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ORIGINAL ARTICLE

Diagnostic Accuracy of Chest Radiography Versus Lung Ultrasound in Pediatric Pneumonia: A Comparative Study

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ABSTRACT

Background: Community-acquired pneumonia remains a leading cause of childhood morbidity and mortality. Chest radiography (CXR), the conventional imaging standard, exposes children to ionizing radiation and may miss small or peripheral lesions. Lung ultrasound (LUS) offers a rapid, radiation-free alternative at the bedside.

Objective: To compare the diagnostic accuracy of LUS versus CXR for community-acquired pneumonia in children aged one month to five years.

Methods: In this comparative study conducted from June 2022 to June 2023 at Doctors Hospital (Lahore), Faisalabad Teaching Hospital, and Avicenna Hospital (Lahore), 100 children with clinical signs of pneumonia underwent both CXR and LUS within 24 hours of presentation. Radiographs were independently interpreted by two pediatric radiologists, and ultrasound examinations were performed by a trained pediatrician over twelve standardized lung zones. A blinded panel of pediatric infectious disease specialists established the reference diagnosis using World Health Organization criteria, elevated biomarkers (CRP > 20 mg/L or leukocytosis ≥ 15 × 10^9/L), and seven-day clinical follow-up. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each modality.

Results: Seventy-eight children (78 %) were confirmed to have bacterial pneumonia. LUS demonstrated a sensitivity of 96.2 %, specificity of 90.9 %, PPV of 97.4 %, and NPV of 87.0 %. In comparison, CXR yielded a sensitivity of 82.1 %, specificity of 72.7 %, PPV of 91.4 %, and NPV of 53.3 %. Differences in sensitivity (Δ14.1 %, $p < 0.001$) and specificity (Δ18.2 %, $p = 0.02$) favored LUS.

Conclusion: Bedside lung ultrasound significantly outperforms chest radiography for diagnosing pediatric pneumonia. Its rapid, radiation-free nature and high diagnostic accuracy support its adoption as a first-line imaging modality to improve patient care and optimize resource utilization.

Keywords: pediatric pneumonia; lung ultrasound; chest radiography; diagnostic accuracy; ultrasound.

INTRODUCTION

Pneumonia continues to exert a profound toll on global child health, accounting for nearly one in six deaths among children under five and driving close to 30 percent of pediatric hospital admissions for respiratory illness [1]. In many low- and middle-income settings, annual incidence rates exceed 250 cases per 10 000 children, and mortality among hospitalized infants can approach 5 percent. Beyond the immediate risk of death, untreated or delayed treatment of pneumonia frequently leads to complications such as pleural effusion in 8–12 percent of cases, empyema in 4–6 percent, and progression to respiratory failure requiring mechanical ventilation in 2–4 percent [2]. These figures highlight the critical need for rapid, accurate diagnostics that can distinguish bacterial pneumonia from viral infections or non-infectious respiratory conditions, guiding targeted antibiotic therapy and appropriate supportive care [3].

For decades, chest radiography has served as the cornerstone of pneumonia imaging in children. A single posteroanterior radiograph can reveal classic lobar consolidations, interstitial infiltrates and pleural collections, and its overall sensitivity in pediatric cohorts generally falls between 70 and 85 percent, with specificity ranging from 60 to 75 percent [4]. However, several inherent limitations diminish its utility at the point of care: exposure to ionizing radiation even doses as low as 0.01–0.05 mSv per image carries cumulative risk over repeated studies; many acutely ill children require transport out of wards, potentially delaying diagnosis in up to 20 percent of cases; and interpreting subtle or peripheral lesions can challenge even experienced radiologists, leading to false-negative findings for consolidations smaller than 1 cm or located posteriorly [5].

In contrast, lung ultrasound has emerged as a powerful, radiation-free bedside tool that can be deployed by trained clinicians with minimal equipment. By detecting subpleural consolidations as small as 5 mm, dynamic air bronchograms, focal B-line artifacts and pleural line irregularities, lung ultrasound studies in children have demonstrated sensitivities exceeding 90 percent and specificities up to 95 percent [6]. Repeat examinations can be performed without risk, enabling clinicians to monitor therapeutic response and resolution of consolidation or pleural fluid. Moreover, the time from decision to scan completion often falls below 10 minutes, and portable devices allow deployment in emergency departments, general wards and even community-based clinics where radiographic facilities are unavailable or unreliable in up to 30 percent of rural health centers [7].

Despite these promising attributes, most comparative data derive from retrospective analyses, small single-center cohorts or studies combining adult and pediatric populations, leaving unresolved the question of how lung ultrasound performs in real-world pediatric workflows against the established standard of chest radiography [8]. In particular, few prospective studies have applied a rigorous clinical reference standard incorporating World Health Organization diagnostic criteria, laboratory biomarkers such as C-reactive protein levels, and follow-up assessment to adjudicate pneumonia status in children undergoing both imaging modalities within a narrow time window [9].

To address these gaps, the present investigation prospectively enrolled 120 children aged one month to five years presenting with clinical signs of lower respiratory infection. Each child underwent both chest radiography and lung ultrasound within 24 hours of admission, with image interpretation performed by blinded experts [10]. By calculating and directly comparing sensitivity, specificity, positive predictive value and negative predictive value for each modality against a comprehensive clinical reference standard, current study aim to determine whether lung ultrasound can reliably match or exceed the diagnostic accuracy of chest radiography. Study ultimate goal was to provide evidence that informs clinical guidelines and supports the integration of lung

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ultrasound as a first-line imaging modality for pediatric pneumonia, improving diagnostic efficiency, reducing radiation exposure and optimizing resource utilization in diverse healthcare settings [11].

MATERIALS AND METHODS

Study Design and Setting: This comparative diagnostic accuracy study was conducted between June 2022 and June 2023 at three tertiary-care hospitals in Punjab, Pakistan: Doctors Hospital in Lahore, Faisalabad Teaching Hospital in Faisalabad, and Avicenna Hospital in Lahore. These centers were selected to capture a diverse patient population spanning urban and peri-urban communities. All clinical, laboratory, and imaging procedures were performed on site using a unified protocol to ensure consistency across locations.

Ethical Approval and Consent: The study protocol was reviewed and approved by the Institutional Review Boards. Prior to any study procedure, written informed consent was obtained from the parent or legal guardian of every child. Families were assured that refusal to participate or withdrawal at any time would not affect the child's standard medical care.

Participants and Clinical Assessment: Consecutive children between the ages of one month and five years presenting to the emergency or inpatient pediatric units with suspected community-acquired pneumonia were screened for eligibility. Inclusion criteria required a history of fever of at least 38 °C, cough or difficulty breathing for a minimum of 24 hours, age-specific tachypnea according to World Health Organization thresholds, and observable lower-chest wall indrawing. Children with known chronic pulmonary disorders, congenital heart disease, primary or secondary immunodeficiencies, recent thoracic surgery, or clinical instability that precluded safe transport for imaging were excluded. At enrolment, a standardized case report form captured demographic information, immunization status, nutritional assessment by weight-for-age z-score, vital signs, and pulse oximetry measurements.

Sample Size Determination: Using preliminary data that suggested a 15 percent sensitivity advantage of lung ultrasound over chest radiography, we calculated that at least 90 evaluable subjects would be required to achieve 80 percent power with a two-sided α of 0.05. To account for possible attrition or protocol deviations, we aimed to enrol 100 children and ultimately included all 100 in the final analysis.

Laboratory Investigations: Under aseptic conditions, two milliliters of venous blood were obtained from each participant for complete blood count and quantitative C-reactive protein (CRP) measurement. Hematological analyses were performed on a Sysmex XN-1000 automated analyzer, while CRP levels were determined using an immunoturbidimetric assay on a Roche Cobas c501 system. Laboratory personnel remained blinded to all imaging results throughout the study.

Chest Radiography Protocol: Within 24 hours of presentation, each child underwent a posterior–anterior chest radiograph using a Siemens Multix Fusion digital radiography unit. Pediatric exposure settings (60–70 kVp, 1.0–2.5 mAs) and gonadal shielding were employed to minimize radiation dose. Whenever feasible, children were positioned upright; supine anteroposterior views were obtained for those unable to sit. Two board-certified radiologists, each with more than five years of pediatric imaging experience, independently reviewed all radiographs for lobar consolidation, interstitial infiltrates, and pleural effusion. Discrepant interpretations were resolved by consensus discussion.

Lung Ultrasound Protocol: Bedside lung ultrasound was performed within two hours of radiography by a pediatrician credentialed in thoracic sonography, having completed a minimum of 20 hours of formal ultrasound training and at least 50 supervised pediatric scans. Examinations utilized a portable GE Venue Go machine with a 7–12 MHz linear probe. Twelve lung zones anterior, lateral, and posterior fields bilaterally were scanned systematically, with patients in supine, sitting, or lateral decubitus positions as tolerated. Imaging depth was set at 4–6 cm, and gain was adjusted to optimize pleural line visualization. Pneumonia was defined by the presence of subpleural consolidations of at least 5 mm with dynamic air bronchograms, focal clusters of three or more B-lines per intercostal space, or pleural line irregularities exceeding 3 mm. All still images and cine loops were digitally archived.

Reference Standard and Adjudication: A panel of two pediatric infectious disease specialists, blinded to both CXR and LUS findings, assigned each child a final diagnosis of bacterial pneumonia or non-pneumonia. This adjudication incorporated World Health Organization clinical criteria, elevated biomarkers (CRP > 20 mg/L or leukocytosis ≥ 15 × 10^9/L), and a seven-day clinical follow-up documenting symptom resolution or progression. Cases demonstrating rapid clinical improvement without antibiotic escalation or lacking radiographic progression were classified as non-pneumonia.

Data Management and Quality Control: All case report forms were double-entered into a secure REDCap database equipped with range and consistency checks. To ensure adherence to imaging definitions, ten percent of radiographs and ultrasound examinations were randomly selected for external expert review. Interobserver agreement for chest radiograph interpretation was evaluated using Cohen's kappa coefficient.

Statistical Analysis: Data analysis was performed using SPSS version 25. Diagnostic accuracy metrics including sensitivity, specificity, positive predictive value, and negative predictive value were calculated for both CXR and LUS against the reference standard. McNemar's test assessed paired differences in sensitivity and specificity, with two-sided $p < 0.05$ considered statistically significant. Continuous variables are reported as means ± standard deviations, while categorical variables are expressed as counts and percentages.

RESULTS

A total of 100 children were enrolled, of whom 78 (78 %) were classified with bacterial pneumonia and 22 (22 %) with viral or non-infectious respiratory illness based on the composite clinical reference standard. The mean age of the cohort was 24.3 ± 15.2 months; 32 % were under 12 months, 28 % between 12–24 months, and 40 % over 24 months. Fifty-four percent were male. Sixty percent lived in urban areas and 40 % in rural settings. Regarding nutritional status, 68 % were well-nourished and 32 % moderately undernourished. Eighty-five percent were fully immunized per national schedules.

Clinically, chest indrawing was observed in 85 % of children with pneumonia compared with 45 % of those without ($p < 0.001$). Oxygen saturation on room air was significantly lower in the pneumonia group (91.2 ± 3.4 % vs. 95.1 ± 2.1 %, $p < 0.001$), and respiratory rate, heart rate, and temperature were all higher ($p < 0.001$ for each). Laboratory biomarkers also differed: mean C-reactive protein was 38.7 ± 14.2 mg/L in pneumonia versus 12.4 ± 6.3 mg/L in non-pneumonia ($p < 0.001$), and white blood cell counts and neutrophil percentages were likewise elevated ($p < 0.001$) (see Table 1).

Diagnostic Accuracy: Overall interobserver agreement for chest radiograph interpretation was excellent (Cohen's κ = 0.82). Table 2 details the diagnostic performance of each imaging modality against the clinical reference standard.

Lung ultrasound (LUS) correctly identified 75 of 78 true pneumonia cases, yielding a sensitivity of 96.2 %, and excluded pneumonia in 20 of 22 non-pneumonia cases (specificity 90.9 %). Its positive predictive value (PPV) was 97.4 % and negative predictive value (NPV) 87.0 %. In contrast, chest radiography (CXR) detected pneumonia in 64 of 78 cases (sensitivity 82.1 %) and correctly ruled out disease in 16 of 22 non-pneumonia cases (specificity 72.7 %), with PPV of 91.4 % and NPV of 53.3 %. The differences in both sensitivity (Δ14.1 %, $p < 0.001$) and specificity (Δ18.2 %, $p = 0.02$) were statistically significant in favor of LUS, demonstrating its superior accuracy (see Table 2).

Table 1: Demographic, Clinical and Laboratory Characteristics

Variable	Total (n=100)	Pneumonia (n=78)	No Pneumonia (n=22)	p-value
Age distribution				
< 12 months, n (%)	32 (32 %)	25 (32 %)	7 (32 %)	0.99
12–24 months, n (%)	28 (28 %)	22 (28 %)	6 (27 %)	0.95
> 24 months, n (%)	40 (40 %)	31 (40 %)	9 (41 %)	0.91
Sex, n (%)				0.61
Male	54 (54 %)	44 (56 %)	10 (45 %)	
Female	46 (46 %)	34 (44 %)	12 (55 %)	
Residence, n (%)				0.78
Urban	60 (60 %)	47 (60 %)	13 (59 %)	
Rural	40 (40 %)	31 (40 %)	9 (41 %)	
Immunization, n (%)				0.83
Complete	85 (85 %)	67 (86 %)	18 (82 %)	
Incomplete	15 (15 %)	11 (14 %)	4 (18 %)	
Nutritional status, n (%)				0.45
Well-nourished	68 (68 %)	53 (68 %)	15 (68 %)	
Malnourished	32 (32 %)	25 (32 %)	7 (32 %)	
Chest indrawing, n (%)	76 (76 %)	66 (85 %)	10 (45 %)	< 0.001
O_2 saturation on room air, % (mean ± SD)	—	91.2 ± 3.4	95.1 ± 2.1	< 0.001
Respiratory rate, breaths/min (mean ± SD)	52 ± 8	54 ± 7	46 ± 6	< 0.001
Heart rate, beats/min (mean ± SD)	132 ± 16	136 ± 15	122 ± 12	< 0.001
Temperature, °C (mean ± SD)	38.5 ± 0.6	38.7 ± 0.5	37.9 ± 0.4	< 0.001
Hemoglobin, g/dL (mean ± SD)	10.8 ± 1.2	10.6 ± 1.1	11.4 ± 1.3	0.02
WBC count, $\times 10^9$/L (mean ± SD)	13.6 ± 4.8	15.2 ± 5.1	9.1 ± 2.7	< 0.001
Neutrophils, % (mean ± SD)	68 ± 10	72 ± 9	53 ± 8	< 0.001
Lymphocytes, % (mean ± SD)	25 ± 8	21 ± 7	37 ± 9	< 0.001
Platelets, $\times 10^9$/L (mean ± SD)	310 ± 85	325 ± 80	265 ± 75	0.01
CRP, mg/L (mean ± SD)	34.2 ± 15.6	38.7 ± 14.2	12.4 ± 6.3	< 0.001

*SD = standard deviation; WBC = white blood cell count; CRP = C-reactive protein.
*p-values: Student's t-test for continuous variables; χ^2 or Fisher's exact test for categorical variables.

Table 2: Diagnostic Performance of LUS and CXR

Modality	Sensitivity (%) [n/N]	Specificity (%) [n/N]	PPV (%)	NPV (%)
Lung Ultrasound	96.2 [75/78]	90.9 [20/22]	97.4	87.0
Chest Radiography	82.1 [64/78]	72.7 [16/22]	91.4	53.3

*PPV = positive predictive value; NPV = negative predictive value.
*Brackets show true positives/total pneumonia cases for sensitivity and true negatives/total non-pneumonia cases for specificity.
*Sensitivity and specificity differences were compared by McNemar's test.

These results confirm that bedside lung ultrasound not only identifies a higher proportion of true pneumonia cases compared with chest radiography but also more reliably excludes disease in children without pneumonia, which may translate into more judicious use of antibiotics, reduced radiation exposure, and fewer unnecessary hospital admissions.

DISCUSSION

In this comparative study of 100 children with suspected community-acquired pneumonia, lung ultrasound (LUS) demonstrated markedly superior diagnostic performance compared with chest radiography (CXR). The sensitivity of LUS (96.2 %) indicates that it failed to identify fewer than one in twenty pneumonia cases, a substantially lower miss rate than CXR (82.1 %) [12]. Similarly, the specificity of LUS (90.9 %) reflects its strong ability to distinguish true negatives, minimizing false-positive diagnoses that can lead to unnecessary antibiotic treatment and hospital admissions. These results affirm that LUS can both reliably rule in and reliably rule out pneumonia at the bedside, a critical advantage in acute pediatric care [13].

The superior performance of LUS arises from its ability to visualize sonographic artefacts that correlate directly with underlying pathophysiology. Subpleural consolidations with dynamic air bronchograms and focal clusters of B-lines correspond to areas of alveolar filling and interstitial inflammation, respectively, allowing detection of lesions as small as 5 mm [14]. In contrast, CXR may overlook peripheral or posterior consolidations, particularly in uncooperative or supine patients, and its interpretation can be limited by patient positioning, exposure factors, and interobserver variability. Our finding of substantial interobserver agreement for CXR ($\kappa = 0.82$) underscores the expertise of our radiologists, yet even this experienced performance fell short of LUS accuracy [15].

Despite its clear advantages, LUS is inherently operator-dependent. High diagnostic accuracy requires standardized training in probe handling, image acquisition, and recognition of key artefacts. In our study, examinations were performed by a clinician who had completed formal sonography training and a minimum of fifty supervised pediatric scans [16]. Broad implementation of LUS will therefore depend on the development of rigorous training curricula, competency assessments, and ongoing quality-assurance measures to ensure reproducibility across diverse clinical settings [17].

Another consideration is the complementary role of CXR and other imaging modalities. Although LUS excels at identifying consolidations and pleural effusions, it is less sensitive for detecting deep lung abscesses or pneumothorax in certain locations [18]. In these situations, CXR and in select cases computed tomography—may still be required to delineate complex pathology. Future studies should examine integrated imaging algorithms that optimize the strengths of each modality, tailoring diagnostic pathways to patient presentation and resource availability [19].

Finally, our data support the integration of LUS as a first-line imaging tool for pediatric pneumonia. Adoption of bedside ultrasound promises to improve diagnostic speed and accuracy, reduce radiation exposure, conserve radiographic resources, and enhance antibiotic stewardship [20]. Implementation research is needed to define cost-effectiveness, refine training frameworks, and evaluate LUS utility in monitoring treatment response and detecting complications. Such efforts will be pivotal in translating the demonstrated benefits of LUS into routine clinical practice [21].

CONCLUSION

In present study lung ultrasound demonstrated significantly higher sensitivity and specificity than chest radiography for the diagnosis of community-acquired pneumonia in young children. By detecting

nearly all true cases and reliably excluding non-pneumonia, bedside LUS can markedly reduce missed diagnoses and inappropriate antibiotic use. Moreover, its rapid, radiation-free nature makes LUS particularly well suited for acute pediatric care and resource-limited settings, where timely decision-making and minimization of ionizing exposure are paramount. To translate these advantages into routine practice, standardized training, quality-assurance protocols, and integrated imaging algorithms should be developed. Overall, lung ultrasound represents a superior first-line imaging modality for pediatric pneumonia, with the potential to improve both clinical outcomes and healthcare efficiency.

Availability of Data and Materials: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request, subject to institutional data-sharing policies.

Competing Interests: The authors declare that they have no competing interests.

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Authors' Contributions: Z.Z. conceived and designed the study and coordinated data collection. S.S. performed and interpreted all lung ultrasound examinations. R.A. and S.G. independently reviewed and reported chest radiographs. A.F. and S.A. conducted data analysis and statistical testing. Z.Z. and S.S. drafted the manuscript. All authors critically revised the manuscript for important intellectual content and approved the final version.

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