International Journal of Contemporary Pediatrics
Shetty N et al. Int J Contemp Pediatr. 2020 Jun;7(6):1237-1242
http://www.ijpediatrics.com
pISSN 2349-3283 | eISSN 2349-3291

DOI: http://dx.doi.org/10.18203/2349-3291.ijcp20202071

Original Research Article

Utility of lung ultrasound in childhood pneumonia in a tertiary care center

Niharika Shetty, Sarala Sabapathy*, Mallesh K.

Department of Pediatrics, Bangalore Medical College and Research Institute, Bangalore, Karnataka, India

Received: 06 May 2020
Accepted: 11 May 2020

***Correspondence:**
Dr. Sarala Sabapathy,
E-mail: sarala.s@hotmail.com

ABSTRACT

Background: Pneumonia is a major cause of childhood mortality and morbidity worldwide. Chest radiography has been used as a modality for diagnosing but has the disadvantage of radiation exposure and inter-observer variability. Hence studies have explored the possibility of using lung ultrasound in the diagnosis of pneumonia. To assess lung ultrasound (LUS) findings in childhood pneumonia and to correlate lung ultrasound findings with clinical findings.
Methods: 210 children between 2 months to 5 years admitted in the hospital with diagnosis of pneumonia were enrolled in the study. They underwent LUS within 24 hours of admission and the results were analysed.
Results: Out of the 210 patients enrolled in the study, 41 (19.5%) had positive LUS findings. However, LUS findings correlated well with clinical findings in cases with very severe pneumonia.
Conclusions: This study showed that lung ultrasound cannot be used a sole diagnostic tool in childhood pneumonia, but it has a valuable role in detection of complications. Lung ultrasound will require more training for detection of early indicators of pneumonia.

Keywords: Childhood pneumonia, Consolidation, Lung, Lung ultrasound

INTRODUCTION

Pneumonia is a major cause of childhood morbidity and mortality worldwide. This is even more so in the developing countries and in under-five years of age. Acute respiratory infections (ARI) may cause inflammation of respiratory tract anywhere from nose to alveoli, with a wide range of combination of symptoms and signs. Pneumonia accounts for an estimated 1.2 million (18%) total deaths annually.[1]

The diagnosis of pneumonia is made clinically by symptoms such as tachypnea, fever, lethargy, cyanosis according to ARI control programme (Table 1). Chest radiographs should be obtained in all patients hospitalised for management of community acquired pneumonia to document the presence, size, and character of parenchymal infiltrates and identify complications of pneumonia that may lead to interventions beyond antimicrobial agents and supportive medical therapy.[2] Chest radiography has its own set of disadvantages - exposure to radiation (even though plain radiographs have small amounts of radiation dose exposure about 0.01-1.5 mSv, children are more susceptible to non-deterministic stochastic effects of radiation than adults, difficulty in acquiring both postero-anterior and latero-lateral projections in critically ill patients.[3,4]

CT chest, which is considered gold standard in diagnosis of pneumonia is expensive, impractical in critically ill and has higher radiation exposure than chest X-ray. Also, it is not easily available in resource poor setting.

Lung ultrasound has been long used in the diagnosis of pleural effusion and pneumothorax. It is less expensive, more user friendly, easy to transport and has no exposure to radiation. In view of increasing awareness of exposure to radiation and also minimal use of chest ultrasound for the diagnosis, this study was conducted to know the findings of lung ultrasound in childhood pneumonia and its use as a preferential mode for diagnosis of childhood pneumonia.

Objectives of the study is to assess lung ultrasound findings in childhood pneumonia and to correlate lung ultrasound findings with clinical findings

METHODS

This was a prospective observational study conducted from November 2017 to May 2019 at a tertiary care centre in south India, involving patients admitted between 2 months to 5 years of age with a diagnosis of pneumonia. Clinical data were collected in predesigned proforma. Patients were investigated and treated as per standard protocol. Lung ultrasound was done in 24 hours and the results were analysed.

Inclusion criteria

- Parents willing to give written informed consent
- Children between the ages of 2 months to 5 years.
- Children with signs and symptoms suggesting pneumonia according to ARI control programme.

Exclusion criteria

- Children who are on ventilator.
- Children with major cardiac and lung anomalies.

The children coming to the hospital with symptoms suggestive of pneumonia according to ARI control programme were admitted (Table 1). Demographic data was collected and clinical evaluation was done. Within 24 hours of admission, lung ultrasound was done by a radiologist.

Table 1: ARI control programme.

No pneumonia	Pneumonia	Severe pneumonia	Vry severe disease
No fast breathing	Fast breathing	Fast breathing	Not feeding well
No chest indrawing	No chest indrawing	Chest indrawing	Convulsions
Child feeding well	Child feeding well	No central cyanosis	Abnormally sleepy/difficult to wake
		Child able to drink	Stridor in a calm child
			Wheezing/grunting
			Severe chest indrawing
			Central cyanosis
			Apnoea
Treat at home	Treated at home with oral cotrimoxazole for 2 days and reassessed. If symptoms improved then antibiotic continued for 5 more days	Requires hospitalization	Requires hospitalization

The ultrasound was done using a curvilinear probe with transducer frequency of 6-13 MHz in Fujifilm Sonosite machine manufactured by ELPAC Electronics. Each hemithorax was divided into anterior, lateral and posterior zones and subdivided into upper and lower halves. Each zone was then scanned along anatomical lines: parasternal, mid-clavicular, anterior axillary, mid-axillary, posterior axillary, mid-scapular and paravertebral. The lung was visualised through the intercostal window and the probe was rotated both perpendicular and parallel to the ribs and moved from one intercostal space to the next, usually in a caudal direction from the apices to the costophrenic angles. If an area of pathology is visualised, a focused assessment of that area is done. The patient was examined in both supine and sitting position, as sitting position would provide better assessment of lateral and posterior areas of chest.[5] The presence of hepatization, B-lines and air bronchograms were considered to be suggestive of pneumonia.

Method of statistical analysis

The following methods of statistical analysis have been used in this study. The Excel and SPSS (SPSS Inc, Chicago v 18.5) software packages were used for data entry and analysis respectively. The results were averaged (mean±standard deviation) for each parameter for continuous data in Table and Figure. Proportions were compared using Chi-square test of significance.

RESULTS

During the study period, a total of 321 cases were admitted with pneumonia out of which 44 children were intubated at admission and 67 children had pre-existing cardiac illness and were excluded from the study and hence 210 cases were included in this study and the results obtained are as follows (Figure 1).

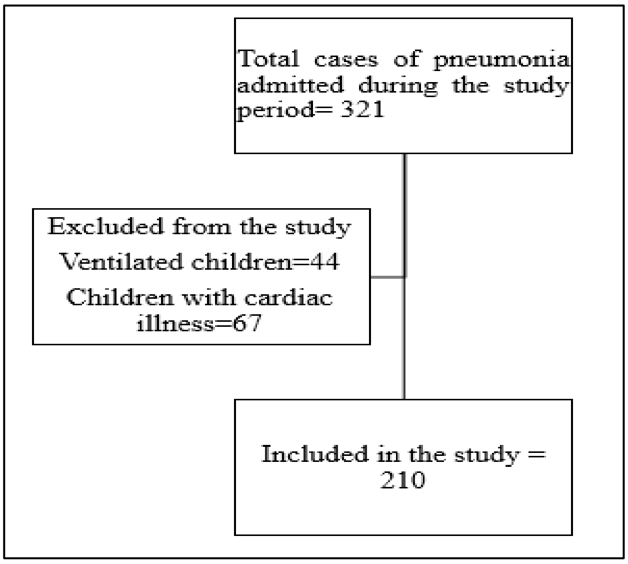

Figure 1: Case selection algorithm.

According to the data, the majority of the population belonged to the age group of 2-12 months (n=153, 72.8%) which shows that the majority of the patients being affected with pneumonia are infants. In this study, males formed the major chunk (n=137, 65.2%) and the females accounted for 34.8% of the population. In this study authors observed that, 57.1% (n=120) were immunized according to the national immunization schedule up to their chronological age. 37.1% (n=78) were not completely immunized and 5.8% (n=12) were unimmunized (Table 2).

Table 2: Demographic data of the study population.

Parameter	Frequency(n)	Percentage (%)
Age		
2-12 months	153	72.8
1-3 years	48	22.9
3-5 years	9	4.3
Sex		
Males	137	65.2
Females	73	34.8
Immunisation status		
Complete	120	57.1
Incomplete	78	37.1
Unimmunised	12	5.8

All the cases included in this study had cough as a presenting symptom. Next common complaints were fever and hurried breathing (99.5%). 98.1% of this patients had abnormal respiratory rate with respect to their age. 76.2% of this study population presented with oxygen saturation below 90%. 38% had tachycardia (Table 3).

Table 3: Symptoms and vitals at admission.

Parameter	Frequency (n)	Percentage
Cough	210	100
Fever	209	99.5
Hurried breathing	209	99.5
Chest indrawing	161	76.7
Lethargy	69	32.8
Refusal of feeds	31	14.8
Tachycardia	80	38
Tachypnea	206	98.1
SpO2 <90%	160	76.2

The cases were categorised into different types according to ARI control programme. In this study, the most common was severe pneumonia accounting for 66.2% (n=139). 23.8% (n=50) presented with very severe pneumonia and 10% (n=21) presented with pneumonia. In this study, 10% (n=21) had pneumonia, 66.2% (n=139) had severe pneumonia and 23.8% (n=50) had very severe pneumonia (Table 4).

Table 4: Types of pneumonia according to ARI control programme.

Parameter	Frequency	Percentage
Pneumonia	21	10
Severe pneumonia	139	66.2
Very severe pneumonia	50	23.8

These cases were subjected to lung ultrasound to determine the changes seen in childhood pneumonia. Out of this 19.5% (n=41) showed abnormalities on lung ultrasound. Out of 21 pneumonia cases, only 1 (4.8%) had ultrasound changes. In case of severe pneumonia, 20 (14.4%) cases had ultrasound changes. In case of very severe pneumonia, 20 (40%) cases had ultrasound changes (Table 5). The predominant ultrasound change seen was consolidation, present in 19.5% of cases (Table 6). Ultrasound, however did detect the presence of pleural effusion, even minimal, before the onset of clinical features in 11.9% (n=25) of the cases.

Table 5: Percentage of lus abnormal in different types of pneumonia.

Diagnosis	Ultrasound feature on admission		Total
	Normal	Abnormal	
Pneumonia	20	1	21
	95.2%	4.8%	100.0%
Severe Pneumonia	119	20	139
	85.6%	14.4%	100.0%
Very Severe Pneumonia	30	20	50
	60.0%	40.0%	100.0%
Total	169	41	210
	80.5%	19.5%	100.0%

Table 6: Distribution of lus findings.

LUS findings	Number	Percentage
Consolidation	41	19.5%
Pleural effusion	25	11.9%
Empyema	3	1.4%

DISCUSSION

Pneumonia is the leading cause of death in children. But confirmation of a clinically suspected diagnosis, either to guide management or for consistent case definition in epidemiological and vaccine studies, remains problematic. Chest radiography is generally considered the first-line standard-of-care imaging modality to investigate suspected pneumonia, with alveolar consolidation or interstitial infiltrates considered diagnostic for bacterial pneumonia.[6-12] However, chest radiography cannot be considered a diagnostic gold standard as a result of wide inter- and intraobserver variability when interpreting results, differing radiologic manifestations of pneumonia and possible lack of sensitivity and specificity.[6-12] Due to the potentially harmful effects of radiation exposure, some clinical guidelines advise against the routine use of chest radiography in uncomplicated acute lower respiratory infections in childhood populations.[13,14] More recently, due to its potential to decrease radiation exposure, there has been a renewed interest in the use of lung US as a first-line imaging modality for the diagnosis of pneumonia, especially in children.

Normally, in lung ultrasound, the chest wall appears as sequences of echogenic soft tissue layers, denoting the layers of muscles and the fascia planes.[15] The ribs appear on transverse scans as curvilinear structures with posterior acoustic shadowing beneath the chest wall soft tissue. With a high resolution linear probe, the visceral and parietal pleura describes as two echogenic lines under the ribs.[15] A hyperechoic and sliding line, moving forward and backward with respiration, notes 0.5 cm underneath the rib line, and mentions as the "pleural line". A-lines are hyperechoic lines running parallel to the pleural line that are, in fact, reverberation artefacts of the pleural line. B-lines (which are alternatively referred to as lung comets or comet-tail artefacts) are hyperechoic lines arising from and running perpendicular to the pleura up to the deep edge of the image, without fading, and obliterating the A-lines where they cross. The origin of B-lines is from arbitrary air-fluid interfaces produced in the lung parenchyma by adjacent fluid and air-filled structures such as alveolar air and interstitium, which become increasingly dense with a corresponding increase in extravascular lung water or decrease in aeration.[16] On a macroscopic level, B-lines correlate with thickened interlobular septae or ground-glass appearance identified on computed tomography (CT).[17,18] The ultrasound changes in pneumonia include: a) loss of pleural line echogenicity over the area of consolidation and the absence of A-lines within the area, b) increased B-lines surrounding the area of consolidation, c) B-lines often arising from the deep edge of the consolidation rather than from the pleura and d) sonographic air bronchograms seen as multiple hyperechoic punctate or lenticular specs within the area of consolidation or branching tree-like structures depending on the plane at which they are cut by the ultrasound beam. Large consolidations tend to have a characteristic liver-like appearance, referred to as hepatization. Atelectasis or lung collapse has a similar appearance to consolidation.[19-21] The standard look of pleural effusion is an anechoic fluid in between the both layers of pleura.[15] In pleural effusion, there is a sustained appearance of the vertebral bodies from the abdomen into the thoracic cavity, which is not normally visualised.[15] The sign of presence of air in the pleural space (Pneumothorax) is the "Barcode sign" or "Stratosphere sign" on M-mode. The air will produce only the horizontal lines throughout the image (Figure 2).[22]

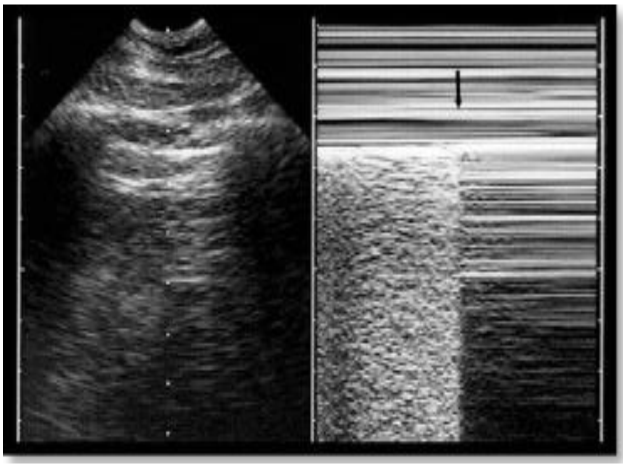

Figure 2: Stratosphere sign in pneumothorax.

The present study was undertaken to study the lung ultrasound findings in childhood pneumonia as a useful diagnostic tool for early detection of childhood pneumonia.

When compared to other studies, this study also showed higher incidence of pneumonia in infancy. The studies also showed higher incidence in males as compared to females.[23,24] These studies also had higher cases with complete immunisation.[23,25]

With respect to categories of pneumonia, like this study, there was higher incidence of severe pneumonia.[23,26]

This study showed that only 40% of the study subjects had changes in lung ultrasound, even when the child had clinical findings suggestive of severe disease. This was in contrast to studies which showed higher sensitivity and specificity of lung ultrasound in detection of features of pneumonia.[27-29] The reason for lower incidence of lung ultrasound changes in this study could be attributed to inability of the ultrasound is able to pick up changes in lung parenchyma near to the pleural surface and changes deep within the lung parenchyma. In the study conducted by Tirdia et al, they found 93.5% had subpleural consolidation by lung ultrasound and 35.9% had B-lines.[30] In this study, the lung ultrasound had picked up consolidation which was closer to the pleural surface and hence the high sensitivity reported. This study also had included age groups up to 18 years with a mean age group of 3 years which has high incidence of bacterial pneumonia which usually presents with consolidation. In the meta-analysis conducted by Pereda et al they found that lung ultrasonography had a sensitivity of 96% and specificity of 93% with positive and negative likelihood ratios of 15.3 and 0.06 respectively, but, there was no direct comparisons between the clinical presentation and lung ultrasound which resulted in heterogeneity of results reported.[31]

Limitations of ultrasound in pneumonia include the following:

- Ultrasound is time consuming with a median time of 10 minutes with no difference between the experienced and novice operators.[32-35]
- To identify pneumonia by lung ultrasonography, a consolidation needs to reach the pleura and be within an intercostal window.[34]
- Atelectasis may present as small consolidation and be misinterpreted as pneumonia by lung ultrasound.[34]
- Inability of the ultrasound to demonstrate certain features routinely assessed by chest radiography including hyperinflation, cardiac size and shape as well as airway position, size and patency.[21]

It is possible that ultrasound lung examination in children especially for pneumonia, pneumothorax, and consolidation is under stressed with most of the attention and time spent on x-ray, CT, MRI and ultrasound of abdomen.

A major feasibility concern is the learning curve and training requirements for clinicians to perform and interpret lung ultrasound in children. A recent study showed that ultrasound performed well in the hands of general practitioners after they received individualised training over a 7-day period from an expert radiologist.[23] Adequate training should not be underestimated and there is indeed a learning curve to confidently perform and interpret lung US scans. Supervised training and quality assurance by logging and reviewing scans with an experienced operator is therefore advised as part of any training program. It is imperative from authors observation that structured training for post graduate residents in critical care setting as well as radiology residents is the need of hour to make use of what is probably going to be a non-invasive, less expensive, and least at risk modality to diagnose childhood pulmonary diseases.

Limitations of this study was that lung ultrasound was not compared against any standardised reference diagnostic modality, the study was conducted in a single centre and the study was conducted without prior individualised training.

CONCLUSION

This study concluded that in case of very severe pneumonia, ultrasound could detect changes in the lung parenchyma as compared to pneumonia and severe pneumonia. As there are increasing reports regarding the utility of ultra sound in the diagnosis of pneumonia and it's complications due to its advantages over chest x-ray or CT, it may become the next line investigation of choice prior to x-ray chest and CT. Hence, there is a need for structured training of critical care clinicians and radiology residents.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Kelly MS, Sandora TJ. Community Acquired Pneumonia. In: Kleigman RM, Stanton BF, St Geme JW, Schor NF, eds. Nelson textbook of paediatrics. 20th ed, Vol 2. New Delhi: Thomson Press; 2015:2088.
2. Bradley JS, Byrington VL, Shah SS, Alverson B, Carter ER, Harrison C et al. The management of community acquired pneumonia in infants children older than 3 months of age: clinical practice guidelines by the Pediatric Infectious Diseases Society and the Infectious Diseases Society of America. Clin Infect Dis. 2011;53:e25-e76.
3. Shah S, Bachur R, Kim D, Neuman MI. Lack of predictive value of tachypnea in the diagnosis of pneumonia in children. Pediatr Infect Dis J. 2010;29(5):406-9.
4. Park MY, Jung SE. Patient Dose Management: Focus on Practical Actions. J Korean Medi Sci. 2016;31(Suppl 1):S45-54.
5. Copetti R, Cattarossi L. Ultrasound diagnosis of pneumonia in children. Radiol Med. 2008;113:190-8.
6. Bada C, Carreazo NY, Chalco JP, Huicho L. Inter-observer agreement in interpreting chest X-rays on children with acute lower respiratory tract infections and concurrent wheezing. Sao Paulo Medi J. 2007 May;125(3):150-4.
7. Johnson J, Kline JA. Intraobserver and interobserver agreement of the interpretation of pediatric chest radiographs. Emerg Radiol. 2010 Jul 1;17(4):285-90.
8. Edwards M, Lawson Z, Morris S. The presence of radiological features on chest radiographs: how well do clinicians agree? Clin Radiol. 2012;67:664-8.

9. Levinsky Y, Mimouni FB, Fisher D, Ehrlichman M. Chest radiography of acute paediatric lower respiratory infections: experience versus interobserver variation. Acta Paediatr. 2013 Jul;102(7):e310-4.
10. Cherian T, Mulholland EK, Carlin JB, Ostensen H, Amin R, Campo MD, et al. Standardized interpretation of paediatric chest radiographs for the diagnosis of pneumonia in epidemiological studies. Bull WHO. 2005;83:353-9.
11. Hagaman JT, Panos RJ, Rouan GW. Admission chest radiograph lacks sensitivity in the diagnosis of community-acquired pneumonia. Am J Med Sci. 2009;337:236-40.
12. Tanaka N, Emoto T, Suda H, Matsumoto T, Matsunaga N. Community-acquired pneumonia: a correlative study between chest radiographic and HRCT findings. Japan J Radiol. 2015 Jun 1;33(6):317-28.
13. Harris M, Clark J, Coote N, Fletcher P, Harnden A, McKean M, et al. British Thoracic Society Standards of Care C. 2011. British Thoracic Society guidelines for the management of community acquired pneumonia in children: update 2011. Thorax. 2011;66(Suppl 2):ii1-ii23.
14. National Collaborating Centre for Women's and Children's Health (UK. Bronchiolitis: diagnosis and management of bronchiolitis in children.
15. Koh DM, Burke S, Davies N, Padley SP. Transthoracic US of the chest: clinical uses and applications. Radiographics. 2002 Jan;22(1):e1.
16. Stadler JAM, Andronikou S, Zar HJ. Lung ultrasound for the diagnosis of community-acquired pneumonia in children: Pediatr Radiol. 2017;47:1412-9.
17. Lichtenstein D, Meziere G, Biderman P, Gepner A, Barre O. The comet-tail artifact: an ultrasound sign of alveolar-interstitial syndrome. Am J Resp Criti Care Medi. 1997 Nov 1;156(5):1640-6.
18. Martelius L, Heldt H, Lauerma K. B-lines on pediatric lung sonography: comparison with computed tomography. J Ultrasound Medi. 2016 Jan;35(1):153-7.
19. Riccabona M. Ultrasound of the chest in children (mediastinum excluded). Eur Radiol. 2008 Feb 1;18(2):390-9.
20. Toma P. Lung ultrasound in bronchiolitis. Eur J Pediatr. 2013 May 1;172(5):713.
21. Tomà P, Owens CM. Chest ultrasound in children: critical appraisal. Pediatr Radiol. 2013 Nov 1;43(11):1427-34.
22. Lichtenstein DA. Lung ultrasound in the critically ill. Ann Inten Care. 2014 Dec;4(1):1.
23. Chavez MA, Naithani N, Gilman RH, Tielsch JM, Khatry S, Ellington LE, et al. Agreement between the World Health Organization algorithm and lung consolidation identified using point-of-care ultrasound for the diagnosis of childhood pneumonia by general practitioners. Lung. 2015 Aug 1;193(4):531-8.
24. Ansari MDE, Kumar A, Aggarwal KC, Meena KR, Kamal M. Outcome predictors of severe and very severe pneumonia in children between 2-59 months of age admitted in a tertiary care hospital. Ind J Child Health. 2017;4(1):39-43.
25. Gothankar J, Doke P, Dhumale G, Pore P, Lalwani S, Quraishi S, et al. Reported incidence and risk factors of childhood pneumonia in India: a community-based cross-sectional study. BMC Pub Health. 2018 Dec;18(1):1-1.
26. Shekhawat YS, Sharma P, Singh A, Vikas P. Bacteriological and clinical profile of community acquired pneumonia in hospitalised children with associated co-morbidity in a tertiary care centre of Western Rajasthan, India. Int J Contemp Pediatr. 2016 Nov;3(4):1360-84.
27. Tiewsoh K, Lodha R, Pandey RM, Broor S, Kalaivani M, Kabra SK. Factors determining the outcome of children hospitalized with severe pneumonia. BMC Pediatr. 2009 Dec 1;9(1):15.
28. Calder A, Owens CM. Imaging of parapneumonic pleural effusions and empyema in children. Pediatr Radiol. 2009 Jun 1;39(6):527-37.
29. Tirdia PR, Vajpayee S, Singh J, Gupta RK. Accuracy of lung ultrasonography in diagnosis of community acquired pneumonia in hospitalised children as compared to chest x-ray: Int J Contemp Pediatr. 2016 Aug;3(3):1026-31.
30. 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 Apr 1;135(4):714-22.
31. Kombade B, Komwad A, Patil S, Kadam M. Chest Ultrasound versus chest xrays for detecting pneumonia in children. MedPulse- Int Med J. December 2016;3(12):1102-5.
32. 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;167:119-25.
33. Chavez MA, Naithani N, Gilman RH. Agreement between the World Health Organization algorithm and lung consolidation identified using point of care ultrasound for the diagnosis of childhood pneumonia by general practitioners. Lung. 2015;193:531-8.
34. Claes A-S, Clapuyt P, Menten R. Performance of chest ultrasound in pediatric pneumonia. Eur J Radiol. 2017;88:82-7.
35. Reali f, Sferrazza Papa GF, Carlucci P. can lung ultrasound replace chest radiography for the diagnosis of pneumonia in hospitalized children? Respiration. 2016;88:112-5.

Cite this article as: Shetty N, Sabapathy S, Mallesh K. Utility of lung ultrasound in childhood pneumonia in a tertiary care center. Int J Contemp Pediatr 2020;7:1237-42.