Original Research Article

A prospective observational study depicting role of lung ultrasound in pediatric pneumonias

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ABSTRACT

Background: Pneumonia is a major cause of morbidity and mortality in children under five years of age. Chest x-ray poses radiation hazard to children and thus an alternative safe imaging modality must be explored for pediatric pneumonias.

Methods: This prospective observational study included all children below 18 years of age. Majority of patients were below five years of age. All clinically suspicious patients were subjected to chest x-ray and lung ultrasound (LUS). Chest x-ray was considered as imaging diagnostic standard for pneumonia. Consolidation and dynamic air bronchogram were looked on LUS.

Results: A total of 55 patients were included in study with 26 (47.2%) as infants and up to 47 (85.3%) as under five children. Out of 55 cases 32 cases (58.20%) were diagnosed as lobar pneumonia while 23 (41.8%) as bronchopneumonia on chest x-ray. LUS demonstrated high sensitivity and specificity of 90.63% and 100% for lobar pneumonia and 86.96 and 90.63% for bronchopneumonia respectively. Dynamic air bronchogram sign was found in all cases of lobar pneumonia on LUS and with sensitivity of 73.91% in bronchopneumonia.

Conclusions: LUS proved itself as highly sensitive and specific modality for detecting consolidation and owing to safe non ionizing nature of ultrasound, it must be considered as an alternative to chest x-ray as an imaging diagnostic tool for pediatric pneumonia.

Keywords: Bronchopneumonia, Lung ultrasound (LUS), Pediatric, Lobar pneumonia, Chest x-ray

INTRODUCTION

In everyday pediatric practice, a large number of acute respiratory infections are encountered. These infections can be bacterial, viral or fungal. Pneumonia is infection and inflammation of airspaces in the lungs which leads to activation of inflammatory cascade. This leads to leakage of plasma, exudates and loss of surfactant resulting in air space loss and consolidation. Globally pneumonia is leading cause of pediatric morbidity and mortality particularly in children younger than 5 years of age.¹ In

India Pneumonia accounts for 15.6 % of under 5 deaths and estimated incidence of clinical pneumonia in India is 0.37 episodes per child year.^{2,3}

Pneumonia is broadly classified into community acquired pneumonia, hospital acquired pneumonia and aspiration pneumonia. Community acquired pneumonia is a major form of pediatric pneumonia and is broadly classified further into lobar pneumonia and bronchopneumonia. Lobar pneumonia is an acute bacterial infection with resultant hepatization of lung parenchyma. There is

confluent consolidation involving partial or whole lobe of lung. In bronchopneumonia there is a patchy consolidation involving 1/more lobes, in same or bilateral lungs.

In infants, pneumonia is usually caused by organisms like *S. pneumoniae*, *S. aureus*, and *H. influenza*, most common being *S. pneumoniae*.⁴ In children aged between 2-5 years, main causative agents are viruses like haemophilus influenzae and respiratory syncytial virus (RSV).⁵⁻⁷ *Streptococcus pneumoniae* is common bacterial agents in this age group. In older children, *S. pneumoniae* and mycoplasma pneumoniae are main causative agents.^{8,9,10}

In pneumonia, first line imaging modality is chest x-ray. Imaging can also include CT in some cases for detecting complications and differentiation from other pathologies. The sensitivity of CT is higher, however, chest x-ray continues to be the main diagnostic modality for pneumonia as the cost and radiation hazard of CT is very high.^{11,12} A chest x-ray delivers 0.1 mSv, while a chest CT delivers 7 mSv which is 70 times as much radiation as compared to x-ray.¹³ The risk from x-ray imaging is small when compared to CT, but repeated x-rays accumulate radiation exposure. So, efforts should be made to minimize radiation risks by reducing unnecessary exposure to ionizing x-rays.

Ultrasound is fast, non-ionizing and widely available imaging modality which can be used as a possible alternative to x-ray. In a normal subject the pleura is the only visible structure and due to high acoustic impedance of the air, ultrasound waves are almost completely reflected. Due to repetitive reverberation A-lines are generated that are parallel to the pleura and are seen as a series of echogenic parallel lines distally, equidistant from one another.¹⁴ However lung parenchyma can become accessible to ultrasound beams if air content is replaced by pathological process. Pneumonia leads to consolidation and if the consolidation reaches the pleural surface, it is possible to visualize the lesion by ultrasound.

On USG consolidation appears as a hypoechoic area that contains multiple echogenic lines that represent air bronchograms.¹⁵ It is important to differentiate consolidation from obstructive atelectasis. The presence of dynamic air bronchogram which shows branching echogenic linear lines moving to and fro movements with breathing helps to differentiate consolidation from obstructive atelectasis.¹⁶ In case of whole lobe involvement consolidation appears as well defined. But in cases of small lobar consolidations deeper borders of consolidation demonstrate irregular interface due to underlying aerated lung.

The objective of this study was to compare the diagnostic ability of lung ultrasound with chest x-ray in pediatric pneumonia to assess whether lung ultrasound can be used

as an alternative imaging modality and avoid long term effects of radiation using X rays.

METHODS

This was a prospective observational study, conducted in department of radio-diagnosis at Indira Gandhi medical college and hospital, Shimla (Himachal Pradesh) from 1st July 2018 to 30th June 2019.

There were 70 patients with clinical diagnosis of pneumonia who reported to department of radiodiagnosis for CXR, out of which 55 were enrolled for study. Rest of the patients had severe pneumonia and therefore were excluded from study. The inclusion criteria were, age of children <18 years, indoor or outdoor patients with clinical suspicion of pneumonia. Children having severe pneumonia, having respiratory distress requiring oxygen or septic shock were excluded from study.

The research procedure was in accordance with the approved ethical standards of institute. An informed written consent was taken from the parents/guardians of the admitted children. Each child with clinical suspicion and blood investigations suggestive of pneumonia was taken for chest x-ray. Chest x-ray AP supine or PA view were done depending on age of child. Patients with positive finding for pneumonia on chest x-ray were subjected to lung ultrasound. The lung ultrasound was performed on GE LOGIQ P6 ultrasound machine, using convex probe with frequency range of 4-5.5 MHz and linear probe with frequency range of 10-13 MHz transducer. During LUS, longitudinal and transverse scans of the anterior, lateral and posterior aspects of thorax were performed. Thorax was scanned in supine and seated positions. The anterior chest wall was delineated from the parasternal to the anterior axillary line. The lateral area was delineated from the anterior to the posterior axillary line. The posterior area was considered as the zone beyond the posterior axillary line. Lung ultrasonography findings were described as either normal pattern with A-lines or subpleural lung consolidations. Lobar and patchy consolidations were separately described. Air bronchogram and dynamic air bronchogram were subsequently looked for in every consolidation patch detected by ultrasound. Data was compared for determining diagnostic accuracy of lung ultrasound with chest x-ray. The sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, negative likelihood ratio with 95% confidence interval were calculated using software Epi info version 7.

RESULTS

This study was performed on 55 children fulfilling inclusion criteria, out of which 33 (60%) were male and 22 (40%) females. The mean age was 3.7 years. Maximum patients were in age group of 0-1 year (n=26) comprising 47.2% of total (Table 1).

Table 1: Age distribution.

Age group (years)	N	Percentage (%)
0-1	26	47.2
>1-3	11	20
>3-5	10	18.1
>5-18	8	14.54

On chest x-ray abnormalities were detected in all 55 cases. Out of 55 cases, on basis of chest x-ray final diagnosis of lobar pneumonia was made in 32 (58.20%) cases and bronchopneumonia in 23 (41.80%) cases. Among 32 cases of lobar pneumonia, LUS detected consolidation in 29 (90.6%) cases 3 (9.37%) cases were not picked by LUS. So, LUS was found to be an effective imaging modality for lobar pneumonia with high sensitivity (90.63%) and specificity (100%) (Table 2).

Among 23 cases of bronchopneumonia diagnosed on chest x-ray, consolidation patches were detected in 20 (86.9%) cases by LUS. Remaining 3 (13.04%) cases were not detected by LUS while 3 cases were false positive for patchy consolidation. LUS was found to be slightly less sensitive (86.96%) and specific (90.63%) for bronchopneumonia in comparison to its ability in lobar pneumonia (Table 3).

Dynamic air bronchograms were seen consistently with high sensitivity and specificity in lobar pneumonia consolidation patches, however sensitivity of dynamic air bronchogram sign was on lower side in bronchopneumonia as (Table 4 and 5).

Table 2: Comparison of LUS with chest x-ray positive cases of lobar pneumonia.

Variables	CXR		Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Positive	Negative						
Positive	29	0	29	90.63%	100%	100%	88.46%	94.55%
Negative	3	23	26					
Total	32	23	55					

Table 3: Comparison of LUS with chest x-ray positive cases of bronchopneumonia.

Consolidation on LUS	CXR		Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Positive	Negative						
Positive	20	3	23	86.96%	90.63%	86.96%	90.63%	89.09%
Negative	3	29	32					
Total	23	32	55					

Table 4: Comparison of dynamic air bronchogram sign on LUS with chest x-ray positive cases of lobar pneumonia.

Dynamic air bronchogram	CXR		Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Positive	Negative						
Positive	29	0	29	90.63%	100%	100%	88.46%	94.55%
Negative	3	23	26					
Total	32	23	55					

Table 5: Comparison of dynamic air bronchogram sign on LUS with chest x-ray positive cases of bronchopneumonia.

Dynamic air bronchogram	CXR		Total	Sensitivity	Specificity	PPV	NPV	Accuracy
	Positive	Negative						
Positive	17	0	17	73.91%	100%	100%	84.21%	89.09%
Negative	6	32	38					
Total	23	32	55					

DISCUSSION

Mortality due to pneumonia is strongly linked to factors like undernutrition, air pollution and lack of adequate health care. UNICEF and NFHS accounts 15% of under five deaths due to pneumonia.^{17,18}

Awasthi et al, in a study conducted on 3351 children found that children in the age group of 2-11 months have 3 to 5 times higher incidence of community acquired pneumonia than those in 12-59 months age category.¹⁹

Our study showed that maximum number of patients were in age group of 0-1-year i.e., infants which constituted 47.2 % of all cases. Children up to 5 years of age constituted 85.3% of all cases in our study.

Chest x-ray is primary imaging modality for diagnosing pneumonia in children. Owing to radiations risks in children chest ultrasound was tried as an alternative imaging modality. Reali et al in a study comparing chest x-ray with lung ultrasound showed that ultrasound has sensitivity and specificity of 94% and 96% respectively for detection of consolidation in pneumonia.²⁰ Balk et al in similar study reported that LUS has a sensitivity of 95.5% and specificity of 95.3% for detection of pneumonia.²¹ Caiulo et al and Maria et al showed similar high diagnostic capability of lung ultrasound for lobar pneumonia.^{22,23} Our study showed that LUS has high sensitivity and specificity for detection of lobar pneumonia as well as for bronchopneumonia. Two cases with lobar consolidation and similarly three cases of bronchopneumonia were not detected by LUS as consolidation patches were lying deep to scapula and had no pleural contact. Bronchopneumonia was found to be comparatively hard to detect on LUS owing to small patchy consolidation and motion artefacts while performing LUS on child.

Dynamic air bronchograms on LUS are linear or dot like hyper-echoic artefacts in consolidation which are visualized propagating with respiration. They are specific for consolidation because dynamic nature proves that small bronchi in consolidation are in communication with main bronchi and are not just air trapped in atelectasis. Lichtenstien et al described, that the dynamic air bronchogram has a sensitivity of 61% and specificity of 94% for detection of consolidation on LUS.¹⁶ Bitar et al studied 73 cases with consolidation on LUS and found dynamic air bronchogram in 58 patients with sensitivity of 73.41%.²⁴ Our study is in accordance with these studies reported in literature which showed dynamic air bronchogram sign in every case of lobar consolidation detected by LUS. In bronchopneumonia sensitivity of dynamic air bronchogram was on lower side compared to lobar pneumonia. It was due to the fact that some infants and toddlers were uncomfortable during scan, so dynamic nature of air bronchogram was difficult to record. Furthermore, dynamic air bronchogram was difficult to record in small subpleural patches of consolidation. The limitations of study were small sample size and non-availability of portable ultrasound unit. Statistical analysis could have been better with large sample size. Portable ultrasound unit could have helped in recruiting more patients in study.

CONCLUSION

In India, Pneumonia is a major cause of morbidity and mortality in pediatric age group. Imaging of pediatric pneumonia is relied mainly upon chest x-ray. The present study was undertaken to evaluate lung ultrasonography as

an alternative to chest x-ray in pneumonias. In our study, lung ultrasound showed high accuracy, sensitivity, and specificity in detection of lobar consolidation as well as for bronchopneumonia. Only drawback of ultrasound in comparison to chest x-ray was that it was unable to detect deep lying consolidation patches having no pleural contact. Dynamic air bronchogram sign, which differentiates consolidation from atelectasis, was found consistently in all lobar pneumonia cases detected by LUS. In bronchopneumonia dynamic air bronchograms were missed in few cases resulting in lower sensitivity of 73.91% due to difficulty of detecting sign in small consolidation patches. On the basis of the findings in this study and non-ionizing nature of ultrasound, it is recommended that lung ultrasonography should be considered as an alternative to chest x-ray in pediatric pneumonias.

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Ethical approval: The study was approved by the Institutional Ethics Committee

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