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Original Research Article

ROLE OF LUNG ULTRASOUND IN THE DIAGNOSIS OF CHILDHOOD PNEUMONIA

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ABSTRACT

Background: Childhood pneumonia remains one of the major causes of morbidity and hospitalization among children worldwide. Early and accurate diagnosis is essential for prompt treatment and prevention of complications. Lung ultrasound has recently emerged as a valuable bedside imaging modality for diagnosing pediatric pneumonia due to its non-invasive and radiation-free nature. **Aim:** To assess lung ultrasound findings in childhood pneumonia and to correlate lung ultrasound findings with clinical findings.

Materials and Methods: This prospective observational study was conducted among 150 children aged 1 month to 12 years clinically diagnosed with pneumonia. Detailed clinical examination and lung ultrasound assessment were performed in all cases. Ultrasound findings including consolidation, pleural effusion, empyema, B-lines, and pleural abnormalities were documented and correlated with clinical severity. Statistical analysis was carried out using SPSS software version 26.0, and $p<0.05$ was considered statistically significant.

Results: Majority of children belonged to the age group of 2–12 months (64.0%) with male predominance (62.7%). Fever (96.7%), cough (100%), tachypnea (94.0%), and chest indrawing (72.7%) were the most common clinical findings. Severe pneumonia accounted for 47.3% of cases, while very severe pneumonia constituted 18.0%. Abnormal lung ultrasound findings were significantly more common in severe and very severe pneumonia cases ($p<0.05$). Consolidation was the most common ultrasound finding observed in 32.7% of cases followed by pleural effusion in 14.0% and empyema in 3.3% of children.

Conclusion: Lung ultrasound is an effective, rapid, bedside, and radiation-free diagnostic modality for childhood pneumonia. Ultrasound findings correlate significantly with clinical severity and can aid in early diagnosis, severity assessment, and identification of complications in pediatric pneumonia.

Keywords: Childhood pneumonia, Lung ultrasound, Pediatric pneumonia, Consolidation.

INTRODUCTION

Childhood pneumonia remains one of the leading causes of morbidity and mortality among children worldwide, particularly in developing countries. Despite significant advances in vaccination programs, nutritional support, and antimicrobial therapy, pneumonia continues to contribute substantially to pediatric hospital admissions and healthcare burden. The World Health Organization (WHO) estimates that pneumonia accounts for a considerable proportion of deaths in children under five years of age, especially in low- and middle-income nations where delayed diagnosis and limited diagnostic facilities are common.[1]

Accurate and early diagnosis of childhood pneumonia is essential for prompt initiation of therapy and reduction of complications. Conventionally, diagnosis is based on clinical examination supported by chest radiography. Clinical findings such as fever, tachypnea, chest retractions, crackles, decreased breath sounds, and hypoxia are commonly used for diagnosis; however, these findings may overlap with other respiratory illnesses

and often lack specificity.[2] Chest radiography has traditionally been considered the imaging modality of choice, but it has several limitations including radiation exposure, variability in interpretation, limited sensitivity in early disease, and restricted accessibility in resource-constrained settings.[3]

In recent years, lung ultrasound (LUS) has emerged as a promising imaging modality for the diagnosis and monitoring of pulmonary diseases in children. Lung ultrasound is a non-invasive, bedside, radiation-free, and easily repeatable technique that has demonstrated high diagnostic accuracy for pneumonia detection. Due to the thinner chest wall and smaller thoracic diameter in children, ultrasound waves can provide superior visualization of peripheral lung lesions and pleural abnormalities.[4] Additionally, portable ultrasound devices have increased the feasibility of point-of-care lung ultrasound in emergency departments, pediatric wards, and intensive care settings.

Several characteristic sonographic findings have been described in childhood pneumonia. These include lung consolidation with air bronchograms, pleural line abnormalities, focal or confluent B-lines, shred sign, and pleural effusion. Studies have shown that these findings correlate well with inflammatory changes in lung parenchyma and may help differentiate bacterial from viral pneumonia.[5] Lung ultrasound can also aid in identifying complications such as empyema, necrotizing pneumonia, and parapneumonic effusion, thereby improving patient management and follow-up assessment.[6]

Comparative studies between lung ultrasound and chest radiography have demonstrated excellent sensitivity and specificity of ultrasound in diagnosing pediatric pneumonia. A recent systematic review and meta-analysis reported that lung ultrasound has diagnostic accuracy comparable to or even superior to chest radiography for community-acquired pneumonia in children.[7] Furthermore, lung ultrasound reduces unnecessary radiation exposure and can be repeated multiple times for monitoring disease progression and therapeutic response.

Another major advantage of lung ultrasound is its usefulness in correlating radiological findings with clinical severity. Studies have reported significant associations between ultrasound findings such as extent of consolidation, bilateral involvement, and diffuse B-lines with oxygen requirement, respiratory distress, prolonged hospitalization, and disease severity scores.[8] Thus, LUS not only assists in diagnosis but may also serve as a valuable prognostic and monitoring tool in pediatric respiratory infections.

The growing interest in point-of-care ultrasonography has encouraged incorporation of lung ultrasound into pediatric clinical practice and emergency medicine training programs. Its rapid bedside applicability and cost-effectiveness make it particularly beneficial in resource-limited settings where access to radiography may be delayed or unavailable.[9] Despite these advantages, the interpretation of lung ultrasound remains operator-dependent, and standardized pediatric protocols are still evolving. Therefore, further clinical studies are necessary to evaluate the utility and correlation of lung ultrasound findings with clinical manifestations in childhood pneumonia.

Hence, the present study was undertaken to assess lung ultrasound findings in childhood pneumonia and to correlate lung ultrasound findings with clinical findings in affected children.[10]

MATERIALS AND METHODS

This hospital-based prospective observational study was conducted in the Department of Pediatrics of a tertiary care teaching hospital over a period of 18 months after obtaining approval from the Institutional Ethics Committee. The study included children clinically suspected to have pneumonia and admitted to the pediatric ward and pediatric intensive care unit during the study period.

A total sample size of 150 children was included in the study. Children aged between 1 month and 12 years presenting with symptoms and signs suggestive of pneumonia such as fever, cough, tachypnea, chest indrawing, respiratory distress, abnormal breath sounds, or hypoxia were enrolled consecutively after obtaining written informed consent from parents or guardians. Children with congenital heart disease, chronic lung disease, pulmonary tuberculosis, thoracic trauma, known malignancy, or those whose guardians refused consent were excluded from the study.

Detailed demographic and clinical data of all enrolled children were recorded using a predesigned proforma. Clinical evaluation included history taking and thorough physical examination with documentation of temperature, respiratory rate, oxygen saturation, chest retractions, nasal flaring, cyanosis, auscultatory findings, and signs of respiratory distress. Severity assessment was performed based on clinical presentation and standard pediatric pneumonia guidelines.

All patients underwent lung ultrasound examination performed by a trained radiologist or pediatrician experienced in point-of-care ultrasonography using a high-frequency linear probe and curvilinear transducer where required. Ultrasound examination was conducted in sitting or supine position depending on the age and clinical condition of the child. Multiple lung zones including anterior, lateral, and posterior chest regions were systematically examined bilaterally.

Lung ultrasound findings assessed included presence of lung consolidation, air bronchograms, pleural line abnormalities, focal or confluent B-lines, shred sign, pleural effusion, and bilateral lung involvement. Size and location of consolidations were also documented. Ultrasound findings were correlated with clinical manifestations and severity of disease.

Routine laboratory investigations including complete blood count, C-reactive protein, and other relevant investigations were performed wherever indicated. Chest radiography was done in selected cases as advised by the treating physician and used for supportive clinical assessment.

All collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 26.0. Quantitative variables were expressed as mean ± standard deviation, while qualitative variables were presented as frequency and percentage. Association between lung ultrasound findings and clinical parameters was analyzed using Chi-square test or Fisher's exact test for categorical variables. Independent sample t-test and analysis of variance (ANOVA) were used for continuous variables wherever applicable. Correlation analysis was performed to evaluate the relationship between ultrasound findings and clinical severity indicators. A p-value of less than 0.05 was considered statistically significant.

Ethical clearance for the study was obtained from the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from parents or legal guardians of all participating children. Confidentiality of patient information was strictly maintained throughout the study, and the study was conducted according to the ethical principles outlined in the Declaration of Helsinki.

RESULTS

Table 1 shows the classification of acute respiratory infection according to the ARI control programme among the study population. Out of 150 children, 52 (34.7%) were categorized as pneumonia, 71 (47.3%) as severe pneumonia, and 27 (18.0%) as very severe disease. Children with severe pneumonia and very severe disease commonly presented with chest indrawing, inability to feed, central cyanosis, wheezing, grunting, and hypoxia, requiring hospitalization in the majority of cases.

Table 2 demonstrates the demographic profile of the study participants. Majority of children belonged to the age group of 2–12 months constituting 96 (64.0%) cases, followed by 1–3 years accounting for 41 (27.3%) cases, while only 13 (8.7%) children were above 3 years of age. Male children were predominant with 94 (62.7%) cases, whereas females constituted 56 (37.3%). Immunization status revealed that 101 (67.3%) children were completely immunized, 39 (26.0%) were incompletely immunized, and 10 (6.7%) were unimmunized.

Table 3 demonstrates the symptoms and vital parameters observed at admission. Fever was the most common presenting complaint seen in 145 (96.7%) children followed by tachypnea in 141 (94.0%) and cough in 150 (100%) cases. Chest indrawing was present in 109 (72.7%) children, while hypoxia with SpO_2 <90% was noted in 88 (58.7%) cases. Tachycardia was observed in 69 (46.0%) children and refusal of feeds was documented in 58 (38.7%) cases.

Table 4 depicts the distribution of pneumonia severity according to ARI classification. Severe pneumonia was the most common diagnosis accounting for 71 (47.3%) cases, followed by pneumonia in 52 (34.7%) cases and very severe pneumonia in 27 (18.0%) children.

Table 5 depicts the percentage of abnormal lung ultrasound findings among different categories of pneumonia. Abnormal lung ultrasound findings were observed in 18 (34.6%) children with pneumonia, 46 (64.8%) children with severe pneumonia, and 23 (85.2%) children with very severe pneumonia. Overall, abnormal ultrasound findings were identified in 87 (58.0%) children, indicating increased sonographic abnormalities with increasing severity of pneumonia. The association between pneumonia severity and abnormal lung ultrasound findings was found to be statistically significant ($p<0.05$).

Table 6 illustrates the distribution of lung ultrasound findings among the study population. Lung consolidation was the most common ultrasound finding seen in 49 (32.7%) children followed by pleural effusion in 21 (14.0%) cases. Empyema was detected in 5 (3.3%) children. Multiple ultrasound abnormalities were more frequently associated with severe and very severe pneumonia.

Table 1: ARI control programme classification among study population

Clinical Category	Important Clinical Findings	Management
No pneumonia	No fast breathing, no chest indrawing, feeding adequately	Home care and observation
Pneumonia	Fast breathing, cough, mild fever, no chest indrawing	Oral antibiotics and follow-up
Severe pneumonia	Chest indrawing, tachypnea, respiratory distress	Hospital admission and oxygen support
Very severe disease	Central cyanosis, inability to drink, grunting, apnea, altered sensorium	Urgent hospitalization and intensive care

Table 2: Demographic data of the study population

Parameter	Frequency (n=150)	Percentage (%)
Age		
2–12 months	96	64.0
1–3 years	41	27.3
>3 years	13	8.7
Sex		
Males	94	62.7
Females	56	37.3

Immunization status		
Complete	101	67.3
Incomplete	39	26.0
Unimmunized	10	6.7

Table 3: Symptoms and vitals at admission

Parameter	Frequency (n=150)	Percentage (%)
Cough	150	100
Fever	145	96.7
Hurried breathing	141	94.0
Chest indrawing	109	72.7
Lethargy	48	32.0
Refusal of feeds	58	38.7
Tachycardia	69	46.0
Tachypnea	141	94.0
SpO_2 <90%	88	58.7

Table 4: Types of pneumonia according to ARI control programme

Parameter	Frequency (n=150)	Percentage (%)
Pneumonia	52	34.7
Severe pneumonia	71	47.3
Very severe pneumonia	27	18.0

Table 5: Percentage of LUS abnormality in different types of pneumonia

Diagnosis	Ultrasound Feature Normal	Ultrasound Feature Abnormal	Total	p-value
Pneumonia	34 (65.4%)	18 (34.6%)	52	0.031
Severe pneumonia	25 (35.2%)	46 (64.8%)	71	
Very severe pneumonia	4 (14.8%)	23 (85.2%)	27	
Total	63 (42.0%)	87 (58.0%)	150	

Table 6: Distribution of LUS findings

LUS Findings	Number (n=150)	Percentage (%)
Consolidation	49	32.7
Pleural effusion	21	14.0
Empyema	5	3.3

DISCUSSION

The present study evaluated the utility of lung ultrasound (LUS) in childhood pneumonia and correlated sonographic findings with clinical manifestations among 150 pediatric patients. The study demonstrated that lung ultrasound abnormalities increased proportionately with severity of pneumonia and showed strong correlation with clinical indicators such as tachypnea, chest indrawing, respiratory distress, hypoxia, and feeding difficulty. These findings support the growing role of lung ultrasound as an effective bedside diagnostic tool in pediatric respiratory illnesses.

In the present study, the majority of children belonged to the age group of 2–12 months (64.0%), indicating higher vulnerability of infants to lower respiratory tract infections. Similar age predominance has been reported by Biagi et al., who observed that infancy represents the period of greatest susceptibility due to immature immune defenses and smaller airway calibre.[11] Male predominance was observed in the current study with 62.7% male participants, which is comparable to findings reported in previous pediatric pneumonia studies where male children constituted a larger proportion of admissions.

Clinical features such as cough (100%), fever (96.7%), tachypnea (94.0%), and chest indrawing (72.7%) were the most common presenting symptoms in the present study. These findings are in agreement with the observations made by Pereda et al., who highlighted tachypnea and respiratory distress as important clinical indicators associated with sonographic evidence of pneumonia.[12] The high prevalence of hypoxia among severe cases in the present study further emphasizes the importance of early imaging and bedside assessment for prompt management.

The present study found severe pneumonia to be the most common clinical category accounting for 47.3% of cases, followed by pneumonia (34.7%) and very severe pneumonia (18.0%). Lung ultrasound abnormalities were significantly more common among children with severe and very severe disease. Abnormal ultrasound findings were identified in 64.8% of severe pneumonia and 85.2% of very severe pneumonia cases. This increasing trend of ultrasound abnormalities with disease severity has also been documented by Claes et al., who demonstrated that larger consolidations and multiple B-line patterns were strongly associated with severe pediatric pneumonia requiring hospitalization.[13]

Lung consolidation was the most common ultrasound finding in the current study, observed in 32.7% of children, followed by pleural effusion in 14.0% and empyema in 3.3% cases. Similar findings were reported by Stadler et al., who identified

consolidation with dynamic air bronchograms as the hallmark sonographic feature in childhood bacterial pneumonia.[14] Pleural effusion and empyema were more frequently observed in severe and complicated cases, indicating the utility of ultrasound not only for diagnosis but also for identification of complications. One of the most important observations of the present study was the statistically significant association between abnormal lung ultrasound findings and increasing severity of pneumonia ($p<0.05$). This finding is supported by the work of Balk et al., who concluded that lung ultrasound has high sensitivity and specificity for pediatric pneumonia and correlates well with clinical severity parameters and therapeutic outcomes.[15] Ultrasound also offers several practical advantages including absence of radiation exposure, portability, repeatability, and bedside applicability, making it particularly useful in critically ill children and resource-limited settings.

The present study further emphasizes the role of lung ultrasound as a rapid and reliable diagnostic modality in pediatric pneumonia. Since clinical findings alone may sometimes be insufficient to differentiate severity and complications, lung ultrasound can significantly improve early diagnosis and monitoring. The ability of ultrasound to detect peripheral consolidations, pleural abnormalities, and dynamic air bronchograms makes it superior in many situations compared to conventional chest radiography.

However, the study has certain limitations. Lung ultrasound is operator-dependent and requires adequate training and expertise for accurate interpretation. Additionally, lesions located deep within the lung parenchyma without pleural contact may occasionally be missed. Despite these limitations, the findings of the present study strongly support incorporation of lung ultrasound into routine pediatric respiratory evaluation protocols.

CONCLUSION

The present study concludes that lung ultrasound is a highly useful, non-invasive, bedside imaging modality for evaluation of childhood pneumonia. Lung ultrasound findings showed significant correlation with clinical severity and respiratory manifestations. Consolidation was the most common ultrasound abnormality observed, while pleural effusion and empyema were associated with severe disease. The increasing prevalence of abnormal ultrasound findings with increasing severity of pneumonia highlights its diagnostic and prognostic value. Due to its radiation-free nature, portability, rapid availability, and high diagnostic accuracy, lung ultrasound can serve as an effective alternative and adjunct to chest radiography in the assessment and monitoring of childhood pneumonia.

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