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Original Article

Comparision of Ultrasound and Chest X-Ray in The Detection of Peural Effusion

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ABSTRACT

Background: Pleural effusion is a frequent clinical condition requiring timely imaging-based diagnosis for appropriate management. Chest X-ray is widely used as an initial investigation, but its ability to detect small-volume or loculated effusions may be limited. Thoracic ultrasound provides bedside, radiation-free, real-time visualization of pleural fluid and may improve detection and volume assessment. Objective: To compare thoracic ultrasound and chest X-ray in the detection and evaluation of pleural effusion among patients with clinically suspected pleural fluid accumulation. Methods: This cross-sectional observational comparative study was conducted at Tahir Hospital, Tandlianwala, Pakistan. Fifty adult patients who underwent both chest X-ray and thoracic ultrasound were included. Demographic data, clinical findings, imaging results, effusion side, and ultrasound-estimated volume were recorded. Data were analyzed using SPSS version 27. Categorical imaging findings were compared using Chi-square analysis, volume relationships were assessed using Pearson correlation, and ultrasound-estimated volume across severity categories was evaluated using one-way ANOVA. Results: The mean age was 36.52 ± 9.37 years. Chest X-ray findings were significantly associated with ultrasound findings ($\chi^2 = 6.044$, $p = 0.049$). X-ray-estimated and ultrasound-estimated volumes showed a strong positive correlation ($r = 0.953$, $p < 0.001$). Ultrasound-estimated volume increased across mild, moderate, and large effusion categories, with mean volumes of 254.55 ± 41.56 mL, 752.08 ± 110.81 mL, and 1300.00 ± 100.00 mL, respectively; ANOVA showed a significant between-group difference ($F = 177.249$, $p < 0.001$). Conclusion: Thoracic ultrasound provided clinically stronger assessment of pleural effusion than chest X-ray, particularly for volume estimation and severity classification. Ultrasound should be considered a valuable first-line or complementary imaging modality for suspected pleural effusion, especially when small-volume fluid, loculation, bedside evaluation, or procedural planning is clinically relevant. Keywords: Pleural effusion, thoracic ultrasound, chest X-ray, diagnostic imaging, chest radiography, pleural fluid.

INTRODUCTION

Pleural effusion is a common clinical condition characterized by the abnormal accumulation of fluid within the pleural space between the visceral and parietal pleura. It is associated with a wide range of pulmonary and systemic diseases, including congestive heart failure, pneumonia, tuberculosis, malignancy, pulmonary embolism, and inflammatory disorders. Because pleural effusion may present with nonspecific symptoms such as dyspnea, chest pain, cough, reduced breath sounds, and dullness to percussion, clinical examination alone is often insufficient for accurate diagnosis. Timely imaging-based detection is therefore essential for confirming the presence of pleural fluid, estimating its extent,

identifying clinically significant collections, and guiding appropriate management decisions, including observation, medical treatment, or drainage (1).

Chest radiography has traditionally been used as the first-line imaging modality for suspected pleural effusion because it is inexpensive, widely available, rapid, and familiar to clinicians. On erect posteroanterior or lateral chest radiographs, moderate-to-large effusions may be suggested by blunting of the costophrenic angle, meniscus formation, hemithoracic opacity, or fluid layering. However, the diagnostic performance of chest X-ray is reduced in small-volume effusions, loculated collections, critically ill patients, and patients who cannot be positioned upright. Supine radiographs may further underestimate or miss pleural fluid because fluid distributes posteriorly and does not always produce the classic radiographic signs seen on erect imaging. These limitations create a risk of delayed or incomplete diagnosis, particularly in emergency and intensive-care settings where early bedside decision-making is required (2).

Thoracic ultrasound has increasingly become an important modality for evaluating suspected pleural effusion. Unlike chest radiography, ultrasound provides real-time bedside visualization of pleural fluid, can detect small-volume and loculated effusions, and can help characterize the distribution and internal features of fluid collections. It also avoids ionizing radiation, can be repeated safely, and is useful for procedural planning and ultrasound-guided thoracentesis. Prior studies and reviews have reported that ultrasound is more sensitive than chest radiography for detecting pleural effusion and provides clinically useful information regarding fluid volume, septations, loculations, and safe access sites for intervention (3). In critical-care environments, thoracic ultrasound has been described as particularly valuable because it can be performed rapidly at the bedside without transporting unstable patients and can support both diagnosis and treatment planning (4).

Comparative evidence from bedside and point-of-care imaging studies supports the superiority of ultrasound over chest radiography for pleural and pulmonary abnormalities. Inglis et al. reported that bedside lung ultrasound performed better than mobile chest radiography and physical examination for detecting thoracic abnormalities in critically ill patients, including pleural effusion (5). Similarly, Elnaem et al. found that chest ultrasonography had strong diagnostic utility in dyspneic patients and could reduce diagnostic delay in acute-care settings (6). More recent systematic review evidence has also suggested that point-of-care ultrasound has higher diagnostic accuracy than radiographic thoracic imaging for pleural effusion, especially when small fluid collections are present or when radiographic findings are equivocal (7). These findings indicate that ultrasound may not only complement chest X-ray but may also serve as a more reliable initial imaging option in selected clinical contexts.

Despite this growing evidence, chest X-ray remains commonly used as the initial investigation in many hospitals because of availability, cost, workflow familiarity, and clinician reliance on conventional radiographic assessment. In resource-limited and secondary-care settings, ultrasound may be available but underused for pleural assessment because of operator dependence, lack of standardized protocols, limited training, or uncertainty regarding its comparative diagnostic value. This creates an important practical gap: although ultrasound is widely recognized as sensitive for pleural fluid detection, local comparative data are still needed to clarify how ultrasound findings correspond with chest X-ray findings in routine clinical practice and whether ultrasound provides superior detection and volume assessment in patients with suspected pleural effusion.

Using a PICO framework, the population of interest in this study comprises adult patients presenting with suspected pleural effusion. The index modality is thoracic ultrasound, and the comparator is chest X-ray. The outcomes of interest are detection of pleural effusion, assessment of effusion volume, and correlation between ultrasound and radiographic findings. This comparison is clinically important because a more accurate and accessible imaging approach may improve early diagnosis, reduce missed small or loculated effusions, support safer intervention, and improve patient management in routine hospital settings.

Therefore, the present study was conducted to compare thoracic ultrasound and chest X-ray in the detection and evaluation of pleural effusion among patients presenting with suspected pleural fluid accumulation. The primary objective was to assess the diagnostic performance of ultrasound relative to chest radiography for identifying pleural effusion and evaluating effusion volume. The secondary objective was to determine the correlation between chest X-ray and ultrasound findings. The study hypothesized that thoracic ultrasound would detect pleural effusion more frequently and provide better volume assessment than chest X-ray in patients with suspected pleural effusion (8).

MATERIALS AND METHODS

This cross-sectional observational comparative study was designed and reported in accordance with the principles of observational health research reporting, with the purpose of comparing chest radiography and thoracic ultrasound for the detection and evaluation of pleural effusion in patients with clinically suspected pleural fluid accumulation (9). The study was conducted at Tahir Hospital, Tandlianwala, Pakistan, over a four-month period after synopsis approval. The rationale for using a cross-sectional design was that both imaging modalities were assessed during the same diagnostic episode, allowing direct comparison of chest X-ray and ultrasound findings in the same patient population without assigning any intervention or altering routine clinical management.

The study population consisted of adult patients presenting to the radiology and pulmonology departments with clinical suspicion of pleural effusion. Patients were selected through a non-probability convenient sampling technique. Eligible participants included adult male and female patients who presented with symptoms or clinical signs suggestive of pleural effusion and who underwent both chest X-ray and thoracic ultrasound as part of their diagnostic evaluation. Patients were excluded if they were pregnant or had a known history of other major lung pathology that could substantially interfere with radiographic or sonographic interpretation. After eligibility assessment, patients were informed about the purpose and procedures of the study, and written informed consent was obtained before inclusion. A total of 50 patients who completed both imaging assessments were included in the final analysis.

The sample size was calculated using the Raosoft sample size calculator by applying a 95% confidence level and a 5% margin of error. Although the calculated target sample size was 86, the final analysis was performed on the 50 eligible participants who completed the required paired imaging assessment during the study period. This final analytic sample was used consistently for descriptive and inferential analyses. Each participant underwent clinical assessment followed by chest X-ray and thoracic ultrasound evaluation. Demographic information, including age and gender, was recorded on a structured data collection sheet. Clinical information relevant to suspected pleural effusion, including presenting symptoms and respiratory examination findings such as reduced breath sounds, dullness to percussion, and clinical evidence of fluid accumulation, was documented before imaging interpretation.

Chest radiography was performed as part of routine diagnostic evaluation and interpreted for the presence or absence of pleural effusion, side of effusion, and radiographic impression of effusion extent. Radiographic evidence of pleural effusion was based on recognized findings such as costophrenic angle blunting, meniscus sign, hemithoracic opacity, or dependent fluid layering. Thoracic ultrasound was performed to assess the pleural space for the presence or absence of fluid, side of effusion, estimated volume, and severity category. Ultrasound findings were categorized according to the detected amount of pleural fluid, and effusions were classified as mild, moderate, or large on the basis of ultrasound-estimated volume. Ultrasound was also used to identify small or loculated fluid collections that may not be clearly visible on chest radiography. Both imaging results were recorded on the same standardized proforma to allow paired comparison within each participant.

The main exposure or index assessment in this study was thoracic ultrasound, while the comparator assessment was chest X-ray. The primary outcome was detection of pleural effusion by ultrasound compared with chest radiography. Secondary outcomes included comparison of effusion volume

assessment, side of effusion, and correlation between ultrasound-estimated and X-ray-estimated pleural fluid volume. Pleural effusion was operationally defined as abnormal fluid accumulation in the pleural space identified on imaging. A positive chest X-ray result was defined as radiographic evidence of pleural fluid, while a positive ultrasound result was defined as direct sonographic visualization of an anechoic or hypoechoic pleural fluid collection between the visceral and parietal pleura. Ultrasound volume was operationalized as the estimated amount of pleural fluid measured during sonographic evaluation and categorized into severity groups for statistical comparison.

To reduce information bias, data were collected using a uniform structured form, and the same core variables were recorded for every participant. Both imaging modalities were performed during the same diagnostic workup to reduce temporal variation in pleural fluid status. Classification of findings was based on predefined imaging criteria rather than post hoc interpretation. Potential confounding by age, gender, and disease severity was addressed during analysis by describing baseline demographic patterns and comparing imaging findings across clinically relevant categories. Missing or incomplete values were assessed before analysis; available-case analysis was used for variables in which complete paired observations were present, while the denominator for each analysis was reported according to the number of valid observations.

Data were analyzed using IBM SPSS Statistics version 27. Continuous variables, including age and pleural effusion volume, were summarized as mean, standard deviation, minimum, and maximum values. Categorical variables, including gender, imaging result, side of effusion, and severity category, were summarized as frequencies and percentages. Cross-tabulation was used to compare chest X-ray and ultrasound findings. The Chi-square test was applied to assess the association between categorical imaging findings, with statistical significance set at $p < 0.05$.

Where expected cell counts were small, the results were interpreted cautiously. Pearson correlation analysis was used to evaluate the relationship between X-ray-estimated and ultrasound-estimated effusion volume. One-way analysis of variance was applied to compare mean ultrasound-measured volume across mild, moderate, and large effusion categories, and effect-size estimates were used to assess the strength of the observed group differences. Statistical outputs were checked for internal consistency between sample counts, valid observations, p-values, and reported interpretations before inclusion in the final manuscript.

Ethical approval was obtained from the relevant institutional review authority before data collection. Participation was voluntary, and written informed consent was obtained from all participants. Patient confidentiality was maintained throughout the study by anonymizing data and removing personally identifiable information from the research record.

The study involved non-invasive imaging procedures performed as part of routine clinical evaluation, and no additional therapeutic intervention was introduced for research purposes. All collected data were used only for academic and research purposes. Data integrity was maintained through standardized data entry, verification of imaging and demographic variables before analysis, and preservation of the original data collection sheets for audit and reproducibility. The study was conducted in accordance with accepted ethical principles for research involving human participants (10).

RESULTS

Table 1. Age distribution of study participants

Variable	N	Minimum	Maximum	Mean	SD
Age, years	50	20	66	36.52	9.37

The study included 50 participants with a mean age of 36.52 ± 9.37 years. The recorded age range was 20 to 66 years, indicating that the analyzed sample included adult patients across a broad age distribution.

Table 2. Association between chest X-ray result and ultrasound finding

Test	χ^2	df	p-value	N
Pearson Chi-square	6.044	2	0.049	50
Likelihood ratio	9.117	2	0.010	50
Linear-by-linear association	0.168	1	0.682	50

χ^2: Chi-square statistic; df: degrees of freedom.

Chest X-ray result showed a statistically significant association with ultrasound finding on Pearson Chi-square testing, with $\chi^2 = 6.044$ and $p = 0.049$. The likelihood ratio test also showed an association, with $\chi^2 = 9.117$ and $p = 0.010$. The linear-by-linear association was not statistically significant, with $\chi^2 = 0.168$ and $p = 0.682$, indicating no clear ordered linear trend between the categorized imaging results.

Table 3. Association between chest X-ray result and ultrasound-estimated pleural effusion volume

Test	χ^2	df	p-value	N
Pearson Chi-square	23.582	14	0.051	50
Likelihood ratio	27.232	14	0.018	50
Linear-by-linear association	11.591	1	<0.001	50

χ^2: Chi-square statistic; df: degrees of freedom.

The association between chest X-ray result and ultrasound-estimated pleural effusion volume was borderline on Pearson Chi-square testing, with $\chi^2 = 23.582$ and $p = 0.051$. The likelihood ratio test showed a statistically significant association, with $\chi^2 = 27.232$ and $p = 0.018$. The linear-by-linear association was statistically significant, with $\chi^2 = 11.591$ and $p < 0.001$, suggesting that chest X-ray findings varied systematically across increasing ultrasound volume categories.

Table 4. Correlation between X-ray-estimated and ultrasound-estimated pleural effusion volume

Variables	Pearson r	p-value	Paired N
X-ray volume and ultrasound volume	0.953	<0.001	38

Pearson r: Pearson correlation coefficient.

X-ray-estimated volume and ultrasound-estimated volume showed a very strong positive correlation, with $r = 0.953$ and $p < 0.001$ among 38 paired observations. This indicates that higher X-ray-estimated volume was closely associated with higher ultrasound-estimated volume among participants with paired volume data. However, correlation does not by itself establish agreement between the two methods.

Table 5. Ultrasound-estimated pleural effusion volume by severity category

Severity category	N	Mean	SD	SE	95% CI lower	95% CI upper	Minimum	Maximum
Mild	11	254.55	41.56	12.53	226.62	282.47	200	300
Moderate	24	752.08	110.81	22.62	705.29	798.87	600	900
Large	3	1300.00	100.00	57.74	1051.59	1548.41	1200	1400
Total	38	651.32	310.08	50.30	549.40	753.24	200	1400

SD: standard deviation; SE: standard error; CI: confidence interval.

Ultrasound-estimated pleural effusion volume increased across severity categories. Mean volume was 254.55 ± 41.56 in the mild group, 752.08 ± 110.81 in the moderate group, and 1300.00 ± 100.00 in the large group. The total analyzed ultrasound volume sample included 38 observations, with an overall mean volume of 651.32 ± 310.08.

Table 6. One-way analysis of variance for ultrasound-estimated pleural effusion volume across severity categories

Source	Sum of squares	df	Mean square	F	p-value
Between groups	3237765.650	2	1618882.825	177.249	<0.001
Within groups	319668.561	35	9133.387		
Total	3557434.211	37			

df: degrees of freedom; F: one-way analysis of variance statistic.

One-way analysis of variance showed a statistically significant difference in ultrasound-estimated pleural effusion volume across severity categories, with $F = 177.249$ and $p < 0.001$. This finding is consistent with the increasing mean ultrasound volume observed across mild, moderate, and large effusion categories.

Table 7. Effect-size estimates for ultrasound-estimated pleural effusion volume across severity categories

Effect-size measure	Point estimate	95% CI lower	95% CI upper
Eta-squared	0.910	0.837	0.936
Epsilon-squared	0.905	0.827	0.932
Omega-squared, fixed-effect	0.903	0.824	0.931
Omega-squared, random-effect	0.823	0.700	0.870

CI: confidence interval.

The effect-size estimates were high across all reported measures. Eta-squared was 0.910, epsilon-squared was 0.905, fixed-effect omega-squared was 0.903, and random-effect omega-squared was 0.823. These values indicate that a large proportion of variability in ultrasound-estimated volume was associated with severity grouping in the analyzed sample.

Overall, the results show that chest X-ray findings were associated with ultrasound findings, while ultrasound-estimated volume demonstrated strong statistical separation across severity categories. The strongest numerical finding was the correlation between X-ray-estimated and ultrasound-estimated volume, with $r = 0.953$ and $p < 0.001$, although agreement analysis would be required before concluding that the two methods are interchangeable for volume estimation.

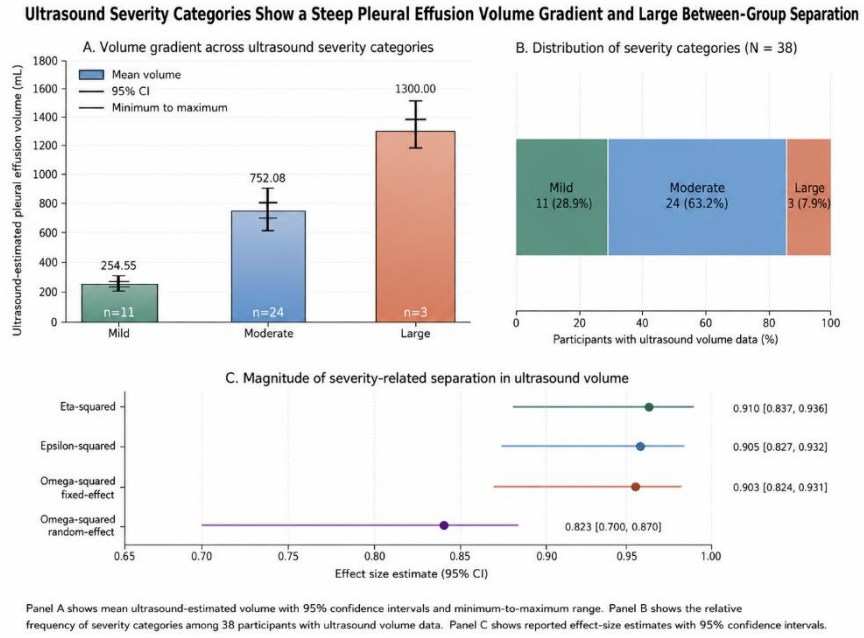

Figure 1 Ultrasound-estimated pleural effusion volume gradient across severity categories.

The figure demonstrates a clear ultrasound-based volume gradient across pleural effusion severity categories. Mean ultrasound-estimated volume increased from 254.55 ± 41.56 mL in mild effusion to 752.08 ± 110.81 mL in moderate effusion and 1300.00 ± 100.00 mL in large effusion. Among the 38 participants with available ultrasound volume data, moderate effusion was the most frequent category, comprising 24 patients (63.2%), followed by mild effusion in 11 patients (28.9%) and large effusion in 3 patients (7.9%). The effect-size estimates were consistently high, including eta-squared 0.910, epsilon-squared 0.905, fixed-effect omega-squared 0.903, and random-effect omega-squared 0.823, indicating substantial between-group separation in ultrasound-estimated volume. These findings support the clinical utility of thoracic ultrasound for grading pleural effusion severity and estimating fluid volume.

DISCUSSION

The present study compared thoracic ultrasound and chest X-ray for the detection and evaluation of pleural effusion in patients with clinically suspected pleural fluid accumulation. The main finding was that ultrasound demonstrated stronger clinical utility than chest radiography for identifying and characterizing pleural effusion, particularly when effusion volume and severity classification were considered. The study population had a mean age of 36.52 ± 9.37 years, indicating that pleural effusion was assessed across a relatively broad adult age range. Although chest X-ray remains an accessible first-line imaging tool in many clinical settings, the observed findings support the role of ultrasound as a more informative modality for pleural fluid assessment, especially when bedside evaluation and volume estimation are clinically relevant.

The association between chest X-ray findings and ultrasound findings was statistically significant on Pearson Chi-square testing, with $\chi^2 = 6.044$ and $p = 0.049$. This indicates that the two imaging modalities were related in their classification of pleural effusion status. However, the relationship should not be interpreted as equivalence between the two modalities. Chest X-ray and ultrasound evaluate pleural fluid through different imaging principles, and ultrasound provides direct visualization of pleural fluid, while radiography depends on indirect signs such as costophrenic angle blunting, meniscus formation, opacity, and fluid layering. This distinction is clinically important because radiographic signs may be absent or subtle in small-volume effusions, loculated collections, or supine patients. Previous evidence has similarly shown that supine chest radiography may underestimate or miss pleural effusion because fluid distributes posteriorly and does not always produce typical radiographic appearances (11).

The relationship between chest X-ray results and ultrasound-estimated pleural effusion volume further supports the clinical relevance of ultrasound. The Pearson Chi-square association between chest X-ray result and ultrasound volume was borderline, with $\chi^2 = 23.582$ and $p = 0.051$, while the likelihood ratio was significant at $p = 0.018$ and the linear-by-linear association was highly significant at $p < 0.001$. These findings suggest that chest X-ray detection improves as ultrasound-estimated volume increases, but radiography may be less reliable at lower volumes. This pattern is consistent with the known limitation of chest X-ray in detecting early or small effusions, while ultrasound is capable of identifying smaller fluid collections and defining their distribution in real time. The significant linear-by-linear association is clinically meaningful because it suggests that radiographic visibility is volume-dependent, whereas ultrasound can provide a more direct assessment across the severity spectrum.

A strong positive correlation was observed between X-ray-estimated and ultrasound-estimated pleural effusion volume, with $r = 0.953$ and $p < 0.001$ among paired observations. This indicates that when both methods estimated volume, higher values on chest X-ray were closely associated with higher values on ultrasound. However, correlation does not establish agreement or interchangeability. A high correlation may occur even if one modality consistently underestimates or overestimates volume compared with another. Therefore, while the correlation supports a shared trend between the modalities, it does not prove that chest X-ray can replace ultrasound for volume assessment. Future analyses using agreement-based methods, such as Bland–Altman analysis, would be more appropriate for evaluating whether X-ray and ultrasound provide comparable volume estimates in individual patients.

Ultrasound-estimated volume increased clearly across severity categories. Mean volume was 254.55 ± 41.56 mL in mild effusions, 752.08 ± 110.81 mL in moderate effusions, and 1300.00 ± 100.00 mL in large effusions. The ANOVA result showed a strong difference across categories, with $F = 177.249$ and $p < 0.001$, and the reported effect-size estimates were high, including eta-squared = 0.910 and fixed-effect omega-squared = 0.903. These findings show that ultrasound-based categorization separated effusion severity levels clearly within the analyzed sample. Clinically, this is important because pleural effusion management depends not only on whether fluid is present, but also on its quantity, distribution, and

suitability for drainage. Ultrasound therefore provides information that is more directly actionable than a binary radiographic impression.

The present findings are consistent with previous studies and reviews emphasizing the diagnostic advantages of thoracic ultrasound in pleural effusion. Thoracic ultrasound has been reported to detect pleural fluid more accurately than chest radiography, particularly for smaller or loculated effusions, and it can guide thoracentesis by identifying a safe site for needle insertion (12). In intensive-care settings, ultrasound has additional value because it can be performed at the bedside without transporting unstable patients, while also supporting real-time procedural decisions (13). Similar comparative studies in critically ill patients have shown that bedside lung ultrasound performs better than mobile radiography and physical examination for detecting pleural and pulmonary abnormalities (14). These findings align with the current study's observation that ultrasound provides stronger volume-based discrimination than chest X-ray.

The clinical implications of these findings are relevant for routine radiology, pulmonology, emergency, and critical-care practice. Chest X-ray remains useful because it is widely available, inexpensive, and able to show broader thoracic findings, including parenchymal lung changes, mediastinal shift, bony structures, and gross cardiopulmonary abnormalities. However, for suspected pleural effusion, particularly when small collections, loculation, or procedural planning are concerns, ultrasound offers several advantages. It is radiation-free, repeatable, portable, and capable of real-time pleural assessment. These characteristics make it especially useful for follow-up evaluation, critically ill patients, and cases where repeated imaging may be needed. Previous systematic review evidence has also supported point-of-care ultrasound as a more accurate bedside imaging approach than radiographic thoracic imaging for pleural effusion assessment (15).

Despite these strengths, the findings should be interpreted with methodological caution. The study was observational and cross-sectional, so causal conclusions cannot be drawn. The final analyzed sample included 50 patients, which limits the precision and generalizability of subgroup findings. In addition, no independent reference standard such as CT, thoracentesis confirmation, or expert adjudication panel was used. Therefore, the study should be interpreted as a comparative assessment of ultrasound and chest X-ray findings rather than a definitive diagnostic-accuracy study. Without a reference standard, sensitivity, specificity, positive predictive value, and negative predictive value cannot be validly estimated. The available results are better described in terms of detection patterns, association, correlation, and volume stratification.

Another important limitation is the operator-dependent nature of thoracic ultrasound. Although ultrasound offers real-time and high-resolution pleural assessment, its diagnostic quality depends on operator training, scanning technique, machine quality, and interpretation criteria. Standardized protocols and adequate training are therefore necessary before ultrasound can be reliably integrated into routine pleural effusion pathways. This is particularly important in secondary-care and resource-limited settings, where variation in operator expertise may influence diagnostic consistency. Nevertheless, increasing availability of portable ultrasound devices and structured training programs has made thoracic ultrasound increasingly feasible in routine clinical practice (16).

The study also highlights the need for improved statistical planning in future research. Since both imaging modalities were performed in the same participants, future studies should use paired diagnostic methods such as McNemar's test for binary detection comparisons and Cohen's kappa for agreement analysis. For volume comparison, Bland–Altman analysis would provide more clinically interpretable information about agreement, bias, and limits of agreement between chest X-ray and ultrasound estimates. Larger prospective studies should also stratify patients by effusion size, patient position, side of effusion, body habitus, and clinical setting, because these factors may influence radiographic visibility and ultrasound performance.

Overall, this study supports the growing evidence that thoracic ultrasound is a clinically valuable imaging modality for pleural effusion detection and severity assessment. The statistical findings show meaningful associations between chest X-ray and ultrasound, but the volume-based results favor ultrasound as the more informative modality for pleural fluid evaluation. Rather than viewing chest X-ray and ultrasound as fully interchangeable tests, the findings suggest that ultrasound should be considered a preferred or complementary imaging tool when pleural effusion is suspected, particularly when small-volume effusion, loculation, bedside assessment, or procedural guidance is clinically important.

CONCLUSION

This cross-sectional observational comparative study found that thoracic ultrasound provided stronger clinical assessment of pleural effusion than chest X-ray, particularly for volume estimation and severity classification. Chest X-ray findings were significantly associated with ultrasound findings, and X-ray-estimated volume showed a strong positive correlation with ultrasound-estimated volume; however, the results do not establish interchangeability between the two modalities. Ultrasound-estimated pleural effusion volume increased clearly across mild, moderate, and large severity categories, with a statistically significant between-group difference and large effect-size estimates. These findings support the use of thoracic ultrasound as a valuable first-line or complementary imaging modality for suspected pleural effusion, especially where small-volume fluid, loculated effusion, bedside assessment, or procedural planning is clinically relevant. Final interpretation should remain cautious because the study did not include an independent reference standard, and future larger studies using paired diagnostic and agreement-based analyses are recommended.

REFERENCES

1. Karkhanis VS, Joshi JM. Pleural effusion: diagnosis, treatment, and management. Open Access Emerg Med. 2012;4:31-52.

2. Emamian SA, Kaasbøl MA, Olsen JF, Pedersen JF. Accuracy of the diagnosis of pleural effusion on supine chest X-ray. Eur Radiol. 1997;7(1):57-60.

3. Shao RJ, Du MJ, Xie JT. Use of lung ultrasound for the diagnosis and treatment of pleural effusion. Eur Rev Med Pharmacol Sci. 2022;26(23).

4. Brogi E, Gargani L, Bignami E, Barbariol F, Marra A, Forfori F, Vetrugno L. Thoracic ultrasound for pleural effusion in the intensive care unit: from diagnosis to treatment. Crit Care. 2017;21(1):325.

5. 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. Crit Care Resusc. 2016;18(2):116-24.

6. Elnaem WH, Tammam HM, Zidan MA, Mahmoud MI. The relative efficacy of chest ultrasonography in comparison to other diagnostic modalities in the evaluation of dyspneic patient. Egypt J Chest Dis Tuberc. 2017;66(1):165-8.

7. Zaki HA, Albaroudi B, Shaban EE, Shaban A, Elgassim M, Almarri ND, Basharat K, Azad AM. Advancement in pleural effusion diagnosis: a systematic review and meta-analysis of point-of-care ultrasound versus radiographic thoracic imaging. Ultrasound J. 2024;16(1):3.

8. Kumar K, Kumar A. Comparative assessment of pleural effusion using ultrasound and chest radiography. Int J Curr Pharm Rev Res. 2024;16(4):921-6.

9. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. Strengthening the reporting of observational studies in epidemiology: the STROBE statement. Ann Intern Med. 2007;147(8):573-7.

10. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191-4.

11. Shehata SM, Almalki YE, Basha MA, Hendy RM, Mahmoud EM, Abd Elhamed ME, Alduraibi SK, et al. Comparative evaluation of chest ultrasonography and computed tomography as predictors of malignant pleural effusion: a prospective study. Diagnostics. 2024;14(10):1041.

12. 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):263-76.

13. Shero DM, Aldabbagh A, Sediq AA. Chest ultrasonography vs. chest X-rays for diagnosing pleural effusion in intensive care unit patients. Adv Med J. 2025;10(3):142-50.

14. Danish M, Agarwal A, Goyal P, Gupta D, Lal H, Prasad R, Dhiraaj S, 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;47(4):307.

15. Soni NJ, Franco R, Velez MI, Schnobrich D, Dancel R, Restrepo MI, Mayo PH. Ultrasound in the diagnosis and management of pleural effusions. J Hosp Med. 2015;10(12):811-6.

16. Walsh MH, Zhang KX, Cox EJ, Chen JM, Cowley NG, Oleynick CJ, Smyth LM, Ma IW. Comparing accuracy of bedside ultrasound examination with physical examination for detection of pleural effusion. Ultrasound J. 2021;13(1):40.

17. Alrajab S, Youssef AM, Akkus NI, Caldito G. Pleural ultrasonography versus chest radiography for the diagnosis of pneumothorax: review of the literature and meta-analysis. Crit Care. 2013;17(5):R208.

18. Bourcier JE, Paquet J, Seinger M, Gallard E, Redonnet JP, Cheddadi F, Garnier D, Bourgeois JM, Geeraerts T. Performance comparison of lung ultrasound and chest X-ray for the diagnosis of pneumonia in the ED. Am J Emerg Med. 2014;32(2):115-8.

19. Heuvelings CC, Bélard S, Andronikou S, Lederman H, Moodley H, Grobusch MP, Zar HJ. Chest ultrasound compared to chest X-ray for pediatric pulmonary tuberculosis. Pediatr Pulmonol. 2019;54(12):1914-20.

20. Balk DS, Lee C, Schafer J, Welwarth J, Hardin J, Novack V, Yarza S, Hoffmann B. Lung ultrasound compared to chest X-ray for diagnosis of pediatric pneumonia: a meta-analysis. Pediatr Pulmonol. 2018;53(8):1130-9.

21. Mateos González M, García de Casasola Sánchez G, Muñoz FJ, Proud K, Lourdo D, Sander JV, Jaimes GE, et al. Comparison of lung ultrasound versus chest X-ray for detection of pulmonary infiltrates in COVID-19. Diagnostics. 2021;11(2):373.

22. Caiulo VA, Gargani L, Caiulo S, Fisicaro A, Moramarco F, Latini G, Picano E. Lung ultrasound in bronchiolitis: comparison with chest X-ray. Eur J Pediatr. 2011;170(11):1427-33.

23. Jaszczołt S, Polewczyk T, Dołęga-Kozierowska M, Woźniak M, Doniec Z. Comparison of lung ultrasound and chest X-ray findings in children with bronchiolitis. J Ultrason. 2018;18(74):193.

24. Sperandeo M, Tinti MG, Rea G. Chest ultrasound versus chest X-rays for detecting pneumonia in children: why compare them each other if together can improve the diagnosis? Eur J Radiol. 2017;93:291-2.

25. Al Nufaiei ZF, Alshamrani KM. Comparing ultrasound, chest X-ray, and CT scan for pneumonia detection. Med Devices Evid Res. 2025;18:149-59.

26. Mahfouz A. Comparison of diagnostic accuracy between lung ultrasound and X-ray for detection of pleural effusion, pneumothorax, and lung pathology in dogs and cats [master's thesis]. Kaunas: Lithuanian University of Health Sciences; date unavailable.