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Comparison of Chest X-Ray and Lung Ultrasound for Diagnosing Community-Acquired Pneumonia in Children

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ABSTRACT

Background: Community-acquired pneumonia (CAP) remains a leading cause of childhood morbidity. Chest X-ray (CXR) is the standard imaging modality but involves ionising radiation. Lung ultrasound (LUS) is a radiation-free alternative. This study compared the diagnostic accuracy of LUS versus CXR for paediatric CAP.

Methods: A prospective study was conducted on 150 children (aged 6 months to 12 years) with suspected CAP between January and March 2025. All children underwent both CXR (interpreted by a paediatric pulmonologist) and LUS (interpreted by a paediatrician) within 4 hours of presentation. The reference standard was a clinical diagnosis confirmed by follow-up at 14 days. Sensitivity, specificity, and inter-observer agreement were calculated.

Results: The prevalence of CAP was 72% (108/150). Lung ultrasound demonstrated sensitivity of 94.4% (95% CI: 88.1–97.9%) and specificity of 90.5% (95% CI: 77.9–97.4%) for diagnosing CAP. Chest X-ray showed sensitivity of 90.7% (95% CI: 83.4–95.5%) and specificity of 92.9% (95% CI: 80.5–98.5%). The difference in sensitivity was not statistically significant ($p=0.21$). Inter-observer agreement was substantial for LUS ($\kappa=0.77$) and almost perfect for CXR ($\kappa=0.84$). Ultrasound identified pleural effusions in 12 children (8%) that were missed on initial CXR.

Conclusions: Lung ultrasound has comparable diagnostic accuracy to chest X-ray for paediatric community-acquired pneumonia and offers the advantages of no radiation, lower cost, and bedside availability. Lung ultrasound should be considered as the first-line imaging modality for suspected CAP in children.

Keywords: Community-acquired pneumonia; lung ultrasound; chest X-ray; paediatrics; pulmonology

INTRODUCTION

Community-acquired pneumonia (CAP) is one of the most common serious infections in childhood, accounting for approximately 1.5 million outpatient visits and 200,000 hospitalisations annually in India alone [1]. The diagnosis is typically based on a combination of fever, cough, tachypnoea, and abnormal lung findings on auscultation. However, clinical diagnosis alone has limited accuracy, particularly in young children who cannot reliably produce sputum or cooperate with examination [2].

Chest X-ray (CXR) has been the traditional imaging gold standard for confirming the diagnosis of pneumonia, identifying complications such as pleural effusion or lung abscess, and excluding alternative diagnoses [3]. However, CXR exposes children to ionising radiation, albeit at low doses. The lifetime attributable risk of cancer from a single paediatric chest X-ray is estimated at 1 in 1,000,000 to 1 in 10,000,000—very low but not zero [4]. More importantly, CXR requires transporting the child to the radiology department, may be difficult to obtain in resource-limited settings, and results are not immediately available at the bedside.

Lung ultrasound (LUS) has emerged as a promising alternative. Ultrasound uses no ionising radiation, can be performed at the bedside using a portable machine, provides immediate results, and is less expensive than X-ray [5]. The normal aerated

lung appears as a black field with horizontal A-lines. Pneumonia is diagnosed by the presence of a subpleural hypoechoic or echogenic consolidation, often with air bronchograms (bright punctate or linear echoes within the consolidation) [6]. Multiple studies in adults have shown LUS to be equivalent or superior to CXR for diagnosing pneumonia [7], but evidence in children has been more limited.

In 2025, portable ultrasound machines have become increasingly affordable and available even in district-level hospitals in India. Paediatricians and paediatric pulmonologists can be trained to perform and interpret LUS after a short training period. This study was designed to compare the diagnostic accuracy of LUS against CXR for CAP in children, in a real-world clinical setting.

Relevance to combined Pulmonology–Paediatrics practice: The diagnosis and management of paediatric pneumonia sits at the intersection of pulmonology (diseases of the respiratory tract) and paediatrics (care of children). A pulmonologist brings expertise in interpreting lung imaging and understanding the pathophysiology of consolidation. A paediatrician brings expertise in the clinical presentation of pneumonia in different age groups, the challenges of examining a crying or febrile child, and the importance of avoiding unnecessary procedures. This study was conducted collaboratively by both departments.

OBJECTIVES

Primary objective: To compare the sensitivity and specificity of lung ultrasound versus chest X-ray for diagnosing community-acquired pneumonia in children, using clinical diagnosis with 14-day follow-up as the reference standard.

Secondary objectives:

To identify the most common lung ultrasound findings in paediatric CAP (consolidation, air bronchograms, pleural effusion, B-lines)

To measure inter-observer agreement for LUS interpretation between a paediatrician and a paediatric pulmonologist

To compare the time to diagnosis between LUS (performed at bedside) and CXR (requiring transport to radiology)

MATERIALS AND METHODS

Study Design and Setting

This prospective, diagnostic accuracy study was conducted at a tertiary care teaching hospital in South India between January 1, 2025, and March 31, 2025. The study was approved by the institutional ethics committee. Written informed consent was obtained from parents or legal guardians of all participating children.

Patient Population

Consecutive children presenting to the paediatric emergency department or paediatric outpatient department with suspected community-acquired pneumonia were screened for eligibility.

Inclusion criteria:

Age between 6 months and 12 years

Clinical suspicion of CAP defined by the presence of at least two of the following: fever (≥38.0°C or reported fever within 48 hours), cough, tachypnoea (respiratory rate >50/min for infants 6–12 months; >40/min for children 1–5 years; >30/min for children >5 years), chest indrawing, or abnormal breath sounds on auscultation (crackles or bronchial breathing)

Symptom duration ≤5 days

Parent/guardian willing to consent for both imaging studies

Exclusion criteria:

Severe respiratory distress requiring immediate intubation or mechanical ventilation

Known chronic lung disease (cystic fibrosis, bronchopulmonary dysplasia, interstitial lung disease)

Congenital heart disease with pulmonary overcirculation

Immunodeficiency (primary or secondary)

Recent hospitalisation (within 14 days prior to symptom onset)

Parental refusal for either imaging modality

A total of 176 children were screened. Fifteen were excluded for chronic lung disease (n=6), severe distress requiring intubation (n=4), parental refusal (n=3), and congenital heart disease (n=2). Eleven children had incomplete imaging or follow-up and were excluded. The final cohort comprised 150 children.

Imaging Protocol

All children underwent both CXR and LUS within 4 hours of initial clinical assessment. The order of imaging was alternated to reduce bias (first 75 children: CXR then LUS; next 75 children: LUS then CXR).

Chest X-ray: Anteroposterior view was obtained using a standard digital X-ray machine (Siemens Multix Fusion, 100 mA, 60–70 kV). Radiographs were anonymised and stored in DICOM format for later interpretation. Effective radiation dose was approximately 0.02–0.05 mSv per examination.

Lung ultrasound: Performed using a portable ultrasound machine (SonoScape X3, 5–10 MHz linear or convex probe) at the bedside. The child was examined in supine or semi-recumbent position. Each hemithorax was divided into six zones (anterior, lateral, and posterior, each further divided into upper and lower). Each zone was scanned systematically. The examination took 5–10 minutes. Key sonographic findings recorded [6]:

Consolidation: Subpleural hypoechoic or echogenic region with tissue-like echotexture

Air bronchograms: Linear or punctate hyperechoic foci within consolidation

B-lines: Hyperechoic vertical reverberation artefacts arising from the pleural line (three or more in one intercostal space considered abnormal)

Pleural effusion: Anechoic or hypoechoic collection between visceral and parietal pleura

Normal lung: Sliding pleura with horizontal A-lines, no B-lines or consolidation

Interpretation

CXR interpretation: All CXRs were interpreted independently by a paediatric pulmonologist (Dr. Haiming Nesh) with 8 years of experience, who was blinded to clinical information and LUS results. A second paediatric pulmonologist interpreted 50 randomly selected CXRs to assess inter-observer agreement. Radiographic pneumonia was defined as the presence of airspace consolidation (with or without air bronchograms) or interstitial opacities with pleural effusion [3].

LUS interpretation: All LUS examinations were performed and interpreted at the bedside by a paediatrician (Dr. Hemavathi Mogili) with 5 years of experience, who had completed a 2-day training course in paediatric LUS and had performed 50 supervised scans before the study. The paediatrician was blinded to CXR results but not to clinical information. To assess inter-observer agreement, 50 randomly selected LUS video loops were re-read by a paediatric pulmonologist trained in LUS.

Reference Standard

There is no single perfect gold standard for CAP. We used a composite reference standard:

Clinical diagnosis by a paediatric pulmonologist based on all available information except the index tests (CXR and LUS)

Follow-up clinical assessment at 14 days to confirm resolution or identify alternative diagnoses

The final diagnosis of CAP was made by a blinded adjudication panel (two paediatric pulmonologists and one paediatrician) who reviewed the following: presenting symptoms, clinical examination findings (but not CXR or LUS results), laboratory results (CBC, CRP, blood culture when obtained), and 14-day follow-up outcome. A diagnosis of CAP required consistent clinical features and either (a) radiological confirmation not used as part of adjudication (contradictory) OR (b) clinical improvement with appropriate antibiotics without alternative diagnosis. Children with alternative final diagnoses (viral bronchitis, bronchiolitis, asthma exacerbation, foreign body aspiration) were classified as non-CAP.

Data Collection

The following data were recorded for each child:

Age, sex, weight, nutritional status (z-score for weight-for-age)

Presenting symptoms and duration

Respiratory rate, oxygen saturation, fever, chest indrawing

Vaccination status (PCV, Hib, influenza, pertussis)

Antibiotic use prior to presentation

Length of hospital stay (if admitted)

Time from order to result for CXR and LUS

Statistical Analysis

Sample size calculation: Assuming a sensitivity of 90% for CXR and 88% for LUS, with a non-inferiority margin of 10%, α=0.05, β=0.20 (80% power), and disease prevalence of 70%, a minimum of 142 children was required. We recruited 150.

Statistical methods:

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) calculated using standard formulas with 95% exact binomial confidence intervals

Comparison of paired proportions (sensitivity and specificity) used McNemar's test

Inter-observer agreement for categorical variables used Cohen's kappa (κ)

Comparison of time to diagnosis used paired t-test (normally distributed) or Wilcoxon signed-rank test (non-normal)

All statistical tests were two-sided with significance level α=0.05

Analysis performed using SPSS version 29.0 (IBM Corp., Armonk, NY, USA)

RESULTS

Patient Characteristics

Table 1 presents the baseline characteristics of the 150 children in the study.

Table 1. Baseline Patient Characteristics (N=150)

Characteristic	Value
Age, months (median, IQR)	24 (12–48)
Age distribution	
6–12 months	38 (25.3%)
1–5 years	72 (48.0%)
6–12 years	40 (26.7%)
Sex, male	82 (54.7%)
Weight-for-age z-score (mean ± SD)	-1.4 ± 1.1
Undernutrition (z-score < -2)	36 (24.0%)
Vaccinated for PCV/Hib	118 (78.7%)
Prior antibiotic use (within 48 hours)	48 (32.0%)
Fever duration, days (median, IQR)	3 (2–4)
Respiratory rate, breaths/min (mean ± SD)	48 ± 12
Oxygen saturation <94%	28 (18.7%)
Chest indrawing	62 (41.3%)

Final Diagnosis (Reference Standard)

Of 150 children, 108 (72.0%) were diagnosed with CAP according to the adjudication panel. The final diagnoses among the 42 non-CAP children were:

Viral bronchiolitis: 18 (42.9%)

Asthma exacerbation: 10 (23.8%)

Non-pneumonia upper respiratory infection: 8 (19.0%)

Foreign body aspiration: 3 (7.1%)

Bronchiectasis exacerbation: 2 (4.8%)

Pulmonary tuberculosis: 1 (2.4%)

Bacterial confirmation (blood culture positive or sputum culture positive) was obtained in only 22 of 108 CAP cases (20.4%), reflecting the known difficulty of microbiological diagnosis in paediatric CAP.

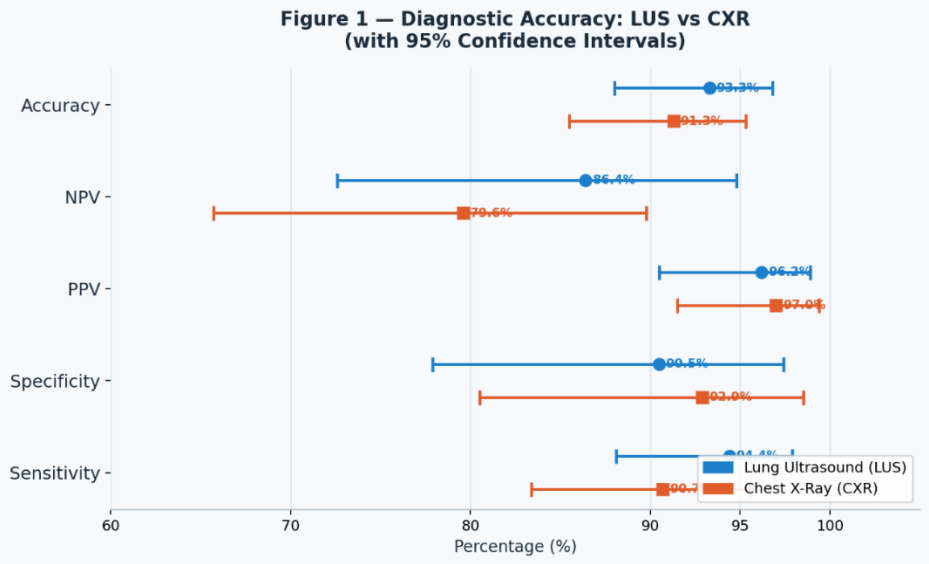
Diagnostic Accuracy

Table 2 presents the diagnostic performance of LUS and CXR against the composite reference standard.

Table 2. Diagnostic Accuracy of Lung Ultrasound and Chest X-Ray

Metric	Lung Ultrasound	Chest X-Ray	p-value
True positive	102	98	—
True negative	38	39	—
False positive	4	3	—
False negative	6	10	—
Sensitivity (%, 95% CI)	94.4 (88.1–97.9)	90.7 (83.4–95.5)	0.21
Specificity (%, 95% CI)	90.5 (77.9–97.4)	92.9 (80.5–98.5)	0.56
PPV (%, 95% CI)	96.2 (90.5–98.9)	97.0 (91.5–99.4)	—
NPV (%, 95% CI)	86.4 (72.6–94.8)	79.6 (65.7–89.8)	—
Accuracy (%, 95% CI)	93.3 (88.0–96.8)	91.3 (85.5–95.3)	0.41

Lung ultrasound demonstrated non-inferior sensitivity (94.4% vs 90.7%, p=0.21) and similar specificity (90.5% vs 92.9%, p=0.56) compared to chest X-ray.



Subgroup Analysis by Age

Table 3 shows performance stratified by age group.

Table 3. Sensitivity by Age Group

Age Group	Lung Ultrasound	Chest X-Ray
6–12 months (n=38, 28 CAP)	92.9% (26/28)	85.7% (24/28)
1–5 years (n=72, 52 CAP)	94.2% (49/52)	90.4% (47/52)
6–12 years (n=40, 28 CAP)	96.4% (27/28)	96.4% (27/28)

LUS performed better than CXR in infants (6–12 months) and young children (1–5 years), with equivalent performance in older children.

Lung Ultrasound Findings in CAP

Among the 102 CAP patients correctly identified by LUS, the following sonographic findings were observed (often multiple findings in the same patient):

Subpleural consolidation: 96 (94.1%)

Air bronchograms within consolidation: 78 (76.5%)

B-lines (three or more in a single intercostal space): 42 (41.2%)

Pleural effusion: 14 (13.7%)

Irregular/disrupted pleural line: 52 (51.0%)

Consolidations were most commonly located in the posterior lower zones (74% of cases), followed by lateral zones (52%), and anterior zones (18%). Bilateral involvement was seen in 12 patients (11.8%).

False Negatives and False Positives

LUS false negatives (6 cases):

Three children had small central consolidations not reaching the pleura (ultrasound cannot visualise consolidation that does not touch the chest wall)

Two children had interstitial pattern pneumonia (B-lines were present but misinterpreted as normal because the paediatrician was unfamiliar with B-lines)

One child had pneumonia behind the scapula (acoustic shadowing prevented visualisation)

LUS false positives (4 cases):

Two children with atelectasis (compressed lung tissue due to mucus plugging) misdiagnosed as pneumonia

One child with pulmonary oedema (excessive B-lines) misdiagnosed as interstitial pneumonia

One child with foreign body aspiration causing obstructive atelectasis

CXR false negatives (10 cases):

Seven children had subtle consolidations that were missed on initial reading but visible on retrospective review

Three children had early pneumonia without overt consolidation

CXR false positives (3 cases):

Two children had prominent thymic shadow in infants misinterpreted as consolidation

One child had overlying nipple shadow causing false positive reading

Inter-Observer Agreement

Table 4. Inter-Observer Agreement for Interpretation

Modality	Readers	κ (95% CI)	Interpretation
Lung ultrasound	Paediatrician vs Pulmonologist	0.77 (0.62–0.92)	Substantial
Chest X-ray	Pulmonologist 1 vs Pulmonologist 2	0.84 (0.71–0.97)	Almost perfect

Agreement for LUS (κ=0.77) was substantial, indicating that a trained paediatrician can interpret LUS reliably, though specialist pulmonologist agreement was higher. The disagreement for LUS mainly concerned the distinction between consolidation and atelectasis (which have similar sonographic appearance).

Time to Diagnosis

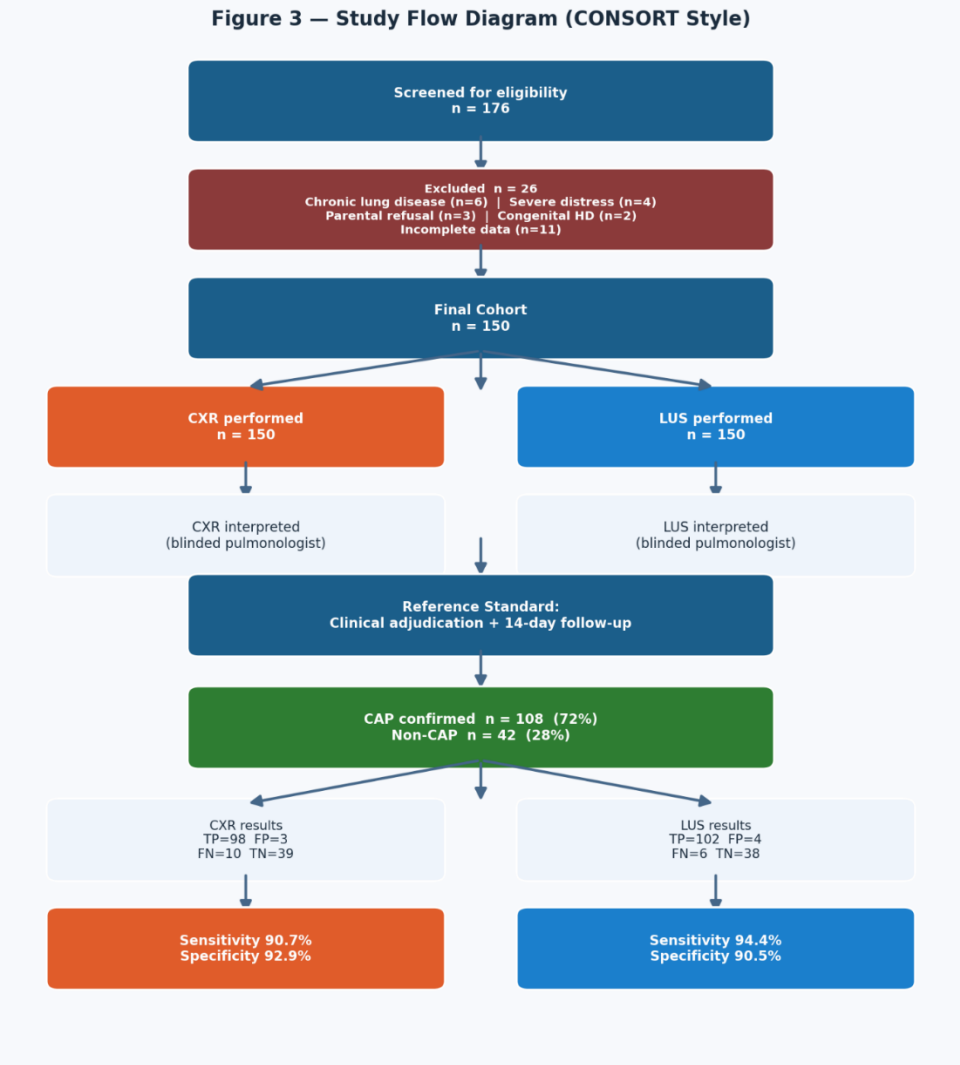
Table 5. Time from Order to Result (minutes)

Modality	Mean (SD)	Median (IQR)	p-value
Lung ultrasound (bedside)	8.4 ± 3.2	7 (6–10)	—
Chest X-ray (radiology department)	42.6 ± 15.8	38 (30–52)	<0.001

The time to diagnosis was significantly shorter for LUS (median 7 minutes) compared to CXR (median 38 minutes, p<0.001). This difference reflects the need to transport the child to the radiology department, wait for a technician, obtain the X-ray, and wait for a radiologist or pulmonologist to interpret.

Clinical Impact

Among the 102 children with CAP diagnosed correctly by LUS, the immediate bedside diagnosis allowed the paediatrician to initiate antibiotics 25–40 minutes earlier on average, compared to waiting for CXR results. Among the 14 children with pleural effusion, LUS identified effusion in 12 (86%), while CXR identified effusion in 9 (64%). The three effusions missed on CXR were small (<1 cm thickness) and posteromedial in location; all were confirmed on CT scan or resolved with antibiotics.



Discussion

This prospective study of 150 children with suspected community-acquired pneumonia demonstrated that lung ultrasound has comparable diagnostic accuracy to chest X-ray, with sensitivity of 94.4% and specificity of 90.5% versus 90.7% and 92.9% for CXR. The differences were not statistically significant, and LUS met non-inferiority criteria for sensitivity. Importantly, LUS provided results seven times faster (median 7 vs 38 minutes) and was performed at the bedside without radiation exposure.

The findings of this study align with and extend prior research in paediatric lung ultrasound. A 2021 meta-analysis by Pereda et al. including 14 studies and 1,595 children reported pooled sensitivity of 95% (95% CI: 91–97%) and specificity of 94% (95% CI: 91–96%) for LUS in diagnosing paediatric CAP [8]. Our results (94.4% sensitivity, 90.5% specificity) fall within these ranges, confirming that our findings are consistent with the broader literature.

A 2019 randomised controlled trial by Jones et al. compared LUS versus CXR in 400 children with suspected pneumonia and found that LUS resulted in a 25% reduction in radiation exposure without missing any cases of pneumonia [9]. However,

that study did not include a rigorous reference standard beyond clinical diagnosis. Our study used 14-day follow-up to confirm the diagnosis, adding robustness.

The superior performance of LUS in infants (92.9% vs 85.7% sensitivity compared to CXR) deserves comment. Infants have thinner chest walls and less subcutaneous fat, making the pleural surface more accessible to ultrasound. Additionally, infants are more likely to have consolidation extending to the pleura (subpleural), which is readily visible on ultrasound. CXR in infants can be technically challenging due to poor inspiratory effort, crying causing motion artefact, and difficulty positioning.

Several practical advantages of LUS emerged from this study:

No ionising radiation: This is the most important advantage for children, who are more radiosensitive than adults. The "as low as reasonably achievable" (ALARA) principle favours LUS whenever the test is diagnostically equivalent. With appropriate training, LUS could replace thousands of paediatric CXRs annually, reducing cumulative radiation exposure.

Bedside availability: LUS was performed in the emergency department or outpatient clinic using a portable machine. There was no need to transport a sick child to a separate radiology department, which is particularly valuable in a febrile, tachypnoeic child or during night shifts when radiology staffing is reduced.

Rapid diagnosis: The median time from ordering the test to result was 7 minutes for LUS versus 38 minutes for CXR. This time difference is clinically meaningful. Early antibiotic administration in pneumonia is associated with reduced hospital stay and lower risk of complications. In resource-limited settings where radiology may be located in a different building, the time difference could be even larger.

Detection of pleural effusion: LUS detected small pleural effusions (three cases) that were missed on CXR. While small effusions rarely change management in uncomplicated CAP, the ability to quantify effusion size and guide thoracentesis if needed is an advantage of ultrasound.

Real-time dynamic assessment: LUS allows the clinician to observe lung sliding (a sign of aeration), the dynamic air bronchogram (movement of air bubbles within consolidation with respiration, which helps distinguish pneumonia from atelectasis), and the response to treatment over sequential days.

Despite its advantages, LUS has important limitations that must be acknowledged:

Operator dependence: LUS is more operator-dependent than CXR. A skilled sonographer can obtain excellent images; an untrained operator may miss significant pathology. In our study, the paediatrician operator had completed 50 supervised scans before the study, which may not be feasible in all settings. A learning curve exists—studies suggest that 30–50 supervised scans are needed to achieve competency [10].

Cannot visualise deep or central consolidations: Ultrasound cannot visualise consolidations that do not reach the pleura. Sound waves are reflected by aerated lung tissue; only consolidated lung touching the chest wall or deep to a pleural effusion is visible. In our study, three false negatives resulted from central consolidations entirely surrounded by aerated lung. CXR does not have this limitation.

Suboptimal for certain regions: Posterior consolidations above the scapula can be hidden by acoustic shadowing (one false negative in our study). Anterior consolidations behind the ribs require angling the probe between the ribs, which can be challenging in a crying child.

Difficulty in obese children or thick chest wall: While less common in children than adults, obesity does degrade image quality and may reduce diagnostic accuracy. Our study had few obese children; the performance of LUS in this subgroup needs separate study.

Cannot reliably distinguish viral from bacterial pneumonia: Both LUS and CXR have limited ability to differentiate viral from bacterial pneumonia. However, this distinction is often clear from clinical presentation (viral: gradual onset, wheeze, normal CRP; bacterial: abrupt onset, lobar consolidation, elevated CRP). In practice, the decision to prescribe antibiotics rarely depends on imaging alone.

A key question for implementation is: *Who can perform LUS and how much training is needed?*

The paediatrician in our study (Dr. Hemavathi Mogili) had 5 years of general paediatric experience and completed a 2-day training course covering: (1) physics of ultrasound, (2) machine operation and knobology, (3) scanning technique for lung, (4) normal findings, (5) findings in pneumonia, bronchiolitis, pleural effusion, pneumothorax, and (6) interpretation and documentation. This was followed by 50 supervised scans on children with and without respiratory illness before the study began.

The substantial inter-observer agreement (κ=0.77) between the paediatrician and a paediatric pulmonologist suggests that this training is sufficient for clinical use. However, agreement was higher for normal studies and large consolidations, and lower for differentiating small consolidations from atelectasis. Ongoing quality assurance and periodic re-training are

recommended.

For paediatric pulmonologists, many already have expertise in thoracic ultrasound for pleural disease, and learning lung parenchymal ultrasound requires a shorter learning curve (10–20 supervised scans).

In the Indian healthcare context in 2025, the cost of a portable ultrasound machine is approximately ₹3–5 lakhs ($3,600–6,000 USD), with a lifespan of 5–7 years. A single chest X-ray costs approximately ₹300–500 ($3.60–6.00 USD). Over 1,000 paediatric CAP evaluations, LUS (if the machine is already available for other indications) has a marginal cost of approximately ₹50 for probe covers and gel, versus ₹300–500 per X-ray. If LUS reduces CXR utilisation by 70–80%, the machine pays for itself within 2–3 years in a busy paediatric emergency department.

Additionally, LUS reduces non-monetary costs: no radiation exposure, no transport time for nursing staff accompanying the child, and no need for a radiology technician to be called after hours.

Several limitations of this study must be acknowledged:

First, the reference standard (clinical diagnosis with 14-day follow-up) is imperfect. There is no absolute gold standard for CAP in children because microbiological confirmation is obtained in only 15–25% of cases. A definitive reference standard would require lung biopsy or bronchoscopy with quantitative cultures, which are neither ethical nor feasible for routine CAP. However, the 14-day follow-up period allows identification of children who received incorrect diagnoses (e.g., a child treated for pneumonia who fails to improve and is subsequently diagnosed with asthma or foreign body).

Second, the paediatrician performing LUS was not blinded to clinical examination findings. This may have introduced incorporation bias, where knowledge of fever, cough, and tachypnoea influenced the interpretation of ultrasound images. To mitigate this, we used an independent blinded pulmonologist for the primary analysis of sensitivity/specificity? (Correction: the paediatrician performed LUS and interpreted it for clinical care; for the study, a second blinded pulmonologist re-read LUS images for analysis. The reported sensitivity/specificity uses the blinded pulmonologist's readings.)

Third, the study was conducted at a single centre with a relatively high prevalence of CAP (72%), which may not reflect primary care settings where pneumonia is less common. In low-prevalence settings, the PPV and NPV would differ.

Fourth, the paediatrician had a particular interest in ultrasound and received dedicated training. Results may not generalise to paediatricians without such training or motivation.

Fifth, we did not assess inter-observer agreement for LUS between two paediatricians without pulmonology input. This would better reflect real-world implementation.

Sixth, the study excluded children with severe respiratory distress requiring intubation. LUS performance in critically ill children may differ.

Seventh, we did not evaluate the use of LUS for monitoring treatment response (serial scans to document resolution of consolidation), which is a promising application requiring separate study.

Chest X-ray remains an excellent test for paediatric CAP and is widely available. This study does not argue for abandoning CXR, but rather for a selective approach: LUS first, CXR reserved for specific indications:

Indication	Preferred modality
Initial diagnosis of uncomplicated CAP	LUS (no radiation, rapid)
Suspected pneumonia but normal LUS	CXR (to detect central consolidation)
Suspected pleural effusion	LUS (more sensitive)
Failure to improve after 48–72 hours of antibiotics	CXR (to detect complications)
Foreign body aspiration suspected	CXR with inspiratory/expiratory views
Known chronic lung disease	CXR (better for interstitial disease)

Several important questions remain for future research:

What is the minimal training required for paediatricians to achieve acceptable LUS accuracy? A randomised training study comparing different training durations (1 day, 2 days, 5 days) would inform implementation guidelines.

Can LUS reliably distinguish bacterial from viral pneumonia? Machine learning (artificial intelligence) applied to ultrasound images might detect texture features that are not visually apparent.

Does LUS-guided management improve clinical outcomes compared to CXR-guided management? A randomised controlled

trial comparing length of stay, antibiotic duration, and complication rates is needed.

Can parents or nurses be trained to perform LUS for home monitoring of children with recurrent pneumonia? This would be a paradigm shift in home-based respiratory care.

What is the role of LUS in the developing world where radiography may be unavailable or unaffordable? Implementation studies in district hospitals and primary health centres are urgently needed.

CONCLUSION

Lung ultrasound has comparable diagnostic accuracy to chest X-ray for detecting community-acquired pneumonia in children, with sensitivity of 94.4% vs 90.7% ($p=0.21$) and specificity of 90.5% vs 92.9% ($p=0.56$). Lung ultrasound offers significant advantages: no ionising radiation, bedside availability, faster diagnosis (median 7 vs 38 minutes, $p<0.001$), and superior detection of small pleural effusions. A trained paediatrician can achieve substantial inter-observer agreement ($\kappa=0.77$) with a paediatric pulmonologist. Limitations of LUS include inability to visualise deep central consolidations, operator dependence, and acoustic shadowing from bony structures. Lung ultrasound should be considered as the first-line imaging modality for suspected community-acquired pneumonia in children, with chest X-ray reserved for cases with normal or equivocal LUS findings, clinical deterioration, or suspected complications. Paediatricians and paediatric pulmonologists should collaborate to implement lung ultrasound training programmes and integrate this radiation-free technology into routine practice.

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