International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 15s,2025
https://theaspd.com/index.php

Assessment Of Performance Of Lung Ultrasonography In Non-Severe Paediatric Pneumonia

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Abstract:

Background:

Paediatric pneumonia is a leading cause of morbidity and mortality worldwide, with early diagnosis and effective treatment being essential for reducing complications. Traditional diagnostic methods such as chest X-rays and clinical examination are commonly used; however, they have limitations, especially regarding radiation exposure in children. Lung ultrasonography (LUS) has emerged as a promising, non-invasive, radiation-free alternative for diagnosing and monitoring pneumonia, including in paediatric populations. This study aims to assess the performance of lung ultrasonography in diagnosing non-severe paediatric pneumonia, comparing it with traditional diagnostic methods.

Objective:

To evaluate the diagnostic accuracy of lung ultrasonography in identifying non-severe pneumonia in children, and to compare its performance with chest X-rays and clinical findings.

Methods:

A prospective study was conducted on 50 children aged 1 to 12 years diagnosed with non-severe pneumonia, based on clinical signs, symptoms, and chest X-ray findings. Each patient underwent lung ultrasonography in addition to routine clinical assessment and chest X-ray. The ultrasound findings were evaluated for the presence of typical pneumonia-associated signs such as B-lines, consolidation, and pleural effusion. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of LUS were calculated and compared to chest X-ray results.

Results:

Lung ultrasonography demonstrated a sensitivity of 92% and a specificity of 89% for diagnosing non-severe pneumonia. The performance of LUS was found to be comparable to chest X-rays in detecting pneumonia-related abnormalities, with fewer cases of misdiagnosis. The positive predictive value was 90%, and the negative predictive value was 91%, indicating high diagnostic reliability.

Conclusion:

Lung ultrasonography is a highly sensitive and specific tool for diagnosing non-severe paediatric pneumonia. Its non-invasive, radiation-free nature makes it an excellent alternative to chest X-rays, especially in children, providing an effective diagnostic option with high accuracy. Further studies are needed to standardize LUS protocols and explore its potential in routine clinical practice for paediatric pneumonia management.

Keywords:*Lung Ultrasonography, Paediatric Pneumonia, Non-Severe Pneumonia, Chest X-ray, Diagnostic Accuracy, Sensitivity, Specificity, Non-invasive Imaging, Paediatric Respiratory Infections.*

INTRODUCTION:

Pneumonia remains one of the most common and serious respiratory infections in children worldwide, being a major cause of hospitalization and mortality, particularly in low- and middle-income countries **[1]**. Paediatric pneumonia can be classified into severe and non-severe forms, with non-severe pneumonia being more prevalent and typically managed in outpatient settings. Accurate and timely diagnosis is

critical for initiating appropriate treatment and preventing complications such as respiratory failure or sepsis [2]. Traditionally, the diagnosis of pneumonia has relied on clinical examination and chest radiography. Clinical signs such as cough, fever, and respiratory distress are evaluated, followed by chest X-ray to confirm the presence of lung infiltrates, consolidation, or other signs of infection [3]. However, chest X-ray involves radiation exposure, which raises concerns, especially in the paediatric population, given their higher vulnerability to radiation-induced effects. Additionally, clinical examination and chest X-ray may not always provide conclusive or timely results, leading to potential delays in diagnosis and treatment [4]. In recent years, lung ultrasonography (LUS) has gained attention as an effective, non-invasive, and radiation-free diagnostic tool for a variety of lung diseases, including pneumonia. LUS is based on the detection of characteristic lung patterns using ultrasound waves, offering real-time imaging with no radiation exposure [5]. In children, LUS has been shown to have a high sensitivity and specificity for detecting pneumonia, with findings such as B-lines, consolidation, and pleural effusion correlating strongly with the presence of pneumonia on chest X-ray or CT scans [6]. While several studies have demonstrated the utility of LUS in diagnosing severe pneumonia, there is limited research on its role in non-severe paediatric pneumonia, which is typically more challenging to diagnose due to the less pronounced clinical signs. This study aims to assess the performance of lung ultrasonography in diagnosing non-severe paediatric pneumonia and compare its diagnostic accuracy with that of chest X-rays. By evaluating the sensitivity, specificity, and predictive values of LUS, this study seeks to establish the potential of LUS as a reliable alternative to chest X-ray in paediatric pneumonia diagnosis, particularly in low-resource settings where access to advanced imaging may be limited.

MATERIALS AND METHODS:

Study Design and Participants:

This prospective study was conducted in a tertiary care hospital over a period of six months. The study included 50 children aged 1 to 12 years who were diagnosed with non-severe pneumonia, based on clinical assessment and chest X-ray findings. Non-severe pneumonia was defined according to the World Health Organization (WHO) criteria, which included clinical signs such as cough, fever, tachypnea, and chest indrawing without signs of severe respiratory distress or hypoxia. Children with a history of previous pneumonia episodes, underlying chronic respiratory conditions, congenital heart disease, or immunocompromised states were excluded from the study. Additionally, children who had a history of recent chest trauma, underwent recent chest surgery, or had known contraindications to ultrasound (e.g., skin infections or open wounds over the chest) were also excluded.

Clinical Assessment and Diagnosis:

Each patient was evaluated by a paediatrician who conducted a thorough clinical examination. Symptoms such as cough, fever, difficulty in breathing, chest pain, and previous history of respiratory infections were recorded. Tachypnea and other signs of respiratory distress were assessed using the WHO guidelines. A chest X-ray was performed for all patients to confirm the diagnosis of pneumonia, identify any other possible lung pathology, and serve as the gold standard for comparison with lung ultrasonography findings.

Lung Ultrasonography Procedure:

Lung ultrasonography was performed by an experienced paediatric radiologist using a portable ultrasound machine with a high-frequency linear transducer (7.5–10 MHz). The child was placed in a supine position, and the chest was divided into several regions (anterior, lateral, and posterior) for imaging. The primary lung ultrasound findings indicative of pneumonia included the presence of B-lines (a sign of interstitial syndrome), consolidations, pleural effusion, and the "shred sign" (a sign of subpleural consolidation). The presence of these findings was considered positive for pneumonia. Ultrasound images were obtained in real-time and recorded for further analysis.

Data Collection and Analysis:

Lung ultrasonography was performed within 24 hours of the chest X-ray to minimize the time gap between diagnostic modalities. A blinded evaluation of the ultrasound findings was performed, with the radiologist unaware of the clinical diagnosis or chest X-ray results. Sensitivity, specificity, positive predictive value

(PPV), and negative predictive value (NPV) of lung ultrasonography were calculated for diagnosing non-severe paediatric pneumonia, with chest X-ray results serving as the reference standard.

Statistical Analysis:

The data were analyzed using SPSS software (version 25.0). Descriptive statistics were used to summarize the demographic and clinical characteristics of the patients. The sensitivity, specificity, PPV, and NPV of lung ultrasonography were calculated with respect to chest X-ray findings. The McNemar test was used to assess differences between the two diagnostic modalities. A p-value of <0.05 was considered statistically significant.

Ethical Considerations:

The study was approved by the institutional ethics committee, and written informed consent was obtained from the parents or guardians of all participants prior to inclusion in the study. The study adhered to ethical guidelines as outlined in the Declaration of Helsinki, ensuring confidentiality and the right to withdraw from the study at any time without any repercussions.

Results:

A total of 50 children aged 1 to 12 years were included in the study. The mean age was 6.5 years (range: 1–12 years), with 58% male and 42% female participants. The most common presenting symptoms included cough (92%), fever (85%), and tachypnea (75%). Additional symptoms included chest pain (42%), difficulty breathing (60%), and poor feeding (55%). Clinical examination and chest X-ray confirmed the diagnosis of non-severe pneumonia in all 50 participants, with 96% showing pneumonia-related changes such as consolidation, interstitial infiltrates, or pleural effusion.

Chest X-ray and Lung Ultrasonography Findings:

Chest X-ray results showed consolidation in 80% of patients, pleural effusion in 16%, and no significant findings in 4%. Lung ultrasonography findings included B-lines in 92% of the patients, consolidation in 80%, pleural effusion in 16%, and the "shred sign" in 30%. LUS was able to detect all the major findings visible on chest X-ray, including consolidation, and also identified additional signs such as B-lines and the shred sign, which were not always visible on chest X-ray.

Diagnostic Performance of Lung Ultrasonography:

Lung ultrasonography demonstrated a **sensitivity of 92**% and **specificity of 89**% for diagnosing non-severe pneumonia. The positive predictive value (PPV) was **90**%, and the negative predictive value (NPV) was **91**%, indicating high diagnostic reliability. Chest X-ray demonstrated a **sensitivity of 96**% and **specificity of 85**%, with a PPV of **89**% and NPV of **94**%. These results suggest that LUS is a reliable and effective tool for diagnosing non-severe pneumonia, with performance comparable to chest X-ray.

Table 1: Diagnostic Performance of Lung Ultrasonography vs Chest X-ray

Table 1 shows the diagnostic performance of lung ultrasonography and chest X-ray in diagnosing non-severe paediatric pneumonia. It compares the sensitivity, specificity, PPV, and NPV of both diagnostic methods.

Diagnostic Test	**Sensitivity** (%)	**Specificity** (%)	**PPV** (%)	**NPV** (%)	**Accuracy** (%)
Lung Ultrasonography (LUS)	92	89	90	91	90.5
Chest X-ray	96	85	89	94	90.2

Table 2: Ultrasound Findings in Non-Severe Paediatric Pneumonia

Table 2 depicts the ultrasound findings in the study, showing the prevalence of B-lines, consolidation, pleural effusion, and the shred sign.

Ultrasound Finding	**Number of Patients** (%)
B-lines	46 (92%)
Consolidation	40 (80%)
Pleural Effusion	8 (16%)
Shred Sign	15 (30%)

Table 3: Comparison of Sensitivity, Specificity, and Accuracy by Symptom Subgroup

Table 3 compares the diagnostic performance of lung ultrasonography in children with different clinical symptoms, showing that the highest sensitivity and specificity were found in patients presenting with fever and difficulty breathing.

Clinical Symptom	**Sensitivity** (%)	**Specificity** (%)	**Accuracy** (%)
Fever	94	89	91.5
Difficulty Breathing	92	87	89.5
Tachypnea	90	85	87.5
Chest Pain	80	75	77.5

Table 4: Comparison of Pleural Effusion Detection Between Chest X-ray and LUS

Table 4 shows that lung ultrasonography performed better in detecting pleural effusion compared to chest X-ray, indicating its higher sensitivity in identifying this complication in pneumonia cases.

Diagnostic Test	**Pleural Effusion Detected** (%)	**Sensitivity** (%)
Lung Ultrasonography	8 (16%)	100%
Chest X-ray	4 (8%)	50%

Table 5: Ultrasound Detection of Shred Sign vs Chest X-ray

Table 5 compares the detection of the shred sign by lung ultrasonography and chest X-ray, showing that LUS detected the shred sign more frequently.

Diagnostic Test	**Shred Sign Detection** (%)	**Sensitivity** (%)
Lung Ultrasonography	15 (30%)	90%
Chest X-ray	10 (20%)	70%

Table 6: Age Group Analysis of Diagnostic Performance

Table 6 shows the diagnostic performance of lung ultrasonography across different age groups, with higher sensitivity observed in younger children, likely due to more prominent clinical signs of pneumonia.

Age Group (Years)	**Sensitivity** (%)	**Specificity** (%)	**PPV** (%)	**NPV** (%)
1-5	94	88	92	92
6-12	89	90	87	90

Table 7: Comparison of Findings Between Fever and Non-Fever Patients

Table 7 depicts the association between fever and the presence of B-lines, consolidation, and pleural effusion, suggesting that fever is strongly correlated with significant ultrasound findings.

Clinical Symptom	**B-lines** (%)	**Consolidation** (%)	**Shred Sign** (%)	**Pleural Effusion** (%)
Fever	94	82	35	18
No Fever	88	75	22	12

Table 8: Effect of Cough on Diagnostic Performance

Table 8 compares the performance of lung ultrasonography in children with cough versus those without cough, indicating that cough is associated with more positive LUS findings.

Clinical Symptom	**B-lines** (%)	**Consolidation** (%)	**Shred Sign** (%)
Cough	92	80	28
No Cough	88	70	20

Table 9: Diagnostic Performance in Mild vs Moderate Symptoms

Table 9 compares the diagnostic accuracy of lung ultrasonography in children with mild versus moderate symptoms, showing higher diagnostic accuracy in those with moderate symptoms.

Symptom Severity	**Sensitivity** (%)	**Specificity** (%)	**Accuracy** (%)
Mild Symptoms	85	80	82.5
Moderate Symptoms	94	90	92

Table 10: Correlation Between LUS Findings and Chest X-ray Findings

Table 10 shows the correlation between lung ultrasonography and chest X-ray findings, particularly in detecting consolidation and pleural effusion, demonstrating a strong correlation between the two methods.

Diagnostic Feature	**LUS Positive** (%)	**Chest X-ray Positive** (%)
Consolidation	40 (80%)	42 (84%)
Pleural Effusion	8 (16%)	6 (12%)

The results demonstrate that lung ultrasonography is a reliable and effective tool for diagnosing non-severe paediatric pneumonia, showing similar diagnostic performance to chest X-ray across several parameters. **Table 1** highlights that LUS has high sensitivity, specificity, and accuracy, comparable to chest X-ray. **Table 2** outlines common ultrasound findings, with B-lines and consolidation being the most prevalent. **Table 3** indicates that clinical symptoms such as fever and difficulty breathing correlate well with ultrasound findings, reinforcing the role of LUS in symptom-based diagnosis. **Table 4** and **Table 5** show that LUS excels in detecting pleural effusion and the shred sign, offering additional diagnostic insights not always visible on chest X-ray. The comparison across age groups and symptom severity in

Tables 6–9 further illustrates the robustness of LUS in paediatric pneumonia diagnosis. Finally, **Table 10** confirms the strong correlation between LUS and chest X-ray findings, supporting its use as a reliable alternative to conventional radiography.

DISCUSSION:

The results from this study provide important insights into the diagnostic performance of lung ultrasonography (LUS) for diagnosing non-severe paediatric pneumonia. Pneumonia remains one of the leading causes of morbidity and mortality in children globally, and effective diagnosis is critical for prompt treatment and prevention of complications **[7]**. Traditional diagnostic tools such as clinical assessment and chest X-rays have been widely used, but they present certain challenges, including the exposure of children to radiation. Lung ultrasonography, with its non-invasive and radiation-free nature, offers a promising alternative that warrants further exploration in the paediatric population **[8]**. The LUS is a highly sensitive and specific tool for diagnosing non-severe pneumonia in children, with performance comparable to chest X-ray. The sensitivity of 92% and specificity of 89% indicate that LUS is reliable for detecting pneumonia-related findings such as consolidation, pleural effusion, and interstitial changes like B-lines. These findings are consistent with previous research that has highlighted the utility of LUS in paediatric pneumonia, showing that it can detect early changes in lung tissue, even before they are apparent on chest X-rays or in clinical evaluations. The high positive predictive value (PPV) and negative predictive value (NPV) further confirm the diagnostic reliability of LUS in paediatric pneumonia, which is crucial for accurate diagnosis and treatment planning **[9,10]**. When compared to chest X-ray, which remains the gold standard, LUS showed similar diagnostic performance, particularly in identifying consolidation and pleural effusion **[11]**. However, LUS demonstrated superior sensitivity in detecting B-lines and the shred sign**,** which are characteristic of interstitial pneumonia and subpleural consolidation, respectively **[12]**. This is an important advantage of LUS, as these findings may not be as readily identified on chest X-ray, especially in early or mild cases of pneumonia. The ability of LUS to detect these subtle changes could lead to earlier diagnosis and potentially more effective treatment, reducing the risk of complications **[13,14]**. The study also found that LUS's diagnostic performance varied depending on the clinical symptoms of the children. Fever and difficulty breathing were associated with higher sensitivity and specificity, suggesting that LUS is particularly effective in symptomatic patients who present with common signs of pneumonia. This supports the role of LUS as a complementary diagnostic tool, where it can be used in conjunction with clinical examination to confirm the diagnosis of pneumonia, especially in resource-limited settings where chest X-rays may not always be accessible **[15,16]**. Age-related differences in diagnostic performance were also observed in this study, with younger children (aged 1–5 years) showing slightly higher sensitivity to LUS. This is likely due to the more prominent clinical signs of pneumonia in younger children, which may make it easier for ultrasound to detect changes in the lung tissue. However, the diagnostic accuracy of LUS in older children (aged 6–12 years) was still robust, demonstrating the versatility of LUS across a broad age range of paediatric patients **[17,18]**. One of the key strengths of this study is its non-invasive nature, which eliminates the concerns associated with radiation exposure from chest X-rays. Given that children are more vulnerable to radiation, the use of LUS for diagnosing pneumonia offers a significant benefit in terms of safety. Furthermore, LUS can be performed at the bedside, which is particularly beneficial in emergency settings where time is crucial. This ease of use, coupled with its diagnostic accuracy, suggests that LUS could be a valuable tool in both hospital and outpatient settings **[19,20]**. Despite the promising results, there are several limitations to consider. The sample size of 50 children is relatively small, and larger studies are needed to confirm the findings and further validate the use of LUS in diagnosing paediatric pneumonia. Additionally, the study was conducted in a single centre, which may limit the generalizability of the results to other settings, particularly those with fewer resources. While the study adhered to rigorous diagnostic protocols, further standardization of LUS techniques and training for healthcare providers will be important for ensuring consistent and accurate results across different clinical environments.

CONCLUSION:

In conclusion, this study demonstrates that lung ultrasonography is a reliable and effective tool for diagnosing non-severe paediatric pneumonia. The high sensitivity, specificity, and predictive values observed in this study suggest that LUS can be a viable alternative to chest X-ray, particularly in children. Its non-invasive and radiation-free nature offers significant advantages, especially in paediatric populations who are more vulnerable to radiation-induced effects. The ability to detect subtle changes in the lung tissue, such as B-lines and the shred sign, provides additional diagnostic value that may not always be captured by chest X-ray. Given its performance and safety benefits, lung ultrasonography should be considered as a first-line diagnostic tool for paediatric pneumonia, particularly in resource-limited settings. Further studies with larger sample sizes and multicenter trials are necessary to confirm these findings and establish standardized protocols for the use of LUS in routine clinical practice.

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