Review Article

Endoscopic ultrasound-guided evaluation of the pleura and cases of pleural effusion

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ABSTRACT

The most efficient and cost-effective approach for the diagnosis of pleural exudates remains uncertain and is a subject of controversy. Essential factors to be considered include the respective diagnostic yields of thoracocentesis, closed pleural biopsy, and thoracoscopy. The role of endoscopic ultrasound (EUS) of the esophagus as a modality for the evaluation of pleural exudates has not yet been evaluated. The applied anatomy of the pleura has been discussed. The techniques involved in the EUS imaging of different aspects of the pleura in normal cases and in cases with pleural effusion are elaborated. The practical application of this knowledge can be useful in EUS-guided sampling of the pleural wall, pleural nodules, and in cases of pleural effusion.

KEY WORDS: Benign pleural effusion, exudative pleural effusion, hydrothorax

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BACKGROUND

Pleural diseases affect approximately 300 per 100,000 people per year worldwide.[1] In the presence of pleural effusion, thoracocentesis has a diagnostic yield of 60% for malignancy and >90% for tuberculosis.[2] Approximately 40% of the cases of pleural effusion remain undiagnosed after initial diagnostic thoracocentesis, and further diagnostic approaches in such cases remain uncertain and controversial, particularly if the acquisition of pleural tissue is required.[3] A definitive diagnosis depends on the histologic evidence obtained through positive pleural fluid cytology or pleural biopsy.[4] Many clinicians favor thoracoscopy as the first-line investigative method of choice in cases of exudative pleural effusion where thoracocentesis is nondiagnostic and when malignancy is suspected.[5] Access to thoracoscopy is, however, limited in many parts of the world due to the requirement of significant resources and expertise.[6] Medical thoracoscopy is not always possible in frail patients; the pleural fluid may be heavily loculated, or the lung could be adherent to the chest wall.[7] The efforts to restrict the use of thoracoscopy because of its limited availability and the need for operator expertise have led to the search for alternative methods of evaluation.[8] Computed tomography (CT)-guided percutaneous transthoracic biopsy has been used for the diagnosis of mediastinal masses.[9] In addition, endoscopic ultrasound (EUS)-guided pleural aspiration has been performed as a part of staging in nonsmall cell lung cancer.[10] Detailed descriptions of the anatomy of the pleura and pleural recesses have also been reported.[11] However, a description of the appearance of the pleura and pleural fluids on EUS is currently not available. In this paper, we discuss the applied anatomy of the pleura and the techniques involved in the EUS imaging of different aspects of the pleura in normal cases and in cases with pleural effusion.

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PROCEDURE

The applied anatomy of the pleura

The mediastinum completely separates the right from the left pleural space in humans. The pleura comprises visceral pleura, which covers the external surface of lung, and parietal pleura, which lines the inner thoracic wall, in addition to the diaphragm and mediastinum. The visceral pleura also extends into the interlobar fissures. The parietal pleura is attached through endothoracic fascia to the inner surface of the thoracic wall. The visceral and the parietal pleura meet at the lung root. Below the root of the lung, the visceral and parietal pleura continue as a double layer of pleura in the anterior and posterior aspects of the root of the lung and join the medial aspect of the lung to the mediastinum as the pulmonary ligament [Figure 1]. The parietal pleura changes direction at three walls (costal, diaphragmatic, and mediastinal). The pleural reflection refers to the lines where the parietal pleura changes its direction while passing from one wall of the pleural cavity to another wall. The pleural recesses are potential spaces at these lines of reflection; these potential spaces are occupied by the lung during inspiration and include the posterior and anterior costomediastinal recesses, mediastinodiaphragmatic recess, and costodiaphragmatic recess [Figure 2] [Supplemental Figures 1 and 2]. The mediastinodiaphragmatic recesses extend from the posterior aspect of the sternum to the posterior termination of the 11th intercostal space; they are related to different anatomical structures on the right and left sides. On the right, the recess lies between the right border of the esophagus and the pericardium. Further, the pericardium separates the recess from the right atrium and inferior vena cava. On the left side, the recess lies between the left border of the esophagus and pericardium that separates the recess from the descending thoracic aorta. The costodiaphragmatic recesses extend obliquely downward and backward. Anatomically, they are related with the liver on the right side and with the spleen on the left [Supplemental Figure 2]. On both sides, the costodiaphragmatic recesses are situated in relation with perirenal spaces, posterior aspects of the kidneys, and adrenal glands in front of the 11th rib.

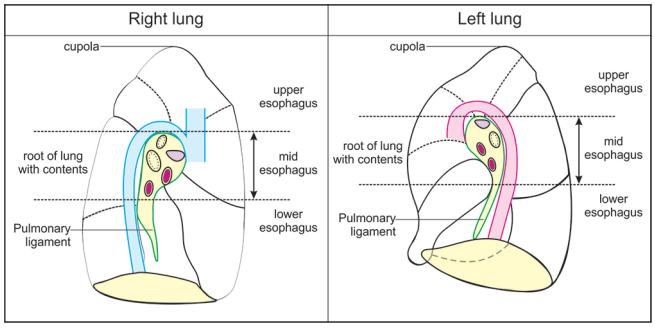

Figure 1: The root of the lung and pulmonary ligament. Each pulmonary ligament has an internal border, an external border, a lower border, and an apex. The internal border corresponds to mediastinal pleura. The external border corresponds to the mediastinal aspects of the lower lobes of the lung below the hilum. The lower border may end in a free falciform border or may be attached to the diaphragm. The apex includes the pulmonary veins

Techniques of pleural examination: The home base structures

The mediastinal pleura does not cover the anterior and posterior aspects of the esophagus. It comes into contact with the lateral wall of the esophagus directly or around the intervening vascular structures [Supplemental Figure 3]. The vascular structures in contact with esophagus and pleura include azygos venous system (azygos and hemiazygos vein), arch of the aorta, descending aorta, and great vessels of the neck. These vascular structures can be used as easily identifiable home base structures. A home base structure is an identifiable anatomical landmark that can be found through the manipulation of the scope if the orientation is lost during the imaging procedure of endosonography. Other commonly identifiable home base structures that can assist in the evaluation of the pleura include vertebral bodies, ribs (especially in the presence of pleural effusion), liver, and spleen. The techniques involved in imaging the left and right sides of the pleura are different and have been separately described.

Imaging of the right pleura

Mediastinal pleura

The examination of the mediastinal pleura commences from the middle part of the esophagus, where the left atrium and the right pulmonary artery are easily located. A clockwise rotation traces the right pulmonary artery into its branches and the left atrium into the right pulmonary veins. These structures then enter the root of the lung along with the right bronchus [Supplemental Figure 4 and Video 1]. The pleura is identified as an echogenic outline surrounding the root of lung. The imaging of the mediastinal pleura from the root of lung to the diaphragmatic pleura is facilitated by pushing

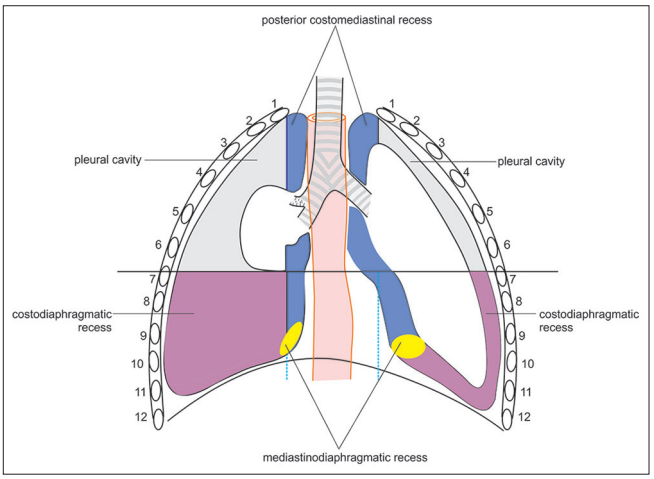

Figure 2: The coronal section shows the relationship of three recesses. The anterior costomediastinal recesses extend from the sternoclavicular joints superiorly to the seventh costal cartilages inferiorly. The left anterior costomediastinal recess is larger because of the cardiac notch of the left lung

the scope along the right lateral wall of the esophagus. This movement follows the pleura downward as the pulmonary ligament. This tracing of pleura is sometimes possible up to the diaphragm, where the pulmonary ligament is variably attached [Figure 3a and b, Video 2]. The follow-up of the pleura in an upward direction from around the root of the lung is possible along the intermediate and right main bronchus only up to the trachea. A higher and more cranially directed follow-up of the echogenic outline of the pleura is possible after a clockwise rotation toward the right posterior costomediastinal recess. Here, the echogenic outline is visible along the lateral border of the azygos vein [Figure 3c and Video 3]. The posterior costomediastinal recess is filled with fluid between the esophagus and the visceral pleura in the presence of pleural effusion. The presence of effusion provides an opportunity to visualize the outline of visceral and parietal pleura separately; however, in the presence of effusion, the pleura is no longer seen as a hyperechoic line [Figure 3d and Video 4]. In a normal person, a slow pull out of the transducer along the wall of the esophagus traces the echogenic pleura from the lateral border of the azygos vein to the cupola [Video 5]. During this follow-up, the pleura becomes less visible against the aerated lung while curving away from the transducer and moving toward the cupola [Figure 4].

Diaphragmatic pleura

In a normal person, the presence of the lung interferes with the visualization of the pleura. The diaphragmatic pleura of the right side can be visualized through the liver window from the esophagogastric junction. Nonetheless, the presence of pleural effusion, consolidation of the lung, or tumor adjacent to the wall of esophagus can also provide a suitable window for examination [Figure 5a-c, Supplemental Figure 5, and Video 6].

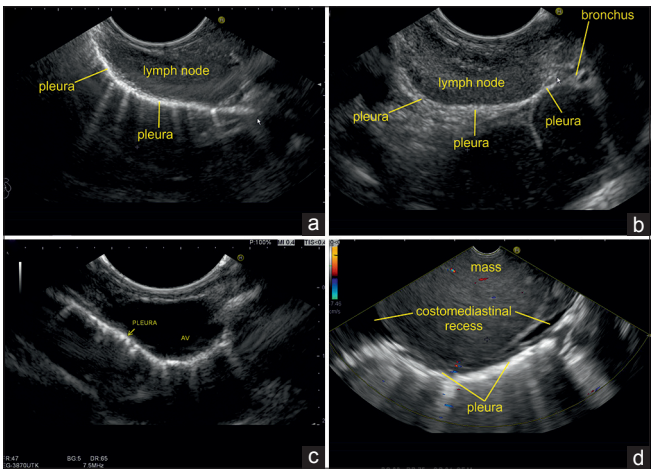

Figure 3: (a) The endoscopic ultrasound scope shows a subcarinal lymph node. The hyperechoic outline beyond the node represents the pleura, and the movement of the lung rockets confirms the pleural slide during endoscopic ultrasound. (b) The pleura reaches up to the intermediate bronchus from where the outline of the right bronchus can be traced. (c) A clockwise rotation, after visualization of the lung hilum, traces the pleura beyond the azygos vein. (d) A mass is seen close to the esophagus. The pleura is seen beyond the costomediastinal recess

Pleural effusion in the costomediastinal recess merges with the pleural cavity, which is also related to the mediastinodiaphragmatic and costodiaphragmatic recesses [Videos 7-10]. Examination of the diaphragmatic pleura is also possible from the fundus of the stomach, lesser curvature of the stomach, or duodenal bulb [Figure 5d].

Costal pleura

The EUS-guided evaluation of the costal pleura is mainly enabled owing to the presence of pleural effusion or the presence of a consolidated lung. The presence of effusion collapses the lung toward the lung hilum. The upper part of the lung is not attached to the chest wall; therefore, it collapses in the presence of effusion and allows the visualization of entire chest cavity above the apex of collapsed lung from the upper esophagus [Supplemental Figure 6a and Video 11]. In the upper part of the esophagus, the visualization of brachiocephalic trunk helps in the localization of the upper boundary of an area of massive effusion. This can extend approximately 1 cm above the upper end of the first rib in the supine position [Supplemental Figure 6b and Video 12]. The visualization of costal pleura is limited from the middle part of esophagus because of the presence of the root of lung. The visualization of costal pleura from the lower part of the esophagus is partly limited due to the presence of the pulmonary ligament and the attachment of the lower lobe of the lung.

Imaging of the left pleura

Mediastinal pleura

The root of the left lung is easily identified by locating the left atrium, which is easily found at approximately 33 cm distance from incisor. The pleura is identified around the root of the lung [Supplemental Figure 7 and Video 13]. The

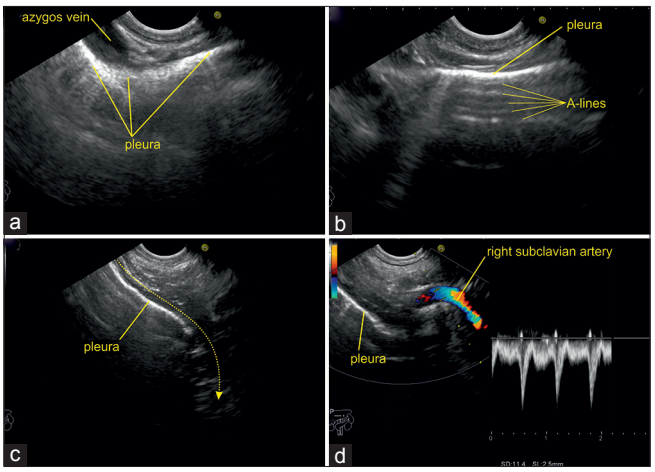

Figure 4: The pleura is easily traced pos¬¬terolaterally up to the lower border of azygos vein, which is identified as the curving part of azygos vein away from the probe toward the superior vena cava (a). Imaging from the azygos vein to the cupola can be performed by following the pleural outline which comes in close contact with esophagus (b). At this position, the pleura creates multiple reverberation artifacts (A lines) (c). On further pull out, the pleura moves away from the probe toward the cupola. The presence of the cupola is confi rmed by the presence of the brachiocephalic trunk (d).

imaging of the mediastinal pleura from the root of the lung to the diaphragmatic pleura is accomplished by pushing the scope along the left lateral wall of the esophagus. The pericardium, left ventricle, left lobe of liver, and diaphragmatic pleura are seen from the lower end of the esophagus [Supplemental Figure 8, Videos 8 and 14]. In the presence of fluid in costomediastinal recess, effusion may be continuous with the fluid in the mediastinodiaphragmatic recess above the left diaphragmatic surface [Supplemental Figure 9 and Video 15]. In the lower part of the mediastinum, the mediastinal pleura is in close contact with the thoracic aorta as the pulmonary ligament and can be followed down to the diaphragm just above the abdominal aorta [Supplemental Figure 10]. The presence of minimal amounts of pleural fluid in the costomediastinal recess is evident near the pulmonary ligament [Supplemental Figure 10 and Video 16]. If larger amounts of fluid are present, it is seen beyond the outer border of the aorta; this can extend above the level of the arch of aorta [Supplemental Figure 11]. At the lower end of the esophagus, the hemiazygos vein is commonly seen beyond the aorta and the pulmonary ligament is seen between aorta and hemiazygos vein. If a small amount of effusion is present, then it is observed in the posterior costomediastinal or costodiaphragmatic recesses beyond the hemiazygos vein [Figures 6a and b, Video 17]. Counterclockwise rotation can trace the pleura from the root of the lung to the outer border of the aorta and slow pullout can trace the pleura toward the cupola beyond the left subclavian artery (LSCA) [Figure 6c and d, Video 18].

Diaphragmatic pleura

The diaphragmatic pleura can be observed above the left lobe of the liver. In the presence of pleural effusion, the

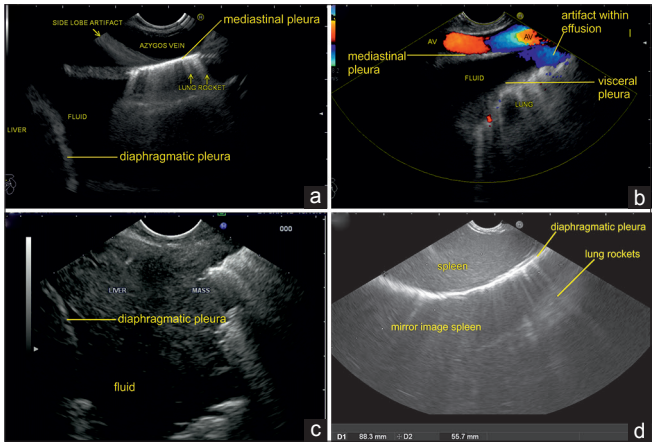

Figure 5: (a) In this case, pleural effusion is seen along the posterior costodiaphragmatic recess, above the diaphragmatic pleura. (b) An approximate assessment of the amount of fluid is possible by measuring the distance between the esophagus and the visceral pleura of the collapsed lung. (c) In this case, a mass is seen in the mediastinodiaphragmatic recess. The diaphragmatic pleura can be observed beyond the pleural deposit. (d) The diaphragmatic pleura is visualized through the spleen. The presence of lung rockets indicates the absence of pathology immediately above the diaphragm

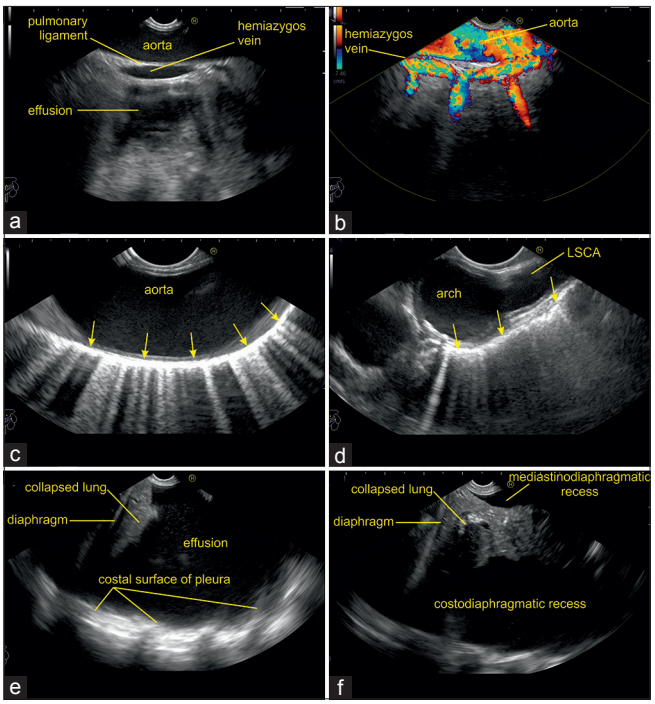

Figure 6: (a and b) The hemiazygos vein is seen beyond the aorta from the lower end of the esophagus. The pulmonary ligament is seen between the aorta and hemiazygos vein. (c and d) The visceral pleura is seen beyond the outer border of the aorta. Subsequently, the pleura can be visualized toward the cupola beyond the left subclavian artery. (e and f) The collapsed lung is seen just above the diaphragm. Slight rotation shows that the collapsed lung is separating the mediastinodiaphragmatic recess from the costodiaphragmatic recess

Table 1: The relationship of pleura, pleural fluid, and recesses related to pleural cavity with the home base structures during endoscopic ultrasound imaging

Home base structure	Location of fluid	Recess	Figure number
Imaging from mediastinum			
Descending aorta	Fluid beyond aorta	Left posterior costomediastinal recess	17, 18, 20
Arch of aorta	Fluid beyond arch of aorta	Left posterior costomediastinal recess	18
Azygos vein	Fluid beyond azygos vein	Right posterior costomediastinal recess	10
Hemiazygos vein	Fluid beyond hemiazygos vein	Left posterior costomediastinal recess	20
Left ventricle	Fluid between esophagus and left ventricle	Left mediastinodiaphragmatic recess	16
Right atrium, IVC	Fluid between esophagus and right atrium and or IVC	Right mediastinodiaphragmatic recess	15, 25
Ribs or chest wall	Fluid beyond left lateral wall of esophagus	Costomediastinal and costodiaphragmatic recess	13, 17, 18, 20, 21
Imaging from stomach			
Liver	Fluid above liver	Mediastinodiaphragmatic and costodiaphragmatic recess	10, 11, 15, 16, 25
Kidney, adrenal, spleen	Fluid above diaphragm	Costodiaphragmatic recess	12

IVC: Inferior vena cava

fluid can be seen in the mediastinodiaphragmatic recess [Figure 6e and f, Video 19]. This recess continues into the costodiaphragmatic recess if there is a large amount of effusion. On the left side, the diaphragmatic pleura can also be visualized through the left lobe of the liver or spleen from the fundus of the stomach.

Costal pleura

The costal pleura is mainly visualized in the presence of effusion [Figure 6e and f, Video 19]. In the upper part of the esophagus, the pleura is followed up along the outer border of the arch of the aorta to the cupola by following the echogenic line beyond the arch of the aorta and the LSCA [Figure 7 and Video 20]. In the presence of effusion, the lung collapses and the costal pleura is mainly visualized from the upper and lower parts of the esophagus. The presence of the lower lobe of the lung divides the pleural cavity near the lower end of the esophagus into two compartments, i.e., posterior costodiaphragmatic recess and costomediastinal recess [Figure 6e and f].

DISCUSSION

The use of EUS-guided examination offers an endoscopic window for the evaluation of the pleura from the esophagus. The visualization of the mediastinal aspect of pleura is easily accomplished by EUS. The visualization of a part of the diaphragmatic and costal pleura is possible using the home base structures as reference points. A larger extent of the pleura is visualized in cases of pleural effusion; the presence of fluid provides an

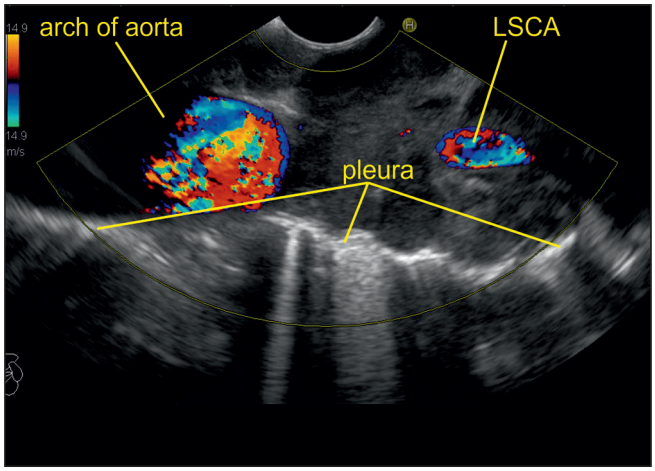

Figure 7: In this case, a tumor is seen encasing the arch of the aorta and the left subclavian artery. At this level, the pleura is seen beyond the outer border of the arch of the aorta and the left subclavian artery

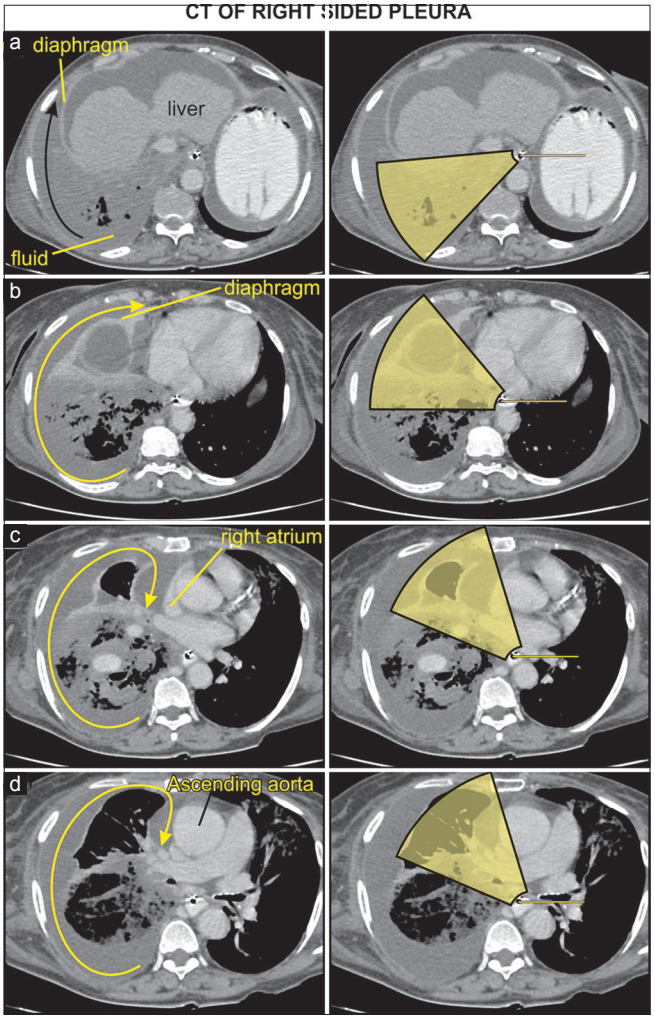

Figure 8: Computed tomography of the right-sided pleura: (a) Fluid is noted in the posterior costomediastinal recess. (b) Fluid is noted in the posterior costomediastinal recess along the right lateral wall of the chest. (c) Fluid is noted in the posterior costomediastinal recess extending laterally between the heart and lower lobe of the lung along the right atrium. (d) Imaging from the middle part of the esophagus shows fluid in the posterior costomediastinal recess

Table 2: Comparison of ultrasound and endoscopic ultrasound for imaging of walls of pleura and pleural recesses

	US	EUS
Extent of evaluation	Costal >diaphragmatic >mediastinal	Mediastinal >diaphragmatic >costal
Costal pleura	Narrow intercostal window requires systematic evaluation through each space	Wide esophageal window allows relatively easy evaluation from all parts of esophagus
Mediastinal pleura	Not seen directly	Easily seen directly
Diaphragmatic pleura	Seen near liver and spleen	Seen near liver and spleen
Anterior costomediastinal recess	Difficult to evaluate in lower part of chest. Evaluation near upper chest wall is possible	Difficult to evaluate in lower part of chest. Evaluation near upper chest wall is possible
Posterior costomediastinal recess	Evaluation limited due to thickness of chest wall	Easily evaluated
Mediastinodiaphragmatic recess	May be possible	Is usually possible
Costodiaphragmatic recess	Easily possible	Easily possible

US: Ultrasonography, EUS: Endoscopic ultrasound

excellent window of examination. The pleural recesses, which are anatomically well-defined in normal patients, become less defined in the presence of massive pleural effusion and merge with each other. Table 1 summarizes the home base structures and the pleural recesses, which can be visualized in the presence of pleural effusion. The consideration of EUS examination for the evaluation of the pleura necessitates a CT scan image for concordant evaluation. This is particularly useful for inexperienced operators mapping the anatomical abnormalities following a cross-check with the CT scan images. A CT scan image of the occurrence of right- and left-sided effusion is shown for the comparison of the location and the expected localization of these recesses by the probe of EUS [Figures 8 and 9]. Ultrasonography (US) of the pleura has been described.[12,13] Image-guided sampling through CT and/or US has become standard practice; these investigations provide a rapid, more accessible, and cheaper alternative to blind pleural biopsy and minimize the risk of visceral puncture or pneumothorax.[14] The addition of EUS and EUS-guided fine needle aspiration to image-guided sampling may offer more options for procuring the pleural tissue. A comparison of US and EUS examination of the pleura is shown in Table 2. The advantages of EUS-guided evaluation as compared to other imaging modalities are summarized in Table 3 [Figure 10].

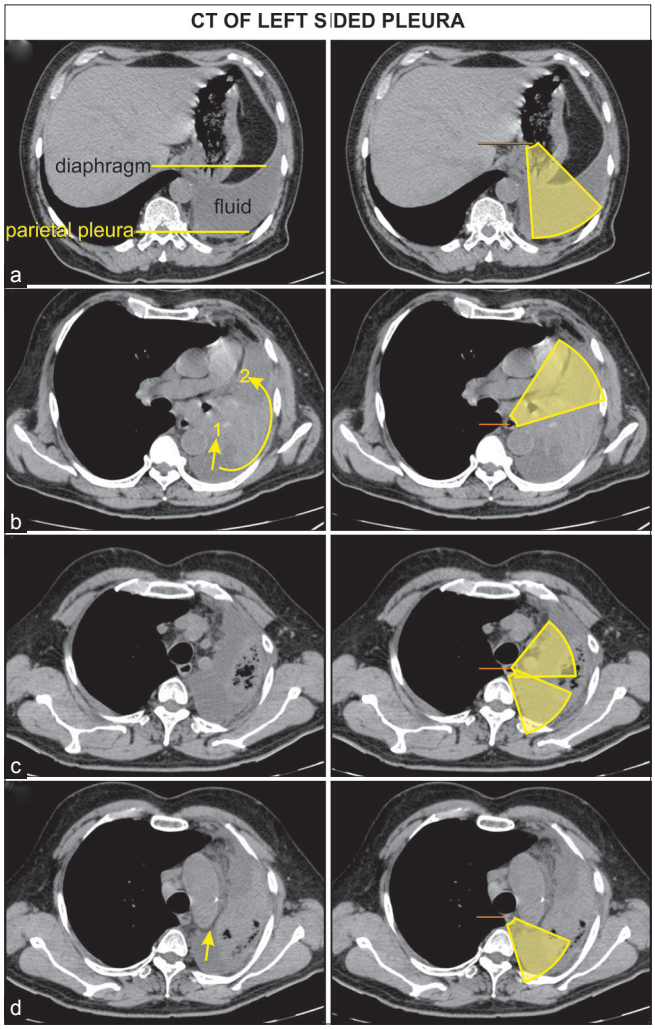

Figure 9: Computed tomography of the left-sided pleura. (a) Fluid is noted in the left posterior costomediastinal recess through the posterior wall of the stomach. (b) Fluid is noted along the medial aspect of the lung toward the root of the lung (1) and along the lateral aspect of the chest wall (2). (c) Fluid is noted above the arch of the aorta, extending toward the apex of the lung. (d) Fluid is noted along the arch of the aorta anteriorly from the posterior costomediastinal recess

CONCLUSIONS

An understanding of the anatomy of the lines of the pleural reflection, pulmonary ligaments, and pleural recesses is important for performing the procedures of thoracocentesis and guided biopsies. In addition, the EUS-guided evaluation of the pleura provides a different perspective when compared with CT scan, US, or thoracoscopy. In the era of multimodality imaging, EUS-guided evaluation can be used as an alternative, optional, or additional imaging modality for the diagnostic evaluation of pleural pathologies. The following factors are likely to determine the order of selection between these modalities: local expertise, availability, cost constraints, and potential need for the evaluation of pleural diseases. In addition, the choice of evaluation can also be influenced by the pretest probability for malignancy or tuberculosis, image findings, feasibility of the procedure, risk of sedation and anesthesia, and general condition of the patient. We believe that the current review shall be useful for clinicians and endosonographers who may require EUS-guided evaluation of the pleura.

Table 3: Advantages of endoscopic ultrasound guidance

Advantages of EUS guidance	Figure number
Locates most minimal pleural effusion	17
Alternative method of guided thoracocentesis	-
Alternative method of evaluation of pleural septations	25
Allows Doppler/elastographic assessment of collapsed lung/tumor	26
Allows direct examination of diaphragmatic and costal pleura/pleural deposits	10, 13, 21, 25
Allows direct examination of mediastinal aspect of pleura/ allows biopsy with minimal risk of visceral puncture	8

EUS: Endoscopic ultrasound

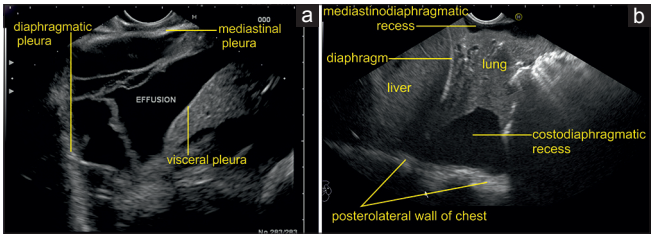

Figure 10: (a) In this case, septated effusion is noted on the right side above the liver. The collapsed lung is seen. The fluid above the diaphragm is within the posterior costomediastinal and costodiaphragmatic recesses. (b) The posterior costomediastinal recess and mediastinodiaphragmatic recess are separated by the quadrangular shape of the collapsed lower lobe of the lung. Application of color Doppler shows the presence of vascularity within the lung and rules out the possibility of malignancy within the visualized lung

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Conflicts of interest
There are no conflicts of interest.

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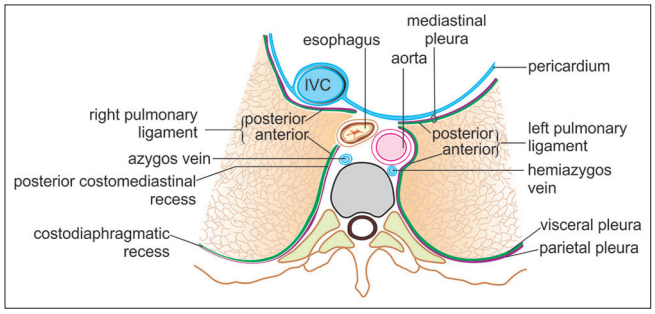
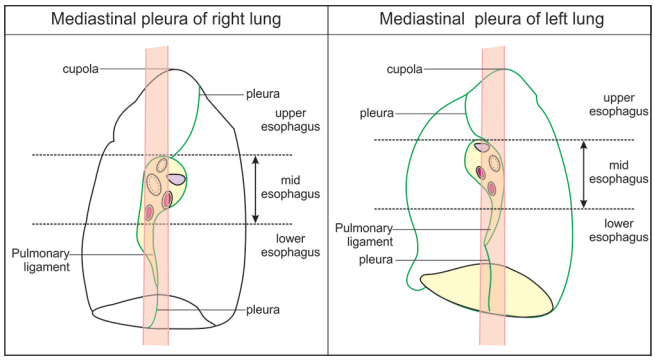
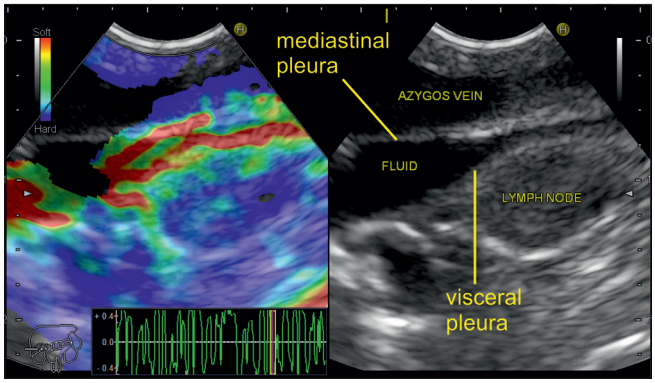
ADDITIONAL SUPPORTING MATERIAL



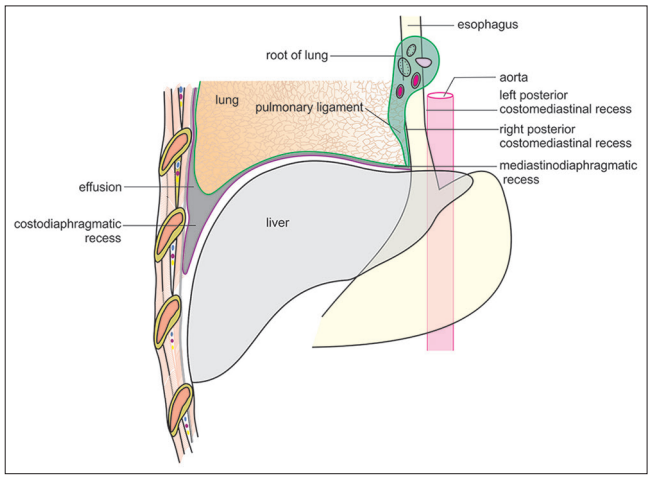
Supplemental Figure 1: The posterior costomediastinal recesses extend vertically along the costovertebral gutters from the first rib to the 11th intercostal space. The recesses are related to the costovertebral junctions, origin of the posterior intercostal arteries, and azygos venous system (azygos vein on the right side and hemiazygos vein on the left side)



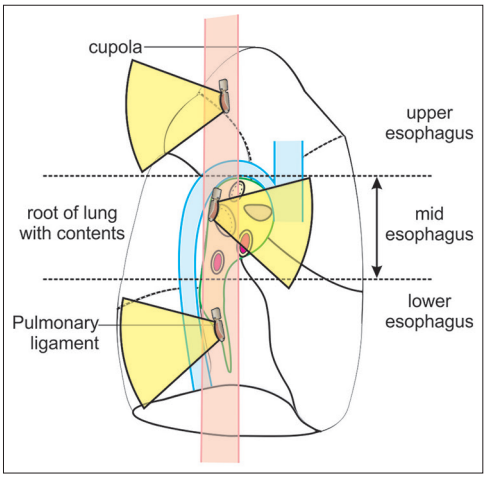
Supplemental Figure 3: The area of pleural contact with esophagus: There is maximal direct contact between the pleura and the upper esophagus. There is minimal direct contact between the pleura and the middle esophagus, close to the root of lung. The contact between the pleura and the lower esophagus is absent in the area where the attachment of the pulmonary ligament joins the lower esophagus with the lower lobe of the lung



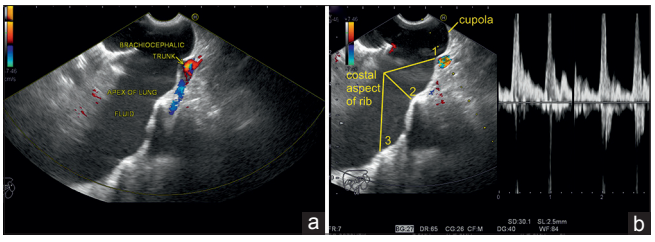
Supplemental Figure 5: In this case, a subpleural deposit/lymph node is seen in the wall of the lung beyond the pleural fluid just below the visceral pleura. A subpleural deposit that ruptures into the pleural cavity is often the cause of tubercular pleural effusion



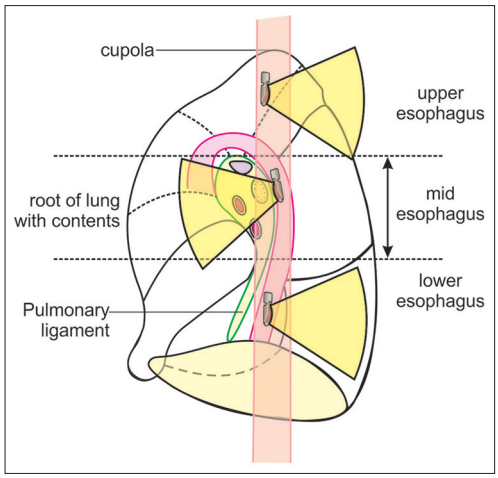
Supplemental Figure 2: The costodiaphragmatic recesses extend from the seventh costal cartilage anteriorly to the neck of the 12th rib posteriorly. Their course is obliquely downward and backward



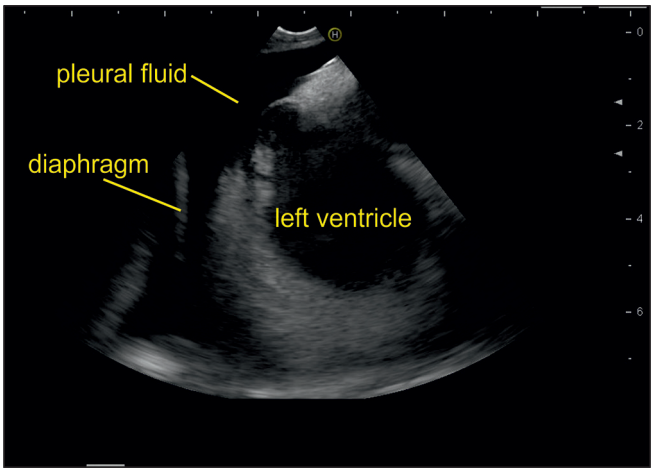
Supplemental Figure 4: The pleura is identified as an echogenic outline around the root of the lung. It can be followed downward as the pulmonary ligament and cranially along the lateral border of the azygos vein



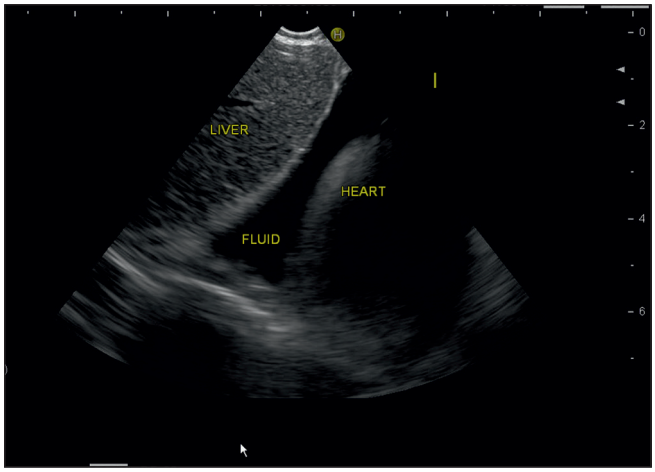
Supplemental Figure 6: (a) An approximate assessment of the amount of fluid is possible by measuring the distance between the esophagus and the visceral pleura of the collapsed lung. In a supine position, the maximum depth of the fluid is seen from the upper esophagus, where the collapsed part of apex of lung is visualized. The visualization of the brachiocephalic trunk (identified by arterial pulsation) marks the upper end of first rib. (b) The pleural effusion extends about 1 cm above the upper end of the first rib in the supine position. The numbers indicate the number of rib



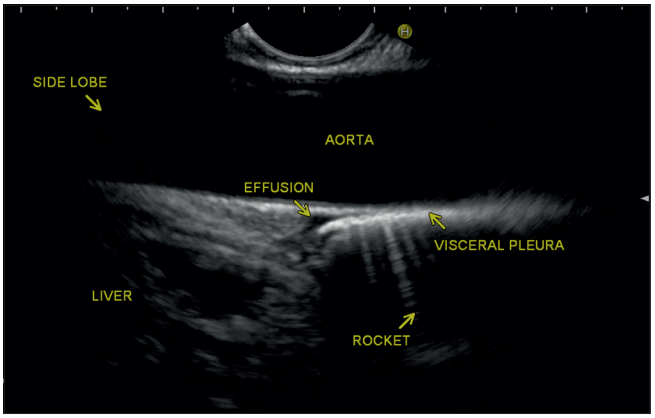
Supplemental Figure 7: The root of the left lung is easily identified. The pleura is identified near the root of lung. Counterclockwise rotation can trace the pleura from the root of the lung to the outer border of the aorta and toward the cupola beyond the left subclavian artery



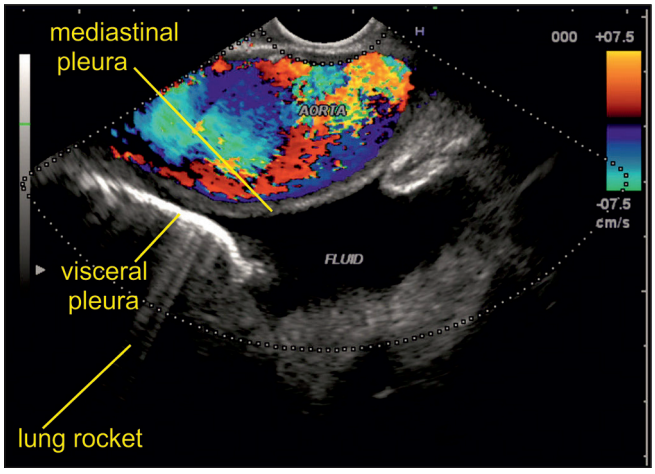
Supplemental Figure 8: In this image, the pericardium, left ventricle, left lobe of liver, and diaphragmatic pleura are visualized from the lower end of the esophagus. The pleural cavity shows fluid in the mediastinodiaphragmatic recess



Supplemental Figure 9: In this image, the left ventricular chamber of the heart is visualized through the wall of the esophagus and the pleural effusion. The fluid is seen in the left mediastinodiaphragmatic recess



Supplemental Figure 10: Ultrasound reveals minute pleural effusions (5 mL) and endoscopic ultrasound can detect very minimal pleural effusion. In this image, the amount of effusion is approximately 2 ml. The effusion is identified by the triangular appearance of the fluid and the absence of lung rockets in the adjacent visceral pleura



Supplemental Figure 11: In this case, the fluid is seen above and beyond the arch of the aorta. The pleura is seen only along the lower part of the aorta where the lung rockets are seen in the part of visceral pleura in direct contact with aorta