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The Role of Thoracic Ultrasound in the Identification and Characterization of Pleural Effusion: A Literature Review

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ABSTRACT

Pleural effusion is a common clinical condition characterized by abnormal fluid accumulation within the pleural cavity and is associated with numerous cardiopulmonary and systemic diseases. This literature review evaluates the role of thoracic ultrasound in the detection, characterization, and management of pleural effusion. Relevant studies were identified through searches of PubMed, Scopus, Science Direct, and Medline databases. Evidence demonstrates that thoracic ultrasound has superior sensitivity compared with chest radiography for detecting even small pleural effusions. Sonographic features such as echogenicity, septations, and loculations assist in differentiating transudative and exudative effusions. Ultrasound also plays a critical role in guiding thoracentesis and chest tube insertion, reducing procedural complications and improving patient safety. Compared with computed tomography and conventional radiography, ultrasound offers real-time bedside assessment without radiation exposure. Despite limitations related to operator dependency and inability to determine biochemical fluid composition, thoracic ultrasound remains a valuable first-line imaging modality for pleural effusion evaluation. Future advances including contrast-enhanced ultrasound and artificial intelligence-assisted imaging may further improve diagnostic performance.

Keywords: Pleural effusion, Thoracic ultrasound, Sonography, Thoracentesis, Exudate, Transudate.

INTRODUCTION

Pleural effusion is a common clinical condition of the chest that results from abnormal accumulation of fluid within the pleural cavity. It arises from various pathological processes, including congestive heart failure, infectious diseases (pneumonia, tuberculosis and empyema), malignant tumors, liver cirrhosis, and renal diseases. Accurate diagnosis of pleural effusion and identification of its underlying cause are vital for appropriate treatment, prevention of complications, and reduction of mortality (Awan et al., 2024).

Traditionally, plain chest radiography and computed tomography (CT) have been used for the detection of pleural effusion. Although useful, these modalities have limitations; small effusions may not be visible on plain radiographs, and CT scanning is not practical for every patient due to higher radiation exposure and cost. Sonography is considered a safe, cost-effective, and bedside alternative that addresses these limitations (Zaki et al., 2024).

Compared to radiography, ultrasonography has the advantage of being non-invasive, cost-effective, readily available, and repeatable. It is also radiation-free. Furthermore, chest ultrasonography shows better sensitivity and reliability than radiography (Eibenberger KL et al., and Azoulay E., 2003).

Over the past decade, point-of-care ultrasound (POCUS) has become increasingly integrated into emergency medicine, critical care, and pulmonary practice. The portability, absence of ionizing radiation, and immediate bedside availability of ultrasound have expanded its role in the diagnosis and management of pleural diseases. Consequently, thoracic ultrasound is now recommended by several international guidelines as a first-line imaging modality for pleural effusion assessment.

Although several studies have evaluated the diagnostic performance of thoracic ultrasound, few reviews have comprehensively addressed its role in identification, characterization, volume estimation, and ultrasound-guided management of pleural effusion within a single radiology-focused review.

This review aims to fill this gap by integrating current evidence regarding diagnostic and therapeutic applications of thoracic ultrasound.

Epidemiology

Pleural effusion is a widespread clinical problem worldwide, affecting millions of individuals annually. A large-scale study estimated the prevalence of pleural effusion at 4,684 per 1 million Chinese adults. The study highlighted that the top three causes were Parapneumonic pleural effusion/empyema (25.1%), malignant neoplasm (23.7%), and tuberculosis (12.3%). Also It is estimated that approximately 1.5 million new cases are reported each year in the United States alone. Congestive heart failure accounts for approximately 40–50% of cases, malignant tumors for about 25%, and infectious diseases such as pneumonia, tuberculosis, and empyema represent other major causes (Awan et al., 2024).

Geographically, in developed countries, heart failure and malignancies are the most common causes of pleural effusion, whereas in developing countries tuberculosis-related pleural effusion is more frequently observed. The condition is more common in middle-aged and elderly individuals and occurs slightly more often in males.

Pathophysiology and Clinical Significance

Under normal conditions, approximately 15 mL of fluid is present within the pleural cavity, serving lubrication, facilitating lung movement, and providing mechanical stability between the parietal and visceral pleura (Burgener FA et al., 2008). The balance between fluid production and absorption is maintained through hydrostatic and oncotic pressures, vascular permeability, and lymphatic drainage. Any disruption of this balance results in pleural effusion (Ielo et al., 2023).

From a radiological perspective, understanding pathophysiology assists in interpreting sonographic appearances. Anechoic and homogeneous effusions typically suggest transudate fluid, whereas echogenic, septated, or heterogeneous effusions may indicate exudative processes, infection, or malignancy. Therefore, sonography not only detects fluid presence but also contributes to etiological estimation (Evans et al., 2021).

Types of Pleural Effusion

Transudative Effusion

Transudative effusion occurs due to imbalance in fluid dynamics without direct injury to the pleural membrane. The fluid is usually clear, low in protein, anechoic, and homogeneous, without internal septations or echoes. Major causes include congestive heart failure, liver cirrhosis, and renal diseases (Evans et al., 2021).

Exudative Effusion

Exudative effusion results from direct pleural membrane injury and is characterized by elevated protein, LDH, and inflammatory cells. Sonographically, it often appears complex, hypoechoic or heterogeneous, with internal echoes, fibrin strands, and sometimes loculations. Common causes include infectious diseases such as pneumonia, tuberculosis, empyema, malignancy, and inflammatory conditions (Ielo et al., 2023).

Sonographic Identification of Pleural Effusion

Sonography can easily differentiate pleural fluid from parietal pleural thickening and detect even minimal amounts of fluid (3–5 mL), demonstrating its higher sensitivity compared to chest radiography (Lessa L et al., 2013).

A 2–5 MHz convex probe was used to visualize deep structures and fluid collections. Patients were examined in sitting, lateral, and supine positions, and both pleural spaces were systematically evaluated. When the probe is placed in the coronal plane between the mid-axillary and posterior axillary lines, the supra diaphragmatic space normally appears filled due to liver or splenic reflection and disappears during inspiration. Under normal conditions, the thoracic spine is not visualized because of lung aeration (Lichtenstein, 2016).

When fluid accumulates above the hemidiaphragm:

The hepatic echogenic reflection is no longer visible.

The thoracic spine sign becomes visible because fluid, instead of air, now serves as an excellent acoustic window.

Specific Sonographic Signs

Quad Sign

Defines pleural fluid boundaries:

Two posterior rib shadows represent horizontal borders.

The parietal and visceral pleura form the remaining two borders.

The visceral pleura attached to lung tissue is referred to as the lung line.

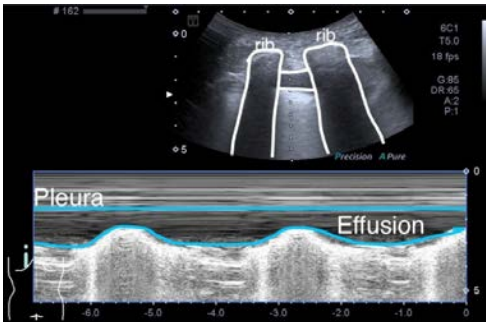

Figure 1. Quad sign.

Sinusoid Sign

During respiration, reduction in fluid depth produces a sinusoidal movement on M-mode imaging. If the fluid is highly viscous, this sign may not be visible.

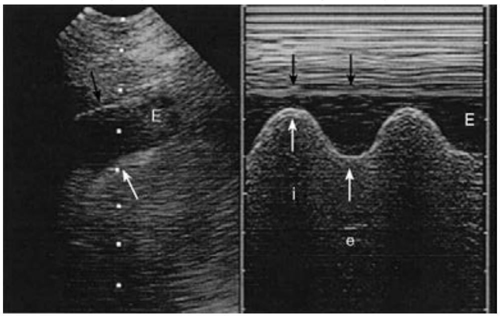

Figure 2. Sinusoid sign.

If the lung is floating within the fluid, its movement on B-mode resembles a jellyfish — termed the jellyfish sign, considered a variant of the sinusoid sign.

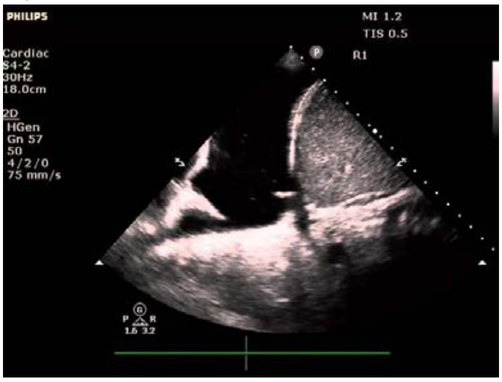

Figure 3. Jellyfish sign.

Sonographic Patterns According to Fluid Type

Transudative effusion appears anechoic, homogeneous, and without septations or internal echoes.

Exudative effusion often appears complex, hypoechoic, with internal echoes, fibrin septations, and loculations. Pleural thickening may also be observed, suggesting infectious or malignant effusion (Lichtenstein, 2016).

Volume Assessment

Ultrasound can estimate pleural fluid volume. Measurement of a pleural effusion volume with point-of-care ultrasonography may be a useful tool for intensivists and is an active area of research in critical care (Ibitoye BO et al., 2018). Ultrasound precise volumetric calculations exist, they are time-consuming and rarely used in practice. Simpler formulas estimate fluid volume by measuring the interpleural distance using calipers.

In controlled settings ultrasound may detect constitutive pleural fluid, can reliably detect effusions >20 mL in clinical settings, and may approach the sensitivity and specificity of computed tomography. Assessment of pleural effusions by ultrasound has historically been semi-quantitative, a gestalt of whether the effusion appears minimal, mild, moderate, or severe (Kocijancic I et al., 2003).

Measurement

Some intensivist's emergency physicians also use ultrasonography to directly quantify the volume of a given pleural effusion, incorporating this measurement with an assessment of gas exchange in deciding whether to drain the fluid collection (Havelock T et al., 2010).

To this end, one formulae have enjoyed robust support in the literature, and are used commonly in clinical practice:

Balik formula

The Balik formula was originally validated in mechanically ventilated intensive care patients and should be applied cautiously in ambulatory or non-ICU populations.

patient supine with mild (15°) trunk elevation, transducer perpendicular to the dorsolateral chest wall, measurements taken at end-expiration

operator measures the maximum distance (in millimeters) between the visceral and parietal pleura

Pleural effusion volume (mL) = (measured distance) x 20 (Balik M et al., 2008).

Therapeutic Role of Sonography

Beyond diagnosis, ultrasound plays a major therapeutic role. Ultrasound-guided thoracentesis is now standard practice, significantly reducing complications such as dry tap and hemi thorax misidentification.

It is also highly useful in guiding chest tube placement, pleurodesis for prevention of recurrent effusion, and biopsy, especially in suspected malignancy.

Its portability makes it invaluable in emergency departments, intensive care units (ICUs), and resource-limited settings.

Advantages and Limitations

Advantages

High sensitivity for detecting small effusions.
Real-time imaging for guided procedures.
Differentiation between transudate and exudate based on imaging features.
Non-invasive and radiation-free.
Cost-effective and widely available compared to CT and MRI.

Limitations

Cannot determine biochemical nature without laboratory analysis.
Operator-dependent accuracy.
Posterior or loculated effusions may not be fully visualized.

Future Research and Developments

Recent advances such as contrast-enhanced ultrasound, elastography, and artificial intelligence-assisted imaging systems are promising for improving diagnostic accuracy.
Future research should establish standardized sonographic criteria and integrate ultrasound into structured clinical protocols for both advanced and resource-limited healthcare settings.

CONCLUSION

Thoracic ultrasound is a highly sensitive, safe, and radiation-free imaging modality for the detection and characterization of pleural effusion. It provides valuable information regarding pleural fluid morphology and plays an essential role in guiding thoracentesis and other pleural interventions. Although laboratory analysis remains necessary for definitive fluid classification, ultrasound significantly improves diagnostic accuracy, procedural safety, and clinical decision-making. Therefore, it should be considered a first-line imaging tool in the evaluation and management of pleural effusion.

Recommendations

It is recommended that sonography be prioritized in the evaluation of pleural effusion to avoid unnecessary radiation exposure and high costs.
Future studies should focus on advanced techniques such as contrast-enhanced ultrasound and elastography to further improve diagnostic accuracy.

AUTHOR CONTRIBUTIONS

Sayed Azizullah Hashimi contributed to the conception and design of the study, literature review, data interpretation, manuscript drafting, critical revision of the manuscript, and final approval of the version to be published. He also supervised the overall scientific content of the manuscript. **Nasimullah Rahmatzai** contributed to the literature search, data collection, organization of references, manuscript editing and formatting, and review and revision of the final draft. He also contributed to the interpretation of relevant findings and revision of the manuscript for important intellectual content.

REFERENCES

Abramowitz Y, Simanovsky N, Goldstein MS, Hiller N. Pleural effusion: characterization with CT attenuation values and CT appearance. AJR Am J Roentgenol. 2009;192(3):618–623. doi:10.2214/AJR.08.1286.
Awan MM, Saqib H, Zafar I, Kalsoom F, Amin M. Diagnostic accuracy of point-of-care ultrasound versus chest radiography in pleural effusion: a systematic review and meta-analysis. Pak J Chest Med. 2024;30(2):263–276.
Azoulay E. Pleural effusions in the intensive care unit. Curr Opin Pulm Med. 2003;9(4):291–297. doi:10.1097/00063198-200307000-00008.
Balik M, Plasil P, Waldauf P, Pazout J, Fric M, Otahal M, et al. Ultrasound estimation of volume of pleural fluid in mechanically ventilated patients. Intensive Care Med. 2006;32(2):318–321. doi:10.1007/s00134-005-0024-2.
Burgener FA, Kormano M, Pudas T. Differential Diagnosis in Conventional Radiology. 3rd ed. New York: Thieme; 2008.
Cotton D, Lenz R, Kerr B, Ma IWY. Point-of-care ultrasound for the general internist: pleural effusions. Can J Gen Intern Med. 2018;13(2):22–28. doi:10.22374/cjgim.v13i2.231.
Eibenberger KL, Dock WI, Ammann ME, Dorffner R, Hörmann MF, Grabenwöger F. Quantification of pleural effusions: sonography versus radiography. Radiology. 1994;191(3):681–684. doi:10.1148/radiology.191.3.8184046.
Esmadi M, Lone N, Ahmad DS, et al. Multiloculated pleural effusion detected by ultrasound only in a critically ill patient. Am J Case Rep. 2013;14:63–66. doi:10.12659/AJCR.883816.
Evans PT, Zhang RS, Cao Y, Breslin S, Panebianco N, Baston CM, et al. The use of thoracic ultrasound to predict transudative and

exudative pleural effusion. POCUS J. 2021;6(2):97–102. doi:10.24908/pocus.v6i2.15193.
Grimberg A, Shigueoka DC, Atallah AN, Ajzen S, Iared W. Diagnostic accuracy of sonography for pleural effusion: systematic review. Sao Paulo Med J. 2010;128(2):90–95. doi:10.1590/S1516-31802010000200009.
Havelock T, Teoh R, Laws D, Gleeson F; British Thoracic Society Pleural Disease Guideline Group. Pleural procedures and thoracic ultrasound: British Thoracic Society Pleural Disease Guideline 2010. Thorax. 2010;65(Suppl 2)–ii76. doi:10.1136/thx.2010.137026.
Ielo S, Fratini A, Amante E, Spinelli M. Identify the type of pleural effusion with lung ultrasound: a state-of-the-art review. Clin Res J Intern Med. 2023;4(2):504–509.
Islam ZU, Awan MM, Saqib HA, Firdous A, Saeed U. Evaluation of pleurodesis success in malignant pleural effusion using radiologic modalities. Pak J Chest Med. 2024;30(1):93–99.
Connolly JA, Dean AJ, Hoffmann B, et al. Emergency Point-of-Care Ultrasound. Hoboken, NJ: Wiley-Blackwell; 2017.
Ibitoye BO, Idowu BM, Ogunrombi AB, Afolabi BI. Ultrasonographic quantification of pleural
doi:10.1186/s13089-023-00356-z.
Porcel JM, Light RW. Diagnostic approach to pleural effusion in adults. Am Fam Physician. 2006;73(7):1211–1220.

Hooper C, Lee YC, Maskell N; BTS Pleural Guideline Group. Investigation of a unilateral pleural effusion in adults: British Thoracic Society Pleural Disease Guideline. Thorax. 2010;65(Suppl 2)–ii17. doi:10.1136/thx.2010.136978.
Mayo PH, Copetti R, Feller-Kopman D, Mathis G, Maury E, Mongodi S, et al. Thoracic ultrasonography: a narrative review. Intensive Care Med. 2019;45(9):1200–1211. doi:10.1007/s00134-019-05725-8.
effusion: comparison of four formulae. Ultrasonography. 2018;37(3):254–260. doi:10.14366/usg.17050.
Kocijancic I, Vidmar K, Ivanovič-Herceg Z. Chest sonography versus lateral decubitus radiography in the diagnosis of small pleural effusions. J Clin Ultrasound. 2003;31(2):69–74. doi:10.1002/jcu.10141.
Lichtenstein DA. BLUE-protocol and FALLS-protocol: two applications of lung ultrasound in the critically ill. Chest. 2015;147(6):1659–1670. doi:10.1378/chest.14-1313.
Lichtenstein DA. Current misconceptions in lung ultrasound: a short guide for experts. Chest. 2019;156(1):21–25. doi:10.1016/j.chest.2019.02.332.
Soni NJ, Franco R, Velez MI, Schnobrich D, Dancel R, Restrepo MI, et al. Ultrasound in the diagnosis and management of pleural effusions. J Hosp Med. 2015;10(12):811–816. doi:10.1002/jhm.2434.
Zaki HA, Albaroudi B, Shaban EE, Shaban A, Elgassim M, Almarri ND, et al. Advancement in pleural effusion diagnosis: a systematic review and meta-analysis of point-of-care ultrasound versus radiographic thoracic imaging. Ultrasound J. 2024;16:3.

Light RW. Pleural diseases. 7th ed. Philadelphia, PA: Wolters Kluwer; 2022.
Feller-Kopman D, Light R. Pleural disease. N Engl J Med. 2018;378(8):740–751. doi:10.1056/NEJMra1403503.