International Journal of Contemporary Pediatrics
Tirdia PR et al. Int J Contemp Pediatr. 2016 Aug;3(3):1026-1031
http://www.ijpediatrics.com
pISSN 2349-3283 | eISSN 2349-3291

DOI: http://dx.doi.org/10.18203/2349-3291.ijcp20162385

Research Article

Accuracy of lung ultrasonography in diagnosis of community acquired pneumonia in hospitalized children as compared to chest x-ray

Prahlad R. Tirdia, Shailja Vajpayee*, Jagdish Singh, RK Gupta

Department of Pediatrics, SPMCHI, SMS Medical College and Attached Hospitals, Jaipur, Rajasthan, India

Received: 01 June 2016
Accepted: 02 July 2016

***Correspondence:**
Dr. Shailja Vajpayee,
E-mail: dr.shlvajpayee@gmail.com

ABSTRACT

Background: The ultrasound signs of lung and pleural diseases described in adults are also found in pediatric patients. LUS is at least as accurate as chest radiography in diagnosing pneumonia. The objective of the study was to define the lung ultrasonography (LUS) characteristics at presentation and follow up of hospitalized children with community acquired pneumonia (CAP) and to define the accuracy of LUS as compared to chest X-ray (CXR) in diagnosing CAP.
Methods: It was a hospital based prospective study done at department of paediatrics, SMS hospital, Jaipur. A total of 139 children between 2 months to 18 years of age admitted in hospital with diagnosis of CAP who fulfilled the inclusion and exclusion criteria were included in the study after obtaining informed written consent. Clinical driven CXR was done on day of the admission. LUS was done in all patients. The LUS findings obtained were compared with those of CXR. The data was analyzed by using standard statistical methods.
Results: Of 139 patients, LUS characteristically shows sub pleural consolidation (absolute consolidation or with other findings) in 93.5 % (130/139), confluent B-lines abnormalities 35.9 % (50/139), pleural line abnormalities in 17.2% (24/139), and pleural effusion in 15.8 % (22/139) patients, while LUS was indicative of pneumonia in 136 (97.84%), CXR was suggestive of pneumonia in 126 (90.64%) patients ($p < 0.01$). The LUS had sensitivity of 97.84%. Consolidation was reported in 130 (93.53%) patients by LUS as compared to 107 (76.97%) patients by CXR ($p<0.001$). During follow up, LUS in seven patient initially showed increase in size of consolidation consistent with clinical deterioration then gradual decrease in size of consolidation due change in antibiotics.
Conclusions: LUS was highly accurate for the diagnosis as well as for follow up of CAP in hospitalized children. It avoids the use of ionizing radiation. Therefore, the use of ultrasound needs to be encouraged not just as a valid diagnostic alternative but as a necessary ethical choice.

Keywords: Lung ultrasound, Chest x-ray, Radiation, Imaging tool, Consolidation

INTRODUCTION

Pneumonia is the leading cause of childhood morbidity and mortality worldwide. The global annual incidence of pneumonia is 150 to 156 million cases.[1] Each year, approximately 1.4 million children die from pneumonia and pneumonia accounts for almost 15% of childhood mortality.[2] Estimated number of pneumonia deaths for children under age 5 in India in 2013 was 174,000.[2]

Diagnosis of community acquired pneumonia CAP) is done clinically but with poor diagnostic specificity.[3,4] Chest X-ray (CXR) is considered as the first imaging step for further evaluation. 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.[5,6] In addition, the interpretation of CXR findings is dependent on the quality of the film and the expertise of the reader.[7,8]

The use of ultrasound for the evaluation of the lung is relatively recent. Lung ultrasound (LUS) is inexpensive, portable and non-ionizing imaging tool. It is relative easy to teach.[9] The various studies had shown that LUS performs well in adults.[10,11] LUS is being increasingly studied in children and neonates in various thoracic conditions.[12,13]

In light of increasing awareness of radiation exposure risks in children, we designed a study to define the LUS characteristics of CAP in hospitalized children at presentation and during follow up and to compare these LUS findings with the CXR findings to determine if LUS could serve as a useful alternative to CXR. To our best knowledge, no previous such studies have been published from India.

METHODS

It was a hospital based prospective observational study done at department of paediatrics, SMS hospital, Jaipur from April 2013 to March 2014. This study was approved by the local ethics committee. Children between 2 months to 18 years of age who hospitalized for clinical suspicion of CAP were enrolled. Cases fulfilling the inclusion and exclusion criteria were included in the study after obtaining informed written consent. Diagnosis of pneumonia was confirmed by 2 expert pediatricians clinically on the basis of initial presentation and follow up clinical course (3). Clinical driven CXR was done on day of the admission in PA view in erect posture. In all patients, LUS was done on the day of the admission, defined as day 1, within 24 hours of obtaining CXR. Follow up LUS was done between days 3 and 6, 7 and 10, and 11 and 14. LUS was performed by trained pediatric sonologist blinded to CXR findings but was known to the clinical findings**.** LUS was performed using 3-7 MHz linear probe. A predesigned structural proforma was used to collect information. Data was collected with reference to clinical examination, routine investigations, CXR findings and LUS findings. Continuous variables are expressed as mean ± standard deviation (SD) values. Categorical variables are expressed as numbers and percentages. The data was analysed by using Chi square test and Z- test.

Inclusion criteria

- Clinical signs and symptoms suggesting CAP.
- Children aged 2 months ≤18 years.
- Presence of clinical driven CXR.
- Availability of a paediatric sonographer expert in LUS.

Exclusion criteria

- Unwilling parents/guardians.
- Patients with congenital or acquired heart disease, chronic lung diseases and/or metabolic disorders.
- Pre-established cases of pyrexia and cough other than pneumonia.
- Seriously ill patients or patients with multi organ failure.
- >24 hours duration between first LUS and CXR.

RESULTS

Table 1: Baseline characteristics of patients.

Patients, No. (%)	139 (100%)
Age, mean ± 95% CI, y Median, y	3.28 ± 0.62 1.5
Sex, Female Male	No. (%) 48 (34.5%) 91 (65.5%)
Weight, mean ± 95% CI, kg Median, kg	12.76 ± 1.62 9.2
Geographical distribution Rural Urban Slum	No. (%) 72 (51.79%) 57 (41.00%) 10 (7.19%)
Immunization status Complete immunization Partial immunization Unimmunized	No. (%) 61 (43.88%) 67 (48.20%) 11 (7.91%)
Previous history of hospitalization due to respiratory distress Yes No	No. (%) 22 (15.82%) 117 (84.17%)
Localization of LUS characteristic Right Left Both	No. (%) 97 (71.3%) 26 (19.1%) 13 (9.6%)
Lung consolidation shown by LUS CXR p value	No. (%) 130 (93.53%) 107 (76.97%) 0.001

Table 2: LUS findings on day 1.

LUS characteristics	No. of patients (%) N=139
Sub pleural lung consolidation	43 (30.93%)
Confluent B-lines + consolidation	44 (31.65%)
Confluent B-lines + Pleural line abnormalities	2 (1.43%)
Consolidation + pleural line abnormalities	22 (15.82%)
Pleural effusion + consolidation	21 (15.10%)
Focal or multiple confluent B-lines	3 (2.15%)
Confluent B-lines + Pleural effusion	1 (0.72%)
Normal	3 (2.15%)

Table 3: Comparison of chest X-ray and LUS characteristic findings for the diagnostic findings of pneumonia.

	USG Positive	USG negative	Total	p value
Chest X-ray positive	125	1	126 (90.64%)	
Chest X-ray negative	11	2	13 (9.35%)	
Total	136 (97.84%)	3 (2.16%)	139 (100%)	< 0.01

A total 139 patients were enrolled. Descriptive characteristics are given in Table 1. The most common symptom of pneumonia was cough (95%) and most common sign was tachypnea (99.23%). Most common finding on auscultation was crepitation (58.99%). Oxygen saturation of <90 % was observed in 12 (8.63%) patients. Leucocytosis was observed as 60.8% in group of 2 months to 5 years, 77.41% in 5 to 10 years and 81.81% in 10 to 18 years of age. The difference was insignificant (p = 0.1).

CXR showed consolidation (absolute or with other abnormality) in 76.9% (107) patients, peribronchial thickening in 10.07% (14) and synpneumonic pleural effusion in 10.7% (15) patients. CXR was negative for pneumonia in 13 patients.

On day 1 LUS characteristically showed sub pleural consolidation (absolute or with other findings) in 93.5 % (130), confluent B-lines abnormalities 35.9% (50), pleural line abnormalities in 17.2% (24), and pleural effusion in 15.8% (22) patients. Overall LUS findings are tabulated in Table 2.

Of 139 patients who were clinically diagnosed as pneumonia, CXR was suggestive of pneumonia in 126 (90.64%) patients while LUS was indicative of pneumonia in 136 (97.84%) patients (Table 3) (p=0.01). One patient with negative LUS had abnormal CXR but11 patients with negative CXR had LUS findings suggestive of pneumonia with clinical course consistent with pneumonia (p <0.01). LUS was negative in 3 patients with clinical course consistent with pneumonia while CXR failed to detect abnormality in 13 patients. The difference was significant.

In this study, consolidation and pleural effusion were two characteristics findings common in CXR and LUS. Consolidation was reported in 130 (93.53%) patients by LUS and in 107 (76.97%) patients by CXR and the difference was statistically highly significant (p<0.001). A synpneumonic pleural effusion was reported in 22 (15.83%) patients by LUS as compare to 15 (5.03%) by CXR.

Table 4: Follow up of lung consolidation and pleural effusion as reported by LUS.

Maximum thickness of consolidation [pleural effusion] mm	No. of patients (%)			
	Day 1	Day 3-6	Day 7-10	Day 11-14
< 15 mm	57 (41.0%) [13]	70 (50.3%) [16]	30 (21.6%) [10]	7 (5.03%) [2]
15 – 29 mm	66 (47.4%) [8]	15 (10.7%) [2]	6 (4.3%) [0]	5 (3.5%) [1]
≥ 30 mm	7 (5.0%) [1]	5 (3.5%) [1]	2 (1.4%) [0]	0 (0.0%) [0]
Total	130 (93.52%) [22 (15.8%)]	90 (64.75%) [19 (13.7%)]	38 (27.34%) [10 (7.2%)]	12 (8.63%) [3 (2.2%)]

Table 5: Follow-up characteristics of LUS in patients.

LUS characteristics	No. of patients (%)			
	Day 1	Day 3-6	Day 7-10	Day 11-14
Confluent B-lines	50 (36.0%)	40 (28.8%)	20 (14.4%)	8 (5.8%)
Pleural line abnormalities	24 (17.3%)	18 (13.0%)	12 (8.6%)	6 (4.3%)
Total	74 (53.24%)	58 (41.73%)	32 (23.02%)	14 (10.07%)

Follow up LUS characteristic are summarized in Table 4 and 5. On day 1, LUS showed consolidation in 130 (93.52%) with maximum thickness of <15 mm in 57 (43.84%), between 15-29 mm in 66 (50.76%) while ≥30 mm in 7 (5.38%). During follow up between day 3-6, 7-10, and 11-14 of illness LUS shows consolidation in 90 (64.75%), 38 (27.34%) and 12 (8.63%) patients respectively. The size of consolidation steadily declined on subsequent follow-up LUS consistent with clinical improvement reflected by increase in number of patients with consolidation thickness <15 mm on day 3-6 as other patient who were initially have more severe findings falls

in this category after treatment. LUS in seven patients initially showed increase in size of consolidation consistent with clinical deterioration then gradual decrease in size of consolidation due to change in treatment. A total of 22 patients had pleural effusion on day 1 with maximum thickness of <15 mm in 13 (59.1%), 15-29 mm in 8 (36.4%) and ≥30 mm in 1 (4.5%) with decrease in size consistently during follow up. Similar improvement was reported for other LUS findings.

DISCUSSION

Early diagnosis and management of pneumonia are critical to short- and long-term health outcomes. Clinical examination is highly sensitive but lacks specificity and results in over diagnosis contributing to the overuse of antibiotics.[14] CXR is considered the test of choice for further evaluation. The main limitations of radiography is the risk of damage from ionizing radiation with a greater risk than adults because children have more rapidly dividing cells and increased life expectancy.[5,6] Other concerns with radiography are great variability in the interpretation lack of reproducibility and delay in availability of the film.[7,8] Also in complicated pneumonia CXR is less reliable and chest computed tomography (CT) scan is known to be the gold standard.[15] However, its use has been discouraged due to high radiation, high cost and the need for sedation in young children.

Medical radiation exposure is increasing rapidly. The radiological risk is cumulative in nature. The chest is the most frequently evaluated region of the body in children. There is research that suggests hepatoblastoma risk may increase due to repeated chest X-rays in intensive care unit patients.[5,6] Unfortunately, paediatricians are often unaware of these risks. It is often possible to significantly decrease medical radiation exposure without compromising patient care.

Weinberg et al first described the use of LUS in evaluating CAP.[16] Subsequent studies have demonstrated that LUS is able to diagnose pneumonia in adults with high accuracy.[10,11] Later on studies had demonstrated high efficacy of LUS in diagnosing pneumonia in children.[17,18] Recently LUS has been indicated as a clinically useful diagnostic tool in pediatric patients with suspected pneumonia.[19] The LUS features of pneumonia mainly included sub pleural lung consolidation, pleural line abnormalities, confluent B-lines and synpneumonic pleural effusions.[17,18]

In our study, the various LUS findings are similar to the data in the literature. The detection of pneumonia using LUS was better (97.84%) than with chest radiography (90.64%). LUS was able to detect consolidation in 130 (93.53%) patients as compared to 107 (76.97%) patients by CXR of total 139 patients. LUS was normal in 3 patients with clinical course consistent with pneumonia while CXR failed to detect abnormality in 13 patients. MC Ho et al also found similar results with chest radiography able to detect 151 (92.6%), whereas LUS detected 159 (97.5%) out of 163 patients with pneumonia.[20] Pereda in meta-analysis found that LUS had a sensitivity of 96% and specificity of 93% (21). Other published data also showed that LUS is more sensitive than CXR in the diagnosis of pneumonia in children.[22-24]

This study also addresses the follow-up LUS characteristics, showing the dynamic changes of pleuro-pulmonary abnormalities over time determining the effectiveness of LUS in the on-going management of pneumonia over the course of an illness. The size of consolidation and other abnormalities showed persistent improvement on subsequent follow-up LUS examination consistent with clinical improvement. Similar results were found by Caiulo et al and Stefania et al.[22,23] In this study, LUS in seven patient initially showed increase in size of consolidation consistent with clinical deterioration then gradual decrease in size of consolidation due to change in treatment.

Thus, our study demonstrates that LUS is safe and accurate for the diagnosis suspected cases of CAP and it is more sensitive than CXR and allows a radiation free follow up of patients.

Some technical advantages such as shorter thoracic width, thinner chest wall, and small lung mass theoretically enable LUS examination in children easier than in adults.[19] Pleural effusion, lung consolidation, interstitial syndrome, and pneumothorax are accessible to LUS. LUS is useful in the evaluation of lung consolidation as it can also differentiate consolidations due to pulmonary embolism, pneumonia, or atelectasis.[25] LUS also has the potential for diagnosing the nature of the effusion and differentiating bacterial and viral pneumonia.[26,27] LUS also had a consistently high diagnostic accuracy of pneumonia when compared with chest CT scan as the gold standard.[28]

Further research regarding the role of colour Doppler sonography, spectral curve analysis and contrast-enhanced ultrasound is necessary, especially with respect to differential diagnosis of lung consolidations and early detection of complications. Also while LUS is best performed by trained sonographers, medical students, doctors and other health care workers at the bedside are now being trained in it use, albeit cautiously.[9,18] Recent advances in technology have made portable or handheld ultrasonography machines more available. This raises the potential for diagnostic capabilities in rural and remote settings where other imaging modalities are not available.

CONCLUSION

Lung ultrasound shows high accuracy in the detection of pneumonia and possibility of a follow-up without exposure to ionizing radiation. It does not require sedation and can be repeated at any time.

ACKNOWLEDGEMENTS

The authors are thankful to Dr. Anu Bhandari, professor, department of radiology, SMS medical college for her assistance.

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

REFERENCES

1. Rudan I, Tomaskovic L, Boschi PC, Campbell H. WHO Child Health Epidemiology Reference Group. Global estimate of the incidence of clinical pneumonia among children under five years of age. Bull World Health Organ. 2004;82(12):895-903.
2. World Health Organization Pneumonia Fact sheet (November 2013): www.who.int/mediacentre/factsheets/fs331.
3. Harris M, Clark J, Coote N. British Thoracic Society guidelines for the management of community acquired pneumonia in children. Thorax. 2011;66(Suppl 2):ii1-23.
4. Shah S, Bachur R, Kim D, Neuman MI. Lack of predictive value of tachypnea in the diagnosis of pneumonia in children. Pediatric Infectious Disease Journal. 2010;29(5):406-9.
5. Park MY, Jung SE. Patient Dose Management: Focus on Practical Actions. Journal of Korean Medical Science. 2016;31(Suppl 1):S45-54.
6. Gargani L, Picano E.The risk of cumulative radiation exposure in chest imaging and the advantage of bedside ultrasound. Critical Ultrasound Journal. 2015;7:4.
7. Williams GJ, Macaskill P, Kerr M. Variability and accuracy in interpretation of consolidation on chest radiography for diagnosing pneumonia in children under 5 years of age. Pediatr Pulmonol. 2013;48(12):1195-200.
8. Wingerter SL, Bachur RG, Monuteaux MC, Neuman MI. Application of the world health organization criteria to predict radiographic pneumonia in a US-based pediatric emergency department. Pediatr Infect Dis J. 2012;31(6):561-4.
9. Solomon SD, Saldana F. Point-of-care ultrasound in medical education-stop listening and look. N Engl J Med. 2014;370(12):1083-5.
10. Chavez MA, Shams N, Ellington LE. Lung ultrasound for the diagnosis of pneumonia in adults: a systematic review and meta-analysis. Respir Res. 2014;15:50.
11. Ye X, Xiao H, Chen B, Zhang S. Accuracy of Lung Ultrasonography versus Chest Radiography for the Diagnosis of Adult Community- Acquired Pneumonia: Review of the Literature and Meta-Analysis. PLoS One. 2015;10(6):e0130066.
12. Chen SW, Zhang MY, Liu J. Application of Lung Ultrasonography in the Diagnosis of Childhood Lung Diseases. Chinese Medical Journal. 2015;128(19):2672-8.
13. Cattarossi L. Lung ultrasound: its role in neonatology and pediatrics. Early Hum Dev. 2013;89(Suppl 1):S17-9.
14. Zimmerman DR, Kovalski N, Fields S, Lumelsky D, Miron D. Diagnosis of childhood pneumonia: clinical assessment without radiological confirmation may lead to overtreatment. Pediatr Emerg Care. 2012;28:646-9.
15. Donnelly LF, Klosterman LA. The yield of CT of children who have complicated pneumonia and non-contributory chest radiography. AJR Am J Roentgenol. 1998;170(6):1627-31.
16. Weinberg B, Diakoumakis EE, Kass EG, Seife B, Zvi ZB. The air bronchogram: sonographic demonstration. American Journal of Roentgenology. 1986;147:593-5.
17. Copetti R, Cattarossi L. Ultrasound diagnosis of pneumonia in children. Radiol Med (Torino). 2008;113(2):190-8.
18. Iuri D, De Candia A, Bazzocchi M. Evaluation of the lung in children with suspected pneumonia: usefulness of ultrasonography. Radiol Med (Torino). 2009;114(2):321-30.
19. 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(2):119-25.
20. Ho MC, Ker CR, Hsu JH, Wu JR, Dai ZK, Chen IC. Usefulness of lung ultrasound in the diagnosis of community-acquired pneumonia in children. Pediatrics and Neonatology. 2015;56(1):40-5.
21. Pereda MA, Chavez MA, Hooper-Miele CC. Lung ultrasound for the diagnosis of pneumonia in children: a meta-analysis. Pediatrics. 2015;135(4):714-22.
22. Caiulo VA, Gargani L, Caiulo S, et al. Lung ultrasound characteristics of community-acquired pneumonia in hospitalized children. Pediatr Pulmonol. 2013;48(3):280-7.
23. Ianniello S, Piccolo CL, Buquicchio GL, Trinci M, and Miele V. First-line diagnosis of pediatric pneumonia in emergency: lung ultrasound (LUS) in addition to chest-X-ray and its role in follow-up. The British Journal of Radiology. 2016;89:1061.
24. Reali F, Sferrazza Papa GF, Carlucci P, et al. Can lung ultrasound replace chest radiography for the diagnosis of pneumonia in hospitalized children? Respiration. 2014;88(2):112-5.
25. Reissig A, Copetti. Lung ultrasound in community-acquired pneumonia and in interstitial lung diseases. Respiration. 2014;87(3):179-89.
26. King S, Thomson A. Radiological perspectives in empyema. Br Med Bull. 2002;61:203-14.
27. Tsung JW, Kessler DO, Shah VP. Prospective application of clinician-performed lung ultrasonography during the 2009 H1N1 influenza A pandemic: distinguishing viral from bacterial pneumonia. Crit Ultrasound J. 2012;4(1):16.

28. Kurian J, Levin TL, Han BK, Taragin BH, Weinstein S. Comparison of ultrasound and CT in the evaluation of pneumonia complicated by parapneumonic effusion in children. AJR Am J Roentgenol. 2009;193(6):1648-54.

Cite this article as: 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.