From Feliciano DV. Tube thoracostomy. In: Benuoof JL, ed. Clinical Procedures in Anesthesia and Intensive Care. Philadelphia: Lippincott; 1992. Fig. 27-3, with permission.)
SECTION 5

ARTHROCENTESIS

P11: ARTHROCENTESIS – ANATOMICAL LANDMARK AND ULTRASOUND
INTRODUCTION

Joint aspiration is done either for therapy of an acutely swollen joint or for diagnostic purposes. Relief of joint pain is achieved rapidly, whether the joint aspirate is due to a traumatic, gouty, infectious, or rheumatoid arthritis. The only time one should attempt to aspirate a joint that does not contain an effusion is when there is a suspicion of septic arthritis.

KEY POINTS

- Perform on the extensor surface of the joint
- Place in 20 to 30 degrees of flexion to enlarge the joint space
- In small joints, traction is important to open the joint space
- Minimize damage to the articular cartilage from the needle because hyaline cartilage regenerates poorly

INDICATIONS

- Diagnosis. Table 9.1 indicates the findings in different joint effusions. Obtain a leukocyte count, crystals, a Gram stain/culture, and a synovial fluid glucose and protein analysis.
- Therapeutic. Relief of joint pain varies directly with the rate with which the fluid has accumulated.

CONTRAINDICATIONS

- Overlying infection
- Lack of informed consent
- Uncooperative patient

ANATOMICAL POINTS

- Techniques of aspiration based on absolute measurements are unreliable because there is a striking variation between individuals.
- The size and the position of each anatomical structure are used to aid in the localization of the injection site.
- Bony prominences are more readily palpable, constant, and closely related to each articulation.
- If the landmarks are not easily palpable when the joint is placed in the best position for aspiration, these landmarks may become more readily palpable by changing the position of the joint and subsequently moving it to a more optimal position for aspiration.

EQUIPMENT

- Povidone-iodine solution (Betadine)
- Anesthetic preparation
- 1% lidocaine with epinephrine
- Assortment of 1.5-inch needles: 18, 22, and 23 gauge
- Syringes (3, 10, and 20 mL)
- Sterile gloves and towels
- 4 × 4-inch gauze
- Sample tubes for specimens

TECHNIQUE

The general technique for arthrocentesis is described in the next section, followed by specific procedural steps for each joint.

PREPARATORY STEPS

1. Scrub the site of aspiration with povidone-iodine solution for 5-minutes.
2. Drape the area with sterile towels, and perform the procedure under sterile conditions.

3. When performing arthrocentesis over the sites indicated for the various joints, avoid vessels and nerves.

4. In some patients with a markedly distended joint capsule, there is no need to raise a wheal with lidocaine (Xylocaine), and only a brief spray with ethyl chloride solution gives sufficient anesthesia.

PROCEDURAL STEPS

1. When the synovial lining is entered, the folds of synovium or cellular debris may act as a flap valve on the end of the needle, preventing easy withdrawal of fluid.

2. When this is suspected, move the needle about gently and reinject a little fluid already withdrawn to push the tissue or clot away from the tip of the needle.

3. When aspiration must be performed in joints with little fluid (e.g., for the detection of septic arthritis), aspiration may be facilitated by wrapping the joint, except for the site of aspiration, with an elastic bandage to compress the free fluid into that portion of the sac being punctured.

4. In general, always aspirate all readily accessible fluid at the time of aspiration.

AFTERCARE

1. Gauze or Bandage
2. Instruct the patient to return if symptoms worsen

COMPLICATIONS

- Infection. If the site of aspiration is properly prepared, the incidence of infection is reduced to 1:15,000
- Articular cartilage injury

INTERPHALANGEAL JOINT ARTHROCENTESIS

PROCEDURAL STEPS

1. Distract and flex the joint by approximately 20 degrees
2. Insert the needle tip at a point just lateral to the skin crease line on the dorsum of the finger (Fig. 9.1). This line corresponds to the location of the joint.

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Color</th>
<th>Clarity</th>
<th>Viscosity</th>
<th>Leukocytes/mL</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Clear</td>
<td>Transparent</td>
<td>High</td>
<td>200</td>
<td>3.5</td>
</tr>
<tr>
<td>Noninflammatory</td>
<td>Yellow</td>
<td>Transparent</td>
<td>High</td>
<td>200–2,000</td>
<td>3.5</td>
</tr>
<tr>
<td>Degenerative joint disease, osteochondritis dessicans</td>
<td>Yellow–green</td>
<td>Opaque</td>
<td>Low</td>
<td>2,000–50,000</td>
<td>3.5</td>
</tr>
<tr>
<td>Inflammatory</td>
<td>Yellow–green</td>
<td>Opaque</td>
<td>Low</td>
<td>50,000–200,000</td>
<td>3.5</td>
</tr>
<tr>
<td>Septic</td>
<td>Yellow–green</td>
<td>Opaque</td>
<td>Low</td>
<td>50,000–200,000</td>
<td>3.5</td>
</tr>
</tbody>
</table>

*Synovial fluid complement is high in Reiter syndrome but is low in other acute inflammatory arthritides.
3. “Lift up” the extensor tendon, by trying to insert the needle tip under it.

NOTE
The undersurface of the tendon is attached to the dorsal surface of the joint capsule. Placing the needle just under the tendon means that it must be in the joint space.

METACARPOPHALANGEAL JOINT ARTHROCENTESIS

PROCEDURAL STEPS
1. Distract and flex the joint by approximately 20 degrees (Fig. 9.2).
2. Locate the head of the metacarpal and insert the needle dorsally and adjacent to the extensor tendon in the fossa created by distraction.

NOTE
As in arthrocentesis of the interphalangeal (IP) joint, being under the tendon means that the needle is in the joint space.

3. To perform arthrocentesis of the thumb metacarpophalangeal (MCP) joint, place the needle on the radial side of the joint. Insert the needle just radial to the extensor pollicis longus tendon.

THUMB CARPOMETACARPAL JOINT ARTHROCENTESIS

PROCEDURAL STEPS
1. This small joint is a common site of arthritides that may require aspiration for diagnostic purposes (Fig. 9.3).
2. Apply traction of the thumb and flex it and the wrist with the hand held in slight ulnar deviation to aid in increasing the target area.
3. Insert the needle at the dorsal aspect over the radial side of the hand.

RADIOCARPAL (WRIST) JOINT ARTHROCENTESIS

PROCEDURAL STEPS
1. The site for needle insertion is between the ulnar border of the anatomic snuffbox (extensor pollicis longus tendon) and the common extensor tendons (Fig. 9.4).
2. Palpate Lister tubercle on the dorsal aspect of the radius with the wrist relaxed and flexed. Just ulnar and distal to Lister tubercle is a slight depression that marks the site for arthrocentesis.
3. Flex and provide slight ulnar deviation to open the joint cavity dorsally and stretch the capsule and the extensor retinaculum. Additional traction on the hand may further increase the radiocarpal joint space.
4. Insert a needle just distal to the rim of the radius in the depression.
5. Direct the needle between the radius and the lunate (the bone that lies at the floor of the depression).

**INTERCARPAL JOINT ARTHROCENTESIS**

**INDICATIONS**
Intercarpal arthrocentesis is rarely indicated. However, in patients with possible gout, sepsis, or unknown cause of intercarpal joint effusion, this procedure may provide the fluid necessary to make a diagnosis. On examination, the dorsum of the hand is swollen distal to the wrist joint. In fact, the lunate fossa is palpable. The examiner will note swelling between the wrist joint and the middle of the hand metacarpals on the dorsal surface.

**PROCEDURAL STEPS**

- Palpate Lister tubercle with the patient clenching the fist.
- Place the examining finger just distal and ulnar to Lister tubercle. As the patient flexes the wrist, the dorsum of the lunate bone becomes palpable.
- Distal to the lunate bone is a depression between the lunate and the capitate, which is the optimal site for aspiration (Fig. 9.4).
- Thus, radiocarpal arthrocentesis is performed by placing the needle in the depression proximal to the lunate and intercarpal arthrocentesis...
is performed by placing the needle distal to the lunate with the wrist more acutely flexed.

**JOINT ARTHROCEN TISIS**

**PROCEDURAL STEPS**

1. Place the patient in either a sitting or supine position; however, the procedure is more easily performed with the patient sitting (Fig. 9.6).
2. Palpate the bony landmarks: the coracoid process and the head of the humerus, which is palpable just medial to the lesser tuberosity.
3. Abduct the arm 15 to 20 degrees.
4. Obtain further opening of the joint space by having an assistant apply gentle downward traction on the arm.
5. Insert the needle just medial to the head of the humerus between it and the tip of the coracoid process.
6. The needle passes through the coracobrachialis and subscapularis before entering the joint.

**NOTE**

Three bony landmarks are readily palpable on the lateral side of this joint: the lateral epicondyle, the head of the radius, and the tip of the olecranon process.

1. Extend the elbow to approximately 135 degrees with the forearm held midway between pronation and supination (Fig. 9.5).
2. Insert the needle in the middle of a triangle formed by connecting these three bony landmark.
3. Enter the joint at a 90-degree angle to the humerus, traversing the skin and anconeus muscle.

**SHOULDER JOINT ARTHROCENTISIS: ANTERIOR APPROACH**

**PROCEDURAL STEPS**

1. Place the patient in either a sitting or supine position; however, the procedure is more easily performed with the patient sitting (Fig. 9.6).
2. Palpate the bony landmarks: the coracoid process and the head of the humerus, which is palpable just medial to the lesser tuberosity.
3. Abduct the arm 15 to 20 degrees.
4. Obtain further opening of the joint space by having an assistant apply gentle downward traction on the arm.
5. Insert the needle just medial to the head of the humerus between it and the tip of the coracoid process.
6. The needle passes through the coracobrachialis and subscapularis before entering the joint.

![Figure 9.5](image1) Elbow joint arthrocentesis. See text for discussion.

![Figure 9.6](image2) The anterior approach for shoulder arthrocentesis. See text for discussion.
SHOULDER JOINT ARTHROCENTESIS: POSTERIOR APPROACH

PROCEDURAL STEPS

1. Position the arm in 90 degrees of abduction.
2. Have the patient push against the examiner’s hand, which is held behind the arm. This brings out an “indentation” produced by the deltoid and infraspinatus muscles.
3. Insert the needle in this indentation while the shoulder is internally rotated to separate the humeral head from the glenoid fossa (Fig. 9.7).
4. The needle passes through the posterior fibers of the deltoid muscle before entering the joint.

NOTE

Posterior approach is preferred over the anterior approach.

STERNOCLAVICULAR JOINT ARTHROCENTESIS

PROCEDURAL STEPS

1. Place the patient in a supine position with the arm abducted to 90 degrees and dropped backward over the edge of the table. This brings the clavicle forward and permits insertion of the needle from a medial position and avoids the articular disc.

NOTE

• This joint is the most common site for septic arthritis and osteoarthritis in patients who abuse intravenous drugs.
• It is a rather difficult joint to aspirate or inject unless it is distended.
• The sternoclavicular joint is difficult to enter from directly anterior because of the fibrocartilaginous articular disc that lies within the joint.

Figure 9.7 • The posterior approach to shoulder arthrocentesis. The needle is placed in the "fossa" or indentation between the inferior border of the infraspinatus and deltoid.
2. Insert the needle into the joint just adjacent to the suprasternal notch, aiming the needle posteriorly (Fig. 9.8).
3. The joint is entered after a few millimeters.

HIP JOINT ARTHROCENTESIS

PROCEDURAL STEPS

- The hip joint is the most difficult to aspirate because of the large amount of soft tissue around this joint. In the best of hands, a failure rate of more than 50% is reported.
- The anterior approach is the most frequently used; however, the authors believe this procedure is best done under fluoroscopy. The incidence of infection is higher than in all the other types of arthrocentesis combined.
- The head of the femur lies halfway between the anterior superior iliac spine and the lateral tubercle of the pubis and approximately 1 to 1.5 inches distal to the inguinal ligament.

1. Position the patient so that the hip is in maximal extension and internally rotated. This brings the greater trochanter out from under the gluteus maximus muscle and positions the neck of the femur in a plane parallel to the table.

KNEE JOINT ARTHROCENTESIS: PARAPATELLAR APPROACH

PROCEDURAL STEPS

- The knee contains the largest synovial cavity in the body. It is the most commonly aspirated joint in the emergency department.
- Because of the size of this joint and its relatively superficial nature, it is the easiest joint to aspirate, particularly when it is tightly distended with an effusion.
• Suprapatellar, infrapatellar, and parapatellar approaches have been advocated.
• The suprapatellar approach is a good method if large volumes of fluid are present in the suprapatellar pouch; however, this approach has the disadvantage that the suprapatellar bursa is not always continuous with the joint cavity. This problem is especially likely in patients with multilocular joint effusions (e.g., chronic arthritis). Also, if a small effusion or no effusion is present, the bursa may be little more than a potential space.

1. For the parapatellar approach, place the patient in a supine position on the examining table with the knee fully extended (Fig. 9.10).
2. Prepare the knee adequately with an antiseptic agent.
3. Insert the needle at the medial border of the patella 1 to 2 cm proximal to the inferior pole and between the inferior surface of the patella and the patellar groove of the femur.

**NOTE**
The advantages of this approach are that synovial membrane folds are seldom encountered, while the disadvantage is that small effusions are difficult to aspirate and cartilaginous damage can occur.

**KNEE JOINT ARTHROCENTESIS: INFRAPATELLAR APPROACH**

This is the preferred approach by the authors.

**PROCEDURAL STEPS**

1. Use an 18- or 20-gauge needle on a 10-mL syringe, except when performing the procedure for purposes of aspirating a hemarthrosis, in which case, use a 16- to 18-gauge needle on a 20-mL syringe.
2. Position the patella in 90 degrees of flexion (the patient can be sitting with the legs hanging over the edge of the table). Flexion greatly enlarges the vertical dimensions of the joint and stretches the patellar ligament, permitting easy entrance into the joint space.
3. Insert the needle immediately below the apex of the inferior pole of the patella on either side of the patellar ligament and aim the needle centrally toward the the intercondylar fossa (Fig. 9.11).
4. Direct the needle perpendicular to the patellar tendon.

**NOTE**

Most authors prefer the anteromedial approach because there is slightly more space for insertion of the needle.

**ANKLE JOINT ARTHROCENTESIS: ANTEROMEDIAL APPROACH**

**PROCEDURAL STEPS**

1. Place the patient’s foot on the examining table with the ankle in a neutral position.
2. Prepare the ankle adequately with an antiseptic agent.
3. Insert the needle immediately below the apex of the ankle mortise on either side of the ankle joint (Fig. 9.12).
4. Direct the needle anteriorly toward the anterior tibial tendon.
The infrapatellar approach for knee arthrocentesis. The anterior oblique view of the knee is shown with the needle inserted just inferior to the inferior pole of the patella, through the patellar tendon, and into the joint space after traversing the fat pad behind the patellar tendon. Flex the knee to 90 degrees with this approach, to avoid striking the articular surface.

To perform the arthrocentesis of the ankle, two approaches are shown. In the first, the anterior approach is shown with the extensor hallucis tendon identified. Insert the needle underneath the inferior border of the tibia with the foot in plantar flexion just lateral to the extensor hallucis tendon (A). In the second approach (B), insert the needle medial to the extensor hallucis tendon, between that tendon and the end of the tibia. One usually finds that, by inverting the foot against resistance, the tibialis anterior tendon will stand out, revealing a “fossa” inferior to this tendon at the distal end of the medial malleolus. This fossa is the site for insertion of the needle.

1. Place the patient in a supine position with the ankle plantar flexed to permit a wider area for entrance into the joint (Fig. 9.12).
2. If the patient inverts the foot against resistance, a “fossa” will be seen, which is the site of insertion of the needle.
3. Palpate the sulcus medial to the extensor hallucis longus tendon between the medial malleolus and the distal articular surface of the tibia.
4. Insert the needle just distal to the edge of the tibia and medial to the extensor hallucis longus tendon, directing it perpendicular to the floor (in the supine patient) and in line with the medial malleolus.
5. Alternatively, entry can be made just lateral to the extensor hallucis tendon.

ANKLE JOINT ARTHROCENTESIS:
ANTEROLATERAL APPROACH

PROCEDURAL STEPS
1. Place the patient in a supine position (Fig. 9.13).
2. Plantar flex the ankle.
3. After palpation, insert the needle between the medial margin of the lateral malleolus and the extensor digitorum communis tendons.

**NOTE**

This is not our preferred approach; however, in cases in which the medial approach is not feasible (e.g., cellulitis), it may be used.

**SUBTALAR JOINT ARTHROCENTESIS**

**PROCEDURAL STEPS**

- The subtalar joint is very difficult to enter, and arthrocentesis of this joint is not commonly performed in the emergency department. The indications are suspected septic arthritis or gout.
- When an effusion is present, swelling will be noted below the lateral malleolus.

1. Perform the procedure while the patient is supine with the foot held perpendicular to the leg.
2. Insert the needle just below the lateral malleolus, perpendicular to the skin (Fig. 9.14).

**TOE MCP JOINT ASPIRATION**

**PROCEDURAL STEPS**

The first metatarsophalangeal joint is a frequent site of involvement in gouty arthritis. Aspiration is easily performed in the patient with a joint effusion.

1. Use a 22-gauge needle attached to a 5-mL syringe.
2. Apply linear traction to facilitate entry into the joint.
3. Insert the needle on the dorsal surface medial to the extensor tendon between the metatarsal head and the phalanx (Fig. 9.15).

**TOE IP JOINT ASPIRATION**

**PROCEDURAL STEPS**

1. Use a 22-gauge needle.
2. Traction facilitates entry into the joint.
3. Insert the needle over the dorsal surface from either a medial or a lateral direction.
4. Slip the needle beneath the extensor tendon between the cartilaginous surfaces forming the joint (Fig. 9.16).
SECTION 6

INTRAOSSEOUS

P17: UMBILICAL CATHETERS AND IO
Procedure Guidelines for Power-Driven Intraosseous Devices

Purpose

To provide procedural guidance for insertion and maintenance of a power-driven IO device.

Definitions

Intraosseous: situated within, occurring within, or administered by entering a bone

Key Words

Intraosseous, infusion, vascular access

Equipment

1. One power driver
2. Appropriate size intraosseous needle set based on patient size and weight
   o 15mm 3-39 kg
   o 25mm 40 kg and greater
   o 45mm excessive tissue
3. One connector component
4. Three (3) 10 ml syringes
5. Sterile saline solution for flush. Note: Consider 2% lidocaine without preservatives or epinephrine (cardiac lidocaine) for patients responding to pain
6. Two (2) pairs non-sterile non-latex gloves
7. Antiseptic agent per institution protocol
8. One (1) semi-permeable transparent dressing (optional)
9. One (1) sterile 2x2 or 4x4 gauze pad
10. One (1) (appropriate volume and type) intravenous solution
11. One (1) fluid administration set (institution specific)
12. One (1) fluid administration pump or pressure bag (institution specific)
13. One (1) stabilizer component

1. Indications for Use – for power-driven device – Review manufacturer Directions For Use

   1.1 For adults and pediatrics anytime in which vascular access is difficult to obtain in emergent, urgent or medically necessary cases.

2. Contraindications for power driven device – Review manufacturer Directions For Use

   2.1 Fracture of the targeted bone
   2.2 Previous orthopedic procedures near insertion site (prosthetic limb or joint)
   2.3 IO within the past 24 - 48 hours in the targeted bone
   2.4 Infection at the insertion site
2.5 Inability to locate landmarks or excessive tissue over the insertion site

3. Considerations

3.1. Ensure the administration of a rapid SYRINGE BOLUS (flush) prior to infusion NO FLUSH = NO FLOW
   - Rapid syringe bolus (flush) the catheter with 10 ml of normal saline
   - Repeat syringe bolus (flush) as needed

   • Pain: If prescribed by a physician the 2% lidocaine without preservatives or epinephrine (cardiac lidocaine) must be infused slowly to prevent it from being sent directly into the central circulation. Medications intended to remain in the medullary space, such as a local anesthetic, must be administered very slowly until the desired anesthetic effect is achieved.

*Consult pharmaceutical DFU’s for lidocaine 2% (preservative and epinephrine-free) prior to infusion
*Authorized prescriber must authorize appropriate dosage range and titration

4. Procedure

4.1. Explain procedure to patient/family
4.2. Choose appropriate intraosseous needle set and assemble equipment
4.3. Obtain assistance as needed
4.4. Wash hands
4.5. Draw up syringe with sterile saline solution (10 ml)
4.6. Inspect needle set package to ensure sterility
   4.6.1. Connect 10 ml syringe to connector component, primed with sterile saline or lidocaine as appropriate
   4.6.2. Obtain blood samples for laboratory analysis (as necessary) prior to priming connector component
   4.6.3. Leave syringe attached to connector component
4.7. Palpate site to locate appropriate anatomical landmarks for needle set placement
4.8. Locate appropriate insertion site
   • 25mm: (commonly for 40 kg and over)
     o **Proximal Tibia** – Insertion site is approximately 2 cm below the patella and approximately 2 cm (depending on patient anatomy) medial to the tibial tuberosity.
     o **Distal Tibia** - Insertion site is located approximately 3 cm proximal to the most prominent aspect of the medial malleolus. Place one finger directly over the medial malleolus; move approximately 2 cm (depending on patient anatomy) proximal and palpate the anterior and posterior borders of the tibia to assure that your insertion site is on the flat center aspect of the bone.
     o **Proximal Humerus** – Insertion site is located directly on the most prominent aspect of the greater tubercle. Slide thumb up the anterior shaft of the humerus until you feel the greater tubercle, this is the surgical neck. Approximately 1 cm (depending on patient anatomy) above the surgical neck is the insertion site.
- Ensure that the patient’s hand is resting on the abdomen and that the elbow is adducted (close to the body).

- 45mm: (recommended for the proximal humerus application, patients with excessive tissue over the insertion site or when a black line is not visible after penetration into the tissue)
  o **Proximal Tibia** – Insertion site is approximately 2 cm below the patella and approximately 2 cm (depending on patient anatomy) medial to the tibial tuberosity.
  o **Distal Tibia** - Insertion site is located approximately 3 cm proximal to the most prominent aspect of the medial malleolus. Place one finger directly over the medial malleolus; move approximately 2 cm (depending on patient anatomy) proximal and palpate the anterior and posterior borders of the tibia to assure that your insertion site is on the flat center aspect of the bone.
  o **Proximal Humerus** – Insertion site is located directly on the most prominent aspect of the greater tubercle. Slide thumb up the anterior shaft of the humerus until you feel the greater tubercle, this is the surgical neck. Approximately 1 cm (depending on patient anatomy) above the surgical neck is the insertion site.
    - Ensure that the patient’s hand is resting on the abdomen and that the elbow is adducted (close to the body).

- 15mm: (commonly for 3-39 kg, consider tissue depth over the landmark desired)
  o **Proximal Tibia** - If NO tuberosity is present, the insertion is located approximately 4 cm below the patella and then medial along the flat aspect of the tibia. If the tuberosity IS present, the insertion site is located approximately 2 cm medial to the tibial tuberosity along the flat aspect of the tibia. Carefully feel for the “give” or “pop” indicating penetration into the medullary space.
  o **Distal Tibia** - Place one finger directly over the medial malleolus; move approximately 2 cm (depending on patient anatomy) proximal and palpate the anterior and posterior borders of the tibia to assure that your insertion site is on the flat center aspect of the bone.
  o **Proximal Humerus** - The insertion is located directly on the most prominent aspect of the greater tubercle. Slide thumb up the anterior shaft of the humerus until you feel the greater tubercle, this is the surgical neck. Approximately 1 cm (depending on patient anatomy) above the surgical neck is the insertion site. Ensure that the patient’s hand is resting on the abdomen and that the elbow is adducted and positioned at the level of the spine. The proximal humerus may be difficult or impossible to palpate in children less than 5 years of age as the greater tubercle has not yet developed. In these cases the insertion will most likely be a shaft insertion.

4.9. Apply non-sterile latex free gloves
4.10. Drop the following onto non-sterile field:
   4.10.1.1. Antiseptic agent per institution protocol
   4.10.1.2. Semi-permeable transparent dressing (optional)
   4.10.1.3. 2x2 gauze or 4x4 gauze
4.10.1.4. Needle Set, in cartridge, and connector component (with attached syringe)
4.11. Cleanse site using antiseptic agent per institution protocol
4.12. Allow to air dry thoroughly
4.13. Connect appropriate needle set to driver
4.14. Stabilize site
4.15. Remove needle cap
4.16. Insert needle into the selected site. IMPORTANT: Keep hand and fingers away from needle set
   4.16.1. Position the driver at the insertion site with the needle set at a 90-degree angle to the bone surface. Gently pierce the skin with the needle set until the needle set tip touches the bone.
   4.16.2. Check to ensure that at least one black line is visible. If no black line is visible, patient may have excessive soft tissue over selected insertion site and needle set may not reach the medullary space. Consider an alternative site for insertion or a longer needle set.
   4.16.3. Penetrate the bone cortex by squeezing driver’s trigger and applying gentle, consistent, steady, downward pressure (allow the driver to do the work)
   4.16.4. Release the driver’s trigger and stop the insertion process when:
      1. On adult patients when accessing the tibia using the 25mm needle set or the proximal humerus using the 45mm needle set, you may stop by releasing the trigger when the hub is almost flush with the skin.
      2. On pediatric patients when you feel a decrease in resistance indicating the needle set has entered the medullary space, release the trigger.
4.17. Remove power driver from needle set while stabilizing the catheter hub
4.18. Remove stylet from catheter by turning counter-clockwise and immediately dispose of stylet in appropriate biohazard sharps container
   *NEVER return used stylet or cartridge to the device kit or crash cart
4.19. Secure site with stabilizer component
4.20. Connect primed connector component to exposed Luer-lock hub
4.21. Confirm placement
4.22. Syringe bolus: flush the catheter with 10 ml of normal saline
   4.22.1. If the patient is responsive to pain the clinician may consider use of 2% lidocaine without preservatives or epinephrine (cardiac lidocaine) for anesthetic effect prior to the 10ml normal saline flush and it may be necessary to administer additional lidocaine following the saline flush.
4.23. Assess for potential IO complications
4.24. Disconnect 10 ml syringe from connector component extension set
4.25. Connect primed connector component extension set to primed IV tubing
4.26. Begin infusion utilizing a pressure delivery system
4.27. Secure tubing and catheter per institution policy
4.28. Continue to monitor extremity for complications
4.29. Place armband on patient, document time and date

CATHETER REMOVAL

1. Remove the extension set from the needle hub
2. Attach a 5-10 ml sterile syringe (with standard Luer-lock) to act as a handle and to cap the open IO port
3. Grasp syringe and continuously rotate clockwise while gently pulling the catheter out (maintain a 90-degree angle to the bone). DO NOT ROCK OR BEND DURING REMOVAL.
4. Dispose of catheter into a sharps container
5. Apply pressure to site as needed; apply adhesive dressing as indicated
SECTION 7

THORACOTOMY

P18: PARACENTESIS/THORACENTESIS
INTRODUCTION

Emergency department thoracotomy (EDT) is a procedure used for victims of penetrating trauma to relieve pericardial tamponade, control intrathoracic hemorrhage, preserve cardiac output to the brain and the heart, provide direct access for cardiac massage, and to provide intracardiac administration of resuscitative medications. The actual opening of the chest is just a small aspect of the resuscitative thoracotomy. Opening of the pericardium, repair of cardiac injuries, cross-clamping the aorta or pulmonary hilum, and controlling great vessel or lung hemorrhage are the major aspects of the procedure.

KEY POINTS

- For the best outcome of the patient, it is imperative that the following goals be kept firmly in mind, and that once accomplished, the patient be moved expeditiously to the operating room. The window of opportunity is slim and can be wasted by unnecessary time spent in the emergency department when the patient should be rapidly moved to a more controlled environment.

AXIOM

Closure of the thorax requires a surgeon, and no resuscitative thoracotomies should be undertaken unless there is a trauma or cardiothoracic surgeon on-site to complete this task. The goals of and EDT are:

- To stop lethal exsanguination by repair of injuries
- To relieve the pericardial tamponade with restoration of perfusion
- To cross-clamp the aorta for distal abdominal arterial vascular control
- To re-establish meaningful spontaneous cardiac contractions with signs of perfusion

- Left anterolateral approach is the preferred method, even if the presenting wound is on the right side of the chest

RESUSCITATIVE THORACOTOMY

AXIOM

An EDT should always start with opening of the left side of the chest (even if there is penetrating trauma to the right side) as this allows for definitive management of cardiac tamponade, left hilar injury, cardiac wound repair, and thoracic aortic occlusion. When the left side thoracotomy has been completed and there are still no signs of life, the rightsided thoracotomy can then be performed.

- Gaining access to the thoracic cavity should take no longer than 1 to 2 minutes.
- Definitive airway management should occur prior to EDT.
If endotracheal intubation is performed, advance the tube to the right mainstem, which will ventilate the right lung. This will help to avoid injury to the left lung with thoracotomy exposure to the left side, while oxygenating and ventilating the right lung (pass the endotracheal tube to 30 cm).

- Pass a nasogastric tube to help distinguish aorta from the esophagus, to assist during aorta cross-clamp.
- The best access to the heart and great vessels is through the dissection into the fourth intercostal space.
- To make sure the extension into the right cavity is possible, place the rib spreaders with handle downward.
- Avoid injuring the intercostal neurovascular bundle by making the incision above the rib.

The following conditions improve the survival after the EDT:

- Signs of life in the emergency department or prior to arrival there
- Stab wounds versus gunshot wounds, because gunshot wounds do not seal as well and have higher associated kinetic energy, consistent with greater tissue and structural damage
- Thoracic injuries versus abdominal injuries, because of the low neurologic survival rate after cross-clamping of the aorta
- Penetrating injuries versus blunt injuries, because of poor cardiac function after a blunt injury

- Cardiac tamponade that cannot be decompressed via needle aspiration
- Intra-abdominal exsanguinations
- Internal cardiac massage

**CONTRAINDICATIONS**

- Blunt trauma victims should not undergo EDT, with or without vital signs
- Penetrating abdominal trauma without vital signs at the scene or in the transit to the emergency department
- Obvious massive intracranial trauma

**ANATOMICAL POINTS**

- Identify the left fourth intercostal space (in female patients, located along the inframammary line; retract breast upward)
- The incision should follow the curvature of the ribs from the midsternum to the posterior axillary line

**EQUIPMENT**

- Povidone–iodine (Betadine)
- Two Allis clamps
- Tooth forceps
- Sterile field
- Scalpel with a no. 20 (or less ideally, a no. 10) blade
- Mayo scissors (curved), rib spreaders (Finochietto chest retractor)
- Curved Metzenbaum scissors
- Lebsche knife and hammer, hemostats
- Satinsky vascular clamps (two each, large and small)
- DeBakey tangential occlusion clamp (aortic clamp)
- Two Finochietto rib retractors (12-inch spread)
- Suction catheter
- Hemostats
- Tonsil clamps (four)
- Two 10-inch needle drivers (Hegar)
- Various large silk sutures on large curved needles with Teflon pledgets (2-0, 0, 1, 2)
- Adequate suction (two sources preferable)
- Internal defibrillator paddles
- Foley catheters
- Multiple towels
- Thirty 4 × 4-inch sponges

**INDICATIONS**

**EMERGENCY THORACOTOMY BY MECHANISM OF INJURY**

- Control penetrating exsanguinating intrathoracic hemorrhage
**TECHNIQUE**

**PREPARATORY STEPS**
1. Make sure patient has definitive airway management prior to EDT.
2. It is ideal to place a nasogastric tube and apply to suction.

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<td>Placement of the nasogastric tube will allow identification of the esophagus and will assist in allowing easier anatomical identification of structures when attempting cross-clamping of the aorta.</td>
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3. Place large-bore catheter intravenous lines in the upper extremities or have central access to manage ongoing hypovolemia adequately.
4. To give the best exposure during left anterolateral thoracotomy, place several rolled sheets under the left scapula. This allows the posterior aspect of the incision to go back far enough to allow adequate exposure.
5. No anesthesia or analgesia is necessary because these patients are moribund.
6. With the patient intubated, quickly apply povidone-iodine over the anterolateral chest wall bilaterally.
7. Abduct and externally rotate the left arm and place over the head to allow better exposure of the chest wall.

<table>
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<th>CAUTION</th>
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<td>Universal precautions must be used because there is no more invasive procedure than this in the emergency department, and staff can be readily exposed to blood and chards of bone.</td>
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**PROCEDURAL STEPS**
1. Make a single large incision in the fourth or fifth intercostal space extending from the sternum (2 cm lateral to the sternum) to the posterior axillary line (Fig. 4.4), preferably in one large “slashing” stroke; the incision is extended below the nipple line in men and the inframammary line in women. The blade should incise through the skin, subcutaneous fat, and intercostal muscles.

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<td>This incision must be fast and deep, cutting through all the layers in a single cut. Caution should be taken to make sure that the cut is not too deep to injure underlying lung tissue.</td>
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2. Enter the chest cavity using Mayo scissors to separate the intercostal muscles that are not already severed with the scalpel. Use second and third fingers to separate the pleura of the lung from the chest wall.

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<tr>
<td>Be cautious of inadvertant lacerations to any lung tissue adherent to the chest wall. The operator’s fingers should be placed in through the intercostal incision and slide along with the Mayo scissors to avoid this complication.</td>
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</table>
3. Insert Finichetto rib spreader and crank it open for maximal exposure.

### CAUTION

*Rib spreaders may cause fracture of the ribs at multiple places.*

8. Intracardiac epinephrine may be given to augment myocardial resuscitation and may be given according to standard advanced cardiac life support (ACLS) guidelines of 1 mg intracardiac. If there is asystole without evidence of spontaneous movement of heart muscle, then continue vigorous, but careful, cardiac massage (see page 161, open cardiac massage section) along with restoration of intravascular red cell mass and intravascular volume. Again, use epinephrine in this setting to help establish return of spontaneous heartbeats or fibrillation, which can then be cardioverted.

9. Place the hand in the thoracotomy incision and palpate the diaphragm posteriorly. As the fingers are slid posteriorly to the midline, palpate the vertebral bodies, and the diaphragm will be just inferior to the hand. The first palpable structure alongside the vertebral bodies at this junction is the thoracic aorta. The thoracic aorta overlies the vertebral bodies and is separated from the esophagus. Previous placement of a nasogastric tube will assist in identification of the esophagus. The esophagus courses anteriorly and medial to the aorta. The aorta is difficult to palpate in hypovolemic patients as the thoracic aorta may be collapsed. Furthermore with massive hemorrhage, it may be impossible to visualize the aorta. Thus this is most often a blind procedure, and the aorta is mobilized by freeing the pleura above and below, with care taken not to rupture the intercostal arteries. Alternatively, palpate the diaphragm where it joins the spinal vertebral bodies. The aorta is the first tubular structure that lies anteriorly. The esophagus at this point is separated from the aorta by several centimeters. One can then follow the aorta proximally.

### NOTE

The rib spreader should be placed with the crank downward in case the thoracotomy incision needs to be extended to the right side. In this manner, the cranking mechanism will be out of the way.

### CAUTION

*Patients with previous thoracotomy (i.e., previous coronary artery bypass graft surgery) may have multiple adhesions. The operator must open the rib spreaders with extreme caution as these adhesions may cause damage to lung parenchyma and myocardial tissue.*

4. Manually move the lung out of the way and evacuate clots for visual exposure; identify the pericardium.

5. Digital pressure is best when simultaneously performing open cardiac compressions to prevent blood from squirting out during manual systole.

6. If the wound location mandates better exposure for repair, continue the incision across the sternum, using the Lebsche knife, or specially designed sternal cutter that should be in the thoracotomy tray, and continue in the right fourth or fifth intercostal space (clam-shell exposure). Apply the other rib spreaders to the right side or at the at the sternum for maximal exposure.

7. In absence of cardiac injury, initiate open cardiac massage. If ventricular fibrillation is present, apply 10 to 15 J using the open defibrillator paddles to convert the movements into more organized contractions.

### NOTE

The lung will be inflating with ventilation. By pushing the endotracheal tube deeper into the trachea and in essence becoming a right mainstem intubation, the left lung will deflate, which will allow easier visualization of the left hemithorax.
11. If bleeding is identified, apply digital pressure to slow/stop the bleeding source.

12. Sweep the hand inferiorly along the dome of the diaphragm and then come upward along the mediastinum medially, when identifying the pericardial sac. Using Allis clamps or hemostats (not forceps; they have a tendency to lose their “grip,” thus wasting time), grasp the pericardium in a medial-lateral fashion and retract toward the operator, causing a rent in the pericardium that can be cut.

13. With the Metzenbaum scissors, incise the pericardium between the Allis clamps in a vertical fashion, with care given to not transect the left phrenic nerve.

**NOTE**

The phrenic nerve runs longitudinally along the pericardium; therefore, the opening of the pericardium should be through a vertical incision but more anterior than the phrenic nerve. After the opening of the pericardium, the heart is easily exposed and delivered out through the incised pericardium (Fig. 4.6). Then remove pericardial clot, if present, and look for any cardiac injury.

14. Open the pericardium anterior to the phrenic nerve and “birth” the heart out of the pericardial covering. Inspect the heart quickly for occult injuries and continue with cardiac repair if cardiac injury is identified (see page 163, cardiac wound repair section). For control of bleeding, obtain proximal vascular occlusion for each injured organ. For the lung, this may mean cross-clamping the hilum. While performing this, recognize that hypoxia and pulmonary hypertension will ensue, with major stresses on an already ischemic heart (see page 170 hilum and great vessel injuries section).

15. If no injury is identified in the left thorax and there is high index of suspicion of right-sided injury, the right side of the chest may be opened by extending the sternal incision and “mirroring” the left side, performing a right-sided thoracotomy.

**CAUTION**

*If cutting through the sternum, the internal mammary arteries may be cut, leading to further volumetric compromise.*

**AFTERCARE**

1. Remember that when vital signs are restored suddenly after repair of the heart, anesthesia may abruptly be required because the patient may regain consciousness.

2. Once beating is resumed with signs of perfusion and fair hemostasis achieved, take the
patient expeditiously to the operating room for continued resuscitation and definitive repair.

**PEDIATRIC CONSIDERATIONS**
- Children with penetrating thoracic injuries, who are in decompensated shock in the emergency department, should be taken directly to the operating room for resuscitative thoracotomy.
- Ribs in children are very pliable in young children and their neurovascular bundles lie lower on the inferior margin of the ribs.
- Overall approach in children is identical to that of the adult patient.

**COMPLICATIONS**
- Anoxic brain death as high as 50% in survivors
- An elevated hemidiaphragm is frequently mistaken for the pericardial sac. There have been cases in which the diaphragm was mistakenly incised instead of the pericardial sac.
- Delayed diagnosis of ventricular septal defects, aortic valvular irregularities, atrial septal defects, and cardiac conduction defects after cardiac injuries
- Potential transmission of blood-borne pathogens
- Damage to coronary arteries and other intrathoracic organs
- Recurrent bleeding from the internal mammary artery of chest wall