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ORIGINAL ARTICLE

Efficacy of bed side lung ultrasound for detection of lung pathologies in PICU.

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ABSTRACT… Objective: To evaluate the diagnostic accuracy of bedside lung ultrasound (LUS) compared with chest X-ray for detecting common lung pathologies among critically ill children. **Study Design:** Cross-sectional, Analytical, Diagnostic Accuracy study. **Setting:** Pediatric Intesive Care Unit (PICU) of the National Institute of Child Health, Karachi, Pakistan. **Period:** October 2024 to March 2025. **Methods:** A total of 52 children aged 1 month to 15 years, with respiratory distress, or developing new respiratory signs during PICU stay were analyzed. Bedside LUS was performed using a standardized protocol, with operators blinded to chest X-ray findings. Chest X-ray interpreted by radiology served as the reference standard. Diagnostic performance was assessed using McNemar test, taking p<0.05 as significant. **Results:** In a total of 52 children, 34 (65.4%) were males. The median age was 3.0 (IQR 1.4-6.0) years. Bedside LUS identified pneumonia or consolidation in 32 (61.5%) children, while chest X-ray reported in 38 (73.1%). Pleural effusion was detected on LUS in 24 (46.2%) children, and on chest X-ray in 21 (40.4%). Pneumothorax was documented in 6 (11.5%) children on both modalities. Pulmonary edema or interstitial syndrome was observed in 8 (15.4%) children on ultrasound, and in 8 (15.4%) children on chest X-ray. Using paired comparison, there was no significant difference between bedside LUS and CXR in detection rates of pneumonia/consolidation (p=0.109), pleural effusion (p=0.453), pneumothorax (p=1.000) or pulmonary edema/interstitial syndrome (p=1.000). **Conclusion:** Bedside LUS demonstrated clinically meaningful diagnostic performance in critically ill children for pneumothorax, pleural effusion, pulmonary edema or interstitial syndrome, and pneumonia or consolidation.

Key words: Children, Pleural Effusion, Pneumonia, Lung, Ultrasound, X-ray.

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INTRODUCTION

Acute and chronic respiratory illnesses remain a leading cause of pediatric critical care admissions and are strongly associated with avoidable morbidity and mortality.[1] In the pediatric intensive care unit (PICU), rapid and accurate detection of lung pathology is essential for early stabilization, appropriate antimicrobial use, ventilatory strategy selection, and prevention of complications such as pneumothorax and progressive respiratory failure.[2]

Conventional imaging in critically ill children largely relies on chest X-ray (CXR) and, in selected cases, computed tomography (CT). Bedside CXR has recognized limitations in detecting early or subtle disease patterns, including small pleural effusions and mild interstitial changes, particularly in mechanically ventilated patients or those with complex comorbidities.[3] CT provides high anatomical detail but exposes children to ionizing radiation, a concern given evidence that childhood CT exposure is associated with an increased long-term risk of leukemia and brain tumors.[4]

Bedside lung ultrasound (LUS) is emerging as a modality that enables real-time, radiation-free, and repeatable assessment of the pleura and peripheral lung parenchyma.[5] It does not require transportation of unstable patients, reducing delays and minimizing risk in time-sensitive PICU settings. LUS has shown high diagnostic yields for key PICU-relevant conditions such as pneumothorax, pleural effusion, pulmonary edema, and pneumonia.[6,7] A meta-analysis evaluating pediatric pneumonia reported pooled LUS sensitivity and specificity of approximately 0.95 and 0.90, respectively, supporting its clinical reliability when compared with radiographic evaluation.[8]

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Establishing LUS diagnostic performance in local PICU workflows is necessary to guide contextual implementation, training priorities, and imaging pathways. Therefore, this study aimed to evaluate the diagnostic accuracy of bedside LUS compared with chest X-ray for detecting common lung pathologies among critically ill children admitted to the PICU.

METHODS

This cross-sectional analytical diagnostic accuracy study was conducted in the Pediatric Intensive Care Unit (PICU) of the National Institute of Child Health (NICH), Karachi, Pakistan, during October 2024 to March 2025, after approval from the Institutional Ethical Review Board (IERB-42/2024, dated: 25th September, 2024). The PICU is a tertiary-level unit equipped with invasive and non-invasive ventilatory support facilities, centralized monitoring, and portable ultrasound machines. Consecutive non-probability sampling was used to enroll children of either gender aged 1 month to 15 years who were admitted to the PICU with signs and symptoms of respiratory distress or respiratory illness and required respiratory support in the form of non-invasive positive pressure ventilation or mechanical ventilation. Additionally, children who developed new respiratory symptoms or signs suggestive of pulmonary pathology during their PICU stay, such as dyspnea or unexplained desaturation, were also eligible. Patients with a pre-existing known diagnosis of pulmonary pathology due to congenital or structural abnormalities and those with behavioral or non-cooperative characteristics limiting optimal ultrasound examination were excluded. A sample size of 52 was calculated using online OpenEpi sample size calculator, considering the specificity of LUS as 90.5%[9], with 95% confidence level and 8% margin of error.

After obtaining written informed consent from parents or legal guardians, baseline evaluations regarding presenting complaints, and clinical examination were performed. Bedside LUS were performed under standardized acquisition protocols, evaluating three zones in each hemithorax in a supine or semi-recumbent position depending on clinical stability. Lung sliding, pleural line characteristics, M-mode pattern, presence of A-lines, B-lines, consolidations with dynamic air bronchograms, shred sign, tissue-like sign, pleural effusion indicators, and other supportive features were observed and a provisional LUS diagnosis was recorded.

Chest X-ray (CXR) interpretation was considered the reference standard for comparison in this study. All CXRs were obtained as part of routine PICU management and were interpreted by the radiology team as per standard hospital reporting practices. To minimize interpretation bias, the ultrasound operator was blinded to the CXR findings at the time of LUS performance and reporting. Lung ultrasound findings were subsequently compared with CXR findings for the presence of pneumothorax, pleural effusion, pulmonary edema, pneumonia/consolidation, and other radiographic abnormalities, and the level of agreement between modalities was classified as concordant, partially concordant, or discordant.

Data were analyzed using IBM SPSS Statistics version 26. Categorical variables were reported as frequencies and proportions, while age was summarized as median with interquartile range (IQR) as non-normally distributed data. The diagnostic performance of bedside lung ultrasound was evaluated using chest X-ray as the reference standard, and measures of diagnostic accuracy were calculated for each targeted pathology, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall accuracy. Paired comparisons between lung ultrasound and chest X-ray detection rates were performed using the McNemar test. Agreement between the two modalities was quantified using Cohen's kappa (k) statistic, and overall concordance was reported as the proportion of cases with matching findings. P-value < 0.05 was considered statistically significant.

RESULTS

In a total of 52 children, 34 (65.4%) were males, and 18 (34.6%) females. The median age was 3.0 (IQR 1.4-6.0) years, and 28 (53.8%) children were aged 1–5 years (Table-I).

Bedside LUS identified pneumonia or consolidation in 32 (61.5%) children, while chest X-ray reported pneumonia or consolidation in 38 (73.1%). Pleural

effusion was detected on ultrasound in 24 (46.2%) children, and on chest X-ray in 21 (40.4%). Pneumothorax was documented in 6 (11.5%) children on both modalities. Pulmonary edema or interstitial syndrome was observed in 8 (15.4%) children on ultrasound, and in 8 (15.4%) children on chest X-ray. Figure-1 is showing right sided pneumothorax as per chest x-ray, and bedside LUS (showing stratosphere sign).

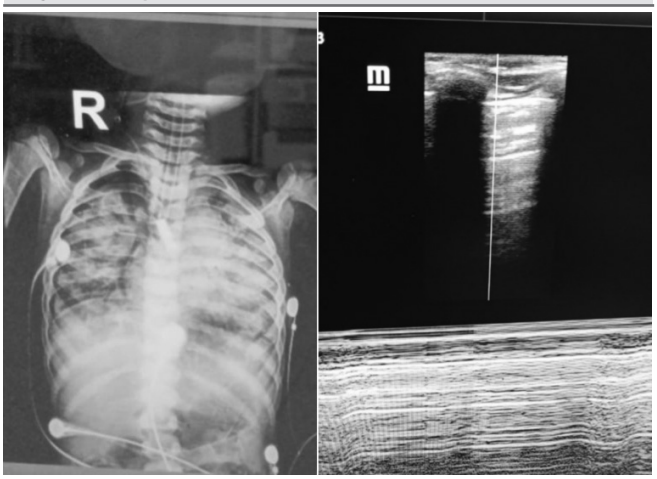
TABLE-I

Characteristics of patients (N=52)

Characteristics		Number (%)
Gender	Male	34 (65.4%)
	Female	18 (34.6%)
Age groups (years)	<1	10 (19.2%)
	1-5	28 (53.8%)
	6-9	6 (11.5%)
	10-15	8 (15.4%)

FIGURE-1

Right sided pneumothorax



Using paired comparison, there was no significant difference between bedside LUS and CXR in detection rates of pneumonia/consolidation (McNemar p=0.109), pleural effusion (p=0.453), pneumothorax (p=1.000) or pulmonary edema/ interstitial syndrome (p=1.000). Agreement between modalities was moderate for pneumonia (κ=0.57), substantial for pleural effusion (κ=0.73) and almost perfect for pneumothorax (κ=0.81) and pulmonary edema (κ=0.85), and the details are given in Table-II.

Diagnostic performance of bedside LUS, using chest X-ray as the reference standard, showed a sensitivity of 78.9% and specificity of 85.7% for pneumonia or consolidation, with PPV 93.8%, NPV 60.0%, and overall accuracy 80.8%. For pleural effusion, ultrasound sensitivity was 90.5% and specificity was 83.9%, with PPV 79.2%, NPV 92.9%, and accuracy 86.5%. For pneumothorax, sensitivity was 83.3% and specificity was 97.8%, with PPV 83.3%, NPV 97.8%, and accuracy 96.2%. For pulmonary edema or interstitial syndrome, sensitivity was 87.5% and specificity was 97.7%, with PPV 87.5%, NPV 97.7%, and accuracy 96.2% (Table-III).

DISCUSSION

Pneumonia or consolidation showed 78.9% sensitivity, 85.7% specificity, 93.8% PPV, 60.0% NPV, and 80.8% accuracy when chest X-ray was used as the reference standard. This pattern is comparable to the performance reported in pediatric intensive care literature, where bedside thoracic ultrasound has demonstrated high rule-in value for consolidation, while negative examinations have limited ability to exclude disease in unstable children. In the heterogeneous PICU population studied by Tripathi et al.[10], LUS was described as a rapid and sensitive tool for consolidation detection, with low negative predictive values that restrict its use as a stand-alone exclusion test.

TABLE-II

Paired comparison and agreement between lung ultrasound and chest x-ray findings (N=52)

Pathology	Lung Ultrasound	Chest X-ray	Overall Agreement	K	P-Value
Pneumonia / consolidation	32 (61.5%)	38 (73.1%)	80.8%	0.57	0.109
Pleural effusion	24 (46.2%)	21 (40.4%)	86.5%	0.73	0.453
Pneumothorax	6 (11.5%)	6 (11.5%)	96.2%	0.81	1
Pulmonary edema / interstitial syndrome	8 (15.4%)	8 (15.4%)	96.2%	0.85	1

TABLE-III

Diagnostic performance of bedside lung ultrasound with respect to chest x-ray findings (N=52)

Pathology	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Pneumonia / consolidation	78.9	85.7	93.8	60.0	80.8
Pleural effusion	90.5	83.9	79.2	92.9	86.5
Pneumothorax	83.3	97.8	83.3	97.8	96.2
Pulmonary edema / interstitial syndrome	87.5	97.7	87.5	97.7	96.2

The current dataset demonstrated a similar profile, with a high PPV of 93.8% and a lower NPV of 60.0%, supporting a clinical workflow in which positive LUS consolidation findings meaningfully strengthen diagnostic confidence, while negative LUS findings require continued clinical integration with respiratory status, laboratory markers, and radiography.[11]

The paired comparison between modalities showed no statistically significant differences. The moderate agreement for pneumonia with (κ=0.57), and overall agreement of 80.8% suggests clinically relevant discordance that is expected in mechanically ventilated children and in complex cardiopulmonary illness. Earlier pediatric work has shown that ultrasound may detect subpleural consolidations missed by chest X-ray, supporting the interpretation that disagreement may reflect both imaging limitations rather than operator error alone.[12] Diagnostic performance for pleural effusion was strong, with 90.5% sensitivity, 83.9% specificity, 79.2% PPV, 92.9% NPV, and 86.5% accuracy. Agreement between LUS and chest X-ray for pleural effusion reached 86.5% with κ=0.73, and detection rates did not differ significantly in paired analysis (p=0.453). Studies comparing LUS with chest X-ray in children have reported excellent sensitivity for pleural effusion, and narrative evidence has highlighted the ability of LUS to distinguish effusion from consolidation and to guide bedside decisions for drainage and follow-up assessment.[13] In this study, the high NPV of 92.9% supports ultrasound use to exclude clinically meaningful effusion at the bedside, an important feature in the PICU where transport for imaging and repeated radiographs may be impractical.[14]

Pneumothorax detection showed 83.3% sensitivity, 97.8% specificity, 83.3% PPV, 97.8% NPV, and 96.2% accuracy, with agreement of 96.2% *(κ=0.81). Pneumothorax frequency was identical by ultrasound and chest X-ray at 6 (11.5%), and paired testing (p=1.000), supporting comparable detection. This finding is clinically important in ventilated children where early recognition of air leak can change airway pressures, trigger urgent decompression, and reduce risk of haemodynamic compromise. International recommendations for point of care lung ultrasound identify absent lung sliding, M-mode patterns, and pleural artefact features as high value markers in acute pneumothorax evaluation, which supports the interpretability and reproducibility of the ultrasound approach used.[15] Evidence from intensive care ultrasound literature has also reported high specificity for pneumothorax detection and strong performance when bedside imaging is required urgently, reinforcing the clinical role of ultrasound as a rapid confirmatory modality in unstable patients.[16]

Pulmonary edema or interstitial syndrome was detected in 8 (15.4%) children by both ultrasound and chest X-ray, with 87.5% sensitivity, 97.7% specificity, 87.5% PPV, 97.7% NPV, and 96.2% accuracy. This high accuracy and near-perfect agreement fits established physiology, where diffuse interstitial involvement generates reproducible B-line patterns that correlate with extravascular lung water and pulmonary congestion.[17] Critical care ultrasound literature has reported high diagnostic performance for alveolar interstitial patterns and consolidation when compared with reference imaging, supporting the reliability of LUS for monitoring cardiogenic pulmonary edema and fluid overload states.[16] Given the clinical profile of tertiary PICU admissions in Pakistan, including congenital heart disease, post-operative cardiac patients, sepsis, and myocarditis, bedside identification of pulmonary edema has immediate treatment implications related to fluid restriction, diuretic therapy, ventilatory optimisation,

and escalation planning.

These results carry practical implications for respiratory imaging strategy in the PICU. High specificity and NPV for pneumothorax and pulmonary edema support bedside LUS as a time critical diagnostic extension of clinical examination, particularly in ventilated children where rapid decisions may prevent deterioration.[18,19] Strong performance for pleural effusion supports ultrasound as a monitoring tool that can reduce repeated radiographs and can guide procedural planning, including drainage decisions and response assessment.[20,21] Consensus guidance and international recommendations support structured training and protocolised acquisition to standardise interpretation and reduce operator variability.[22]

Several limitations should be considered when interpreting these findings. Chest X-ray was used as the reference standard, although radiography has known limitations in early pneumonia, interstitial disease, and small pleural collections, especially in supine ventilated children. The study was single centre with a modest sample size, which limits statistical precision for less frequent pathologies such as pneumothorax and reduces external validity across different Pakistani PICU settings. Lung ultrasound was performed by a single operator, which strengthens internal consistency but limits conclusions regarding interobserver reliability.

CONCLUSION

Bedside lung ultrasound demonstrated clinically meaningful diagnostic performance in critically ill children for pneumothorax, pleural effusion, pulmonary edema or interstitial syndrome, and pneumonia or consolidation when chest X-ray was used as the comparator. This study supports the integration of bedside lung ultrasound into PICU respiratory assessment pathways at tertiary centres in Pakistan.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHORSHIP AND CONTRIBUTION DECLARATION	
1	**Afifa Shahid:** Data collection, drafting.
2	**Murtaza Ali Gowa:** Conception, designed.
3	**Marya Hameed:** Literature review, data analysis.
4	**Aasma Kayani:** Critical revisions.
5	**Shezaib Siddiqui:** Proof reading.
6	**Ghazala Jamal:** Data collection.
7	**Hira Nawaz:** Data entry.