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Introduction

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EMERGENCY CRICOTHYROTOMY

Clinical situation

Typically, this procedure is performed in a hypoxic patient with an obstructed airway who cannot be ventilated with a mask or LMA and cannot be intubated.

Emergency "Stab" Cricothyrotomy

Equipment	• Scalpel, preferably with no. 11 blade • ETT no. 6 • Syringe for inflating cuff • Prep solution such as alcohol, chlorhexidine, or povidone-iodine
Procedure	1. Prep skin if time permits. 2. Identify cricothyroid membrane between cricoid and thyroid cartilages (Fig. 15.1). 3. Make 2- to 3-cm transverse or vertical incision through skin. 4. Make 2.5-cm incision through cricothyroid membrane with single stab (Fig. 15.2). 5. Reverse scalpel, place handle into wound, and turn 90° to expand incision. 6. Pass tracheostomy tube (or standard ETT) into trachea. 7. Inflate cuff on tracheostomy/ETT. 8. Ventilate patient with capnography if possible. 9. Secure tube.

Emergency "Four-Step" Cricothyrotomy

Equipment	• Scalpel with no. 11 blade • Tracheal hook (may be improvised by bending a 16-ga needle into a hook with a hemostat) • ETT no. 6 • Syringe for inflating cuff • Prep solution such as alcohol, chlorhexidine, or povidone-iodine

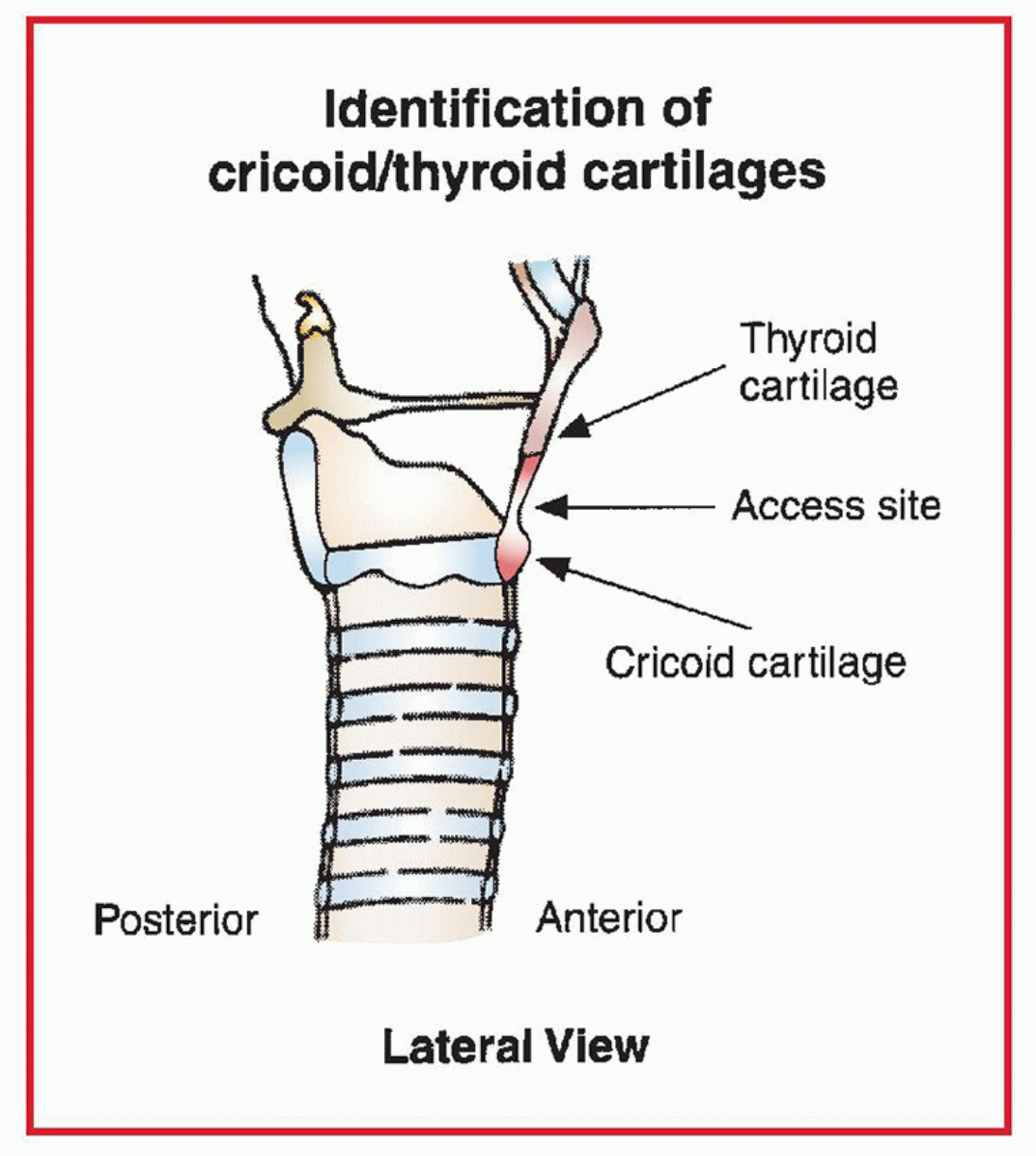

Figure 15.1 Identify cricoid membrane.

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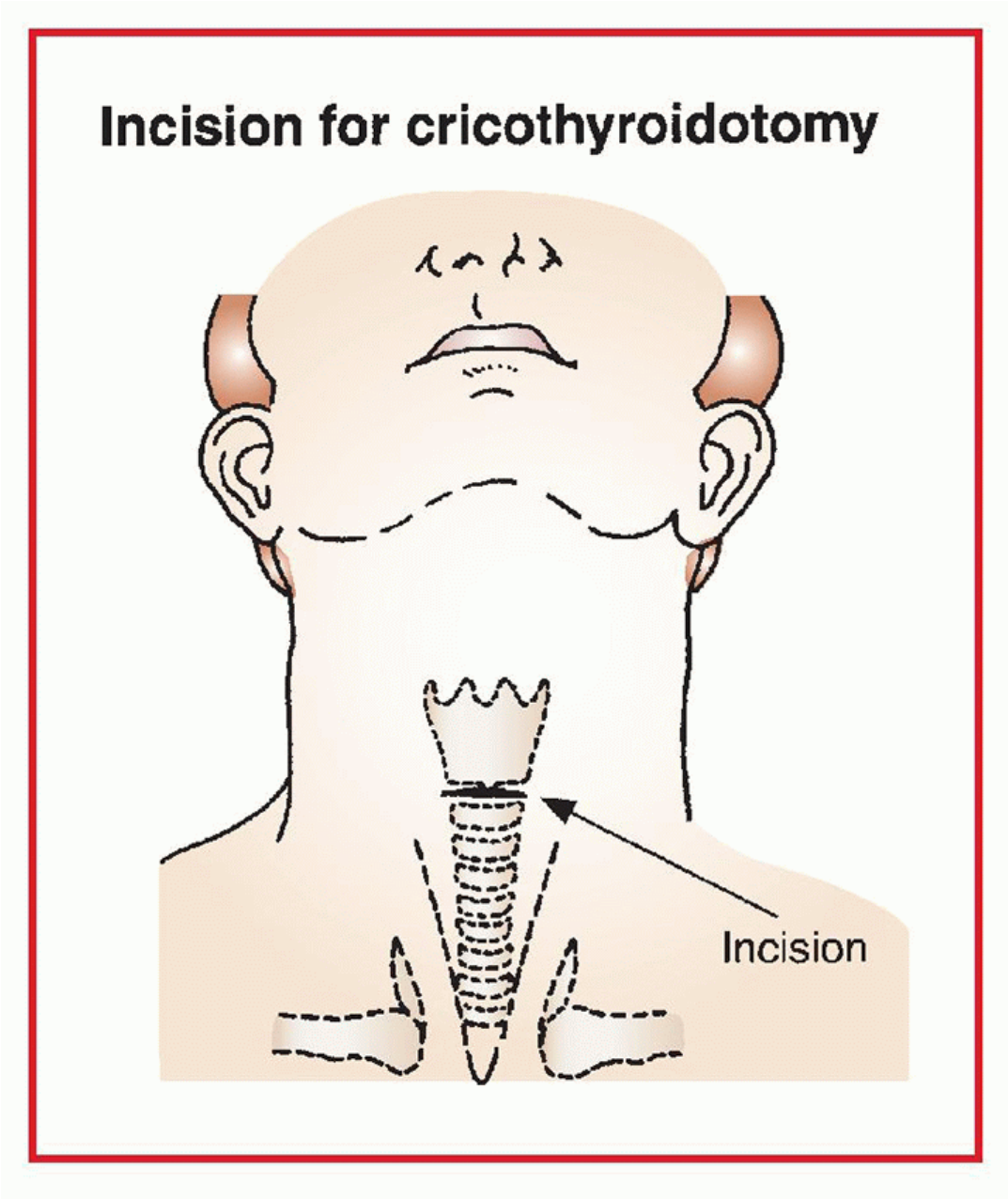

Figure 15.2 If possible, extend head and place bolster between scapula. Palpate thyroid and cricoid cartilages and then identify cricothyroid membrane (CTM). Skin incision may be vertical if unsure of CTM location, as a finger inserted through a vertical incision may have more ability to palpate the CTM by blunt pressure in a vertical or horizontal search.

Procedure

1. Right hand dominant operator stands on patient's left side. Position with head and neck extended.
2. Prep skin if time permits.
3. Nondominant hand identifies cricothyroid membrane while stabilizing thyroid cartilage. Dominant hand makes 2.5-cm transverse incision through skin and cricothyroid membrane with single stab, keeping blade in place.
4. Nondominant hand places tracheal hook into incision, lifting cricoid cartilage ventrally, and then scalpel is removed.

   Dominant hand inserts ETT and then removes tracheal

	hook. 6. Inflate cuff. 7. Ventilate patient with capnography if possible. 8. Secure tube.

Emergency “Bougie-Guided” Cricothyrotomy

Equipment	• Scalpel and hemostat (central line kit) • ETT no. 6 • Syringe for inflating cuff • Bougie (pediatric 10 Fr for ETT 4.0-5.5 or adult 15 Fr for ETT 6.0) • Prep solution such as alcohol, chlorhexidine, or povidone-iodine
Procedure	1. Operator may stand at head or either side of the patient. Position with head and neck extended. 2. Prep skin if time permits. 3. Nondominant hand identifies cricothyroid membrane while stabilizing thyroid cartilage. 4. Dominant hand makes a 3-cm incision (vertical or transverse) through skin. 5. Nondominant hand index finger placed into incision, palpates cricothyroid membrane with a side-to-side motion, and then finger is removed from incision. 6. Dominant hand makes a 2.5-cm horizontal incision in the cricothyroid membrane. 7. Dominant hand inserts coude tip end of bougie via incision seeking tracheal clicks and hang-up sign. 8. Pass ETT over bougie into trachea. If difficult, use hemostat to dilate cricothyroid membrane with bougie in place and then pass ETT (Fig. 15.3). 9. Remove bougie. 10. Inflate cuff. 11. Ventilate patient and monitor capnogram if possible. 12. Secure tube (Fig. 15.4).

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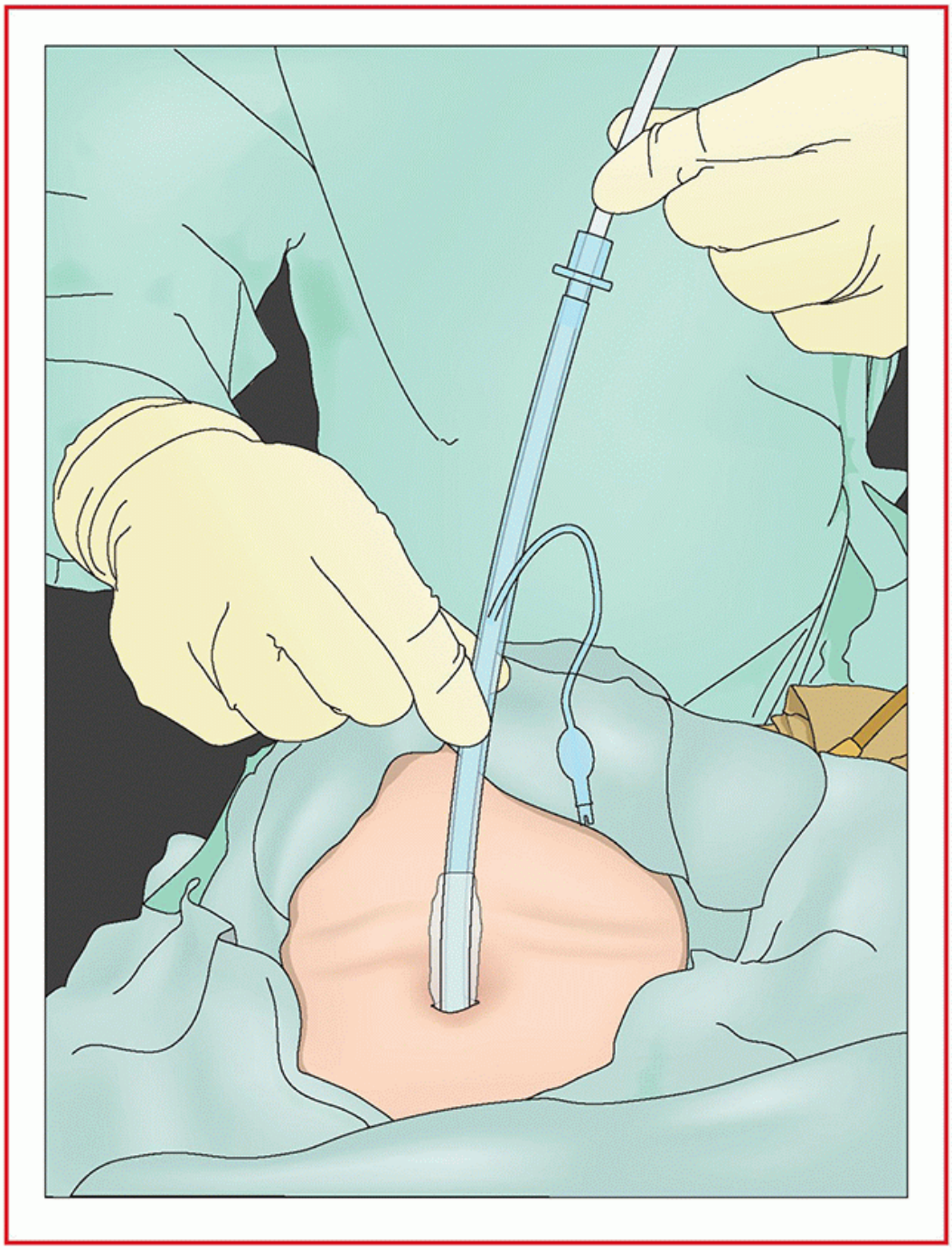

Figure 15.3 Adult bougie 15 Fr passed via incision with coude tip directed caudally attempting to feel for tracheal clicks and/or carinal hang-up sign. Average depth from skin to carina is 12-15 cm. A 6.0 or greater ETT will pass over an Adult 15 Fr bougie.

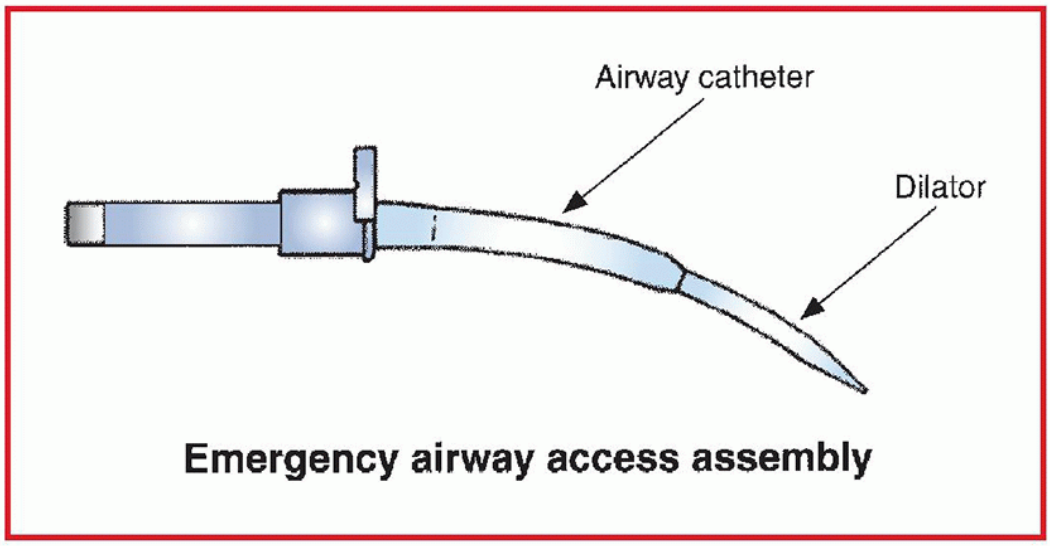

Figure 15.4 Melker cricothyroidotomy kit with dilator passed firmly into airway catheter prior to accessing the CTM.

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EMERGENCY PERICARDIOCENTESIS

Clinical situation

The patient typically has severe ↓BP unexplained by any other causes (e.g., anesthetic drugs, autoPEEP, tension pneumothorax) and consistent with acute cardiac tamponade (dyspnea, tachypnea, ↓BP, ↑HR, electrical alternans, ↓voltage EKG, ↓pulse pressure or pulsus paradoxus, ↑CVP/JVD, distant heart sounds) ± equalization of pressures (RAP ˜ RVEDP ˜ PAD ˜ PAOP) ± confirmation by TEE/TTE. Because of the high intrapericardial pressures, all "filling pressures" of both right and left heart appear high when preload is actually very low. In severe cases, patients will experience cardiac arrest with pulseless electrical activity (PEA).

Equipment	• 10-mL syringe • 18-ga spinal needle
Procedure	1. Identify xiphoid process and point 1 inch below and 1 inch left of midline (Fig. 15.5). 2. Prep skin below xiphoid. 3. An 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. 4. Attach needle to syringe, and direct needle at ≤45° to the skin under rib toward left shoulder (Fig. 15.5). 5. If pericardial fluid is withdrawn, BP will ↑ immediately.

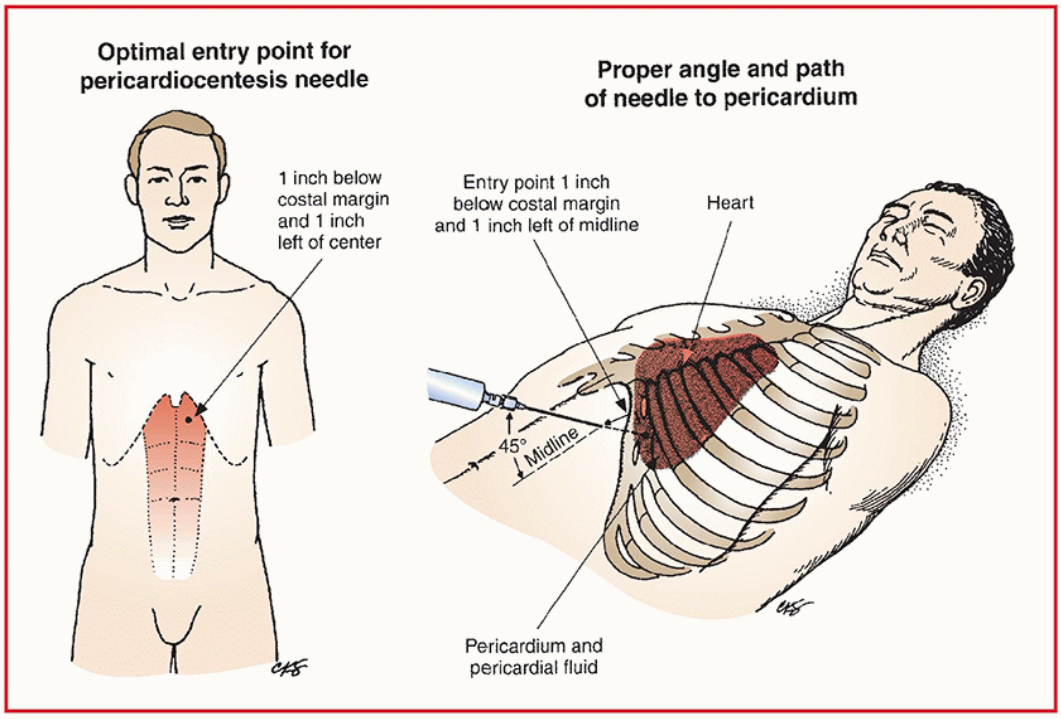

Figure 15.5 Emergency blind pericardiocentesis. Once diagnosis of cardiac tamponade is made, elevate head of bed to 30-45° to allow gravity to assist in fluid access. If hemodynamics do not allow this, place the patient into a supine position. The access site is 2.5 cm below the xiphoid process and 2.5 cm to the patient's left. An 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration. If time allows, anesthetize the route with lidocaine 1-2% 5-10 mL.

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EMERGENCY ULTRASOUND-GUIDED PERICARDIOCENTESIS[1,5]

In the above-described setting of respiratory and hemodynamic stability, ultrasonography may be used to aid in diagnosis and treatment of cardiac tamponade. If you are unfamiliar with basic cardiac ultrasonography, a stat consult with a skilled ultrasonographer is necessary for performance of an ultrasound-guided pericardiocentesis. Precepted hands-on training must be sought prior to using ultrasound for diagnosis or treatment of cardiac tamponade.

Cardiac tamponade is a clinical diagnosis. Ultrasound findings include pericardial fluid with a "swinging heart" (ultrasound visualization of electrical alternans); increasing pericardial pressure causes right atrial systolic collapse, right ventricle diastolic collapse, septal shift toward left ventricle in systole; respiratory variation across tricuspid and mitral valves; in addition, IVC plethora with no respiratory variation may be seen. Patients with normal, stable hemodynamics and pericardial effusion do not require emergent pericardiocentesis.

	Minimum • Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Ultrasound gel or lubricant • Syringe • 18-ga 5-inch spinal needle or 18-ga Tuohy needle or longest 18-ga angiocatheter/needle available
	Preferred

Equipment	• Alcohol, chlorhexidine, or povidone-iodine skin prep • Sterile gloves • Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Sterile ultrasound probe sheath with gel • 10-, 20-, or 60-mL syringe • 18-ga spinal needle • 3-way stopcock • Lidocaine 1-2% 5-10 mL with 5-mL syringe and 3-inch 25-ga needle
Subxiphoid Approach	1. Identify xiphoid process and point 1 inch below and 1 inch left of midline (Fig. 15.5). 2. Prep skin, then attach needle to 3-way stopcock on a syringe. 3. Use ultrasound probe with sterile sheath to find largest accessible collection of pericardial fluid in the subxiphoid space. A subxiphoid four-chamber view or short-axis midpapillary view should be attempted. Note that you may need to pass the needle through the liver to get to the pericardial space. If no chest compressions are being performed, consider positioning the patient in slight head-up or left lateral decubitus position to optimize fluid accessibility. If the patient is conscious, consider local anesthetic injection along anticipated needle path under ultrasound visualization. 4. Place needle next to probe in same alignment to the skin and pericardial fluid (Fig. 15.6). 5. Advance needle tip under direct ultrasound visualization (Fig. 15.6). 6. When needle tip enters fluid collection, withdraw fluid. If flowing freely, continue to withdraw fluid until syringe is full, or you may turn the 3-way stopcock open to atmosphere to allow pericardial pressure to decompress. (If unsure of needle tip position, abort attempt or consider injection of 1- to 3-mL agitated saline via needle to identify location of tip relative to pericardial fluid.) 7. Remove needle once hemodynamics have improved with fluid removal. 8. Monitor patient for reaccumulation of pericardial fluid and consult for formal evaluation and possible pericardial drain placement.

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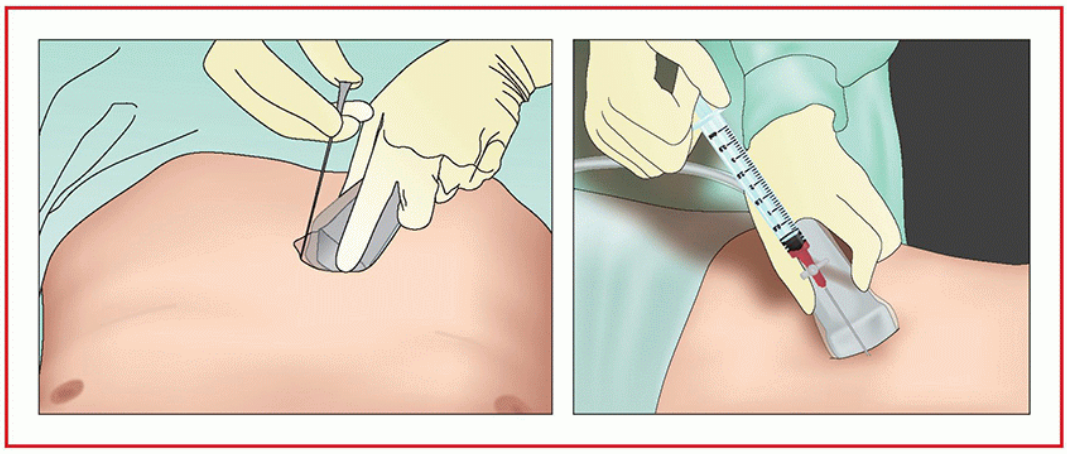

Figure 15.6 Emergency ultrasound-guided pericardiocentesis. Subxiphoid approach. Once ultrasonographic diagnosis of cardiac tamponade is made, elevate head of bed to 30-45° to allow gravity to assist in fluid access. If hemodynamics do not allow this, place the patient into a supine position. The subxiphoid access site is 2.5 cm below the xiphoid process and 2.5 cm to the patient's left. With the ultrasound probe in place, visualizing the effusion and the heart, an 18-ga spinal needle is directed toward the left shoulder and inserted at a ≤45° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration under direct visualization. If unsure of needle tip location, stop advancement and wait for expert help or consider injection of 1-3 mL of agitated saline to visualize tip location. If time allows, anesthetize the route with lidocaine 1-2% 5-10 mL. Both in-plane and out-of-plane techniques are acceptable.

	Prep skin, then attach needle to 3-way stopcock onto syringe. Use ultrasound probe with sterile sheath to find largest accessible collection of pericardial fluid in the parasternal area; 4th or 5th rib interspace along left sternal border. Note that you should not pass the needle through the pleural space/lung/vessels to enter the pericardial space. If patient is conscious, consider local anesthetic injection along anticipated needle path under ultrasound visualization. Place needle next to probe in same alignment to the skin and pericardial fluid. You may use color flow Doppler to visualize vessels in intended needle path.
Parasternal Approach (Fig. 15.7)	Advance needle tip under direct ultrasound visualization. When needle tip enters fluid collection, withdraw fluid. If flowing freely, continue to withdraw fluid until syringe is full, or you may turn the 3-way stopcock open to atmosphere to allow pericardial pressure/fluid to decompress. (If unsure of needle tip position, abort attempt or consider injection of 1- to 3-mL agitated saline via needle to identify location of tip relative to pericardial fluid.) Remove needle once hemodynamics have improved with fluid removal. Monitor patient for reaccumulation of pericardial fluid and consult for formal evaluation and possible pericardial drain placement.

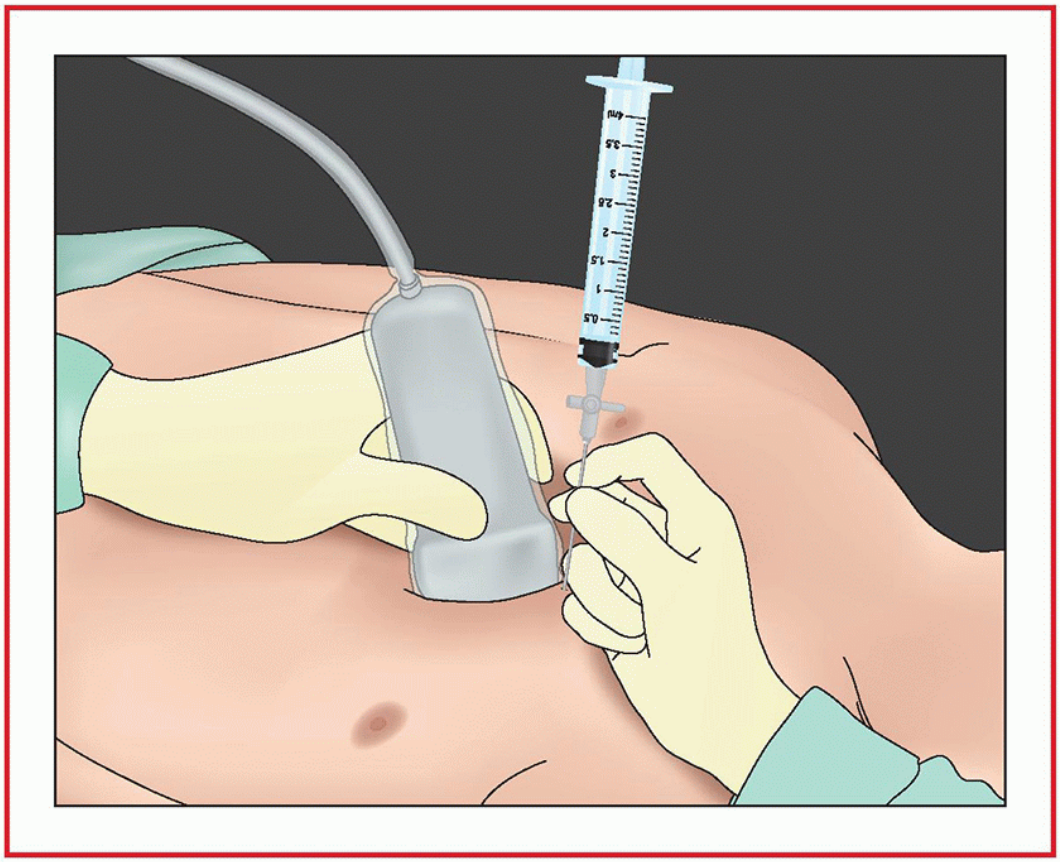

Figure 15.7 Emergency ultrasound-guided pericardiocentesis. Parasternal approach. Place the patient supine or in Trendelenburg to maximize fluid collection size in intended needle path. Identify the heart and fluid collection in the 4th or 5th intercostal space between the sternum and the midclavicular line. Be sure that the lung is not entering into ultrasonographic view. An 18-ga spinal needle is directed toward the patient's back and inserted at a 90° angle to the skin. The stylet is removed, a syringe with stopcock attached, and the apparatus advanced with aspiration under direct visualization. If unsure of needle tip location, stop advancement and wait for expert help or consider injection of 1-3 mL of agitated saline to visualize tip location. If time allows, anesthetize the route with lidocaine 1-2% 5-10 mL.

Suggested Reading

1. Fitch MT, et al: Videos in clinical medicine. Emergency pericardiocentesis. *N Engl J Med* 2012; 366(12):e17.

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Suggested Viewing

Links are available online to the following videos:

Chest tube insertion: https://www.youtube.com/watch?v=hQlt57AyQmg

Emergency surgical airway: https://www.youtube.com/watch?v=BwWIvJNecSg

Cricothyrotomy: https://www.youtube.com/watch?v=_VFJGkJy1G8

Ultrasound-guided pericardiocentesis procedure—SonoSite ultrasound: https://www.youtube.com/watch?v=T6Z9DvPPmXg

Needle thoracostomy—www.proceduresconsult.com: https://www.youtube.com/watch?v=4cuotNQPRNc (subscription required to

view complete video)

Needle decompression (thoracostomy):https://www.youtube.com/watch?v=TZpq8EPJ13Q&list=PLAB3A880AAEFB4992&index=2

Needle decompression hazards:https://www.youtube.com/watch?v=fQqPktj_gFc

Venous cutdown.mp4:https://www.youtube.com/watch?v=AHuJZHvTNGE

EMERGENT NEEDLE/CATHETER THORACOSTOMY

Clinical situation

A patient is experiencing severe hypotension and hypoxemia unexplained by any other cause (e.g., autoPEEP, cardiac tamponade) and consistent with acute tension pneumothorax (dyspnea, tachypnea, tachycardia, syncope, ↑P_{aw}, ↓movement of involved chest, ↓ breath sounds, ↑resonance to percussion, and ↑
rib interspace distance compared to uninvolved side) and cardiovascular Sx related to ↑thoracic pressures and ↓preload (↓BP, ↑HR, ↑pulse pressure, ↑CVP). The CVP is artificially elevated, reflecting the high intrathoracic pressures. Actual (transmural) CVP is very low. In severe cases, patients may experience cardiac arrest with pulseless electrical activity (PEA) because high intrathoracic pressures effectively stop venous return to the heart.

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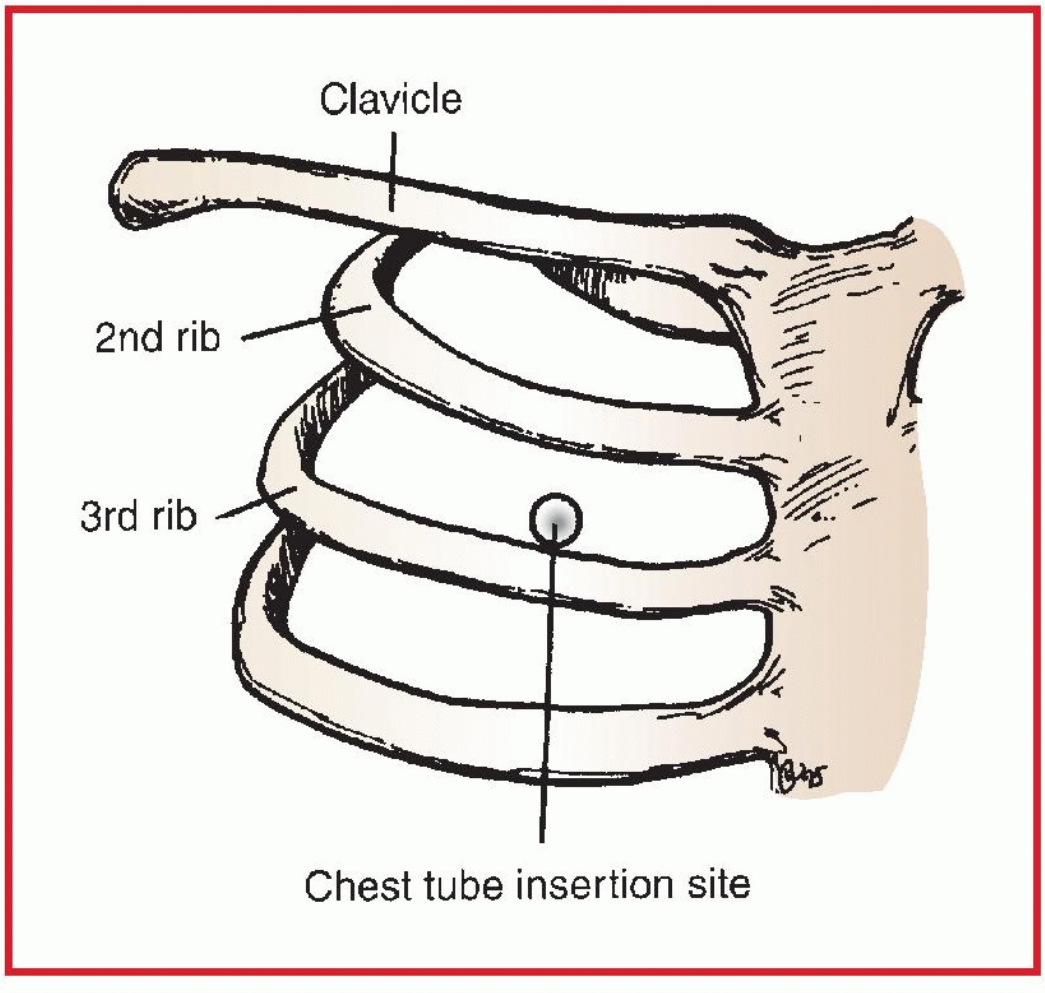

Figure 15.8 Midclavicular 2nd intercostal space. Lateral needle decompression in the 4th or 5th midaxillary line. To

avoid injury to neurovascular bundle, insert needle along upper border of the inferior rib at the selected space.

Note: AutoPEEP MUST be ruled out first, particularly when the diagnosis is bilateral tension PTX. AutoPEEP is effectively ruled out (except with a ball valve airway lesion) by disconnecting the ETT from ventilator/Ambu® bag and allowing patient to exhale. If the patient's condition immediately improves, you have made the diagnosis of autoPEEP.

Note: With a pneumothorax, release of the pressure that has built up in the chest is a lifesaving maneuver. A largebore chest tube does not need to be placed emergently. The much simpler needle/catheter thoracostomy is effective and less demanding for the nonsurgeon.

Equipment	One of the following: • 16-ga needle or iv catheter/needle (preferred) with a length of 5 cm • 16-ga single-lumen CVP kit • Alcohol, chlorhexidine, or povidone-iodine skin prep
Procedure	1. Identify the space. Identify the 2nd intercostal space by palpating the angle of Louis (union of manubrium and sternum); then move laterally to find the insertion of the 2nd rib. The interspace directly below this rib is the 2nd intercostal space (Fig. 15.8). Access should occur in the midclavicular line in this space. Alternatively, the anterior or midaxillary line in the 4th-5th intercostal space may be used. Identify the anterior axillary line by drawing an imaginary line caudally from the anterior axillary fold to rib space at or above the nipple line. 2. Prep skin. 3. Enter the selected intercostal space anteriorly over the upper border of the inferior rib to avoid neurovascular bundle running along the underside of the superior rib. 4. With entry into the pleural space, there may be an audible rush of air and with immediate hemodynamic improvement. 5. Remove needle. 6. The angiocatheter may be held in place until a chest tube is inserted. 7. Note: A more permanent chest tube will still need to be placed (i.e., the patient no longer has a tension pneumothorax, but still has a pneumothorax). This can be done in a more controlled situation by someone skilled in that procedure.

EMERGENT ULTRASOUND-GUIDED NEEDLE/CATHETER THORACOSTOMY

Tension pneumothorax diagnosis and management have been described earlier. If progressive pneumothorax with worsening cardiopulmonary function is suspected, a skilled ultrasonographer is needed to rule out pneumothorax prior to tension pneumothorax development. Lung ultrasound has >90% sensitivity and >90% specificity for *(Print pagebreak 1758)* pneumothorax.[6] A vascular access, curvilinear, or phase array probe with a depth field of 6 cm using 2D imaging may be utilized to detect pneumothorax. 2D and M mode may be used to identify signs to rule in or out a pneumothorax. Precepted hands-on training must be sought prior to using ultrasound to diagnose or treat pneumothorax.

Equipment	• Skilled ultrasonographer • Ultrasound machine with phase array, curvilinear, or vascular access probe • Ultrasound gel or lubricant • 16-ga needle or angiocatheter/needle
Procedure	1. Identify pneumothorax with ultrasound.[7] 2. Scan least dependent area of chest with ultrasound probe (in supine patients—3rd-5th rib interspace midclavicular line) at 6 cm in 2D with indicator toward the patient's head and held perpendicular to chest wall (Fig. 15.9). 3. Identify the pleural line and seek lung sliding. Lung sliding confirms that the lung is touching the chest wall. Presence of lung sliding rules out large tension pneumothorax. 4. Seek B lines in 2D. Presence of B line rules out large tension pneumothorax in the scanned space. 5. Check for seashore sign in M mode at site of lung sliding (Fig. 15.10). Presence of seashore sign rules out large tension pneumothorax in the scanned space. 6. Alternatively, absence of seashore sign and presence of bar code (Fig. 15.11) sign indicate pneumothorax. The lung point sign is a moving dark point seen at the interface of normal lung sliding to the air of the pneumothorax. If lung point sign is present, this indicates pneumothorax. 7. If all the above signs are absent and A lines are present, this does not rule out or in pneumothorax. Other modalities such as CXR or CT for diagnosis or continuing with diagnostic/therapeutic needle thoracostomy will be required. 8. Prep skin. Place angiocath/needle to side of probe. 9. Enter the selected intercostal space anteriorly over the upper border of the inferior rib to avoid neurovascular bundle; attempt to visualize needle tip. 10. With entry into the pleural space, there may be an audible rush of air, and there should be immediate hemodynamic improvement. 11. Remove needle once hemodynamics or ventilation improves to avoid lung laceration. The angiocatheter may be held in place until a chest tube is inserted.

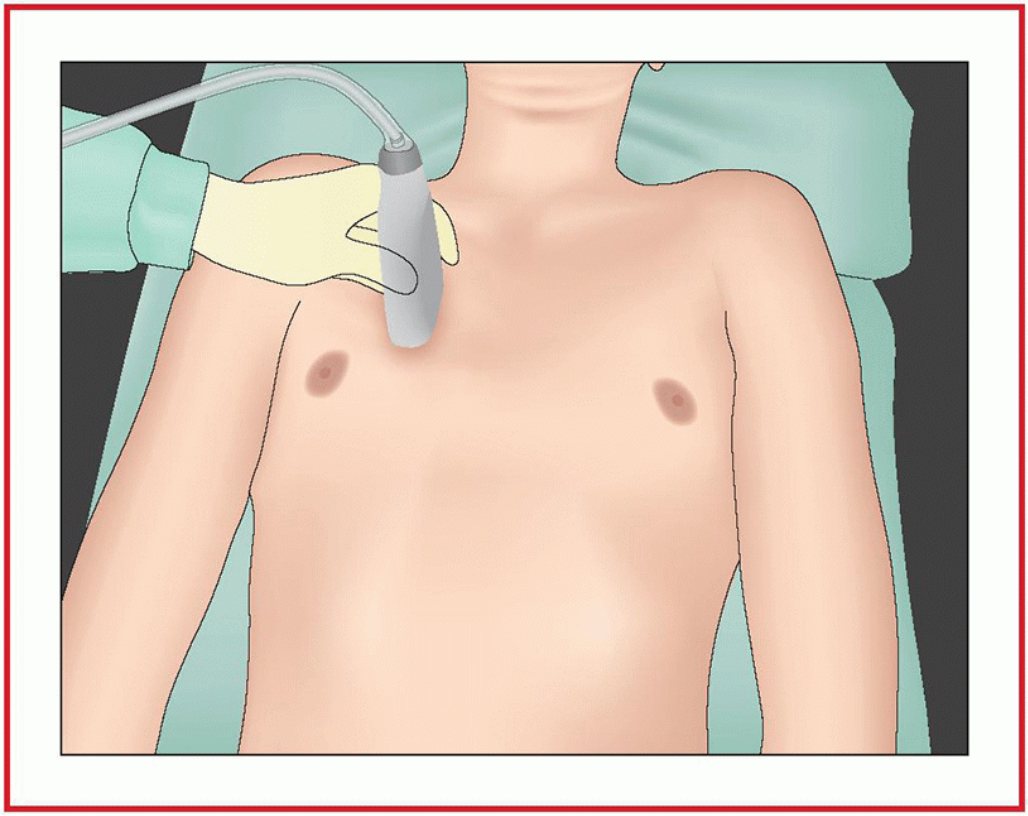

Figure 15.9 Place probe with indicator toward patient's head, perpendicular to chest wall, at the 3rd-5th intercostal space midclavicular line. In a supine patient, gas typically rises to this least dependent area of the chest cavity. You may move the probe caudally to scan multiple rib spaces in the midclavicular and axillary lines. (Ueda K, Ahmen W, Ross AF: Intraoperative pneumothorax identified with transthoracic ultrasound. *Anesthesiology* 2011; 115(3):653-5.[8])

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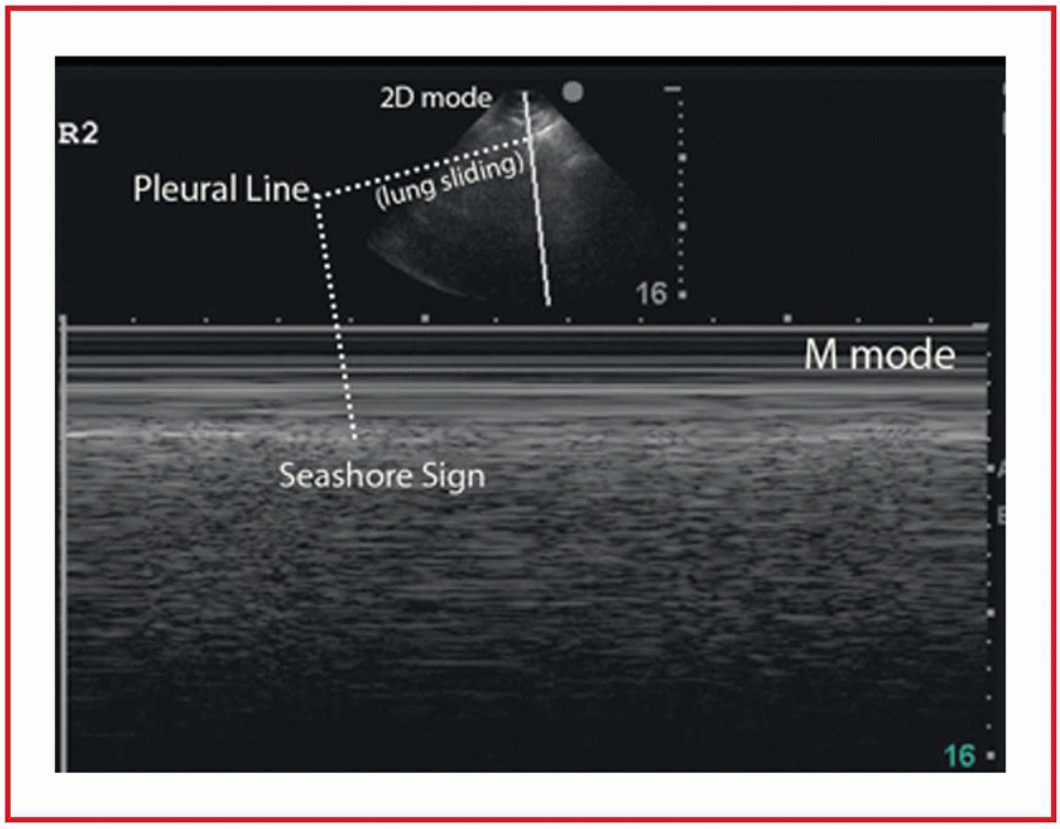

Figure 15.10 Seashore sign. M mode between the rib interspace with normal lung motion. The less mobile subcutaneous tissues and pleural tissues are seen as horizontal lines implying "waves" landing on a "sandy beach," the moving lung tissue represented by granular pattern below the pleural line.

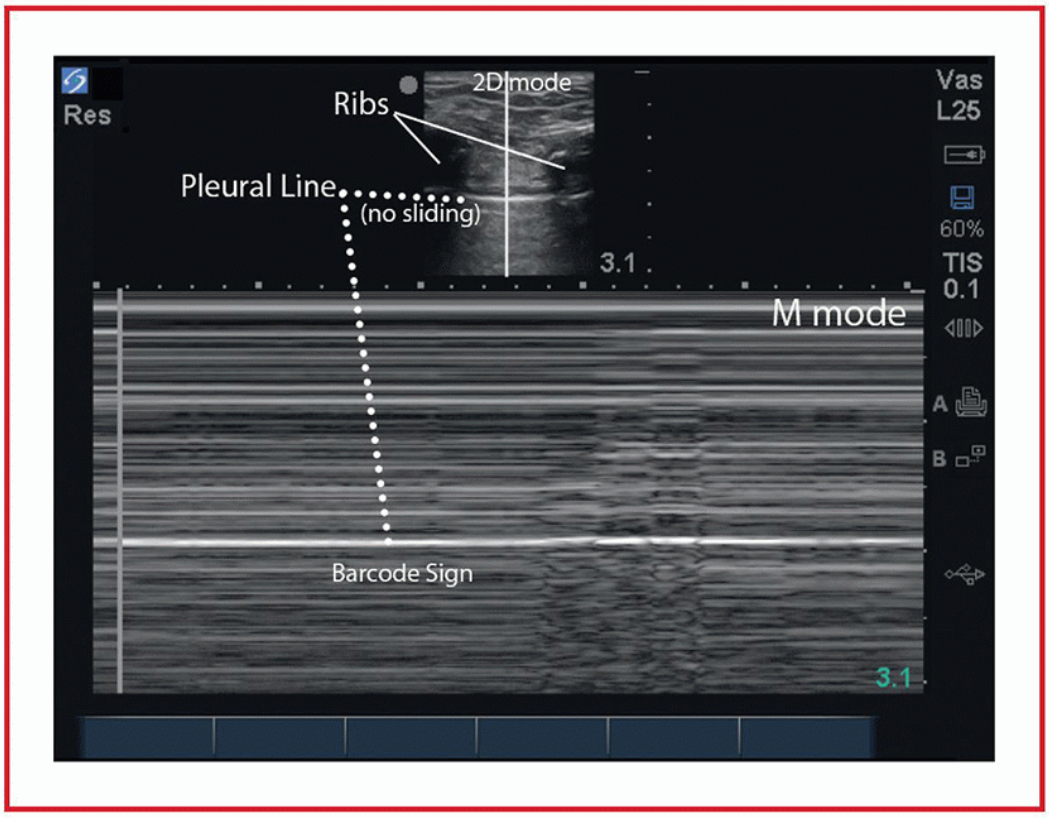

Figure 15.11 Bar code sign. During respiratory cycle, the "sand" (normal granular pattern) under the pleural line is replaced by "bar code" horizontal lines, indicating no lung sliding. (You-Ten KE, Siddiqui N, Teoh WH, et al: Point-of-care ultrasound (POCUS) of the upper airway. *Can J Anaesth* 2018; 65(4):473-84.[9])

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EMERGENCY INTRAOSSEOUS ACCESS

Emergency intraosseous (IO) access is indicated when immediate vascular access is needed, and peripheral/central access is not possible, and endotracheal medication administration will not suffice. We discuss the use of the EZ-IO system of IO access. Contraindications include burn, infection, or fracture of bone selected for access, joint replacement at selected site, or inability to identify landmarks.

1. Prior to attaching the EZ-Connect®: ensure clamp is open. Prime set and purge air. Identify and clean insertion site (Fig. 15.12).

2. Snap EZ-IO needle set with plastic hub onto EZ-IO power driver (Fig. 15.13); (Red 15 ga, 15 mm for <40 kg. Blue 15 ga, 25 mm for >40 kg. Yellow hub 15 ga, 45 mm, >40 kg and excessive tissue or humerus site).

3. Remove needle safety cap.

4. Gently press needle set through skin until tip touches bone.

5. At least 5 mm of the catheter must be visible (Fig. 15.14).

   Squeeze driver trigger and apply gentle, steady pressure.

Procedure	Release trigger when sudden “give” or “pop” is felt, indicating entry into medullary space. If driver stalls or will not penetrate the bone, you may be applying too much downward force. Humerus site: to improve stability, needle should be advanced 2 cm after contact with bone. In adults, advance needle until catheter hub is against the skin. Change sites for access rather than have repeated attempts at the same site. 7. Remove power driver and stylet; confirm catheter stability with at least three of the following four methods: ◦ Stability of catheter ◦ Ability to aspirate ◦ Physiologic or pharmacologic changes with medication administration ◦ Adequate flow rate 8. Secure with EZ-stabilizer or have an assistant manually stabilize hub until secured, roll 2 sets of 4 × 4s into tight cylinders, apply cylinders in a parallel orientation around catheter, “sandwiching” the hub, then secure with tape or transparent adhesive film with hole cut out for hub access. 9. Attach EZ-Connect® extension set. DO NOT ATTACH A SYRINGE DIRECTLY TO THE EZ-IO CATHETER HUB EXCEPT WHEN DRAWING BLOOD FOR LABORATORY ANALYSIS (STABILIZE NEEDLE SET). 10. Flush the EZ-IO catheter with normal saline (10 mL for adults; use appropriate weight-based dose for smaller patients). For patients responsive to pain, consider lidocaine up to 0.2-1 mg/kg io slowly prior to saline flush.
EZ-IO Removal	Attach Luer-lock syringe. Rotate syringe and catheter clockwise while using traction to withdraw catheter—DO NOT ROCK OR BEND THE CATHETER DURING REMOVAL (Fig. 15.15).

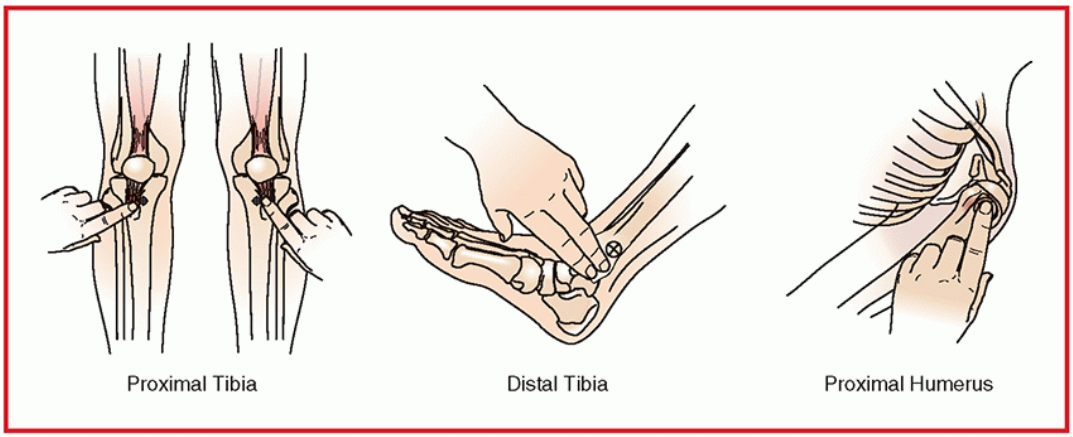

Figure 15.12 Identify and clean insertion site (proximal or distal tibia or humeral head).

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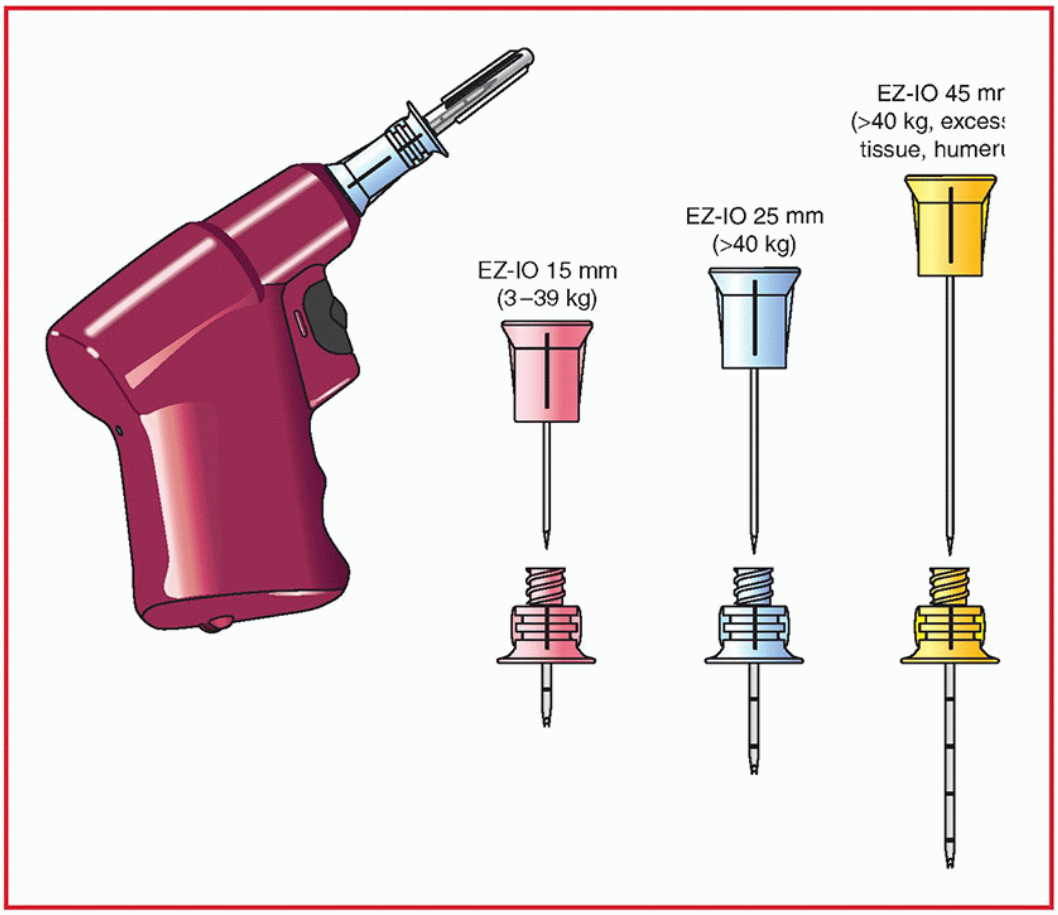

Figure 15.13 EZ-IO power driver and needle set sizes.

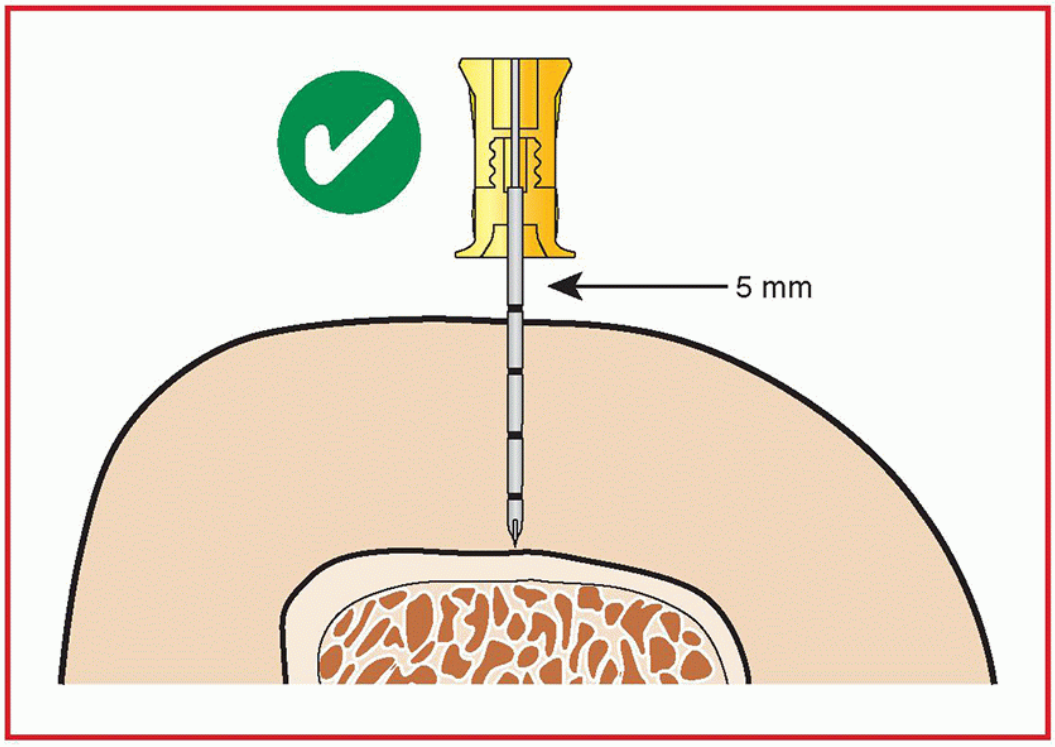

Figure 15.14 At least 5 mm of the catheter must be visible after pressing needle through skin to contact bone and prior to squeezing trigger.

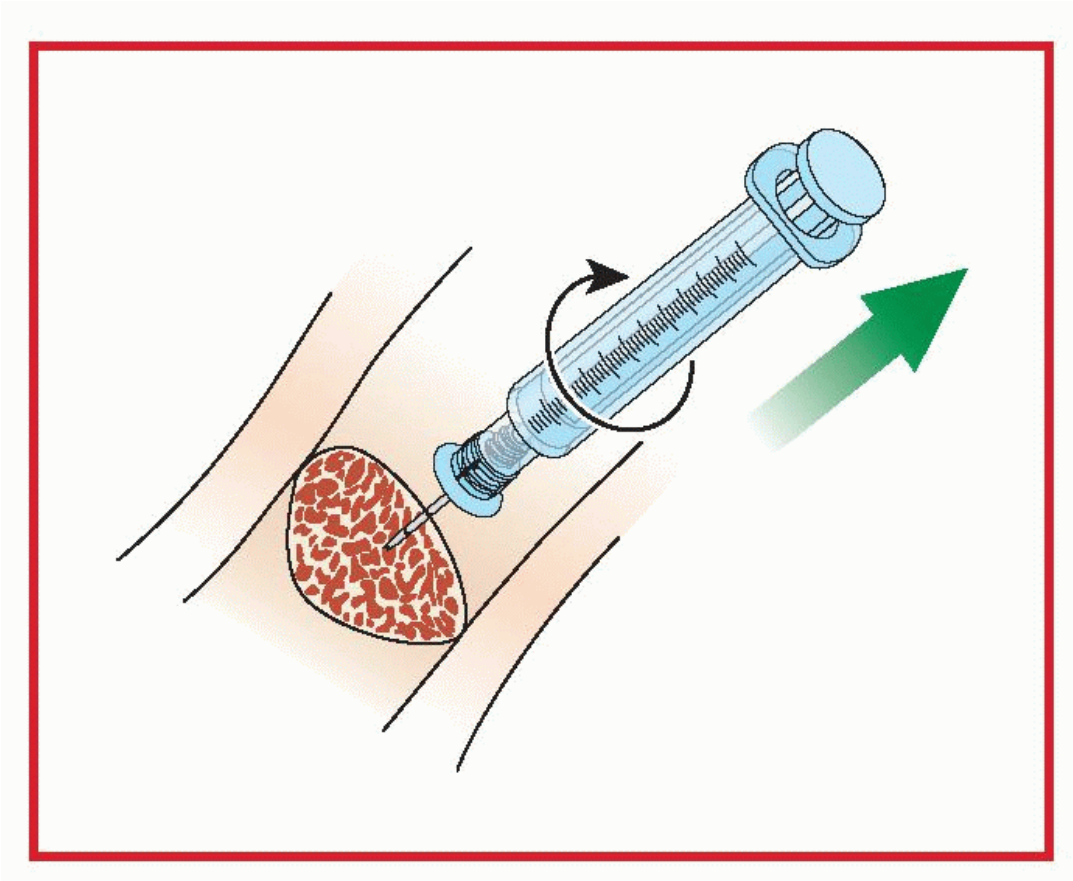

Figure 15.15 To remove EZ-IO catheter, attach Luer-lock syringe. Rotate syringe and catheter clockwise while using traction to withdraw catheter.

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9. You-Ten KE, Siddiqui N, Teoh WH, et al: Point-of-care ultrasound (POCUS) of the upper airway. *Can J Anaesth* 2018; 65 (4):473-84.