Trauma Monthly 2023; 28(3): 850-855

10.30491/tm.2023.403486.1612

Trauma Monthly

Systematic Review

Features of Lung Ultrasound and Chest Radiology in Diagnosing of Pleural Effusion in Critical Care Patients: A Systematic Review

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Received 2023-03-06; **Accepted** 2023-06-16; **Online Published** 2023-06-30

Abstract

Introduction: Pleural effusion (PLEFF) is mainly caused by volume overload, heart failure, trauma, and pleuro-pulmonary infection, it is common in emergency and ICU patients. Although the function of ultrasonography in detecting PLEFF has long been noted, controversial results have been reported. This study aimed to review the literature on ultrasound and radiography in detecting PLEFF.

Methods: A search was done in Medline, ISI Web of Knowledge, EMBASE, and Scopus databases. Two reviewers independently searched, screened, and included the data and a third author resolved any conflict.

Results: The findings proved that as a screening tool, chest ultrasound has greater diagnostic accuracy in identifying multiple pleural effusions than radiography. Chest ultrasound enables clinicians visualize pleural effusions and also helps differentiate between various types. In addition, chest ultrasound is crucial for thoracentesis and thoracostomy drainage as it enhances safeness and reduces life-threatening complications. This is important not only when inserting a needle or tube drain, but also when monitoring the amount of her PLEFF deflated. In addition, chest ultrasound is often more specific and sensitive than chest radiography, helping to diagnose coexisting lung disease without X-ray exposure.

Conclusion: Thoracic Ultrasound (TUS) is a simple, non-invasive, bedside procedure for diagnosing PLEFF with greater sensitivity and specificity than a chest X-ray. This is crucial for visualizing exudate and helps differentiate various forms of her PLEFF. More recently, ultrasound has been used to guide thoracentesis and insert chest tubes to raise the safeness of this invasive method, especially if an ICU patient is on a ventilator or has a small localized pleural effusion. Additionally, TUS can monitor the PLEFF drainage and determine when to extract the drainage.

Keywords: Ultrasonography, CT scan, radiology, Pleural Effusion.

Introduction

Several situations can cause PLEFF, but the most common causes in the ICU and emergency department are volume overload, heart failure, trauma, and pleuro-pulmonary infections[1-3]. Fluid accumulation can happen because of hydrostatic and osmotic imbalances within pulmonary capillaries, raised pleural capillary permeability, and lymphatic obstruction[4-7]. In addition, characteristics known to promote the formation of pulmonary edema in clinical practice (fluid overload, myocardial depression, hypoalbuminemia) are usually coexisting, and the usually high absorptive capacity of the lungs and parietal pleural lymphatics. Beyond this may lead to the worsening of PLEFF-leading symptoms[8-10].

PLEFF can be detected by physical assessment. The absence of breath sounds on auscultation, flatness in beats, and decreased tactile nodule muscles in patients who can speak all indicate the existence of PLEFF. Nevertheless, the physical examination of critically ill patients can be complex because several factors can alter intrathoracic sound transmission[11-14]. As a result, several studies have shown that physical examination

has lower specificity and sensitivity for diagnosing pleural effusion than imaging. Ultrasound is not yet considered the primary diagnostic instrument for detecting PLEFF, and most physicians utilize radiography to detect PLEFF[15]. X-ray images taken horizontally in the lateral position have high sensitivity and specificity in detecting PLEFF. Still, not all patients, especially those with severe illness or trauma, can obtain them. PLEFF occurs often in emergency and ICU cases with an incidence that varies according to the diagnostic procedure[16-18]. Also, it is associated with an increased mortality rate. PLEFF can impair gas exchange, hemodynamic stability, and respiratory dynamics. Drainage improves ventilation, thereby improving oxygenation, respiratory mechanics, and compliance. Perfusion rate and re-expansion of collapsed lung parenchyma. Percutaneous pleural drain insertion is often performed in intensive care units, but incorrect tube insertion can have tragic outcomes. Complications from chest tube placement have been reported in up to 20-30% of cases. Some of these complications can be lethal[19-21].

Although the function of ultrasonography in detecting PLEFF has long been noted, controversial results have been reported. This study aimed to review the literature on ultrasound and radiography detecting PLEFF.

Method

We followed recommended reporting methods for systematic reviews and guidelines for meta-analyses. For suitable studies, we searched PUBMED, SCOPUS, Web of Science, and Google Scholar databases (1997-2023).

Studies using radiography as a reference test were excluded, and only studies in which the definitive diagnosis of pleural effusion was confirmed by CT or surgery were included. Articles from keywords such as “Ultrasonography” OR “Ultrasound” OR “Sonography” OR Pocket-size ultrasound OR “Chest Film” OR CT scan" OR X-ray OR “Chest Radiograph” combined with “Pleural Effusion” OR “Effusion” OR “Pleural Free Fluid” were used. The online databases searched Terms and words using the 'And' and 'Or'.

Two reviewers independently filtered documents for title, abstract, and methodological validity using a data extraction format before inclusion in the final review. Conversations with senior faculty were used to resolve judge disagreements during the judging stage.

Result

Search process and the number of articles obtained in each step are presented in Table 1. Twenty-one studies met the inclusion criteria. One survey was also found through manual search. After detailed evaluation of these surveys 12 studies were included.

The characteristics of included studies are presented in Table 1. The mean age ranging from 4 to 74 years old. The results showed that ultrasonography has high sensitivity and specificity in detecting PLEFF. However, the diagnostic value of radiography has been reported to be lower than ultrasonography. Radiographic sensitivity increased slightly when the analysis was restricted to studies in which the cause of pleural effusion was trauma, surgery, or heart failure. The finding proved that ultrasound is a better detection instrument for PLEFF than radiography.

To prove a suspected diagnosis of PLEFF, utilizing the following imaging tests in studies was suggested:

Plain chest x-ray, ultrasonography, chest computed tomography. CT is assumed to be the gold standard but is expensive and challenging to accomplish in emergency and ICU patients. Cardiophrenic angle blunting, costophrenic angle blunting, and lung opacification can demonstrate pleural effusion.

Nevertheless, technological limitations such as the prone position, posterior-anterior view, and comorbid pulmonary parenchymal disease may donate to substandard radiographic imaging and underdiagnoses of pleural effusion. Exudates as small as 50 mL may be visual on upright lateral X-ray images. However, conventional posterior-anterior imaging requires a volume of at least 200 ml; a volume of around 500 ml destroys the hemidiaphragm. Due to the deep posterior costophrenic angle, his lateral PU radiograph may show less fluid than the poster anterior radiograph. However, an upright or lateral recumbent position is unbelievable in intensive care cases.

Ultrasound measures exudate size more accurately than X-rays of lateral pressure ulcers. A study performed analogizing research ultrasound with lateral PU radiography to detect pleural effusion. They followed that ultrasonography could see pleural effusions less than 15 mm[13]. As a result, several studies have concentrated on introducing ultrasound in the intensive care to reduce the number of chest radiography studies

to decrease X-ray exposure and acquire more precise data[22-38].

Table 1: Studies' characteristics.

Authors' name	patients	Number	Age	Groups	outcomes
Jacobson et al. (2022) [21]	thoracic surgical patients	80	55.29	Ultrasonography/chest X-ray	60% of pleural effusions were missed by chest X-ray and detected by ultrasonography, and only 2.4% were missed by ultrasound.
Phung et al. (2020) [22]	Acute Dyspnea	81		Ultrasonography/chest X-ray	100% vs 73.3%
Tasci et al. (2016) [23]	Critically ill patients	55	<5	Portable Ultrasonography/sector Ultrasonography/chest radiography/ Auscultation	98% vs. 95% vs 89% vs 87%
Inglis et al. (2016) [24]	critically ill patients	145	62	Ultrasonography, chest X-ray/physical examination	fair-to-moderate agreement to detection PLEFF
Lichtenstein et al. (2004) [25]	Acute Respiratory Distress Syndrome	32 patients and 10 healthy volunteers	58	Ultrasonography/chest X-ray	93 %accuracy vs 47 %
Ma et al. (1997) [26]	hemothorax in trauma patients	245	18	Ultrasonography/chest X-ray	96%
Kitazono et al (2010) [27]	Critically ill in ICU	117 vs 83	54	chest X-ray	66%
Rocco et al. (2008) [28]	Thoracic trauma	15	42	Ultrasonography/chest X-ray	94% vs 42%
Zanobetti et al. (2011) [29]	dyspnea	404	73	Ultrasonography/chest X-ray	63% vs 40%
Xirouchaki et al. (2011) [30]	Critically ill patients	84	57	Ultrasonography/chest X-ray	100% vs 69%
Schleder et al. (2012) [31]	hemithoraces	48	65	hand-carried ultrasound/ chest radiography	91% vs 74%
Kasraei et al. (2016) [32]	Critically ill patients in ICU	39	54	portable ultrasound/chest radiography	100% vs 33%
Gazon et al. (2011) [33]	Critically ill patients in ICU	50	62.4	Ultrasonography/chest X-ray	Moderate agreement
Graven et al. (2015) [34]	cardiac surgery	59	67	Pocket-size ultrasound /chest X-ray	Sensitivity 98% vs 40%
Sachdev et al. (2021) [35]	Critically ill patients in ICU	413	4	Ultrasonography/chest X-ray	89% vs 47.6%
Dalen et al. (2015) [36]	heart failure patients	62	74	Pocket-size ultrasound /chest X-ray	all diagnosis criteria≥ 92%
Stock et al. (2015) [37]	internal-medicine	28	68	high-end ultrasound/ Ultrasonography	concordantly 73%, ascites, fatty liver, and identification of severe parenchymal liver damage, sensitivity 80%
Kataoka et al. (2000) [38]	Chronic heart failure	60 patients and 22 free from disease	76	Ultrasonography/chest X-ray	93 %accuracy vs 43 %

Discussion

The findings of this study prove that chest ultrasound is a beneficial and noninvasive technique for detecting PLEFF in emergency and ICU patients [21-38]. However, chest ultrasound is preferable to decubitus radiography in diagnosing the volume of effusion fluid, so the diagnostic power of sonography is greater than radiography in the same thickness of effusion fluid[24-24]. Moreover, the superiority of ultrasonography in diagnosing pleural effusions is recognized in a growing body of professional literature. Kataoka et al. (2000) compared chest ultrasonography with physical examination and upright poster anterior chest radiographs to diagnose pleural effusion in patients with chronic heart failure. They reported diagnostic accuracy of 91% for chest ultrasound, compared with 56% for physical examination and 33% for radiography. Lichtenstein et al. conducted a prospective study comparing the accuracy of physical examination, ultrasonography, and chest radiography with chest CT in 32 patients with acute respiratory distress syndrome and ten volunteers. Lung ultrasonography had a sensitivity of 92%, a specificity of 93%, and a diagnostic accuracy of 93%[25]. Bedside chest radiography and physical examination showed low sensitivity, specificity, and diagnostic accuracy of PLEFF. Rocco et al. (2008) compared bedside radiography and ultrasound for diagnosing pleural effusions in trauma patients. They demonstrated that ultrasound is more accurate than X-rays for detecting pleural effusions[28]. Xirouchaki et al. (2011) compared the diagnostic performance of bedside ultrasonography and chest radiography in intensive care cases. For pleural effusion diagnosis, ultrasound demonstrated 100% sensitivity, 100% specificity, and 100% diagnostic accuracy, whereas X-ray was 65%, 81%, and 69%, respectively. Therefore, the International Consensus Conference on Lung Ultrasound states that ``pulmonary ultrasound is more precise than supine radiography and as accurate as CT for detecting pleural effusions". In particular, ultrasound may help determine the character of the pleural effusion while ruling out pre-existing lung pathology[30].

Compared with the current research results, another study reported similar results. They found that the sensitivity and specificity of ultrasonography were calculated to be 93% and 96%, respectively, whereas the values of radiography were estimated to be 24% and 100%, respectively[39, 40]. Our results were similar to Yousefifard et al. (2016) study[40], and they showed that the higher sensitivity of the radiography in this study might be due to the inclusion of additional investigations in the analysis. Grimberg's study lacked subgroup analysis, so no other comparisons were possible. A further meta-analysis considered his ten papers to evaluate the diagnostic value of ultrasonography in diagnosing pneumonia. They discovered a sensitivity of 94% and a specificity of 96% for this tool[39].

This study showed lung ultrasound is a practical diagnostic modality for detecting pneumonia in critical care patients. Congruent with this study, the current study reported a significant diagnostic value for ultrasonography in detecting PLEFF. One aspect that impacts ultrasonography's accuracy is the ultrasound device's operator and machine, demonstrated by different studies.

Conclusion

Lung ultrasound is a simple, non-invasive, bedside procedure for diagnosing PLEFF with greater sensitivity and specificity than a chest X-ray. This is crucial for visualizing exudate and helps differentiate various forms of her PLEFF. More recently, ultrasound has been utilized to conduct thoracentesis and insert chest tubes to raise the safeness of this invasive method, especially if ICU patients are on a ventilator or have a bit of localized PLEFF. Also, the Lung ultrasound must monitor PLEFF drainage and choose when to pull the drainage.

Acknowledgments

None.

Conflict of Interest Disclosures

None.

Funding Sources

None.

Authors' Contributions

All the authors have contributed to developing the concept and producing the final manuscript.

Ethical Statement

It did not involve data collection at an individual level

or human subjects.

References

1. Maslove DM, Chen BT, Wang H, Kuschner WG. The diagnosis and management of pleural effusions in the ICU. J Intensive Care Med. 2013; 28(1):24–36.

2. Graf J. Pleural effusion in the mechanically ventilated patient. Curr Opin Crit Care. 2009;15(1):10–7.

3. Mattison LE, Coppage L, Alderman DF, Herlong JO, Sahn SA. Pleural effusions in the medical ICU: prevalence, causes, and clinical implications. Chest. 1997;111(4):1018–23.

4. Fartoukh M, Azoulay E, Galliot R, Le Gall JR, Baud F, Chevret S, Schlemmer B. Clinically documented pleural effusions in medical ICU patients: how useful is routine thoracentesis? Chest. 2002;121(1):178–84.

5. Azoulay E. Pleural effusions in the intensive care unit. Curr Opin Pulm Med. 2003;9(4):291–7.

6. Goligher EC, Leis JA, Fowler RA, Pinto R, Adhikari NK, Ferguson ND. Utility and safety of draining pleural effusions in mechanically ventilated patients: a systematic review and meta-analysis. Crit Care (London, England). 2011;15(1): R46.

7. Cartaxo AM, Vargas FS, Salge JM, Marcondes BF, Genofre EH, Antonangelo L, Marchi E, Teixeira LR. Improvements in the 6-min walk test and spirometry following thoracentesis for symptomatic pleural effusions. Chest. 2011; 139(6):1424–9.

8. Kopec SE, Conlan AA, Irwin RS. Perforation of the right ventricle: a complication of blind placement of a chest tube into the postpneumonectomy space. Chest. 1998;114(4):1213–5.

9. Bozzani A, Arici V, Bellinzona G, Pirrelli S, Forni E, Odero A. Iatrogenic pulmonary artery rupture due to chest-tube insertion. Tex Heart Inst J. 2010; 37(6):732–3.

10. Harris A, O'Driscoll BR, Turkington PM. Survey of major complications of intercostal chest drain insertion in the UK. Postgrad Med J. 2010; 86(1012):68–72.

11. Yang PC, Luh KT, Chang DB, Wu HD, Yu CJ, Kuo SH. Value of sonography in determining the nature of pleural effusion: analysis of 320 cases. AJR Am J Roentgenol. 1992;159(1):29–33.

12. Havelock T, Teoh R, Laws D, Gleeson F. Pleural procedures and thoracic ultrasound: British Thoracic Society Pleural Disease Guideline 2010. Thorax. 2010;65 Suppl 2: ii61–76.

13. Neuteboom OB, Heldeweg ML, Pisani L, Smit MR, Lagrand WK, Cherpanath TG, Dondorp AM, Schultz MJ, Tuinman PR. Assessing extravascular lung water in critically ill patients using lung ultrasound: a systematic review on methodological aspects in diagnostic accuracy studies. Ultrasound in Medicine & Biology. 2020 Jul 1;46(7):1557-64.

14. Fagley RE, Haney MF, Beraud AS, Comfere T, Kohl BA, Merkel MJ, Pustavoitau A, von Homeyer P, Wagner CE, Wall MH. Critical care basic ultrasound learning goals for American anesthesiology critical care trainees: recommendations from an expert group. Anesth Analg. 2015;120(5):1041–53.

15. Mayo PH, Beaulieu Y, Doelken P, Feller-Kopman D, Harrod C, Kaplan A, Oropello J, Vieillard-Baron A, Axler O, Lichtenstein D, et al. American College of Chest Physicians/La Societe de Reanimation de Langue Francaise statement on competence in critical care ultrasonography. Chest. 2009; 135(4):1050–60.

16. Strobel D, Bernatik T, Blank W, Will U, Reichel A, Wьstner M, Keim V, Schacherer D, Barreiros AP, Kunze G, Nьrnberg D. Incidence of bleeding in 8172 percutaneous ultrasound-guided intraabdominal diagnostic and therapeutic interventions–results of the prospective multicenter DEGUM interventional ultrasound study (PIUS study). Ultraschall in der Medizin-European Journal of Ultrasound. 2015 Apr;36(02):122-31.

17. Baldi G, Gargani L, Abramo A, D'Errico L, Caramella D, Picano E, Giunta F, Forfori F. Lung water assessment by lung ultrasonography in intensive care: a pilot study. Intensive Care Med. 2013;39(1):74–84.

18. Blackmore CC, Black WC, Dallas RV, Crow HC. Pleural fluid volume estimation: a chest radiograph prediction rule. Acad Radiol. 1996;3(2):103–9.

19. Kocijancic I, Vidmar K, Ivanovi-Herceg Z. Chest sonography versus lateral decubitus radiography in the diagnosis of small pleural effusions. J Clin Ultrasound. 2003;31(2):69–74.

20. Clec'h C, Simon P, Hamdi A, Hamza L, Karoubi P, Fosse JP, Gonzalez F, Vincent F, Cohen Y. Are daily routine chest radiographs useful in critically ill, mechanically ventilated patients? A randomized study. Intensive Care Med. 2008;34(2):264–70.

21. J. Jakobson D, Cohen O, Cherniavsky E, Batumsky M, Fuchs L, Yellin A. Ultrasonography can replace chest X-rays in the postoperative care of thoracic surgical patients. Plos one. 2022 Oct 20;17(10): e0276502.

22. Phung NT, Vo TT, Hon KL. The role of lung ultrasonography in etiologic diagnosis of acute dyspnea in a resource limited setting. Bulletin of Emergency & Trauma. 2020 Apr;8(2):121.

23. Tasci O, Hatipoglu ON, Cagli B, Ermis V. Sonography of the chest using linear-array versus sector transducers: Correlation with auscultation, chest radiography, and computed tomography. Journal of Clinical Ultrasound. 2016 Jul 8;44(6):383-9.

24. Inglis AJ, Nalos M, Sue KH, Hruby J, Campbell DM, Braham RM, Orde SR. Bedside lung ultrasound, mobile radiography and physical examination: a comparative analysis of diagnostic tools in the critically ill. Critical Care and Resuscitation. 2016 Jun;18(2):116-24.

25. Lichtenstein D, Goldstein I, Mourgeon E, Cluzel P, Grenier P, Rouby JJ. Comparative diagnostic performances of auscultation, chest radiography, and lung ultrasonography in acute respiratory distress syndrome. Anesthesiology. 2004;100(1):9–15.

26. Ma OJ, Mateer JR. Trauma ultrasound examination versus chest radiography in the detection of hemothorax. Ann Emerg Med. 1997;29(3):312-6.

27. Kitazono MT, Lau CT, Parada AN, Renjen P, Miller Jr WT. Differentiation of pleural effusions from parenchymal opacities: Accuracy of bedside chest radiography. Am J Roentgenol. 2010;194(2):407-12.

28. 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;52(6):776-84.

29. Zanobetti M, Poggioni C, Pini R. Can chest ultrasonography replace standard chest radiography for evaluation of acute dyspnea in the ED? Chest. 2011;139(5):1140-7.

30. Xirouchaki N, Magkanas E, Vaporidi K, et al. Lung ultrasound in critically ill patients: comparison with bedside chest radiography. Intensive Care Med. 2011;37(9):1488-93.

31. Schleder S, Dornia C, Poschenrieder F, et al. Bedside diagnosis of pleural effusion with a latest generation handcarried ultrasound device in intensive care patients. Acta Radiol. 2012;53(5):556-60.

32. Kasraei M, Abtahi H, Eyoobi Yazdi N, Safavi E, Firoozbakhsh S, Mohammady M. Diagnosis of pleural effusion by portable ultrasound and chest radiography in intensive care unit. Tehran Uni Med J. 2014;72(7):463-70.

33. Gazon M, Eboumbou N, Robert MO, Branche P, Duperret S, Viale JP. Analyse de concordance entre l'йchographie pulmonaire et la radiographie thoracique en rйanimation. InAnnales francaises d'anesthesie et de reanimation 2011 Jan 1 (Vol. 30, No. 1, pp. 6-12). Elsevier Masson.

34. 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;49(1):56-63.

35. Sachdev A, Khatri A, Saxena KK, Gupta D, Gupta N, Menon GR. Chest sonography versus chest radiograph in children admitted to paediatric intensive care–A prospective study. Tropical Doctor. 2021 Jul;51(3):296-301.

36. Dalen H, Gundersen GH, Skjetne K, et al. Feasibility and reliability of pocket-size ultrasound examinations of the pleural cavities and vena cava inferior performed by nurses in an outpatient heart failure clinic. Eur J Cardiovasc Nurs. 2015;14(4):286-93.

37. Stock KF, Klein B, Steubl D, Lersch C, Heemann U, Wagenpfeil S, Eyer F, Clevert DA. Comparison of a pocket-size ultrasound device with a premium ultrasound machine: diagnostic value and time required in bedside ultrasound examination. Abdominal imaging. 2015 Oct; 40:2861-6.

38. Kataoka H, Takada S. The role of thoracic ultrasonography for evaluation of patients with decompensated chronic heart failure. J Am Coll Cardiol. 2000;35(6):1638-46.

39. Yousefifard M, Baikpour M, Ghelichkhani P, Asady H, Nia KS, Jafari AM, Hosseini M, Safari S. Screening performance characteristic of ultrasonography and radiography in detection of pleural effusion; a meta-analysis. Emergency. 2016;4(1):1.

40. 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):90-5. 12. Stroup DF, Berlin JA, Morton SC, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of Observational Studies in Epidemiology (MOOSE) group. JAMA. 2000;283(15):2008-12.