University of Calgary and University of Alberta

General Internal Medicine

Procedural Manual

Ultrasound Guided Thoracentesis

This script is intended for Personal Study Only.
Please send all feedback to corresponding author: ima@ucalgary.ca
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James Kiberd, MD[1]; Alex Chee, MD[2]; Elaine Dumoulin, MD[2]; Kelvin Tran, MD[3]; Irene Ma, MD, PhD, RDMS, RDCS[1]

Peer reviewer: Ada Lam, MD, MSc[3]

[1] Division of General Internal Medicine, University of Calgary

[2] Division of Respiratory Medicine, University of Calgary

[3] Division of General Internal Medicine, University of Alberta

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Useful Online Thoracentesis Videos

1) 22-minute video from Harrison's Principles of Internal Medicine, 20e. Clinical Procedure Tutorial, available via Access Medicine®: Go to Multimedia>Procedural Videos > Pulmonology > VIDEO CP02-1: Clinical Procedure Tutorial: Thoracentesis.[1]

For learners at the University of Calgary:
https://accessmedicine-mhmedical-com.ezproxy.lib.ucalgary.ca/MultimediaPlayer.aspx?MultimediaID=17670475

2) 9-minute video from The New England Journal of Medicine Videos in Clinical Medicine series:[2]
https://www.nejm.org/doi/full/10.1056/NEJMvcm053812

Video on Confirming the Presence of Pleural Effusion Using Ultrasound

1) 6-minute on confirming pleural effusion with Ultrasound
https://sites.google.com/site/calgaryimus/home/lung

Pre-Procedure Checklist

The Canadian Internal Medicine Ultrasound (CIMUS) pre-procedural checklist can be found here:
https://drive.google.com/file/d/1az_ySd4uylZM1t57F_Q0qhIBE4s-iC8e/view?usp=sharing

You can also get to it here: www.cimus.ca > Procedures tab on the left

Notes below are intended for refresher and Personal Study Only. Not for Distribution.

Patient Preparation

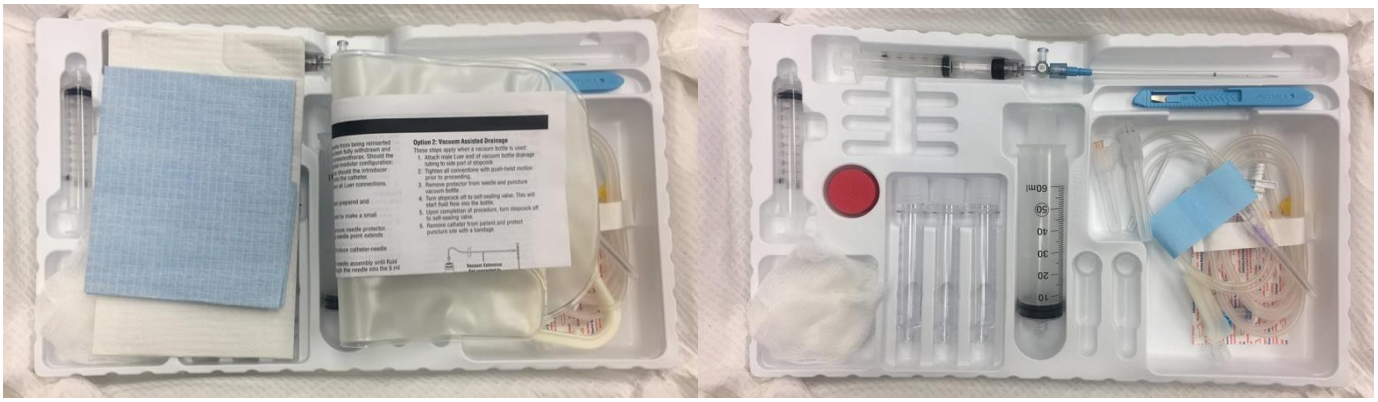
Ensure procedure indicated	• **Diagnostic:** Pleural effusions of unknown cause (especially if unilateral)[3] requiring a diagnosis,[4,5] e.g. need to rule out empyema, those without an obvious cause[2] • **Therapeutic:** To relieve symptoms of dyspnea, pain, discomfort from pleural effusion, or as part of treatment for pleural-based infections
Ensure no contraindication	• Overlying skin or subcutaneous infection[2] • Uncooperative patient (depending on degree of uncooperativeness, may be a relative contraindication) • Patient refusal
Coagulation *Note – refer to latest guidelines for recommendations*	• Thoracentesis is considered a low bleeding risk procedure[6] • In one guideline:[7] Correct if INR $\geq$ 2-3 and platelet transfusion if < 20 x 10^9/L • In another guideline (Thrombosis Canada): [8]warfarin does not need to be interrupted for thoracentesis due to the procedure being of minimal bleed-risk • For patients on direct oral anticoagulants (DOAC), it was felt to be *likely* safe to not interrupt anticoagulation,[9] however, data to support ongoing DOAC use is lacking. Consideration could be made to *hold dabigatran on the day of the procedure* or to *delay the day's dose for 4-6 hours after the procedure*[9] • Antiplatelets can be continued without interruption[10] • In patients with stable cirrhosis (known baseline abnormal coagulation parameters) undergoing thoracentesis, the American Gastroenterological Association recommends against extensive pre-procedural testing (INR, platelet) and against the routine use of blood products (FFP or platelet) for bleeding prophylaxis[11]
Relative contraindications	• Chronic kidney disease, INR > 1.5, and platelet < 50 x 10^9/L are independent risk factors for bleeding[12] thus caution should be exercised in such patients • Hemodynamic or respiratory compromise[2] • Inexperience with ultrasound: All thoracentesis is strongly recommended to be performed under ultrasound guidance[5] • Small or loculated effusion should be drained under direct (dynamic) image guidance, which requires expertise (e.g. interventional radiologists/respirologists or experienced proceduralists)[2] This module covers only static guidance technique • Prior pleurodesis or extensive surgery on ipsilateral side[1] • Severe lung function compromise on contralateral side (e.g. pneumonectomy, pneumothorax)[1]
Obtain patient consent	• Ensure patient has capacity to consent If not, obtain consent from substitute decision maker (SDM) • Go over indications, complications (common and rare but serious ones), options for the patient if he/she does not wish to undergo procedure • Obtain written consent prior to procedure

Common complications	• Pneumothorax in ~6%; 34.1% of these may require chest tube insertion[13]
	  • US guidance lowers the odds of a pneumothorax by 70% (OR 0.3)[13]
	  • Risk of pneumothorax is higher in those receiving mechanical ventilation[13]

	• Pain (2.7%), coughing (0.8%), or dyspnea (1%), vasovagal reaction (0.6%) during procedure[14,15] • Bleeding (hemothorax, bleeding at the puncture site, chest wall hematomas): 1-2%[15,16] • Iatrogenic infection • Fluid re-accumulation • Non expandable lung – not a complication per se, but in lung entrapment (e.g. obstructive atelectasis, interstitial lung disease) or trapped lung (from pleural causes), lung may not re-expand post removal of pleural effusion
Rare complications	• Organ injury: spleen, liver, and pericardium causing tamponade[17] • Re-expansion pulmonary edema, as high as 16% reported,[15] although more commonly reported incidence of <1%[14,16] To minimize this risk: **Never remove more than 1500 cc**[2] • Hypotension (<2%)[15] • Air embolism (lung parenchymal injury can facilitate gas bubble entry into the pulmonary venous system)[18] • Death • Intercostal neurovascular bundle injury • Unsuccessful procedure –Risk of a "dry tap" may be as high as 7.4%.[15] Ensure patient aware there is a risk of being unsuccessful at the bedside, necessitating another attempt or radiologically-guided procedure

Equipment Gathering

Note: Items in purple are already in the standardized kit (see Figure 1)

Ultrasound machine	• Curvilinear transducer and linear transducer (optional, for easier visualization of intercostal vessels) Phased array or microconvex transducer an acceptable alternative to curvilinear transducer • Ultrasound gel • Towel to wipe gel off • Disinfectant wipes
For preparing field	• Blue soaker pad • 3 chlorhexidine swabs (large swabs preferred where available) • Thoracentesis/paracentesis tray (see Figure 1)
 **Figure 1: Thoracentesis/Paracentesis Tray**	
For anesthesia	• 1-2% lidocaine Lidocaine with epinephrine can be considered for patients with higher risks of bleeding.[5] Do NOT exceed maximum dose of lidocaine (see "anesthesia" section in Procedural Steps below for details) • 10 cc syringe* • 25G needle*; 1.5 inch 22G* for deeper tissues 22G spinal lumbar puncture needles can be used if the depth of tissues exceeds 1.5 inches
For procedure	• Sterile gloves, face mask, eye protection, sterile gown (sterile gown optional) • Sterile drapes, sterile gauze • 60 cc syringe* • 18 G over the needle catheter* (Angiocath™) • Or a 5F One Step™ catheter or Caldwell needle with a 3- way stopcock – however we do not recommend this device for novice learners due to the higher risk of accidentally introducing air into the pleural space • Scalpel to get needle through skin Optional: sterile ultrasound probe and sterile gel, if using dynamic technique or if need to confirm the location of structures mid-procedure
For diagnostic collection	NB: specimen tubes needed may be site-specific: **For Calgary:** • Lavender EDTA tube (cell count)

	• Gold-top tube SST (chemistry, albumin) • Aerobic/anerobic culture bottles (need to inoculate 10cc of specimen at bedside) – use of blood culture bottles increases yield[19]; also send sample for C&S in a Starplex container • Blue transfer set for inoculating culture bottles if available (Figure 2); if not, use a blunt fill transfer filterless needle (red hub, see Figure 3 below) • Starplex (orange top) containers (gram stain, culture, cytology) • Arterial blood gas syringe for pH (collect 1.5 cc) • Cytology: Calgary Lab Services will accept a maximum of 3 Starplex containers
	For Edmonton: • Acceptable to send all samples in Starplex containers or the clear specimen tubes that are in the procedural kit • Consider direct inoculation into aerobic/anerobic culture bottles to increase yield (8-10 mL per bottle); also send sample for C&S in a Starplex container For cytology, may send up to 5 Starplex containers (ideally send at least 200 mL for cytology to increase yield)

Figure 2. Transfer set. Transfer set and its packaging (left panel). Remove the white tip (bottom left in middle panel) to connect to the syringe that contains the fluid sample. Keep the inner adapter insert (top right, middle panel) in place for collection into sample tubes. For blood culture bottles, remove the inner adapter insert. When removing the inner adapter insert, be careful not to reach in too deep to where the sharp needle is (yellow arrow, right panel).

Figure 3. Blunt fill (filterless) needle.
Note: the hub should be red in colour, not purple. Needles with purple hubs have filters and will not allow easy transfer of samples

For therapeutic collection	• Large vacuum drainage containers If vacuum containers not available, may use any large containers (e.g. 2L gravity bag in the procedural kit; urine Foley bags)
For post-procedure	• Bandage • Petroleum/parraffin-impregnated gauze (Jelonet)

Items in purple are already in tray (see Figure 1)*

Procedure Steps (after consent obtained): This module will cover static guidance in the sitting position only

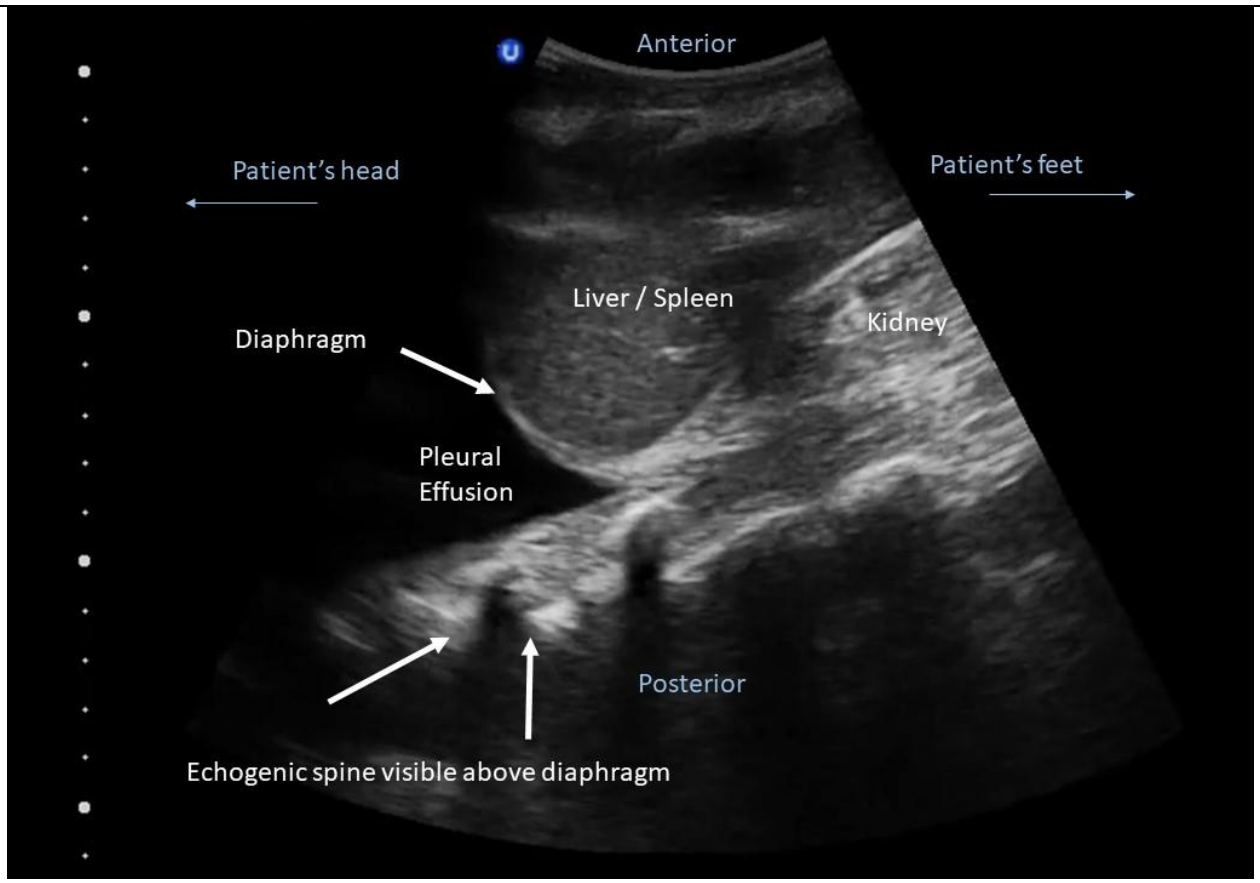
	Gather equipment (see above)
	Print up lab requisition forms (if performing diagnostic taps) and patient labels, where relevant
	For diagnostic thoracentesis, ensure you also have a serum LDH and protein level available
	Wash hands
	Perform initial lung ultrasound (US) scan to confirm the presence of pleural effusion
	US positive spine sign confirmation: With the patient lying in a supine position, or in a supine position with the head of the bed elevated at 10-20^0, perform a coronal scan in the left or right lower lung zone at the level of the diaphragm. The presence of pleural effusion is demonstrated by a positive spine sign (where the spine is visible above the diaphragm (cephalad to the diaphragm), Figure 3) and the presence of anechoic pleural effusion is seen above the diaphragm (see video: https://sites.google.com/site/calgaryimus/home/lung)
	 **Figure 3. Positive Spine Sign.** Positive spine sign, defined as the presence of hyperechoic spinous elements seen above the level of the diaphragm, **must be present** before declaring pleural effusion present. This view is obtained via a coronal view, with the patient in a supine position, transducer marker to the patient's head.
	Optional: While the patient is supine, assess for the presence of normal lung sliding in the anterior lung zone. These results will be helpful for evaluating for peri-procedural pneumothorax post-procedure[20]
	Review radiographic imaging to confirm the presence of free-flowing, non-loculated pleural effusion
	Traditional teaching is that it is reasonable to proceed with thoracentesis if the fluid is > 1cm in height on a lateral decubitus radiograph[21]
	Position the Patient – Note: This manual covers ONLY the sitting position
	Wash hands again
	Obtain a set of baseline vitals
	Have patient sit upright, elbows supported on table, not leaning too far forward (Figure 4).

Figure 4. Patient Positioning for Bedside Thoracentesis. The patient should be seated comfortably at the edge of the bed, arms forward (and supported by a table) to increase the inter-scapular distance.

Place blue soaker pad under the patient

Physical Exam: Percuss out the fluid level and note the possible needle entry site at 1-2 intercostal spaces below the level of the effusion.[2] This site must be at least 5-10 cm lateral to spine (avoid too medial or close to spine due to aberrant vessels) and NEVER below 9th rib[2]

Ultrasound Confirmation

Perform a longitudinal view, with the transducer marker towards the patient's head)

We recommend that needle insertion site be confirmed by ultrasound for the following 9 things:

1) That the **size of effusion is sufficient** for sampling. For novice/inexperienced proceduralists, we recommend at least 5 cm of free fluid between the pleura and underlying lung/diaphragm.
2) That the **underlying lung** is either not visible throughout the respiratory cycle, or if visible, that the underlying lung does not cross the intended needle path even with deep inspiration
3) Locate **the diaphragm and intra-abdominal organs** to ensure that these structures are at least 3-5 cm away from the intended needle path, even with deep inspiration/expiration.
4) Ensure that the intended needle path is sufficiently distant from the **heart** and vascular structures
5) Fan (or tilt) the transducer laterally and medially to ensure that the pocket remains suitable
6) Use Doppler to ensure that the needle insertion site is not **overlying vascular structures (Figure 6)**
7) That the site is **just above a rib** (Figure 5)
8) **Estimate the depth** from skin surface to pleura (Figure 5).[20] If this depth is longer than the length of the freezing needle in the kit (typically 1.5 inches/3.8 cm long), a longer freezing needle will be needed (e.g. a 22G spinal needle could be considered)
9) **Estimate the depth** from skin surface to the underlying lung (Figure5). Needle insertion during the procedure should not exceed this distance

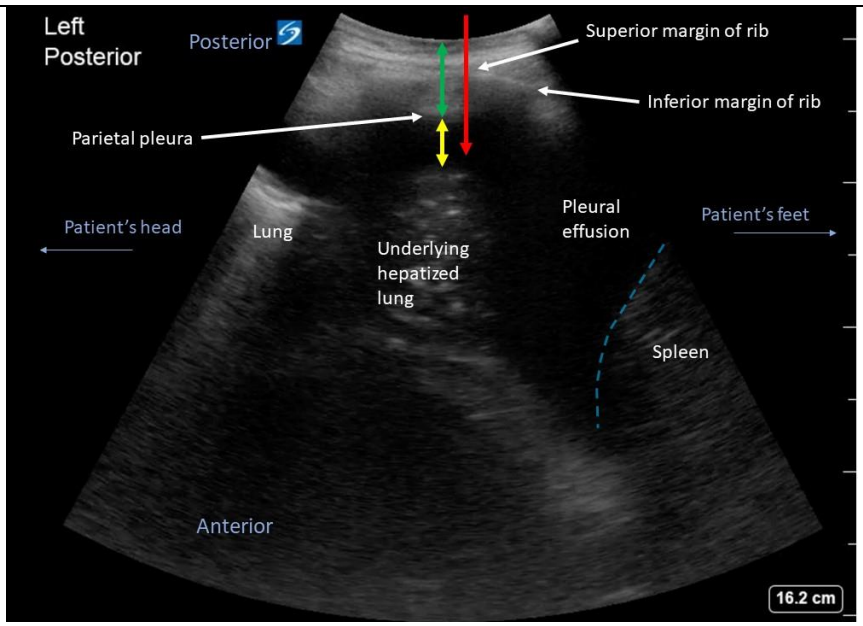


Figure 5. Posterior longitudinal view of an effusion. This amount of fluid depicted in this figure is likely too small for inexperienced trainees/proceduralists to attempt to drain.
Red line indicates direction of intended needle path, just at the superior margin of a rib (transducer marker oriented towards the patient's head). While this site is distant from the spleen and underlying diaphragm (blue dotted line), the size of the effusion to the closest lung border is only approximately 2 cm (indicated by the yellow line with arrow heads). This size is too small for most inexperienced proceduralists and should not be attempted unless closely supervised. The distance from the skin to the parietal pleura can be estimated by the green line (approximately 2.5 cm in this case).

To evaluate for the presence of the intercostal vessels, use colour or power Doppler. Vessels are expected at the inferior margin of the rib (Figure 6). A linear transducer may allow easier visualization.

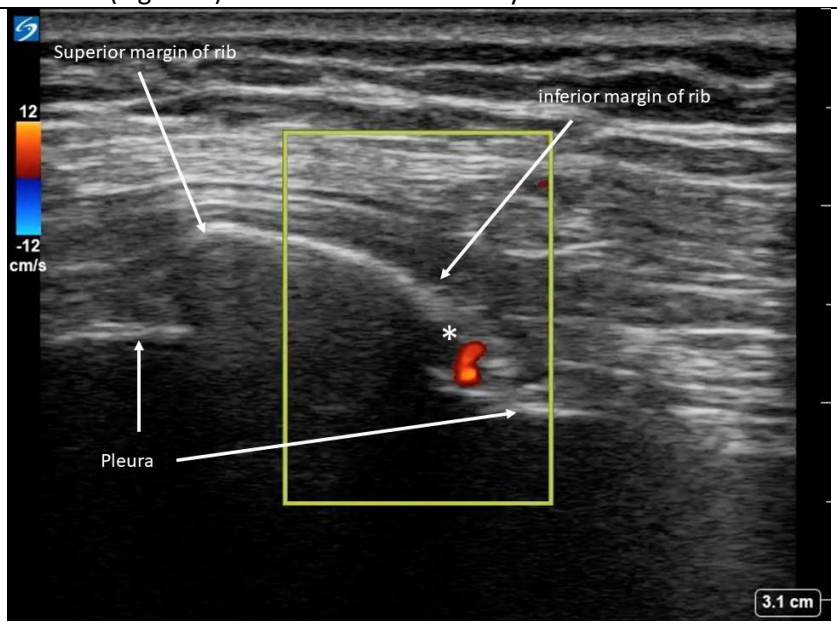
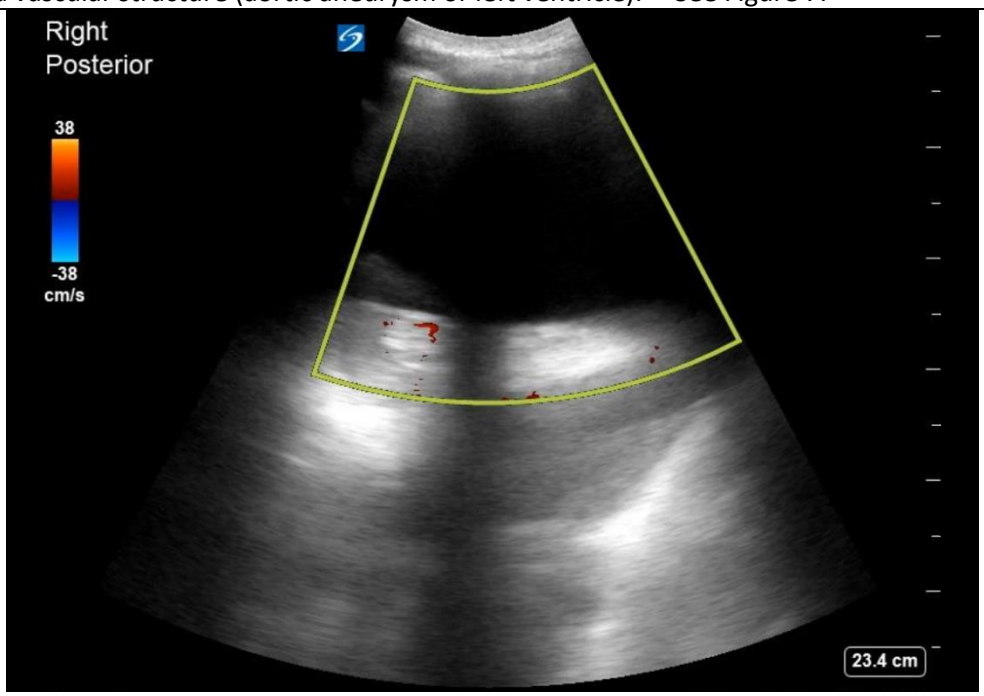
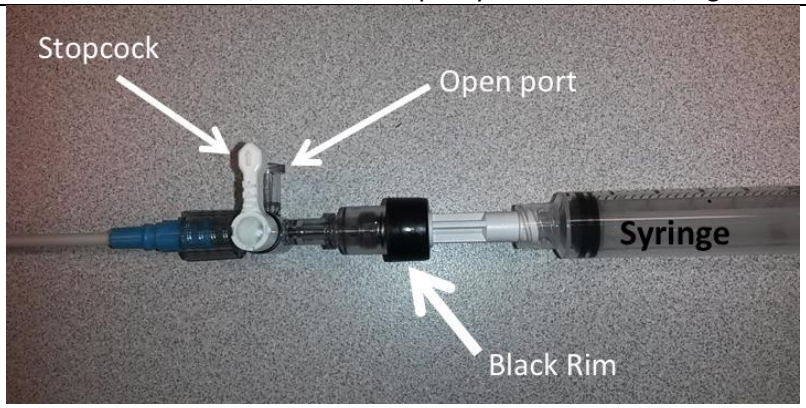


Figure 6. Evaluating for the presence of intercostal vessels with colour Doppler.
A linear transducer, with the marker oriented towards the patient's head, was used to generate this image. The intercostal vessels (marked by the asterisk) are located at the expected location in this case, beneath the inferior margin of the rib. The corresponding area at the superior margin of the rib, should also be assessed to ensure it is free of vasculature.

	Move Doppler box to beneath the pleura to ensure that the anechoic area beneath the pleural line is indeed fluid and not a vascular structure (aortic aneurysm or left ventricle).[22] See Figure 7.
	 **Figure 7. Ensuring the anechoic area seen is not a vascular structure.** To ensure that the anechoic area observed beneath the pleura is not a vascular structure, place the Doppler box over the target area. Absence of signal observed decreases the probability that the area observed is a vascular structure.
	Mark Target Site for Needle Entry
	After ensuring site is free from lung, organs/structures, overlying vessels and has a safe size pocket of effusion, mark with a surgical pen or sustained pressure with end of needle cap
	Wipe off nonsterile gel
	Wash hands and don nonsterile gloves
	If no allergy to chlorhexidine, clean with chlorhexidine swabs x 3, allowing it to dry in between, with application and dry time per manufacturer's recommendations.[23] For example, for the 3M™ SoluPrep™ (2% chlorhexidine gluconate, 70% isopropyl alcohol swabs), a minimum 30 sec application time is recommended[24]
	If using a procedure kit that has sterile chlorhexidine sponges within the kit itself, then cleaning should be done after donning personal protective equipment step (see below)
	If allergy, use 70% alcohol, or iodine[23]
	Don Personal Protective Equipment
	Wash hands again, put on mask, face shield/eye protection, sterile gown (optional), and sterile gloves
	Prepare field
	Remove the sticker from the fenestrated drape and drape this over the site of needle insertion (be careful not to contaminate your gloves during draping)
	Place the non-fenestrated drape beneath (on the bed) to create a larger sterile surface. Again, be careful not to contaminate your gloves
	Anesthesia
	Using 25 G needle, raise lidocaine bleb under skin, aspirate as you go in (to ensure you are not in a blood stream), inject as you come out
	Use a 22G needle for deeper tissues (same technique, aspirate as you go in, inject as you come out) until you are into pleural space. Ensure your needle track is just above the superior aspect of the rib
	Once in the pleural space, inject 3-5 cc more to anesthetize the parietal pleura (do not exceed 30 cc)
	Mentally note the depth and needle angle required to reach the pleural space (should correspond to the

	depth noted on ultrasound)
	Be cautious: overuse of anesthetic in superficial layers may distort landmark, Use the minimum amount to achieve sufficient anesthesia without exceeding the maximum recommended amount – the procedure should be as painless as possible
	Note
	Maximum recommended dose of lidocaine without epinephrine is 4.5 mg/kg or 300mg[25]
	Maximum recommended dose of lidocaine with epinephrine is 7 mg/kg or 500mg[25]
	In practical terms, 1% lidocaine contains 10 mg lidocaine per mL; thus 300 mg = 30 mL
	The amount necessary for sufficient analgesia should be significantly less than 30 mL
	Needle Catheter Insertion
	Optional: if difficulty inserting the needle catheter device, make a small nick (1-2mm) in skin with scalpel
	Palpate marked site to ensure it is above a rib
	Using the needle catheter device, aspirate as you advance the needle; watch for pleural fluid in the syringe.
	Once pleural fluid is aspirated, advance just a few mm (~ 2-5 mm) more to ensure catheter is also fully in the pleural space
	Holding the needle steady (**do not further advance or retract the needle**), slide the catheter off the needle and advance the catheter all the way in. For the hand that is holding the syringe attached ot the needle, you can anchor that arm/elbow to your side to stabilize yourself. Once you have stabilized this, use other hand to push the catheter in. The black hub is the part attached to the catheter, so that's the part you will advance, Figure 8
	 **Figure 8. 8 Fr. Angiocath in Safet-T™ Thora-Para Tray** Once fluid is obtained, hold the syringe steady and advance the black rim/hub, which is connected to the catheter, into the pleural space.
	Remove the needle once catheter fully advanced
	Apply 60 cc syringe to the open port to collect specimens
	Turn the stopcock towards the black rim (Figure 8) to allow flow during fluid collection
	When collection complete, turn the stopcock towards the catheter (side closest to patient) to prevent any air from being introduced into the pleural cavity. Do that first BEFORE removing the syringe
	If additional drainage is needed, connect tubing to the open port and connect the other end of the tubing to a drainage system (vacuum container or drainage bag). Turn the stopcock away from the catheter (towards the black hub) to begin drainage. If vacuum containers are used, lower the suction (negative pressure) applied by using the roller clamp to minimize the risk of re-expansion pulmonary edema and symptoms[26]
	NEVER leave the open port unconnected with the stopcock turned towards the black rim
	When to stop the procedure:
	1) When 1500 cc has been drained or when no further fluid can be drained, whichever comes first. Do NOT drain more than 1500 cc
	2) Patient develops a persistent cough or complains of chest pain[27]
	Note: occasional coughing is not uncommon during the procedure and can be a sign of lung re-expansion, catheter irritation of the underlying lung, or the development of a pneumothorax. If

	coughing is persistent, stop the procedure and consider evaluating with ultrasound and/or obtaining a chest radiograph to rule out a pneumothorax[27]
	Important safety points:
	1) Should not attempt procedure $\geq$ **2 times**.[13] Ask for help if unsuccessful
	2) If you aspirate air upon needle entry, ask for assistance. You may have caused a pneumothorax. Check your stopcock to ensure that the system is not open to air. If it is not open to air (and therefore a pneumothorax is probable), monitor the patient, withdraw the needle, start supplemental oxygen, and perform imaging studies (chest radiograph or ultrasound) for pneumothorax
	3) **NEVER leave the open port** unconnected with the stopcock turned towards the black rim
	4) For therapeutic thoracentesis, limit amount removed to **< 1500 cc** to minimize risks of re-expansion pulmonary edema[2]
	Post-procedure
	Have the patient hum (without an initial deep inspiration, since deep inspiration may precipitate coughing) or have the patient hold their breath during end expiration.[2]
	Remove the catheter while the patient is humming or holding their breath as above and apply occlusive (Jelonet) dressing (Figure 9) and secure dressing
	 **Figure 9. An example of occlusive gauze**
	Dispose of sharps
	Measure vitals (blood pressure and heart rate) post-procedure. Consider monitoring vitals during procedure if large volume of pleural fluid is being removed
	Examine the fluid and send for appropriate labs
	Re-evaluate for the presence or absence of lung sliding post-procedure (at multiple interspace anteriorly, with the patient lying supine)
	Document the procedure (including any complications) in the patient chart
	Post-thoracentesis chest radiograph, while not indicated routinely in asymptomatic low-risk patients[28,29] whose post-procedural ultrasound shows lung sliding, it should be performed if air is aspirated during the procedure,[29] any suspicion of pneumothorax on ultrasound, ultrasound scan for assessing for pneumothorax was suboptimal, presence of symptoms,[28] if the procedure was difficult (e.g. requiring multiple attempts), or if quantitative follow-up of the size of the pleural effusion is indicated.

Troubleshooting Techniques

Sluggish flow or flow stops during drainage	
	Possibly due to loss of vacuum
	Ensure vacuum intact and no tubing leakage If able to manually aspirate using a syringe, but no flow to the vacuum bottles, check for leakage or loss of vacuum. Be careful with the stopcock position during checking with a syringe to ensure you do not accidentally introduce air into the pleural space
	Possibly due to underlying lung blocking ports
	Try: 1) rotating catheter; 2) redirect the angle of catheter; 3) withdraw catheter in 1-2 mm increments. Note that withdrawn portions of the catheter cannot be re-advanced
	Possibly due to a decrease in volume of pleural effusion available
	Redirecting the catheter inferiorly may allow additional fluid to be drained

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