Thoracentesis Technique

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Contents

Abstract

Thoracentesis is defined as drainage of fluid from the pleural cavity. It can be safely performed at a patient's bedside, office or procedure unit, or radiology suite. The most common indication is evaluation of a new pleural effusion of uncertain etiology. The major contraindication of the procedure is bleeding disorders, including various types of coagulopathies, thrombocytopenia, and administration of anticoagulants. The purpose of this chapter is to review in more detail the indications and contraindications for thoracentesis, give a brief review of pleural fluid evaluation, and explain the techniques of how the procedure is performed.

Keywords

Pleural Effusion · Pleural Fluid · Pleural Space · Pleural Pressure · Intrapleural Pressure

1 Introduction

Pleural effusions can cause significant symptoms of cough, fatigue, pleuritic chest pain, increasing dyspnea, and respiratory distress. Physical examination and chest radiograph can confirm the suspected diagnosis. It is caused by a disturbance between pleural fluid formation and impaired removal or drainage. It may not be solely a disease of the chest but may be a manifestation of many diseases elsewhere in the body, such as organ dysfunction of the cardiac, renal, or liver systems, or other systemic inflammatory diseases, such as rheumatoid arthritis or systemic lupus erythematosus [9]. A thorough history and physical examination, laboratory testing, and chest imaging should be completed prior to thoracentesis or sampling of the pleural fluid.

Symptoms of pleural effusion depend on the rapidity of fluid accumulation. Patients with shorter-term fluid buildup tend to be more symptomatic than those in which the fluid accrues over multiple weeks or longer. Symptoms may also depend on the underlying disease. Patients with nephrotic disease, for example, will typically be less symptomatic than those with congestive heart failure or a parapneumonic effusion from bacterial pneumonia. Whether the cause is clear or not and whether the patient is symptomatic or not,

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a new pleural effusion should be evaluated by thoracentesis to confirm the diagnosis [17, 22].

With the presence of pleural fluid, there is an increased distance between the lung and chest wall, interfering with sound transmission through the stethoscope. Changes in auscultation depend on the amount of fluid accumulation. It is difficult to detect fluid less than 250–300 cm^3. Auscultation of pleural fluid becomes possible at volumes of about 500 cm^3, with dullness to percussion and decreased fremitus. When volumes of pleural fluid approach 1000 cm^3, there is decreased expansion of the ipsilateral chest wall and absence of inspiratory retraction. With greater than 1000 cm^3 and progressive lung compression, the physician can see bulging of the intercostal spaces and absence of breath sounds over much of the chest, with bronchovesicular breath sounds at the apex (Table 1).

Chest radiograph can aid in the differential diagnosis [9]. If the effusion is bilateral, it is typically transudative (see below) and due to congestive heart failure, renal failure, liver failure, or hypoalbuminemia. Cardiac enlargement is frequently seen in congestive heart failure. If a bilateral effusion is found to be exudative (see below), malignancy is most common [18] but can also be seen with lupus pleuritis and rheumatoid pleurisy as well. When an isolated pleural effusion is the only abnormality, the physician should suspect infectious causes such as bacterial or tuberculous infections, in the right clinical setting. Rheumatoid pleurisy and lupus pleuritis can also present with an isolated effusion. Interstitial infiltrates in the setting of a pleural effusion are consistent with volume overload and congestive heart failure, rheumatoid disease, asbestos pulmonary disease, lymphangitic carcinomatosis, sarcoidosis, and lymphangioleiomyomatosis (LAM), among others. Nodular disease suggests malignancy but may also be seen with sarcoidosis and rheumatoid disease (Table 2).

Table 1 Volume of pleural fluid and associated findings on physical examination

Volume of pleural fluid	Physical examination findings
<250–300 cm^3	Probable normal examination
500 cm^3	1. Dullness to percussion
	2. Decreased fremitus
	3. Normal vesicular breath sounds but decreased intensity
1000 cm^3	1. Absence of inspiratory retraction, mild bulging of intercostal spaces
	2. Decreased expansion of ipsilateral chest wall
	3. Dullness to percussion up to the scapula and axilla
	4. Decreased or absent fremitus posteriorly and laterally
	5. Bronchovesicular breath sounds
	6. Egophany (E to A change) at the upper level of the effusion
Massive (filling the hemithorax)	1. Bulging of intercostal spaces
	2. Minimal to no ipsilateral chest wall expansion
	3. Dull or flat percussion
	4. Absent breath sounds
	5. Egophany at the apex
	6. Palpable liver or spleen due to diaphragmatic depression

Table 2 Chest radiograph findings of specific diseases

Chest radiograph findings	Diseases
Unilateral effusion	Infection
	Lupus pleuritis
	Rheumatoid pleurisy
	Metastatic malignancy, non-Hodgkin lymphoma, leukemia
	Pulmonary embolism
	Drug-induced pleural disease
	Yellow nail syndrome
	Hypothyroidism
	Uremic pleuritis
	Chylothorax
	Constrictive pericarditis
With mediastinal shift	Metastatic malignancy
Without mediastinal shift	Lung cancer
	Malignant mesothelioma
Diseases below the diaphragm	Transudative: hepatic hydrothorax, nephritic syndrome, urinothorax, peritoneal dialysis
	Exudative: pancreatitis, Meigs syndrome, chylous ascites, subphrenic/hepatic/splenic abscess
Bilateral effusion	Transudative: congestive heart failure, nephrotic syndrome, hypoalbuminemia, peritoneal dialysis, constrictive pericarditis
	Exudative: malignancy, lupus pleuritis, rheumatoid pleurisy
Associated with interstitial infiltrates	Congestive heart failure
	Rheumatoid disease
	Asbestos pulmonary disease
	Lymphangioleiomyomatosis (LAM)
	Viral and mycoplasma pneumonia
	Sarcoidosis
	Pneumocystis jiroveci pneumonia
Associated with multiple nodules	Cancer
	Wegener granulomatosis
	Rheumatoid disease
	Septic pulmonary embolism
	Sarcoidosis
	Tularemia

2 Pleural Fluid Analysis: Briefly

Pleural fluid can establish a definitive diagnosis in a limited number of diseases, such as empyema, malignancy, chylothorax, and rheumatoid pleurisy. It is highly useful in excluding potentially harmful diseases that warrant immediate intervention, such as empyema.

Initial evaluation of the fluid is performed at the time of thoracentesis, as the fluid is aspirated. Careful attention should be paid to the color (straw colored, serosanguinous, bloody, and white), consistency (pus, turbid, debris), and odor (foul smelling) of the fluid.

After visual inspection during the procedure, the fluid is sent for laboratory analysis. Broad classification of the fluid into transudative or exudative by chemical analysis is performed (Tables 3 and 4). Richard Light [15, 16] established a well-known algorithm for distinguishing an exudative pleural effusion based on three tests: (a) pleural fluid lactate dehydrogenase (LDH) > two-thirds the laboratory's upper limit of normal for serum, (b) pleural fluid to serum LDH ratio >0.6, and (c) pleural fluid to serum protein ratio >0.5. Only one of these results needs to be positive to confirm an exudative effusion. Light's criteria have a diagnostic accuracy over 90%, but it drops significantly to below 70–80% if one of the three categories is borderline. Several other laboratory tests can be analyzed in pleural fluid, including but not exclusive to glucose, pH, amylase, cholesterol, albumin, rheumatoid factor, B-type natriuretic peptide (BNP), and adenosine deaminase (ADA). There are many other tests and ways to analyze the pleural fluid from a thoracentesis, but that is outside the scope of this chapter.

3 Indications and Contraindications

The major indication for thoracentesis is the evaluation of an undiagnosed pleural fluid on initial presentation, unless volume overload is obvious, such as typical congestive heart failure (CHF).

Thoracentesis is contraindicated in patients with bleeding disorders until the abnormality has been corrected, or unless emergent, in the setting of respiratory distress. In the setting of anticoagulation administration or thrombolytics, using a small-bore needle can be done safely without increased risk of bleeding. This holds true as well in patients with renal disease and elevated creatinine and uremia levels causing platelet dysfunction. Use of pleural ultrasound at the time of the procedure also decreases risk of complications. Overlying areas of skin irritation, infection, or breakdown should be avoided. Mechanical ventilation is not a contraindication to thoracentesis.

Table 3 Causes of exudative pleural effusions

Causes		
Infectious	**Malignancy**	**Connective tissue disease**
Bacterial pneumonia	Carcinoma	Lupus pleuritis
Tuberculous effusion	Lymphoma	Rheumatoid pleurisy
Fungal disease	Mesothelioma	Mixed connective tissue disease
Atypical pneumonias	Leukemia	Sjögren syndrome
Nocardia, *Actinomyces*	Chylothorax	
Subphrenic abscess		
Hepatic abscess	**Other inflammatory**	**Endocrine dysfunction**
Splenic abscess	Pancreatitis	Hypothyroidism
Hepatitis	BAPE	Ovarian hyperstimulation syndrome
Spontaneous esophageal rupture	Pulmonary infarction	
Parasites	**Radiation therapy**	**Lymphatic abnormalities**
	Sarcoidosis	Malignancy
Iatrogenic	PCIS	Chylothorax
Drug-induced	Hemothorax	Yellow nail syndrome
Esophageal perforation	ARDS	Lymphangiomyomatosis (chylothorax)
Esophageal sclerotherapy	Cholesterol effusion	Lymphangiectasis
Central venous catheter misplacement/ migration		
Enteral feeding tube in pleural space		
	Increased negative intrapleural pressure	**Movement of fluid from abdomen to pleural space**
	Atelectasis	Acute pancreatitis
Vasculitis	Trapped lung	Pancreatic pseudocyst
Wegener granulomatosis		Meigs syndrome
Churg–Strauss syndrome		Carcinoma
Familial Mediterranean fever		Chylous ascites

ARDS acute respiratory distress syndrome, *BAPE* Benign Asbestos pleural effusion, *PCIS* post-cardiac injury syndrome

3.1 Technique

All patients with pleural effusions should undergo a diagnostic and therapeutic thoracentesis, performed in a single setting [17]. The rare exception exists, such as the patient with

a typical presentation for congestive heart failure, but this is not the norm.

There are many commercially available thoracentesis kits on the market. Examples include the Arrow kit (Reading, PA, USA) and the Cardinal Health Kit (Dublin, OH, USA) (Fig. 1).

Patients are positioned in a sitting position, even those who are mechanically ventilated, if hemodynamically stable. (If not, they can be placed in a lateral decubitus position [14].) The patient may sit on a bed or a stool with their back easily accessible to the operator. The patient may use a table or gurney with a pillow in front to rest their arms and a stool beneath their feet. Unless loculated, pleural fluid will bow to the effects of gravity. Therefore, it is best if the back of the patient is as vertical as possible to best ensure the pleural fluid remains posterior. If not, the fluid may flow anteriorly, away from the operator who is positioned posteriorly. The height of the bed or chair should be adjusted to the height of the operator, who may perform the procedure sitting or standing, whichever is more comfortable. A procedure table to the operator's side holds the necessary equipment or kit. Once positioning has been completed, additional assistance is not typically needed, unless patient deconditioning prevents them from maintaining a sitting position with their own strength, in which case extra hands are needed.

Table 4 Causes of transudative pleural effusions

Diagnosis	Comment
Congestive heart failure	Acute diuresis can increase pleural fluid protein and LDH concentrations
Cirrhosis	Uncommon without clinical ascites
Nephrotic syndrome	Typically, small and bilateral; unilateral, larger effusion may be due to pulmonary embolism
Peritoneal dialysis	Large right effusion may develop within 48 h of initiating dialysis
Hypoalbuminemia	Edema fluid rarely isolated to pleural space; small bilateral effusions
Urinothorax	Unilateral effusion caused by ipsilateral obstructive uropathy
Atelectasis	Small effusion caused by increased intrapleural negative pressure; common in ICU patients
Constrictive pericarditis	Bilateral effusions with normal heart size
Trapped lung	Unilateral effusion from imbalance in hydrostatic pressures from a remote inflammatory process
Superior vena cava obstruction	Due to acute systemic venous hypertension or acute obstruction of lymphatics
Duropleural fistula	Cerebrospinal fluid in pleural space; β2-transferrin diagnostic

ICU intensive care unit, *LDH* lactate dehydrogenase

The next steps are considered "safety steps." Prior to the initiation of the procedure and patient positioning, consent is obtained from the patient if able or from the health care proxy. Risks and benefits of the thoracentesis are clearly reviewed and documented in the patient's medical chart. With nursing or other medical staff in the room, a time-out is performed, ensuring the correct procedure is being performed on the correct patient and the correct side is being evaluated. The correct side, left or right, is also initialed by the physician performing the procedure.

After review of chest radiographs, physical examination is used to locate the best location to perform the thoracentesis. Decreased breath sounds are present over the pleural effusion, and there is a loss of tactile fremitus. Thoracentesis should be performed one intercostal space below where tactile fremitus is lost, and percussion becomes dull. However,

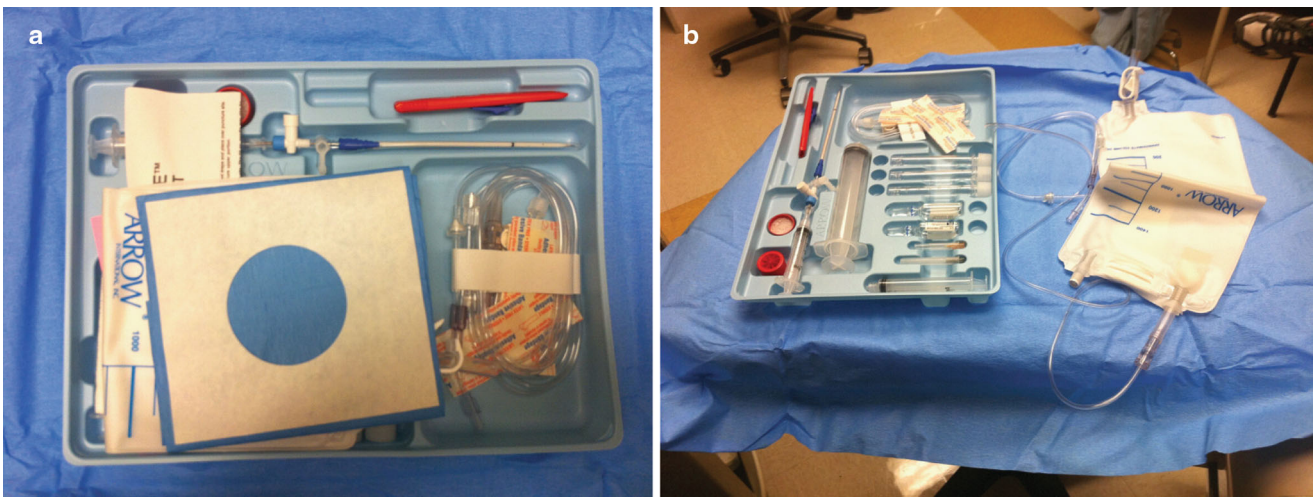

Fig. 1 Internal contents of a standard thoracentesis kit (Arrow, Reading, PA, USA): (**a**) Package with sterile drape inside; (**b**) open kit with collection bag, needles, and specimen tubes

with the use of ultrasound at the time of thoracentesis, a more inferior space closer to the diaphragm may be accessed more safely and allow drainage of more fluid. Thoracentesis is typically performed posteriorly, near the mid-scapular line or at least several inches lateral to the spine. The intercostal bundles, consisting of arteries, veins, and nerves, run behind and along the inferior margin of the rib, in the intercostal notch, along the posterior chest wall. Given this anatomy, needles and catheters accessing the pleural space should be placed on the superior margin of the rib, rather than inferiorly, to minimize complications.

Ultrasound guidance for thoracentesis is a very useful tool and considered standard of care [4, 5, 21]. It should be used real time, not marked by a radiologist or technician earlier in the day, with the thoracentesis then performed later after the patient has changed positioning. A significant reduction in pneumothorax risk has been shown (0% vs. 29% and 3% vs. 18%). It has also been used in successful drainage of pleural fluid after an unsuccessful clinically directed "dry tap" in up to 88% of these patients [23]. It increases the accuracy rate of thoracentesis by 26%. It can also be used to predict the presence of trapped lung or lung entrapment, by evaluating lung motion and visceral pleural thickening (Fig. 2).

Once the patient is in the correct position and the best location for drainage has been marked, the skin is prepped either with chlorhexidine or betadine for sterilization, and a sterile drape is placed. There is no need to prep the entire back, only in and around the area of interest. Mask and sterile gloves should be worn as well during the procedure. Next, the skin and intercostal space is anesthetized; 10 mL of 1% lidocaine without epinephrine is provided in the thoracentesis kits. A subcutaneous wheel should be made using a 25-gauge needle. Subsequently, this needle is replaced with a 22-gauge, 2.5-in needle through the wheel, anesthetizing every 1–2 mm as it is inserted (drawing back on the syringe prior to each

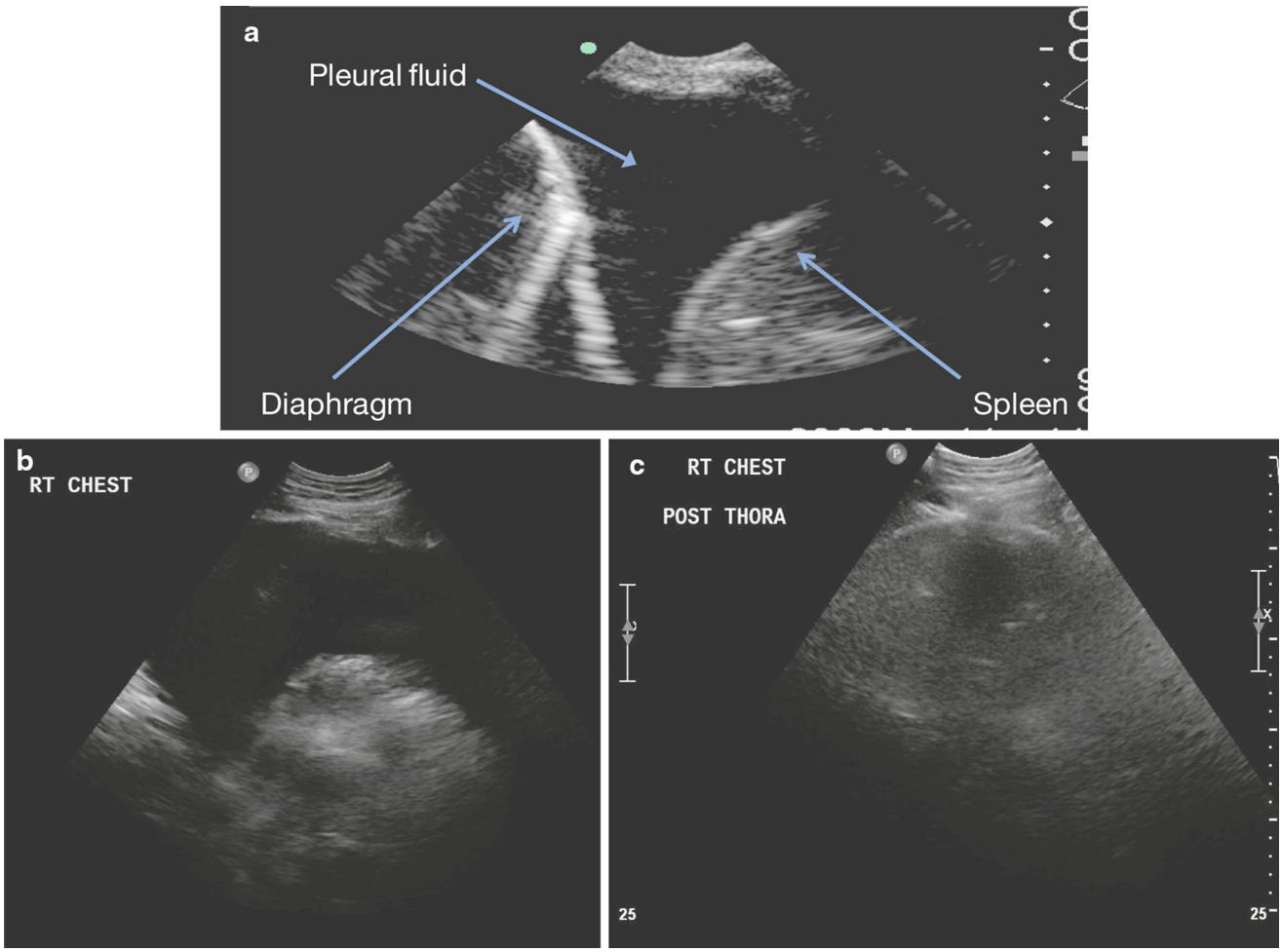

Fig. 2 Thoracic ultrasound: (**a**) Ultrasound demonstrating pleural fluid, diaphragm, and spleen; (**b**) demonstration of pleural effusion prior to thoracentesis; (**c**) post-thoracentesis

injection to ensure no intravascular placement) through the intercostal space directly above the rib into the pleural space. Once pleural fluid is aspirated, additional injection of lidocaine now mixed with pleural fluid is not recommended, as this could contaminate the intercostal space and subcutaneous tissue with infectious or malignant material as well as alter the laboratory tests. It is extremely difficult to anesthetize the parietal pleura, but if adequate anesthesia is provided along the track in the intercostal space, the patient should not feel discomfort during the remainder of the procedure.

After the anesthetizing and finder needle is withdrawn, a small stab incision using a #11 scalpel provided in the above kits is made subcutaneously. The needle with catheter is then inserted through the incision with constant aspiration from the attached syringe until pleural fluid is obtained. The catheter is then advanced over the needle into the pleural space and needle withdrawn. The needle is not advanced further as this increases the risk for complications, such as pneumothorax. Pleural fluid is aspirated using a one-way syringe and tubing until there is either lack of fluid or patient discomfort, exhibited with cough, anterior chest discomfort, referred ipsilateral shoulder pain, or shortness of breath (Fig. 3). Vacutainer (BD, Franklin Lakes, NJ, USA) bottles or wall suction can also be used for fluid removal. However, there is ongoing debate for use of suction due to concern of increased risk for re-expansion pulmonary edema (see below), pneumothorax, and pain. Catheter is removed on an expiratory maneuver to ensure air is not introduced to the pleural space. This can be done by aspiration with the syringe, ensuring the patient is exhaling while withdrawing the needle. It should be timed with the expiratory cycle in mechanically ventilated patients. Site is then covered with sterile gauze to hold pressure in case of any bleeding and dry dressing placed. Post-procedure ultrasound can be performed to assess and document the remainder of pleural fluid (or lack of). Chest radiograph is not routinely done unless there is

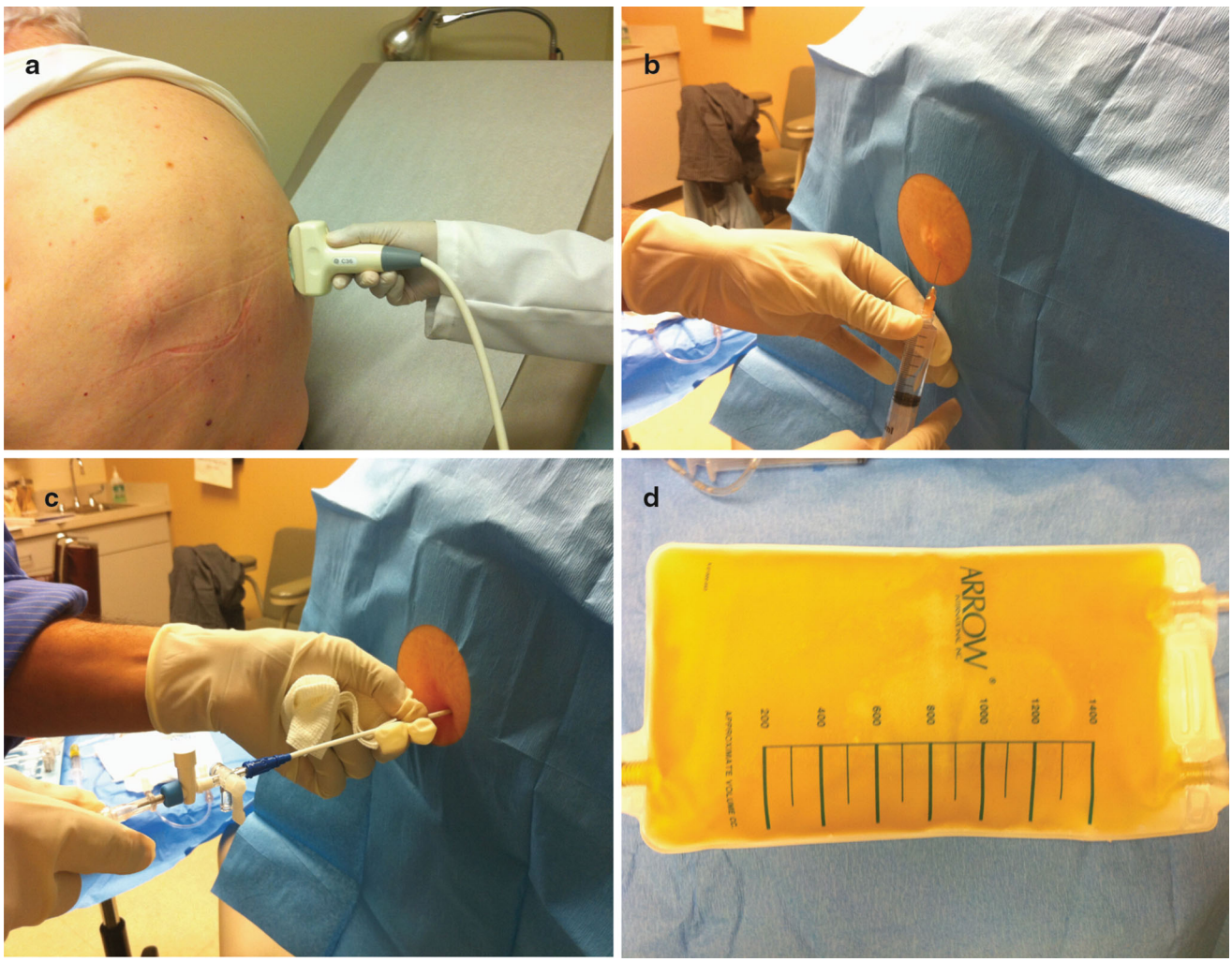

Fig. 3 Thoracentesis: (**a**) Chest ultrasound; (**b**) skin anesthetization after sterile skin prep and placement of sterile drape; (**c**) placement of thoracentesis needle and catheter; (**d**) pleural fluid drained after thoracentesis

high suspicion of pneumothorax, such as aspiration of bubbles during the procedure, multiple attempts at fluid aspiration were unsuccessful, or patient has had other treatment to the thorax, such as radiation [3].

If fluid is not aspirated, one should ensure they are in the same line as the finder needle and catheter is not kinked. Assessment with thoracic ultrasound can be done if not performed initially to confirm fluid.

4 Complications

Pneumothorax, while uncommon, is the most frequent complication of thoracentesis [10, 11]. It is significantly reduced in experienced hands and with the use of thoracic ultrasound. It can be caused by accidental laceration of the lung parenchyma. Bubbles will be seen in the syringe during the procedure. Air can also be introduced into the pleural space through the catheter during the procedure. This rarely results in a large pneumothorax, and air can be aspirated out of the space using a syringe. If the lung is trapped and unable to fill the vacated space after thoracentesis, it will appear as a pneumothorax on chest radiograph. This diagnosis can be suspected by discomfort during the procedure and decrease in pleural pressure on pleural manometry during the thoracentesis.

Vasovagal reactions can occur, characterized by lightheadedness, diaphoresis, bradycardia, and hypotension. Rarely, loss of consciousness occurs. It can be triggered by anxiety, pain, or the sight of blood or the needle. When vasovagal reactions happen, the procedure should be stopped, and the patient placed in the supine or reverse Trendelenburg position to improve venous return and cardiac output. These symptoms are typically short lived.

Cough is common when large amounts of pleural fluid are removed. This is due to a change in intrathoracic and pleural pressures. If the cough becomes excessive, the procedure should be stopped. Pleural manometry can be measured during the procedure (see below) to assess intrapleural pressures. If dropping below -20 cmH_20, the procedure should be stopped, as intrapleural pressure below -20 cmH_20 places the patient at a much higher risk for re-expansion pulmonary edema (RPE). Assessment of intrapleural pressures can only be assessed during manual aspiration. Pressures cannot be evaluated during Vacutainer or suction fluid removal.

Hemothorax is a rare complication but occurs secondary to laceration of an intercostal vessel. It should be suspected after a bloody tap and immediate re-accumulation of fluid on post-procedure imaging. Laboratory analysis will reveal a drop in serum hemoglobin, and patient may exhibit hemodynamic instability, depending on the severity of the bleed. Surgical thoracoscopic evaluation may be required.

Fever after thoracentesis may indicate bacterial contamination of the pleural space. Repeat thoracentesis should be performed to identify a possible new etiology of the effusion [2]. Other uncommon complications include liver or splenic lacerations or soft tissue infection.

5 Drainage Volumes

Intrapleural pressure (Ppl) can be measured during a thoracentesis as a tool to assess risk for re-expansion pulmonary edema (RPE) and evaluate for lung entrapment and trapped lung [6]. It is a measurement of pleural liquid pressure, in contrast to pleural surface pressure, which is the altering of forces between visceral and parietal pleural surfaces. It is best to place the thoracentesis catheter at the most dependent portion of the effusion, such that the pressure measured within the effusion will most accurately reflect the pressure within the pleural space. Increases in pleural fluid typically cause increases in Ppl. As the fluid is removed and the lung re-expands, Ppl should decrease and reach its steady state at FRC, -3 to -5 cmH_20. If the pleural pressure is negative, this can suggest trapped lung (from visceral pleural scarring, typically transudative, chronic, asymptomatic); if it starts out positive and drops quickly, this is more suggestive of lung entrapment (due to visceral pleural thickening, endobronchial obstruction, or interstitial disease, typically exudative, symptomatic).

When assessing risk for RPE with large-volume thoracentesis, measurement of Ppl is vital [7, 8]. Light and Feller-Kopman have looked at changes in Ppl during thoracentesis and pleural elastance (change in pressure divided by change in volume). Three curves were seen: (a) minimal change in pressure despite large volumes removed (normal pleural pressure), (b) normal initial pressure followed by a sharp drop (lung entrapment), and (c) negative initial pressure with a rapid drop (trapped lung). An initial pressure of less than -5 cmH_20 was only seen in patients with malignant effusions and trapped lung [6].

One would ideally like to drain as much fluid as possible during a thoracentesis, to achieve the best symptomatic improvement, to increase the interval between procedures, to increase diagnostic yield, and to document lung re-expansion (for possible subsequent pleurodesis.) Multiple studies have been performed evaluating the amount of fluid drained, symptoms, Ppl, and risk of RPE [1, 6, 8, 12]. It has been thought that a Ppl less than -20 cmH_20 places the patient at a higher risk of RPE. If aspiration is stopped when the Ppl reaches this level, RPE can be avoided. Light suggested stopping drainage at 1000 mL as most operators are not measuring pleural pressures during thoracentesis. Multiple studies since have shown the ability to drain much larger volumes of pleural fluid without increased incidence of

RPE, if drainage is stopped when the Ppl drops below −20 cmH_20, there is no more fluid, or chest discomfort develops. RPE in these circumstances is very rare. There is ongoing evaluation in the literature as to the safety of Vacutainer and wall suction fluid methods for fluid removal during thoracentesis [19, 20]. While pleural pressures cannot be monitored, the GRAVITAS study [13] and subsequent follow up noted no significant difference in procedural discomfort. Vacuum aspiration is also associated with shorter procedure time. However, other studies have reported increased complications, including pneumothorax, hemothorax, RPE and respiratory failure, pain, and early termination. Careful attention to the patient and symptoms must be done during thoracentesis, regardless of pleural pressure monitoring.

6 Conclusions

Thoracentesis is a relatively safe procedure that can provide very useful information regarding a patient's pleural disease. It can also provide symptomatic relief. Risk is reduced dramatically with the use of real-time thoracic ultrasound at the time of the procedure. Large volumes can also be drained with minimal risk of pulmonary edema when monitoring for a change in pleural pressure, dropping below −20 cmH_20, or development of chest discomfort.

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