Original Article

Diagnostic Accuracy of Lung Ultrasound in Diagnosis of Pediatric Pneumonia

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ABSTRACT

Objective: This study was designed to assess the accuracy of lung ultrasound (LUS) in the diagnosis of pneumonia in children in comparison to chest X-ray.

Study Design: Randomized controlled trial study

Place and Duration of Study: This study was conducted at the Pediatrics Medicine Ward, King Edward Medical University/Mayo Hospital, Lahore from August 2016 to February 2017.

Materials and Methods: A total of 282 patients fulfilling the inclusion criteria were enrolled and underwent clinical examination, chest radiograph (AP view, interpreted by a Paediatric radiologist blinded to the sonography results), lung ultrasound (by a pre-specified hospital radiologist) and blood sample analysis in the first 24 hours after admission. The accuracy of US in diagnosing pneumonia (i.e. its sensitivity, specificity, and positive and negative predictive values) was compared with that of chest radiographs

Results: A total of 48 patients had radiographically confirmed community acquired pneumonia (CAP). The sensitivity, specificity, and positive and negative predictive values of LUS in comparison with chest radiograph (CR) were respectively 95.5%, 90.0%, 99.6%, 42.8%.

Conclusion: LUS identified a significantly higher number of cases indicating that it's also a sensitive tool in comparison of chest radiography in the diagnosis of pneumonia in children although its effectiveness in determining the type of lung involvement requires further evaluation.

Key Words: Radiograph, Pneumonia, Ultrasonography, Lung, Worldwide, Predictive Values.

INTRODUCTION

Pneumonia is a leading cause of death in children, having considerable impact on children mortality and morbidity globally[1]. Community acquire pneumonia (CAP) is responsible for 150-160 million new cases each year and 1.1million die with this condition[1]. Majority of these cases occur in developing countries like Pakistan. Studies show that 18% of total under five deaths worldwide are caused by Pneumonia[2].

As pneumonia is one of the major causes of lower respiratory infections in children, its diagnosis remains a challenge in resource limited settings[3]. Signs and symptoms of pneumonia vary depending on a child's age and the etiology of infection.[4–7]

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Moreover, presenting signs and symptoms have poor diagnostic specificity, which may further complicate the diagnosis. The American Academy of Pediatrics recommends the use of chest radiographs (CRs) cautiously for different reasons. First, ionizing radiation in young children may have potential late adverse effects.[8–10] Second, the lack of findings on CR does not rule out the diagnosis if there is a strong suspicion of pneumonia[3]. Finally, although a chest computed tomography (CT) scan has a higher diagnostic yield; it's never been used because of radiation hazard and also requires cooperative patient ,sedation and in our setup availability and cost issue[11] Other disadvantages of both techniques as a tool for the diagnosis of pneumonia, especially in resource-poor settings, include availability and lack of portability. Even though CR is available, there can be a considerable time delay for between ordering and reporting of chestx-ray.

Recently there is an increase in trend of using Lung ultrasound for the diagnosis of pneumonia because of its feasibility and accuracy in diagnosis and at the same time minimum radiation exposure. Advances in ultrasound technology have made lung ultrasound (LUS) an attractive option for the diagnosis of pneumonia. Moreover, it is safe, portable, inexpensive, and relatively easy to teach. With the current lack of worldwide diagnostic criteria, the diagnosis is usually made on clinical manifestations and findings from chest

radiographs. Chest ultrasonography has recently been applied to the detection of pulmonary diseases. However, few evidenced based data have been published showing its effectiveness in detecting pneumonia in children. This study was designed to assess diagnostic accuracy of lung ultrasound (LUS) in diagnosis of pneumonia in children using chest X-ray as gold standard.

MATERIALS AND METHODS

This randomized controlled trial study was conducted at Pediatrics Medicine Ward, King Edward Medical University/Mayo Hospital, Lahore, from August 3, 2016 to February 3, 2017. 282 patients fulfilling the inclusion criteria were recruited. All patients underwent clinical examination, chest radiograph (AP view), lung ultrasound and blood sample analysis in the first 24 hours after admission. Chest radiograph was performed with commercially available X-ray machines. Chest radiographs were interpreted by a pediatric radiologist blinded to the sonography results. Lung ultrasound was carried out by pre-specified hospital radiologist.

Suspected Pneumonia was defined as presence of fever (>100 0F), cough, difficult breathing, fast breathing (respiratory rate > 30/mint), lower chest in-drawings or chest pain in a previously healthy child. Pneumonia on CXR was defined by presence of area of opacity on CXR. Pneumonia on LUS was defined by presence of sub pleural echo-poor or tissue-like structures on lung ultrasound

DATA ANALYSIS PROCEDURE:

Results were analyzed by SPSS version 23.0. Quantitative variables like age, weight and duration of illness were presented as Mean±S.D. Qualitative variables like gender, previous antibiotic treatment and pneumonia on lung ultrasound and chest X- Ray were presented as frequency and percentages. A 2x2 contingency was generated to calculate sensitivity, specificity, PPV, NPV and accuracy of lung ultrasound in diagnosis of pneumonia by taking chest X-ray as gold standard. Data were stratified for age, sex, weight, duration of illness and previous antibiotic treatment (during last 1 week) to address the modifier effect. Post stratification, 2x2 tables were computed to calculate sensitivity, specificity, PPV, NPV and accuracy of lung ultrasound taking chest X-ray as gold standard.

RESULTS

In this randomized controlled trial study 282 patients with clinical features of pneumonia were enrolled. Analysis of data on socio demographic variables of patients revealed that out of 282 participants, 60.3% were male and rest of the participant were female. Age range in this study was from 6 months to 12 years with mean age of 6.5±2.4 years. Majority of the patients 105(37.2%) were >6 years of age group. While 79(28.0%) and 98(34.8%) patients were between 6

months-2 years and 2-6 years of age groups respectively. Majority of the patients 105(37.2%) were >25 kg of weight group. While 79(28.0%) and 98(34.8%) patients were between 7-15 kg and 16-25 kg of weight groups respectively.

Majority of the patients 100(35.5%) were >10 days of duration of illness group. While 100(35.5%) and 82(29.1%) patients were between 3-6 days and 7-10 days of duration of illness groups respectively. Majority of the patients 225(79.8%) did not have history of antibiotic treatment. 273(96.8%) patients were diagnosed on Lung Ultrasound and 260(92.2%) on Chest X-ray. Sensitivity (Se), specificity (Sp), positive predictive value (PPV), negative predictive value (NPV), accuracy and prevalence of lung ultrasonography (US) vs. chest radiography (CR) in diagnosing pneumonia was 95.5%, 90.0%, 99.6%, 42.8%, 95.3% and 96.4% respectively.

Table No.1: Demographic Profile of the Patients Frequency Distribution of Gender, Age and Weight

		Frequency
Gender	Male, n (%)	170 (60.3)
	Female	112 (39.7)
Age	6 months - 2 years	79 (28.0)
	2-6 years	98 (34.8)
	>6 years	105 (37.2)
Weight	7-15 kg	79 (28.0)
	16-25 kg	98 (34.8)
	>25 kg	105 (37.2)

35.5% of patient's duration of illness was 3 to 6 days whereas more than 10 days' duration of illness was observed in 35.5% of patients as well.

Table No.2: Frequency of Distribution of Pneumonia on Lung Ultrasound and Chest X-Ray

		Frequency
Pneumonia on Lung Ultrasound	Yes	273 (96.8)
	No	9 (3.2)
Pneumonia on Chest X-ray	Yes	260 (92.2)
	No	22 (7.8)

96.8% of patients were having pneumonia on Lung Ultrasound while 92.2% of patients were diagnosed on chest X-ray.

Table No.3: Pneumonia on Chest and Lung

Pneumonia on Chest X-ray	Pneumonia on Lung Ultrasound		Total	Sn 95.5% Sp 90.0%
	Yes	No		
Yes	260	1	261	PPV 99.6% NPV 42.8% Accuracy 95.3% Prevalence 96.3%
No	12	9	21	

Table No.4: Stratification with Respect to Age Groups of Lung Ultrasound Vs. Chest X-Ray in Diagnosing Pneumonia

Age Groups	Pneumonia on Chest X-ray	Pneumonia on Lung Ultrasound		Total	
		Yes	No		
6 months - 2 years	Yes	75	1	76	Sn=98.6%, Sp=66.6%, NPV=66.6%, PPV=98.6%, DA=97.4%
	No	1	2	3	
2-6 years	Yes	90	0	90	Sn=95.7%, Sp=100.0%, NPV=50.0%, PPV=100.0%, DA=95.9%
	No	4	4	8	
>6 years	Yes	95	0	95	Sn=93.1%, Sp=100.0%, NPV=30%, PPV=100.0%, DA=93.3%
	No	7	3	10	

DISCUSSION

The diagnosis of pneumonia, once thought to be accomplished by physical examination, history-taking, and specific findings on auscultation, has recently relied more on imaging. Chest radiography has been widely used for the diagnosis of pneumonia because of its convenience and ease of access. However, some studies have shown significant variability in the interpretation of chest radiographs[2] as well as the risk of the development of cancer after radiation exposure in early life[3]. Although the lung is not an ideal target for ultrasonography, once fluid or solid material has accumulated in the lung it can more easily be visualized on an ultrasound scan[4]. Some studies have focused on the use of LUS in the diagnosis and follow up of community-acquired pneumonia in adults. Reissig et al reported the first prospective study of the diagnosis of community-acquired pneumonia using LUS with an excellent sensitivity of 94% and specificity of 98%[5,6]. In our study, the detection of pneumonia using LUS was better (96.8%) than with chest radiography (92.2%). In a prospective study published by Urbanowska et al LUS had a sensitivity of 93.4% and PPV of 95.3% in identification of lung involvement[6]. A meta-analysis including 8 prospective studies performed in neonates and pediatric population and enrolling 765 children showed that LUS had an overall sensitivity of 95% (95%CI: 94-97), positive likelihood ratio of 15.3 and negative likelihood ratio of 0.06 for the presence of pneumonia as diagnosed based on clinical criteria and radiographic findings. Esposito et al. in Milan, Italy in a cohort of 103 patients showed sensitivity and specificity of 97.9% (48/49) and 94.5% (55/58) for

LUS compared with 92.1% (47/52) and 94.5% (52/55) for chest radiograph respectively, CXR was gold standard in this study.[7] Chieh HO et al. in Taiwan showed that LUS was sensitive in detecting consolidation was found to be useful for follow up of consolidation avoiding the unnecessary radiation exposure associated with chest radiograph.[7] Various other studies found similar results in favor of LUS[8-10].There are no local studies conducted in this regard so far. In a study done by Shah et al, Sensitivity and specificity of LUS showed as 86% and 89% respectively[10].

LUS is also a useful tool in the follow up of patients with pneumonia and it could be used to estimate the pneumonia size semi quantitatively[5,11,12]. However, the true pneumonia size estimated by LUS was always underestimated as a result of distal multiple amplification artifacts or air inclusions. Not only can the size of pneumonia be measured by LUS, but a decreased air bronchogram and the volume of pleural effusion compared with baseline can also indicate remission of the disease[11]. For these reasons, we can monitor the progress of the disease in patients and guide our treatment by repeating LUS within a few days[11].The major strength of this study is that an unexplored variable was measured and prospective nature of the study justifies the linear temporal relationship necessary for causation. A standardized questionnaire and ultrasound system were used.

CONCLUSION

This study concludes and provides evidences that for the diagnosis of pediatric pneumonia, lung ultrasound appears more effective than chest x-ray. It is also useful in following up the progress of pneumonia. LUS can be used as a complementary tool to chest radiography in the diagnosis of pneumonia in children.

Author's Contribution:
Concept & Design of Study: Tanveer Ahmad
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Conflict of Interest: The study has no conflict of interest to declare by any author.

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