Original Article

Lung Ultrasonography in the Diagnosis of Childhood Pneumonia

Mohit Sharma, Vinita Rathi, Sunil Gomber and Lalendra Upreti

Department of Radio-diagnosis, University College of Medical Sciences and GTB Hospital, Delhi, India

Abstract

Background. Chest radiograph is presently considered the investigation of choice for diagnosing pneumonia in children. Lung ultrasonogaphy has evolved as a useful alternative technique as it avoids exposure to ionising radiation, is easy to perform at the child's bedside and takes little time to conduct.

Methods. Lung ultrasonography was done in 100 children with clinical suspicion of pneumonia by a radiologist. Chest radiograph was interpreted by another radiologist who had no knowledge of the lung ultrasonography findings. Findings were recorded as positive or negative for pneumonia, on both the imaging modalities. The time taken for lung ultrasonography was also recorded. Considering chest radiograph as the reference standard, the sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of lung ultrasonography were calculated.

Results. The mean time taken to conduct lung ultrasound in children was 6.4 minutes. The sensitivity, specificity, PPV and NPV of lung ultrasonography in detecting pneumonic consolidation was 91%, 73%, 64.5% and 83.3%, respectively.

Conclusions. Performing lung ultrasonography has a short learning curve. Lung ultrasonography appears to be a good alternative to chest radiograph as the investigation of choice for the diagnosis of pneumonia in children.
[Indian J Chest Dis Allied Sci 2019;61:129-133]

Key words: Lung ultrasonogaphy, Pneumonia, Diagnosis, Children.

Introduction

In India more than 400,000 children die due to pneumonia every year. At present, chest radiograph is considered to be the test of choice for diagnosing pneumonia in children.[1] Chest radiograph (CXR) is harmful as it involves the use of ionising radiation;[2] there is a significant intra-observer and inter-observer variation in the interpretation of CXR.[1] Further, conventional CXR is associated with considerable practical delays in processing, away from the immediate clinical setting. Obtaining chest computed tomography (CT), which is considered to be the gold standard for diagnosing pneumonia, is neither practical nor ethical,[3] because of higher ionising radiation exposure, frequent need for sedation, lack of portability, availability and high cost.[4]

In children, the lung mass is small and they have a thinner chest wall. Therefore, lung ultrasonography appears to be a good alternative to CXR in the evaluation of pneumonia.[1] It avoids harmful radiation exposure, is easy to do at a child's bedside, takes little time to perform and interpret the results; and requires no sedation.[4] In a meta-analysis (n=765 children), the sensitivity and specificity of lung ultrasonography for the diagnosis of pneumonia were 96% and 93%, respectively.[5] Lung ultrasonography took an average of 5 to 10 minutes, regardless of whether the physician was skilled or recently trained.[5]

Till date, only three studies[6-8] have been conducted in India to evaluate the role of lung ultrasonography in diagnosing childhood pneumonia, of which one was done in neonates.[8] In the present study we assessed whether lung ultrasonography can replace chest radiograph for the diagnosis of childhood pneumonia in India and estimated the time taken for lung ultrasonography.

Material and Methods

A prospective study was conducted between November 2015 to April 2017 after obtaining approval of the Institutional Ethics Committee. Children upto 12 years of age, with signs and symptoms suggestive of pneumonia as per World Health Organization (WHO) and British Thoracic Society (BTS) guidelines (*i.e.*, high grade fever, tachypnoea breathing difficulty, cough or lower chest wall retraction in a previously healthy child) were included. Children who were haemodynamically unstable, had pre-existing chronic lung disease, congenital heart disease or acute heart failure with pulmonary oedema were excluded from the study.

From the previous studies in the literature, considering the sensitivity and specificity of ultrasonography as 96% and 93%, respectively, expecting sensitivity and specificity as 90% with 5% margin of error on either side and 95% confidence interval, a sample size of 139 pneumonia cases

[Received: July 17, 2018; accepted after revision: January 14, 2019]

Correspondence and reprint requests: Dr Vinita Rathi, 89/2 Radhey Puri Extension-II, Delhi-110051, India; E-mail: vineetarathi@yahoo.com

was required. But due to constraints of time for the study, only 100 consecutive children were evaluated in the present study.

After a preliminary clinical evaluation, an informed consent was taken for chest ultrasonography. Lung ultrasonography was undertaken by Radiologist no.1 using HD-7 XE Colour Doppler Ultrasound, Philips (Bothell, WA, USA) / Logic P6 Pro Colour Doppler (GE USG Korea,Ltd) ultrasound machines. Linear transducer (3-12MHz) was used in all cases. In six cases curvilinear probe (3-5.5.0 MHz) was also used.

The child was scanned by an intercostal approach in the supine position. The posterior thorax was scanned with the child in prone/lateral decubitus/erect/ sitting positions; or the child was held by the parent. The probe was placed perpendicularly and then parallel to the ribs, and moved longitudinally and transversely, respectively. Six lung zone evaluation was done, *i.e.*, the anterior, lateral and posterior thorax (lower and upper) was studied on both right and left sides (in parasternal/mid-clavicular line, mid-axillary line and paravertebral lines, respectively) and the spectrum of ultrasound findings was recorded. The size of the patches of consolidation on sonography and the time taken for lung ultrasonography were also recorded.

Immediately following the lung ultrasonography a chest radiograph was done, which was interpreted by Radiologist no. 2 who had no knowledge of the lung ultrasonography findings. The spectrum of radiographic findings were recorded and the diagnosis was recorded as positive or negative for pneumonia on both lung ultrasonography and chest radiograph.

Statistical Analysis

Sensitivity, specificity, positive predictive value and negative predictive value of lung ultrasonography were calculated for diagnosing pneumonia in children considering the chest radiograph as the reference standard.

Results

The study included 100 children (75 males). Their age ranged from 1 month to 12 years; 84% of the children enrolled in the study were between 1 month to 2 years, the mean age being 2 years 4 months. The most common clinical symptoms were breathlessness (100%), fever (100%) and cough (94%). Wheezing was present in 23% children. In 50% children the duration of symptoms was 1-2 days. On physical examination, fever and tachypnoea were documented in all 100 children. Pulse rate was found to be high (range 134-188 per minute) in 84 children. Chest retraction was seen in 24% children. Crepitations were the most common auscultatory finding in 87 children. Rhonchi were heard on auscultation in 60 children. Bronchial breath sounds were found only in 24 children, while breath sounds were absent on one side of the chest in six children. Laboratory investigation showed that only 15% of the children had a total leucocyte count above 11,000/mm^3. In 23 children, neutrophils were more than 70%. Anaemia was found in 43% of children.

The spectrum of lung ultrasonography findings are listed in table 1. Sub-pleural consolidation seen as a hypoechoic area (Figure 1A) was the most common finding seen in 60% of our children with clinically suspected pneumonia. Sonographic air-bronchogram, *i.e.*, echogenic punctate or linear foci or a tree-like pattern within the hypoechoic area (Figure 1B), was seen in 46% cases.

Table 1. Lung ultrasound findings in 100 suspected cases with pneumonia

Lung Ultrasound Findings	% present
Sub-pleural consolidation	60
Air bronchogram	46
Multiple (>1) consolidations	18
Shred sign	52
Confluent B lines	34
Multiple B lines	4
Confluent and multiple B lines	14
Sub-pleural consolidation and confluent/multiple B lines	28
Fluid alveologram	14
Irregular pleura	34
Pleural effusion	14
Atelectasis	3

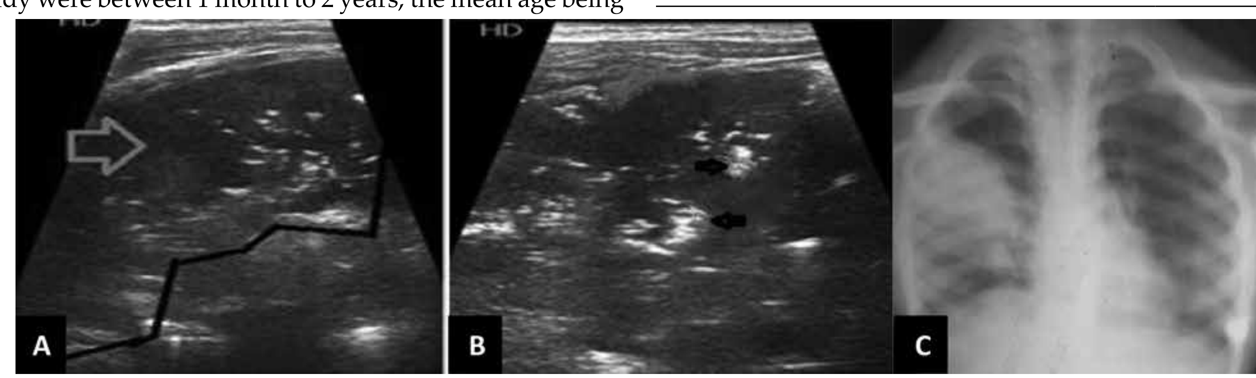

Figure 1. Lung ultrasonography of the right lower anterior and lateral zones showing (A) a large area of consolidation (white arrow) demarcated by zig-zag black line; (B) diffusely scattered, branching, seen in the area of consolidation can be seen air-bronchograms (black arrows); and (C) chest radiograph of the same patient showing large fluffy consolidation in the mid- and lower-zones of the right lung.

Irregular margin of the consolidation called as "shred sign", pathognomonic of consolidation was seen in 52 of the 60 patients with sub-pleural consolidations. Multiple consolidations were seen in 18 children. In the present study, the size of sub-pleural consolidation ranged from 0.5cm to 3.9cm (Table 2). In 35% children the maximum dimension of the sub-pleural consolidation on lung ultrasonography was less than 1.0cm (Figure 2).

Table 2. Maximum size of consolidation detected on lung ultrasound (n=60)

Size of Consolidation (in cm)	Number of Cases (%)
<1	21 (35)
1-2	20 (33.3)
2-3	12 (20)
>3	7 (11.6)

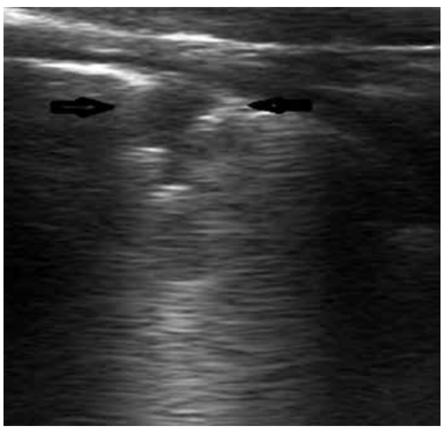

Figure 2. Small sub-centimetre sub-pleural consolidation (between arrows) in a child with suspected pneumonia who had a normal chest radiograph.

Sub-pleural consolidation along with confluent B lines/ multiple B lines was seen in 28% clinically suspected cases of pneumonia in the present study. Most of the confluent B lines (Figure 3A) detected on lung ultrasonography were in the width range of 0-5mm. Time taken to conduct lung ultrasonography in children in the study ranged from 3 minutes to 10 minutes (Table 3). In 72% of cases time taken for lung ultrasonography examination was between 5 to 7 minutes.

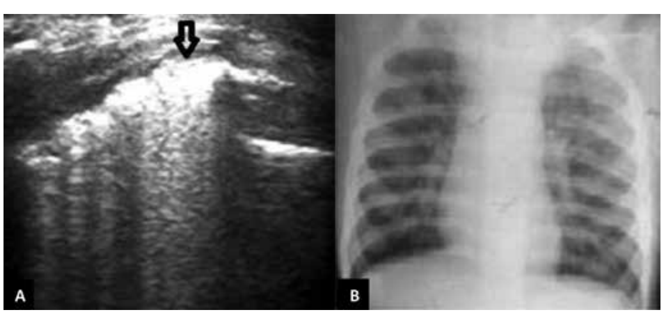

Figure 3. (A) Lung ultrasound showing confluent B lines with overlying thick and irregular pleura (arrow); (B) chest radiograph of the same child showing infiltrates in the left upper-zone.

Out of 100 chest radiographs, eight were sub-optimal or uninterpretable and were excluded from the comparison with lung ultrasonography. 92% children had an optimal chest radiograph. The reason for the poor quality of chest radiographs were improper positioning, under exposure and motion blur. Out of 100 clinically suspected cases of pneumonia, 27% had normal chest radiograph. On chest radiograph, alveolar consolidation was seen in 27% cases, infiltrates in 20% and consolidation with infiltrates in 16% cases. Pleural effusion was the most common associated finding seen in 10 cases of pneumonia; five of these had tappable pleural effusion (>10mm pleural separation).

Table 3. Time taken to conduct lung ultrasound

Time Taken (in minutes)	Number of Clinically Suspected Cases of Pneumonia
3	2
4	7
5	35
6	20
7	17
8	12
9	2
10	5

Out of 92 cases with clinical suspicion of pneumonia in whom an optimal chest radiograph was available for comparison in our study, 86 children had findings indicative of pneumonia on lung ultrasonography; 24 children with negative chest radiograph had lung ultrasonography findings suggestive of pneumonia. Out of these 24 cases, 19 had interstitial pneumonia showing multiple or confluent B-lines on lung ultrasonography. Interstitial community-acquired pneumonia was diagnosed in the presence of B lines or an interruption of the normal course of the pleural line (superficial fluid alveologram).[4]

The sensitivity of lung ultrasonography in diagnosing pneumonia was 91% and specificity was 73% with respect to chest radiograph.

In five cases where pleural effusion masked the underlying lung consolidation on chest radiograph, the consolidation could be detected by lung ultrasonography. Only one child with pneumonia diagnosed on chest radiograph had a normal lung ultrasonography.

Discussion

In the present study, the sensitivity of lung ultrasonography in diagnosing pneumonia was 91% and specificity was 73% with respect to chest radiograph. Similar results were reported in another study[6] where sensitivity was 98.2% and specificity was 64.7%, using chest radiograph as the gold standard. In another study[9] the sensitivity of lung ultrasonography was found to be higher than that of chest radiograph (94% *versus* 82%) in diagnosing community-acquired pneumonia in children, as consolidations extended to the pleura in 98.5% of cases.

In a meta-analysis of eight studies on the use of lung ultrasonography for the diagnosis of pneumonia in children, the sensitivity and specificity of lung ultrasonography was found to be 96% and 93%, respectively.[5] In a sub-group analysis, they found that when the reference standard was limited to findings based on chest radiograph alone, the sensitivity of lung ultrasonography was similar to that when both clinical criteria and chest radiograph were used to define childhood pneumonia; but the specificity of lung ultrasonography decreased from 94% to 84%. This most likely reflected that chest radiograph alone is inadequate for the diagnosis of pneumonia.[5] This is the likely explanation of low specificity of 73% in our study, as chest radiograph alone was considered as the reference standard to diagnose pneumonia.

In another study[10], pneumonia was found more frequently on the chest radiograph in patients with a bacterial infection than in patients with a viral infection.[10] In addition, the interpretation of chest radiograph findings is dependant on the quality of the films and the expertise of the reader. In our study, out of 24 chest radiographs that were negative but was positive on lung ultrasonography, 19 showed features of interstitial pneumonia on lung ultrasonography. So the low specificity of lung ultrasonography is suggestive of poor performance on the chest radiograph, in diagnosing interstitial pneumonia in children. In 5 out of the 24 chest radiograph negative cases of clinical pneumonia, the area of consolidation was masked by pleural effusion, signifying the utility of lung ultrasonography in this setting. In one positive case on chest radiograph, lung ultrasonography result was negative because lung infiltration seen on the chest radiograph in the para-cardiac region probably did not reach the pleural surface.

Alveolar community-acquired pneumonia (CAP) is diagnosed in the presence of lung consolidation with sonographic air-bronchogram, whereas interstitial CAP is diagnosed in the presence of B-lines or superficial fluid alveologram on lung ultrasonography. Among the important features of pneumonia on lung ultrasonography, sub-pleural consolidation was seen in 60% and air-bronchograms in 46% of our children. In a study[2], sub-pleural lung consolidation was observed in 83/89 patients and air-bronchograms were evident in 65/83. The higher incidence of sub-pleural lung consolidation and air-bronchograms in their study could be explained by the fact that the median age of the children evaluated in their study was 5.1 years, whereas in our study it was 1.8 years; and viruses are the most common causes of pneumonia in the first two years of life, accounting for up to 90% of pneumonias.

In another study[7], sub-pleural consolidation was detected in 93.5% cases as this study included diagnosed cases of pneumonia, where the diagnosis was confirmed by two expert paediatricians clinically and on the basis of initial presentation and follow-up; while our study included only clinically suspected cases of pneumonia. Our study results are similar to another report[8] that reported sub-pleural consolidation in 70% and air-bronchograms in 44% cases of neonatal pneumonia.

The mean time taken by a fresh resident in radiology to conduct lung ultrasonography in our study was 6.4 minutes. Our results are similar to the time taken for the six lung zone lung ultrasonography study conducted by Shah *et al*[3] which ranged from 7-9 minutes. Luri *et al*[5] reported the time taken in conducting lung ultrasonography or pneumonia was 10 minutes. Thus lung ultrasonography proved to be a reliable and quick tool for diagnosing pneumonia in children.

In our study the maximum dimension of consolidation seen on lung ultrasonography ranged from 5mm to 39mm with a mean of 2.2cm. Similar observations of size range 6mm to 48mm with a mean of 1.8cm was reported in another study.[2]

Conclusions

In the present study, we observed a high sensitivity and negative predictive value of lung ultrasonography in diagnosing pneumonia in children. Its specificity would have been higher if a composite diagnosis based on clinical criteria and chest radiograph or CT had been used as the gold standard for the diagnosis of pneumonia. More studies are, therefore, required to prove that lung ultrasonography can replace digital portable chest radiography with (PACS) systems. However, since the latter is not available at most government hospitals in the country, lung ultrasonography can be used as an alternative imaging modality to chest radiograph for the diagnosis of childhood pneumonia to avoid the harmful effects of ionising radiation. Bed-side lung ultrasonography can be more accurate in the diagnosis of pneumonia as compared to portable chest radiograph as the latter may be technically inadequate due to rotation, motion artifacts, poor contact, overexposure or under-exposure, etc.

Sub-pleural consolidations as small as 0.5mm can be detected on lung ultrasonography and learning lung ultrasonography is not very difficult, as the diagnosis of pneumonia can be made by fresh radiology residents within 3-10 minutes. However, few pneumonic lesions that do not extend to the accessible pleural line or are hidden behind bony structures are not detectable by lung ultrasonography in children.

References

1. Seif El Dien HM, Abd El Latif DAK. The value of bedside lung ultrasonography in diagnosis of neonatal pneumonia. *Egyptian J Radiol* 2013;44:339–47.
2. Caiulo VA, Gargani L, Caiulo S, Fisicaro A, Moramarco F, Latini G, *et al*. Lung ultrasound characteristics of community-acquired pneumonia in hospitalized children. *Pediatric Pulmonol* 2013;48:280–7.

3. Shah VP, Tunik MG, Tsung JW. Prospective evaluation of point-of-care ultrasonography for the diagnosis of pneumonia in children and young adults. *JAMA Pediatr* 2013;167:19–25.

4. Esposito S, Papa SS, Borzani L, Pinzani R, Giannitto C, Consonni D, *et al*. Performance of lung ultrasonography in children with community-acquired pneumonia. *Ital J Pediatr* 2014;40:37.

5. Pereda MA, Chavez MA, Hooper-Miele CC, Gilman RH, Steinhoff MC, Ellington LE, *et al*. Lung ultrasound for the diagnosis of pneumonia in children: a meta-analysis. *Pediatrics* 2015;135:714-22.

6. Yadav KK, Awasthi S, Parihar A. Lung ultrasound is comparable with chest roentgenogram for diagnosis of community-acquired pneumonia in hospitalised children. *Indian J Pediatr* 2017;84:499–504.

7. Tirdia PR, Vajpayee S, Singh J, Gupta RK. Accuracy of lung ultrasonography in diagnosis of community acquired pneumonia in hospitalized children as compared to chest x-ray. *Int J Contemp Pediatr* 2016;3:1026–31.

8. Dinakar P, Bharat Reddy D, Deepika D, Mithila M. Relevance of lung ultrasound in diagnosis of severe neonatal pneumonia. *J Pediatr Res* 2017;4:130–4.

9. Reali F, Sferrazza Papa GF, Carlucci P, Fracasso P, Di Marco F, Mandelli M, *et al*. Can lung ultrasound replace chest radiography for the diagnosis of pneumonia in hospitalized children? *Respiration* 2014;88:112–5.

10. Graffelman AW, Willemssen FE, Zonderland HM, Neven AK, Kroes AC, van den Broek PJ. Limited value of chest radiography in predicting aetiology of lower respiratory tract infection in general practice. *Br J General Pract* 2008;58:93–7.