International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

ARTICLE TITLE	THE USE OF ULTRASOUND IN THE DIAGNOSIS OF FREE PLEURAL FLUID - A CASE STUDY AND LITERATURE REVIEW
DOI	https://doi.org/10.31435/ijitss.3(47).2025.3769
RECEIVED	03 August 2025
ACCEPTED	14 September 2025
PUBLISHED	17 September 2025
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

THE USE OF ULTRASOUND IN THE DIAGNOSIS OF FREE PLEURAL FLUID - A CASE STUDY AND LITERATURE REVIEW

Jarosław Jarosławski *(Corresponding Author, Email: jaroslawjaroslawski88@gmail.com)*
Department of Anatomy, Institute of Medical Sciences, University of Opole, Oleska Street 48, 45-052 Opole, Poland; Institute of Medical Sciences, The University of Applied Sciences in Nysa, ul. Ujejskiego 12, 48-300 Nysa, Poland
ORCID ID: 0009-0008-7794-8621

Dominik Tenczyński
University Clinical Hospital in Opole, al. Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0000-0002-8182-5279

Michał Kostro
University Clinical Hospital in Opole, al. Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0000-0003-3050-7382

Anna Żurakowska-Zadrożna
Faculty of Medicine, Institute of Medical Sciences, Collegium Medicum of Opole University, Oleska Street 48, 45-052 Opole, Poland
ORCID ID: 0009-0006-0130-0576

Wiktor Warda
Faculty of Medicine, Institute of Medical Sciences, Collegium Medicum of Opole University, Oleska Street 48, 45-052 Opole, Poland
ORCID ID: 0009-0001-1743-4011

Agata Klońska
Faculty of Medicine, Institute of Medical Sciences, Collegium Medicum of Opole University, Oleska Street 48, 45-052 Opole, Poland
ORCID ID: 0009-0004-3251-2200

Patrycja Trentkiewicz
Faculty of Law and Administration of Opole University, Oleska Street 48, 45-052 Opole, Poland
ORCID ID: 0009-0009-3560-5505

Rafał Rajski
University Clinical Hospital in Opole, al. Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0009-0006-2868-4549

ABSTRACT

Introduction: The presence of free pleural fluid is a common cause of dyspnea, particularly in the elderly population with multiple morbidities. There are many causes for this condition, but the most common include heart failure, cancer, lung infections, liver failure, and so on. The most common diagnostic tests for free pleural fluid are X-ray and ultrasonography, and in selected cases, computed tomography. In addition, we present the case of our patient who had a moderate amount of fluid in the pleural cavity, which caused significant clinical symptoms, and who did not consent to undergo an X-ray or CT scan due to his own beliefs.
Method: The aim of this paper is to describe our own experience with using ultrasonography in the diagnosis of free pleural fluid and to conduct a literature review using the Pubmed medical database, examining the sensitivity and specificity of ultrasonography in the diagnosis of free pleural fluid and its comparison to X-ray.
Results: Based on the conducted studies, it can be concluded that ultrasonography is more effective in the diagnosis of free pleural fluid than X-ray. Furthermore, the advantages of ultrasonography include its wide availability, the lack of ionizing radiation, low diagnostic cost, and the ability to perform the examination at the bedside. Thanks to ultrasound, it became possible to diagnose free fluid and then drain it without the use of radiological methods in accordance with the patient's will.
Conclusions: Lung ultrasound is far more sensitive and specific tool in diagnostic of the pleural effusion and significantly increases the safety of invasive therapeutic procedures such as thoracentesis thanks to the possibility of continuous real-time imaging.

KEYWORDS

Pleural Fluid, Ultrasound, Lung, Pocus

CITATION

Jarosław Jarosławski, Dominik Tenczyński, Michał Kostro, Anna Żurakowska-Zadrożna, Wiktor Warda, Agata Klońska, Patrycja Trentkiewicz, Rafał Rajski. (2025) The Use of Ultrasound in the Diagnosis of Free Pleural Fluid - A Case Study and Literature Review. *International Journal of Innovative Technologies in Social Science*. 3(47). doi: 10.31435/ijitss.3(47).2025.3769

Introduction

The pleural cavity is a demarcated space created by the pulmonary pleura and the parietal pleura, which physiologically contains a small amount of fluid that facilitates the sliding of the pleural sheets against each other during respiration [1]. Pathological conditions can also lead to the accumulation of large amounts of fluid, causing difficulty in breathing or even compression of the lung or its fragments [2]. This condition is one of the most common causes of dyspnea in patients, often requiring intervention in the form of thoracentesis [3]. There are many diseases that can lead to the accumulation of fluid in the pleural cavity, but there are no precise methods for visually differentiating this fluid. In addition to the traditional medical history and physical examination, which may lead to the suspicion of free pleural effusion, it is necessary to perform additional imaging tests [3,10]. The most common include X-ray, ultrasonography (USG), and computed tomography (CT). Ultrasonography, thanks to its physical properties, is the safest technique for both the patient and the staff. Furthermore, thanks to its instrumentation, it can be used bedside [12]. Studies have shown that it detects the smallest amounts of fluid compared to other tests, and the procedure and interpretation time are the shortest. Another undeniable advantage is the ability to perform ultrasound-guided thoracentesis of the pleural cavity (currently the gold standard), which significantly increases the safety of the entire procedure. From an economic perspective, it is also the cheapest diagnostic method and does not require transport to a radiology facility [11] Free pleural fluid is primarily identified by the presence of anechoic, mobile areas that localize gravitationally and move with respiration. Large amounts of free pleural fluid can compress the lung, leading to atelectasis (so-called compression atelectasis), described as consolidation with a visible static bronchogram, most often ballooning in the surrounding anechoic fluid [13-14]. In their comments to the recommendations, the authors additionally recommend performing an ultrasound examination after a chest X-ray, especially if the radiological findings are unclear or if thoracentesis is planned. Thickening of the parietal pleura (greater than 2 mm) and/or detection of focal lesions within the parietal pleura may suggest the presence of metastatic fluid [15-18].

Methods:

The study was based on an analysis of the patient's own diagnostic experience gained during routine ultrasound examinations and a literature review for publications comparing ultrasound and X-ray in the diagnosis of free pleural effusion. The search for papers was conducted using Pubmed.

Results:

A patient presented to our emergency department in fair condition with shortness of breath for two days, reporting blunt chest trauma on the right side. He had no fever, vital signs were normal, and a physical examination revealed concerns about the presence of a dull ache in the area of the base of the right lung. The patient refused the proposed radiological examination, believing it to be harmful radiation and that he did not wish to be exposed to radiation. Despite lengthy discussions, the patient maintained his position but consented to an ultrasound examination, which revealed approximately 300 ml of free fluid. The patient consented to drainage, which resulted in the removal of approximately 280 ml of mildly blood-tinged fluid. He was transferred to the pulmonary ward with an immediate improvement in his shortness of breath. After a week, he was discharged home in good general condition. Subsequent outpatient visits showed no deterioration. The patient is reportedly still skeptical of the X-ray examination.

In the systematic review following the selection process, nine publications from 1997 to 2019 from nine countries were finally analyzed. General information is presented in Table 7. A total of 1,456 patients were included in the analysis, of which 659 had confirmed pleural effusion. In eight of the studies, the examination was computed tomography (CT), and in one case, ultrasound performed on a high-quality device by an experienced operator.

		LUS				X-ray			
Publ.	Year	SEN	95% CI	SPE	95% CI	SEN	95% CI	SPE	95% CI
Ma [21]	1997	96%	80-100%	100%	98-100%	96%	80-100%	100%	98-100%
Kataoka [22]	2000	90%	79-96%	95%	77-100%	43%	31-57%	100%	85-100%
Lichtenstein [23]	2004	92%	85-96%	93%	89-96%	39%	29-49%	85%	81-89%
Rocco [24]	2008	95%	82-99%	99%	96-100%	24%	11-40%	96%	91-98%
Xirouchaki [25]	2011	100%	94-100%	100%	84-100%	65%	52-77%	81%	58-95%
Wang [26]	2012	95%	93-98%	87%	85-90%	34%	20-43%	75%	72-77%
Agmy [27]	2014	100%	96-100%	100%	98-100%	55%	45-60%	84%	80-88%
Graven* [28]	2015	98%	93-100%	70%	47-87%	40%	30-51%	78%	56-93%
Danish [29]	2019	88%	80-93%	100%	96-100%	48%	39-57%	77%	62-87%

Based on the above-presented results, it can be concluded that ultrasonography can diagnose pleural effusion with a sensitivity and specificity of 95% and 94%, respectively, while the sensitivity and specificity of X-ray was 49% and 86%, respectively.

Discussion:

The presence of pleural effusion is one of the most common causes of dyspnea, particularly among elderly patients [1-3]. There are many causes of this condition, but the most common include heart failure, chronic cancer, bacterial pneumonia, and liver failure. Imaging methods that can be used to diagnose pleural effusion include X-ray, ultrasound, and CT, as described previously [4, 5-7]. Ultrasonography stands out from other methods not only for its highest safety profile and lowest operating costs, but also for its highest availability, which results from the increasing availability of 24-hour ultrasound scanners in hospital wards [11]. Another important advantage of ultrasound is the ability to perform the examination independently, practically at the patient's bedside, and to plan and safely perform thoracentesis [12]. Due to the lack of ionizing radiation, repeated follow-up examinations of the patient's pleural cavities are possible at any time interval, which would be unacceptable with radiological methods [12-14]. In everyday clinical practice, depending on the center, ultrasonography and X-ray examinations dominate. Based on the results of numerous scientific

studies comparing X-ray and ultrasound, ultrasonography clearly prevails [4-5, 13-14]. The analysis confirmed this hypothesis, as based on selected studies [21-29], the average sensitivity and specificity of ultrasonography were 95% and 94%, respectively, while X-ray had a sensitivity of only 49%. The high specificity of 86% is due to the large volumes of fluid in the pleural cavity, which causes the characteristic X-ray appearance. It is also important to cite data from numerous scientific studies [14, 23, 30-31] regarding the amount of fluid in the pleural cavity that can be diagnosed using these methods. Ultrasonography can detect the presence of as little as 20-30 ml of free fluid, and even 3-5 ml of confined fluid (e.g., in the form of an abscess). These values are many times smaller than for X-ray, where the minimum amounts of fluid detected were 150 ml (PA view), 50-75 ml (lateral view), and 500 ml (supine position). Regarding fluid volume estimation using ultrasound, a good correlation has been demonstrated between mathematical formulas and the actual volume obtained after thoracentesis, but this method is still somewhat controversial [14, 19]. According to skeptics of fluid volume estimation formulas, it is difficult to obtain repeatable results, even in consecutive measurements, much less in measurements performed by different people. Furthermore, accurate fluid distribution, although gravitational in nature, may vary among patients depending on their anatomy. A counterargument is that the estimated fluid volume does not need to be highly accurate, as it is important to determine its order of magnitude, not its exact volume. Furthermore, determining the exact volume is not a factor that would dramatically change the therapeutic approach. Being aware of the advantages and disadvantages of mathematical estimation of the volume of fluid in the pleural cavity, in order to obtain the most reliable results, recommendations have been developed according to which measurements in a given patient should always be made in the same place, in the same position and using the same formula [14, 19, 33]. A precise assessment of the fluid and its nature (exudate, transudate, etc.) is only possible after performing appropriate laboratory tests, however, there are certain ultrasound features based on which its type can be approximately determined. In patients with congestive heart failure, the pleural effusion observed on ultrasound typically appears as an anechoic collection of fluid. The absence of internal echoes is characteristic, and no additional echogenic structures are visualized within the effusion. This clear, echo-free appearance reflects the transudative nature of the fluid, which is usually caused by increased hydrostatic pressure rather than an inflammatory or malignant process.

When the pleural effusion develops in the context of infection, its ultrasound features are more variable. Initially, the fluid may present as anechoic, resembling simple transudates, but as the inflammatory process progresses, the effusion often becomes increasingly echogenic. This transition toward hyperechogenicity suggests the presence of cellular elements, fibrin strands, and proteinaceous material, indicating that the fluid is organizing. Thus, the ultrasonographic appearance evolves with the stage and severity of the infection. A more advanced infectious complication is the pleural empyema, which demonstrates distinct sonographic features. The effusion in this case is typically hyperechogenic, reflecting the presence of a large number of inflammatory cells, bacteria, and debris. The fluid is described as cellular-rich and frequently accompanied by surrounding inflammatory changes in adjacent organs and tissues, which can also be detected on imaging. These sonographic findings correlate with the clinical picture of severe infection and highlight the necessity of urgent drainage and antimicrobial treatment. In patients with lung cancer or metastatic disease, the sonographic characteristics of pleural effusions are also distinctive. The fluid is often echogenic rather than anechoic, suggesting the presence of tumor cells, blood, or proteinaceous material. One particularly notable finding is the so-called plankton sign, which refers to the visualization of suspended particles within the effusion, moving slowly with respiratory or cardiac motion. Additionally, pathological soft-tissue masses are frequently seen in the surrounding pleura or adjacent structures, providing further evidence of malignant infiltration. The combination of these features strongly raises suspicion for a neoplastic etiology. Finally, in the setting of pulmonary embolism, pleural effusions generally appear anechoic, resembling those seen in heart failure. However, the key distinguishing feature is their localization. The fluid is most often found overlying an area of pulmonary infarction, corresponding to the region where vascular obstruction has led to ischemic injury of the lung parenchyma. Although the effusion itself is simple in appearance, the clinical context and distribution help in recognizing its thromboembolic origin. A specific situation that should be mentioned is the possible organization of high-protein fluid and the formation of fibrinous septa in the pleural cavity, which constitutes a contraindication to percutaneous thoracentesis and requires consideration of thoracic surgery [14]. This most often occurs in chronic inflammatory processes of the lungs or in tumors. Blood in the pleural cavity may also raise some controversy. Blood in the pleural cavity, while fresh, is anechoic, but over time, it organizes into a thrombus, which can be confusing for an inexperienced user [14, 21]. Other conditions that should be differentiated from free pleural fluid include lung abscess, pleural empyema, or even lung cyst (case reports) [14, 37].

Conclusions:

Based on the conducted research, the following conclusions can be drawn:

- Ultrasonography is the safest and cheapest diagnostic method for diagnosing pleural effusion.
- Ultrasonography enabled us to quickly make a diagnosis and begin treatment for our patient, who, despite medical contraindications, completely ruled out radiological diagnostics. Nevertheless, we must respect his wishes and suggest other diagnostic methods as long as it does not compromise the patient's well-being, even if we disagree with his views.
- The sensitivity of ultrasonography is significantly higher than that of X-ray (95% vs. 49%), while specificity is only slightly higher (ultrasound 94% vs. X-ray 86%).
- Ultrasonography is the only imaging method that can be used to safely perform thoracentesis with real-time imaging.
- Ultrasonography can detect very small amounts of pleural effusion.
- If one imaging technique is inconclusive, additional tests should be performed using a different technique (1st stage – X-ray, ultrasound; 2nd stage – CT).

Disclosure

Author's contribution:

Conceptualisation: Rafał Rajski
Methodology: Jarosław Jarosławski, Wiktor Warda
Software: Dominik Tenczyński, Michał Kostro
Check: Anna Żurakowska-Zadrożna
Formal analysis: Wiktor Warda, Patrycja Trentkiewicz
Investigation: Agata Wysocka, Jarosław Jarosławki
Resources: Patrycja Trentkiewicz
Data curation: Rafał Rajski, Dominik Tenczyński
Writing-draft preparation: Rafał Rajski, Jarosław Jarosławski
Writing review and editing: Agata Wysocka, Patrycja Trentkiewicz
Project administration: Rafał Rajski,

All authors have read and agreed with the published version of the manuscript.

Funding Statement: The study did not receive special funding.
Institutional Review Board Statement: Not applicable.
Informed Consent Statement: Not applicable.
Data Availability Statement: Not applicable.
Acknowledgments: Not applicable.
Conflict of Interest: The authors declare no conflict of interest.

REFERENCES

1. Yalcin NG, Choong CKC, Eizenberg N. Anatomy and pathophysiology of the pleura and pleural space. *Thorac Surg Clin*. 2013 Feb;23(1):1–10. doi:10.1016/j.thorsurg.2012.10.008. PMID:23206712.
2. Lee KF, Olak J. Anatomy and physiology of the pleural space. *Chest Surg Clin N Am*. 1994 Aug;4(3):391–403. PMID:7953475.
3. Jany B, Welte T. Pleural effusion in adults: etiology, diagnosis, and treatment. *Dtsch Arztebl Int*. 2019 May 24;116(21):377–386.
4. Beaudoin S, Gonzalez AV. Evaluation of the patient with pleural effusion. *CMAJ*. 2018 Mar 12;190(10):E291–E295.
5. Light RW. Pleural effusions. *Med Clin North Am*. 2011 Nov;95(6):1055–1070.
6. McGrath EE, Anderson PB. Diagnosis of pleural effusion: a systematic approach. *Am J Crit Care*. 2011 Mar;20(2):119–127.
7. Light RW. Clinical practice. Pleural effusion. *N Engl J Med*. 2002 Jun 20;346(25):1971–1977.
8. Ferreiro L, San José E, Valdés L. Tuberculous pleural effusion. *Arch Bronconeumol*. 2014 Oct;50(10):435–443.
9. McGrath EE, Blades Z, Anderson PB. Chylothorax: aetiology, diagnosis and therapeutic options. *Respir Med*. 2010 Jan;104(1):1–8.
10. Saguil A, Wyrick K, Hallgren J. Diagnostic approach to pleural effusion. *Am Fam Physician*. 2014 Jul 15;90(2):99–104.

11. Botana Rial M, Pérez Pallarés J, Cases Viedma E, et al. Diagnosis and treatment of pleural effusion: recommendations of the Spanish Society of Pulmonology and Thoracic Surgery. Update 2022. *Arch Bronconeumol*. 2023 Jan;59(1):27–35. doi:10.1016/j.arbres.2022.09.017. PMID: Unavailable.
12. Shao RJ, Du MJ, Xie JT. Use of lung ultrasound for the diagnosis and treatment of pleural effusion. *Eur Rev Med Pharmacol Sci*. 2022 Dec;26(23):8771–8776.
13. Demi L, Wolfram F, Klersy C, et al. New international guidelines and consensus on the use of lung ultrasound. *J Ultrasound Med*. 2023 Feb;42(2):309–344.
14. Buda N, Kosiak W, Wełnicki M, et al. Recommendations for lung ultrasound in internal medicine. *Diagnostics (Basel)*. 2020 Aug 16;10(8):597.
15. Lichtenstein D, Goldstein I, Mourgeon E, et al. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. *Anesthesiology*. 2004 Jan;100(1):9–15.
16. Teichgräber UK, Hackbarth J. Sonographic bedside quantification of pleural effusion compared to computed tomography volumetry in ICU patients. *Ultrasound Int Open*. 2018 Oct;4(4):131–135.
17. Salamonsen M, Dobeli K, McGrath D, et al. Physician-performed ultrasound can accurately screen for a vulnerable intercostal artery prior to chest drainage procedures. *Respirology*. 2013 Aug;18(6):942–947.
18. Brogi E, Gargani L, Bignami E, et al. Thoracic ultrasound for pleural effusion in the intensive care unit: a narrative review from diagnosis to treatment. *Crit Care*. 2017 Dec 28;21(1):325.
19. Peris A, Tutino L, Zagli G, et al. The use of point-of-care bedside lung ultrasound significantly reduces the number of radiographs and computed tomography scans in critically ill patients. *Anesth Analg*. 2010 Sep;111(3):687–692.
20. Mishra P, Pandey CM, Singh U, et al. Selection of appropriate statistical methods for ta analysis. *Ann Card Anaesth*. 2019 Jul–Sep;22(3):297–301.
21. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med*. 1997 Mar;29(3):312–315.
22. Kataoka H, Takada S. The role of thoracic ultrasonography for evaluation of patients with decompensated chronic heart failure. *J Am Coll Cardiol*. 2000 May;35(6):1638–1646.
23. Lichtenstein D, Goldstein I, Mourgeon E, et al. (duplicate of #15).
24. Rocco M, Carbone I, Morelli A, et al. Diagnostic accuracy of bedside ultrasonography in the ICU: feasibility of detecting pulmonary effusion and lung contusion in patients on respiratory support after severe blunt thoracic trauma. *Acta Anaesthesiol Scand*. 2008 Jul;52(6):776–784.
25. Xirouchaki N, Magkanas E, Vaporidi K, et al. Lung ultrasound in critically ill patients: comparison with bedside chest radiography. *Intensive Care Med*. 2011 Sep;37(9):1488–1493.
26. Wang XT, Liu DW, Zhang HM, et al. The value of bedside lung ultrasound in emergency-plus protocol for the assessment of lung consolidation and atelectasis in critical patients. *Zhonghua Nei Ke Za Zhi*. 2012 Dec;51(12):948–951.
27. Agmy G, Mohamed S, Gad Y. Transthoracic chest ultrasound in critically ill patients: comparison with bedside chest radiography. *Eur Respir J*. 2014;44(Suppl 58):P4585.
28. Graven T, Wahba A, Hammer AM, et al. Focused ultrasound of the pleural cavities and the pericardium by nurses after cardiac surgery. *Scand Cardiovasc J*. 2015 Feb;49(1):56–63.
29. Danish M, Agarwal A, Goyal P, et al. Diagnostic performance of 6-point lung ultrasound in ICU patients: a comparison with chest X-ray and CT thorax. *Turk J Anaesthesiol Reanim*. 2019 Aug;47(4):307–319.
30. Maskell NA, Butland RJ; Pleural Diseases Group, Standards of Care Committee, British Thoracic Society. BTS guidelines for the investigation of a unilateral pleural effusion in adults. *Thorax*. 2003 May;58 Suppl 2:ii8–ii17.
31. Gryminski J, Krakówka P, Lypacewicz G. The diagnosis of pleural effusion by ultrasonic and radiologic techniques. *Chest*. 1976 Jul;70(1):33–37.
32. Grimberg A, Shigueoka DC, Atallah AN, et al. Diagnostic accuracy of sonography for pleural effusion: systematic review. *Sao Paulo Med J*. 2010;128(2):90–95.
33. Hansell L, Milross M, Delaney A, et al. Lung ultrasound has greater accuracy than conventional respiratory assessment tools for the diagnosis of pleural effusion, lung consolidation and collapse: a systematic review. *J Physiother*. 2021 Jan;67(1):41–48.
34. Bhatnagar R, Maskell N. The modern diagnosis and management of pleural effusions. *Clin Med (Lond)*. 2015 Jun;15 Suppl 6:s68–s72.
35. Chen HJ, Hsu WH, Tu CY, et al. Sonographic septation in lymphocyte-rich exudative pleural effusions: a useful diagnostic predictor for tuberculosis. *J Ultrasound Med*. 2006 Jul;25(7):857–863.
36. Qureshi NR, Rahman NM, Gleeson FV. Thoracic ultrasound in the diagnosis of malignant pleural effusion. *Thorax*. 2009 Feb;64(2):139–143.
37. Ramasli Gursoy T, Sismanlar Eyuboglu T, Onay ZR, et al. Pleural thickening after pleural effusion: how can we follow-up in children? *J Trop Pediatr*. 2020 Feb 1;66(1):85–94.