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EVALUATION OF PEDIATRIC PNEUMONIA THROUGH LUNG ULTRASOUND AND CHEST RADIOGRAPHY

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Evaluation of Pediatric Pneumonia through Lung Ultrasound and Chest Radiography

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Abstract

Background and Objectives

Pneumonia among children is one of the most common causes of hospitalization requiring urgent treatment to reduce the risk of mortality. Early management and successful treatment highly depend upon the timely and accurate diagnosis of this disease. This study was aimed to check the diagnostic efficiency of chest radiograph and ultrasound for the evaluation of pediatric pneumonia

Methodology

This study was conducted on 83 pneumonia patients based on 5.7%[21] prevalence falling under less than 8year-old age group. Chest x ray and lung ultrasound were carried out and images were evaluated for any characteristic pneumonic finding such as lung consolidation, pleural effusion and B lines in case of lung ultrasound and final diagnosis were documented. Results obtained were coded categorically and analyzed using SPSS 26. False positive and negative and true positive and negative findings were statistically analyzed for sensitivity and specificity.

Results

Chest x-ray was able to identify 58 out of 83 cases while lung ultrasound accurately captured pneumonic findings in 64 patients. False positive results were observed in 4 patients in case of Chest x-ray and 3 patients in case of lung ultrasound. Both Chest x-ray and Lung ultrasound were able to screened out 11 and 12 negative cases respectively. The sensitivity of chest x-ray and lung ultrasound was 85.29% and 94% while specificity was 73% and 80% respectively.

Conclusion

These findings suggested both chest x-ray and lung ultra sound as useful tool for the evaluation of pediatric pneumonia with lung-ultrasound being more efficient due to relatively high sensitivity and specificity.

INTRODUCTION

Pediatric Pneumonia is a global health concern characterized by the acute inflammation of one or both lungs mainly at the alveolar level [1]. It is among one of the most common infections of the

lungs with children less than 5 year of age group being predominantly affected. According to an estimation, almost 120 million to 150 million of children suffer from pneumonia every year among which majority of cases being reported among infants and toddlers. Also, pneumonia associated mortality rate is 15% higher than any other infectious disease with more than eight lakh deaths out of 5.3 million deaths observed annually [2].

In pneumonia, the effected air sac fills with pus and fluid resulting in cough with yellow to green to sometimes bloody mucus in sputum, fever and chest pain along with shortness of breath and low oxygen saturation. If left untreated, this breathing difficulty can result in medical emergency requiring artificial breathing support such as ventilators and often death [3]. Although severity of the disease and symptoms also depends upon the type of causative agent from bacteria and fungi to deadly viruses, children specially of younger age group such as neonates and infants having low immunity are more prone to hospitalization requiring intensive treatment and comprehensive management [4].

Among various causative agents responsible for pneumonia, Streptococcus pneumonia is most common followed by Hemophilus influenzae which effect all age groups of children and are lethal enough requiring hospitalization and antibiotic based interventional strategies for cure [5]. Among viruses, Respiratory Syncytial Virus (RSV) and parainfluenza virus and influenzae virus are most notorious to effect neonates and people underlying 18 years of age leading towards mortality in pediatric population specially targeting neonates, infants and children in their early life [6].

Fungi such as Aspergillus spp., and Pneumocystis jerovecii although less commonly observed, but are significantly potent to cause pneumonia in children because of their low immunity in comparison to adults. These pathogens gain entry through either inhalation or direct exposure with the infected person or environment such as air containing spores [7].

Additionally, many environmental conditions like monsoon and cold weather, and unclean surroundings often favor the growth of these pathogens further exacerbating the condition [8]. Although, pneumonia is leading cause of morbidity and mortality among children, however, majority of cases are being reported from lower- and middle-income countries as systematic analysis revealed that 138 million of children below five-year-old were affected with pneumonia by the end of 2019 worldwide among which 54% were reported from South East Asia region containing lower middle-income countries such as India, Bangladesh and Pakistan [9]. The highest incidence in these regions can be because of many factors which include lack of knowledge, poor hygiene and unequal distribution of medical resources among rich and poor and less access to basic healthcare facilities such as in remote rural area that's why despite of decline in the incidence of pneumonia cases worldwide, an increase in the rate of pneumonia associated hospitalization have been observed in low- and middle-income countries like India and Pakistan residing in South East Asia region of continent [10].

This high incidence rate of pneumonia cases can be controlled through the early diagnosis and management of this disease. Several tests are available for the diagnosis of pneumonia which include clinical assessment on the basis of symptoms, laboratory-based tests and imaging modalities. Symptoms are usually non-specific and can be seen in majority of lower respiratory infection. Laboratory tests such as Complete blood count, C-reactive protein, procalcitonin test and PCR provide supportive evidence but do not provide the clear diagnosis. Similarly, blood or sputum cultures unveil the causative agents but fails to depict the true picture of the extent of lung damage caused by these pathogens. Similarly, biopsy is invasive and not recommended unless atypical cells seen on the sputum microscopy [11,12].

Among imaging modalities, chest X-ray (CXR) is considered as gold standard test as it provides detail about the degree of damage caused by pneumonia through clear visualization of any fluid accumulation, interstitial infiltration and consolidation which guides the physician to plan treatment accordingly. This test is non-invasive, relatively cheap and available in majority of medical setups which makes it approachable to every patient [13]. Although, the radiation exposure in this test is a major health hazard and develops concern especially for its use in pediatric population. Also, patients' consent and

accurate position during test procedure is necessary to generate a clear image for correct diagnosis. Furthermore, it requires an expert radiologist to visualize the image and identify the underlying pathology as any misinterpretation by the radiologist can seriously affect the patient's treatment. Despite of these limitations, CXR is considered as one of the most important tests for the diagnosis of pneumonia because of its diagnostic accuracy and sensitivity in comparison to other traditional tests [14].

Lung Ultrasound (LUS) is another alternative which is considered as quite safe when compared with CXR, as apart from being non-invasive, it does not use radiations instead sound waves of high frequency are utilized to generate clear image of lung and its related parenchyma. This makes it equally safe for use for both pediatric and adult population. It provides clear images of any consolidation, pleural fluid infiltration which are characteristic finding of pneumonia. Also, its bedside availability makes it more suitable for utilization in emergency situations. However, operator dependability and limited penetration may hinder the deep lesions which may require retesting in some cases [15].

As explained earlier, both of these tests are considered as vital tools in the diagnosis and management of pneumonia. However, their accuracy and sensitivity may vary and many comparative studies are being carried out in this regard to check the efficiency of these tests over each other as a study carried on 949 pediatric patients detected with pneumonia showed high sensitivity (0.96) and specificity (0.566) of LUS in comparison to CXR whose sensitivity was 0.793 while specificity was 0.559. These findings suggest higher efficiency of LUS over chest radiograph for the detection of grade three severe pneumonia associated pathological changes reporting it a safe alternative for pediatric population and in emergency cases [16].

Pakistan, underlying in lower- and middle-income countries, is also facing a huge burden of pediatric pneumonia cases which contributes to significant number of deaths every year. According to an estimate, 13% of Pakistan's children are affected from pneumonia with 10 million cases reported every year and incidence of these cases is relatively higher in rural and remote areas which lack in both economical and medical resources [17].

Lahore being largest city of Punjab province and second largest city of Pakistan is living place for more than 13 million people with one half of them being children. This dense population encounter many infectious diseases on daily basis among one of which is pneumonia. According to a study carried out in Lahore's largest Children hospital, 63% of the children admitted to hospital were diagnosed with pneumonia. This finding from a single setting provides the evidence of high prevalence of pediatric pneumonia cases in this city. To cope up this huge burden of pneumonia cases, early and accurate diagnosis is mandatory to estimate the true extent of damage so treatment strategies could be planned accordingly. Although, Chest X-ray and LUS have been used from a long time for the diagnosis of pediatric pneumonia. However, limited literature is available on their comparative efficacy [18,19]. This study was carried out to compare the sensitivity and specificity of both CXR and LUS as diagnostic tool for the detection of pediatric pneumonia. The findings obtained will help clinicians in selection of a suitable diagnostic test for timely diagnosis of pneumonia among children. This early and accurate diagnosis will also limit the over use of antibiotics by providing the true picture of patient health status and will facilitate the healthcare unit in reducing the cases of pneumonia in this region through providing right treatment at right time.[20]

Rational of this Study

This study aims to compare the diagnostic accuracy of Lung Ultrasound and Chest X-ray in evaluating pneumonia in pediatric population, with a focus in determining the sensitivity, specificity, and overall effectiveness of each modality in detecting pneumonia, along with common findings and symptoms thus ensuring timely and accurate diagnosis for improvement in clinical decision-making and patient outcomes.

AIMS AND OBJECTIVES

The aims and objectives of this study were following:

1. To evaluate the role of X-ray and Lung Ultrasound as diagnostic tool for the evaluation of pneumonia in Children.
2. To compare which of these both tools is more efficient for the diagnosis of pediatric pneumonia

MATERIALS AND METHODS

This descriptive cross-sectional analytical study was conducted at Fatima Memorial Hospital, Lahore, over 4 months. A sample size of 83 was calculated using the formula $n = (z^2p\ (1-p))/d^2$ with a 95% confidence interval, 5% error, and 5.7% prevalence [21]. A non-probability sampling technique was used. The study included children under 8 years of both genders, suspected of pneumonia and who underwent both lung ultrasound (LUS) and chest X-ray (CXR). Exclusion criteria included children above 8 years, those not undergoing both tests, and those with chronic or other lung diseases. Data were collected using a data collection sheet.

Chest X-rays were performed using the Siemens Multix Fusion floor-mounted X-ray system, while lung ultrasounds were conducted on the Siemens Sonovista X300 using a curvilinear probe (3–5 MHz). After clinical evaluation, each patient underwent both chest X-ray and lung ultrasound within 24 hours of admission or outpatient visit. Basic demographics and symptoms were recorded. Chest

X-rays were obtained using appropriate AP or lateral views based on the child's age and condition, with exposure settings adjusted to minimize radiation; images were reviewed for infiltration, consolidation, and abnormalities. Lung ultrasound was performed by trained sonographers using the Siemens Sonovista X300, scanning anterior and posterior bilateral lung zones with a child preset. Sonographic findings, including B-lines and consolidation, were documented.

Data was entered, coded, and analyzed using SPSS 26. Descriptive statistics such as mean, frequency and percentages were calculated for demographic data. Sensitivity, specificity for both CXR and LUS were calculated with 95% confidence interval. Comparative analysis was carried to check the efficacy of both CXR and LUS for pneumonia detection.

RESULTS

A total of eighty-three pediatric patients less than 8years in age, suspected of having pneumonia and advised for both CXR and LUS were selected for this study. It included 46 male and 37 female children as shown in Table 4.1 and Fig 4.1.

Table 4.1: Gender wise Distribution of Pediatric Patient Suspected of Pneumonia

Gender Wise distribution			Total
Gender	Male	Count	46
	Female	Count	37
Total		Count	83

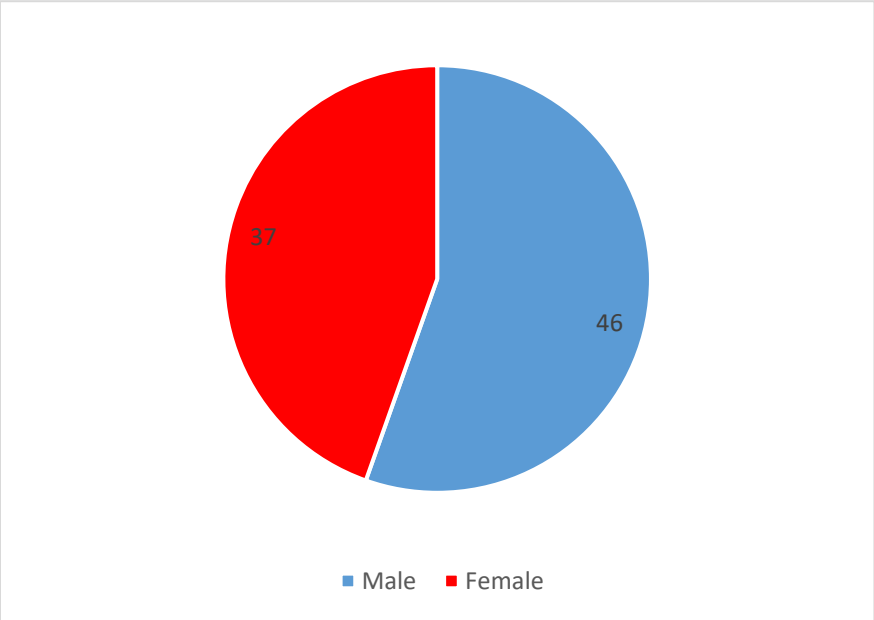

Fig 4.1 Gender wise Distribution of Pediatric Patients Suspected of Pneumonia

These sick pediatric patients were underlying among various age group. It was observed that majority of children (43) affected were belonged to infant to toddler category with age underlying between 1 month to less than 2 years followed by pre-schooled children underlying between 2 to less than 5year age group. While neonates (8) and school age children (4) underlying between 5 to 8 years of age were less commonly observed to be affected as shown in Table 4.2 and Fig 4.2

Table 4.2: Age GroupWise Distribution of Pediatric Patients with Suspected Pneumonia

Age Group wise Distribution		Total
Age group	<1month (Neonates)	8
	1month to<2year (Infants and toddlers)	43
	2 to<5year (Preschool Children)	28
	5-8year (School aged Children)	4
Total		83

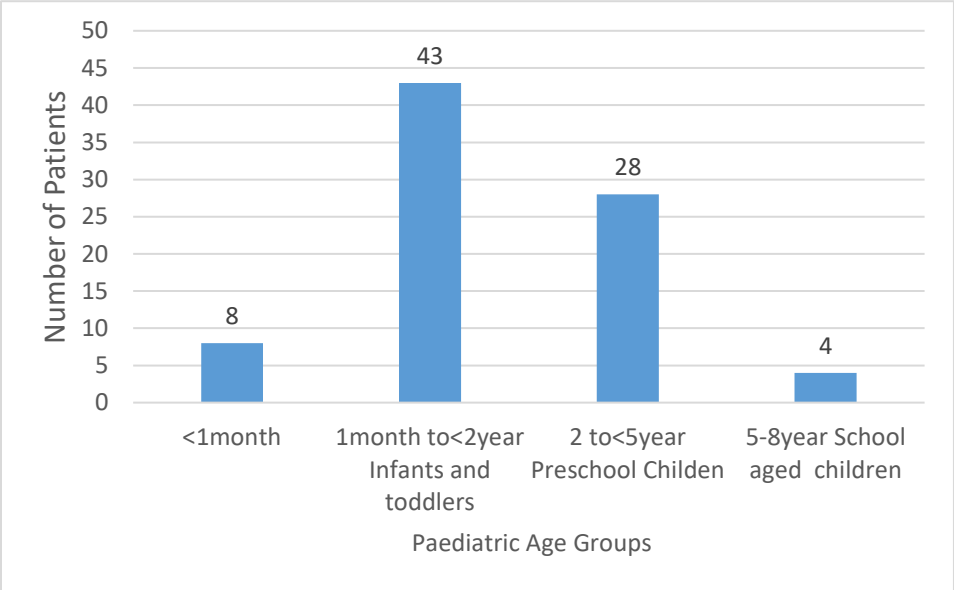

Fig 4.2 Age group wise distribution of Patients Suspected of Pneumonia

Comparative Analysis of CXR and LUS

Chest- X ray and Lung ultrasound was carried out to evaluate diagnostic accuracy of these tools for the detection of the pneumonia in these patients.

Chest X-ray:

In case of chest x-ray, a lowest beam of radiation suitable for children was used to ensure the health safety of the patients. Images were taken from anterior, posterior, and lateral view to clearly speculate the pneumonia associated changes for the confirmation of disease. It was found that chest x-ray was able to detect 62 pneumonia cases among which 58 cases were true positive with lobar involvement and pleural effusion observed on images while it was able to screen out 21 negative cases among which 11 were true negative as shown in Table 4.3.

Table 4.3 Chest X-ray based evaluation of Pneumonia Cases

		Pneumonia status				Total
		Present		Absent		
CXR	Positive	True Positive	58	False Positive	4	62
	Negative	False Negative	10	True Negative	11	21
Total			68		15	83

Sensitivity of Chest X-ray for the diagnosis of pediatric pneumonia was 85.29% as calculated

$$\text{SENSTIVITY} = \frac{\text{TRUE POSITIVES}}{\text{TRUE POSITIVES} + \text{FALSE NEGATIVES}}$$

$$\text{SENSTIVITY} = \frac{58}{58 + 10} = 0.852\ x\ 100 = 85.29\%$$

Similarly, specificity of Chest X-ray for the evaluation of pneumonia cases was 73% calculated as

$$\text{SPECIFICITY} = \frac{\text{TRUE NEGATIVES}}{\text{TRUE NEGATIVES} + \text{FALSE POSITIVES}}$$

$$\text{SPECIFICITY} = \frac{11}{11 + 4} = 0.73\ x\ 100 = 73\%$$

Lung Ultrasound

Lung ultrasound of these 83 pediatric patients was carried out using portable lung ultrasound machine in order to check the diagnostic accuracy of this tool to evaluate pneumonia cases. It was found that LUS diagnosed 64 pneumonia cases with highest accuracy as Lober consolidation, B lines and pleural effusion was clear findings and gave false positive results in case of 3 patients with b lines observed in them along with lobar consolidation. While in case of pneumonia negative cases it was able to screen 12 negative cases with high accuracy and gave false negative indication in 4 cases as shown in Table 4.4

Table 4.4 Lung Ultra Sound based evaluation of Pneumonia Cases

			Pneumonia status			Total
			Present	Absent		
ULTRASOUND	Positive	True Positive	64	False Positive	3	67
	Negative	False Negative	4	True Negative	12	16
Total Patients		Count	68		15	83

Sensitivity of Lung Ultrasound for the diagnosis of pediatric pneumonia was 94.1% as calculated

$$\text{SENSTIVITY} = \frac{\text{TRUE POSITIVES}}{\text{TRUE POSITIVES} + \text{FALSE NEGATIVES}}$$

$$\text{SENSTIVITY} = \frac{64}{64+4} = 0.941\ x\ 100 = 94.1\%$$

Similarly, specificity of Lung Ultrasound for the evaluation of pneumonia cases was 80% calculated as

$$\text{SPECIFICITY} = \frac{\text{TRUE NEGATIVES}}{\text{TRUE NEGATIVES} + \text{FALSE POSITIVES}}$$

$$\text{SPECIFICITY} = \frac{12}{12+3} = 0.80\ x\ 100 = 80\%$$

DISCUSSION

Pneumonia is among one of the most fatal diseases among children requiring medical attention and is responsible for many mortalities every year. In fact, according to WHO it causes two million deaths of children less than five year of age every year. Survival highly depends upon the timely diagnosis to prevent the progression of this disease to a worst level causing serious outcome [22,23]. In this study we tried to evaluate the diagnostic accuracy of two widely used tools Chest x-ray and Lung Ultrasound for the detection of pneumonia in children of Lahore.

This study was carried out on a total of 83 children of variable age presented with the typical symptoms of pneumonia. It was found that children below five years of age were more frequently observed to be effect with pneumonia as compared to school aged children underlying between 5 to 8year age group with male being most commonly affected in comparison to female. Worldwide, the incidence of pneumonia in children below five years of age has been observed to be relatively high as reported it as leading cause of death among children of this age group as these children are more prone to both bacterial and viral infections due to less developed immunity [24, 25].

It was further observed that among them 58 cases were accurately diagnosed with chest x-ray having characteristic findings on images while false positive results were observed in case of 4 patients with lobar consolidation observed in them. Similarly, chest x-ray successfully screened out 11 negative cases with highest accuracy. The sensitivity and specificity of chest x-ray for the evaluation of pneumonia among children was 85.2% and 73% respectively. Ultrasound of same patients' detected pneumonia in 64 cases with pneumonia associated characteristic findings and screened out 12 negative cases. The sensitivity (94%) and specificity (80%) of ultrasound to detect pneumonia in children was observed to be relatively high in comparison to chest x-ray.

These findings were aligned with many studies observed during a meta-analysis review which concluded from these studies that lung ultrasound had sensitivity between 86 to 98% and specificity underling between 85% to 95% for the evaluation of pneumonia which was higher in comparison to chest x-ray sensitivity which ranges from 70-85% and specificity underlying between 80%. to 90% [26].

Another study in this regard carried out in a resource limited small setting also reported a similar observation on 72 patients among which pneumonia was identified on the chest x-ray in only 42 patients while Lung ultra sound based diagnosis revealed 66 patients positive for pneumonia with characteristic findings including lobar consolidation and B lines thus suggesting the lung ultrasound as more efficient diagnostic tool for pneumonia detection in comparison to chest x-ray. Another study [27].

Similar findings were also observed in a study conducted on 84 children having typical symptoms of pneumonia. Chest x-ray of these patients was able to detect the pneumonic lesions in only 47 patients while lung ultrasound identified pneumonia associated changes in 60 patients [54]. While another study carried out on 143 pneumonia suspected children of various age groups also reported higher sensitivity (98%) and specificity (92%) of lung ultrasound for the detection of pneumonia These findings also add significant clinical evidence to our observations suggesting lung ultra sound as more safer, accurate and efficient diagnostic tool in comparison to chest x-ray for the detection of pneumonia in pediatric population [28].

Understanding the health consequences of pneumonia and its associated mortality there is need of gold standard diagnostic tool which can detect the disease in these patients at earliest with highest adequacy and minimum invasion and health hazard. As timely diagnosis is crucial for early management of disease to prevent serious outcomes. Chest-x ray and ultrasound are both offers an idealistic diagnostic approach for timely diagnosis of pneumonia children with efficiency. However, lung ultrasound offers more healthy safety being radiation free with high sensitivity and specificity and easily available at bedside which makes it's a good alternative of chest x-ray.

CONCLUSION

This study describes that although both chest x-ray and lung ultra sound are good diagnostic tools for the evaluation of pneumonia in children. However, the sensitivity and specificity of LUS is relatively high in comparison to chest x-ray. Which makes it a good alternative of chest x ray for the diagnosis of pneumonia in pediatric patients and can be used individually or in combination with it for timely diagnosis of pneumonia with highest accuracy.

LIMITATION AND RECOMMEDATIONS

There are certain limitations and recommendations of this study which are as follow:

1. This study is carried out on small sample size a study carried out on larger sample size can help to identify the sensitivity and specificity of these diagnostic tools over a large population having different course of pneumonic pathological changes.
2. In this study primarily, symptoms were used for the evaluation of pneumonia as a diagnosis at first basis, a more comprehensive alternative along with symptoms such CT scan or microbiological identification can provide a more comprehensive diagnosis of pneumonia.
3. Difference in the image acquisition and its interpretation can impact the sensitivity and specificity of these tools. A structured training and evaluation of the reporting officer before study can provide a true assessment of their knowledge thus minimizing the reporting associated variations in results.

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