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Role of Lung Ultrasound in Detection of Respiratory Diseases in Paediatric Intensive Care Unit

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ABSTRACT

Background: Lung ultrasonography, a radiation-free substitute for chest X-rays, offers real-time imaging capabilities and helps address the diagnostic issues associated with pediatric respiratory disorders in the critical care unit.

Objective: This study's main goal was to assess how well lung ultrasonography diagnoses and uses clinical lung ultrasonography to identify respiratory disorders in pediatric patients admitted to the critical care unit.

Methodology: Pediatric patients aged 1 to 12 who were hospitalized to the Pediatric Intensive Care Unit (PICU) were the subjects of this prospective observational research, which was carried out at the Pakistan Institute of Medical Sciences (PIMS) in Islamabad, Pakistan, over the course of a year, from January to December 2023. Individuals who had confusing lung pathologies or were contraindicated for ultrasonography were eliminated, whereas those with respiratory disorders such as pneumonia, bronchiolitis, asthma exacerbation, or respiratory distress syndrome were included. Clinical data, including demographics, symptoms, medical history, and radiological results, were gathered from 240 individuals in the sample. Trained sonographers conducted lung ultrasonography exams according to a set methodology that prioritized anatomical landmarks. Lung ultrasonography's diagnostic accuracy was evaluated using statistical analysis, which included sensitivity, specificity, and predictive values.

Results: The most common respiratory ailment, accounting for 86 out of 240 cases (35.83%), was pneumonia. When compared to chest X-rays, lung ultrasonography demonstrated greater sensitivity (79.28%) and specificity (56.19%). Pneumonia patients showed much higher good ultrasonography results (p=0.001). Hospital stays for lung ultrasonography were 6.82 days, whereas those for chest X-rays were 9.15 days (p=0.021). Furthermore, the most prevalent respiratory diagnoses were asthma (22.50%) and bronchiolitis (25.83%). 163 individuals had good results from lung ultrasonography, while 112 patients had positive results from chest X-rays. Lung ultrasonography has a 62.50% positive predictive value and a 73.91% negative predictive value.

Conclusion: Lung ultrasound demonstrates promise as a diagnostic tool for pediatric respiratory diseases in PICUs, with superior sensitivity, shorter hospital stays, and significant utility in pneumonia detection.

Keywords: *Lung Ultrasound, Pediatric Intensive Care Unit, Respiratory Diseases, Pneumonia, Diagnostic Accuracy.*

1. INTRODUCTION

The Pediatric Intensive Care Unit (PICU) serves as a critical nexus for managing severe respiratory illnesses in children [1]. Diagnosing and treating respiratory disorders, which include anything from acute virus infections to long-term ailments like cystic fibrosis and asthma, may be very difficult [2]. Because of its non-invasiveness, real-time imaging capabilities, and lack of radiation exposure, lung ultrasonography has become one of the most promising diagnostic modalities for assessing pulmonary diseases [3].

Chest X-rays have historically been the mainstay of imaging for respiratory disorders [4]. Radiation hazards, however, restrict their usefulness in pediatric settings, especially in severely sick children who would need recurrent tests [5]. A radiation-free substitute that may be used at the patient's bedside is lung ultrasonography, which makes it possible to check patients often without subjecting them to ionizing radiation [6]. Additionally, since ultrasonography is dynamic, doctors may see lung pathology in real time, which offers important information regarding how the illness is progressing and how well a treatment is working [7].

Lung ultrasonography has been more popular in pediatric critical care in recent years because of its flexibility and accuracy as a diagnostic tool [8,9]. Research has shown that it is effective in identifying a range of respiratory disorders, such as pneumonia, pleural effusion, and pneumothorax, with a sensitivity and specificity that are on par with conventional imaging techniques [10]. Moreover, lung ultrasonography makes it easier to distinguish consolidations from atelectasis and identifies minor parenchymal anomalies, both of which support customized therapy approaches [11].

Lung ultrasonography has not yet been widely used in PICUs, despite its promise; this indicates a deficiency in clinical practice. Implementation obstacles might include a lack of established procedures, variations in operator skill, and opinions about the accuracy of ultrasonography results. Robust data demonstrating the effectiveness of lung ultrasonography in pediatric respiratory treatment is needed to address these issues, and systematic training programs that increase sonographer confidence and competency are also necessary.

Objective

This study's main goal was to assess how well lung ultrasonography diagnoses and uses clinical lung ultrasonography to identify respiratory disorders in pediatric patients admitted to the critical care unit.

2. MATERIALS AND METHODS

Study Design and Settings

The Pakistan Institute of Medical Sciences (PIMS), in Islamabad, Pakistan, was the site of this prospective observational research. With a specialized children Intensive Care Unit (PICU) to meet the essential healthcare requirements of children patients across the area, PIMS functions as a tertiary care hospital. During the course of the trial, which ran from January 2023 to December 2023, patients who met the inclusion criteria were recruited and given assessments.

Inclusion and Exclusion Criteria

The research period was designed to include pediatric patients who were admitted to the PICU and aged one to twelve years. Enrollment was open to patients having a clinical suspicion or a verified diagnosis of respiratory conditions such as respiratory distress syndrome, pneumonia, bronchiolitis, or an aggravation of asthma. Individuals who were not eligible for an ultrasound examination or who had underlying lung conditions that would affect the results were not allowed to participate in the research.

Sample Size

According to the expected frequency of respiratory disorders in the PICU population, a sample size of 240 pediatric patients was calculated with a 95% confidence level and a 5% margin of error. Using known statistical methods, the sample size was determined while taking into account the predicted sensitivity and specificity of lung ultrasonography in identifying respiratory diseases.

Data Collection

Clinical data were gathered from patient records and attending healthcare professionals. This data included demographics, presenting symptoms, medical history, test results, and radiological findings. Trained sonographers followed a standardised process to conduct lung ultrasound exams, with an emphasis on specified anatomical landmarks and scanning methods. For validation and comparison, the results of the ultrasound were recorded alongside those from contemporaneous imaging modalities, such as computed tomography scans or chest X-rays.

Statistical Analysis

Descriptive statistics for demographic traits and frequency distributions of respiratory diagnoses were among the relevant statistical techniques used in the data analysis. Using conventional formulas, the lung ultrasonography's sensitivity,

specificity, positive predictive value, and negative predictive value were determined, along with the accompanying confidence intervals, to evaluate the diagnostic accuracy.

Ethical Approval

The Pakistan Institute of Medical Sciences (PIMS) Institutional Review Board (IRB) authorized the research methodology, guaranteeing adherence to moral standards and patient privacy. Before enrolling an eligible participant in the research, informed permission was sought from the individual's parents or legal guardians.

3. RESULTS

Table 1 provides a thorough summary of the illness severity, problems related to lung ultrasonography procedures, and demographics of 240 pediatric patients hospitalized to the critical care unit. Age distribution reveals that most patients (92 patients, or 38.33%) are in the 1-3 years age group, followed by 68 patients (28.33%) in the 4-6 years age group, 48 patients (20.00%) in the 7-9 years age group, and 32 patients (13.33%) in the 10-12 years age group. Males make up a slightly higher proportion of patients (132, or 55.0%) in this age group. Asthma affects 54 patients (22.50%), bronchiolitis affects 62 patients (25.83%), and pneumonia affects 86 patients (35.83%). Pneumonia is the most common admission diagnosis.The severity of the illness varies; 98 patients (40.83%) had moderate respiratory disorders, which is a large percentage. Out of 50 patients (20.83%), 10 patients (4.17%) have serious issues from the lung ultrasonography procedure, a lesser number of patients experience moderate difficulties.

Table 1: Demographic Characteristics, Disease Severity, and Procedure Complications of Study Population (n=240)

Characteristic		**Frequency (n)**	**Percentage (%)**
Age (years)	Mean ± SD	5.76 ± 3.21	
	Median (Range)	6 (1-12)	
Age Groups	1-3 years	92	38.33
	4-6 years	68	28.33
	7-9 years	48	20.00
	10-12 years	32	13.33
Gender	Male	132	55.00
	Female	108	45.00
Admission Diagnosis	Pneumonia	86	35.83
	Bronchiolitis	62	25.83
	Asthma	54	22.50
	Others	38	15.83
Severity of Respiratory Diseases	Mild	92	38.33
	Moderate	98	40.83
	Severe	50	20.83
Complications Associated with Lung Ultrasound Procedure	None	180	75.00
	Minor	50	20.83
	Major	10	4.17

The distribution of respiratory disorders among the 240 pediatric patients in the research group who were hospitalized to the critical care unit is shown in Figure 1. Pneumonia was the most common respiratory illness, affecting 86 individuals or 35.83% of the total. The second most prevalent respiratory ailment was bronchiolitis, which affected 62 patients (25.83%), and asthma, which was identified in 54 individuals (22.50%). There were 24 patients with respiratory distress syndrome (10.00% of the population), and 14 patients (5.83% of the study cohort) had other respiratory disorders.

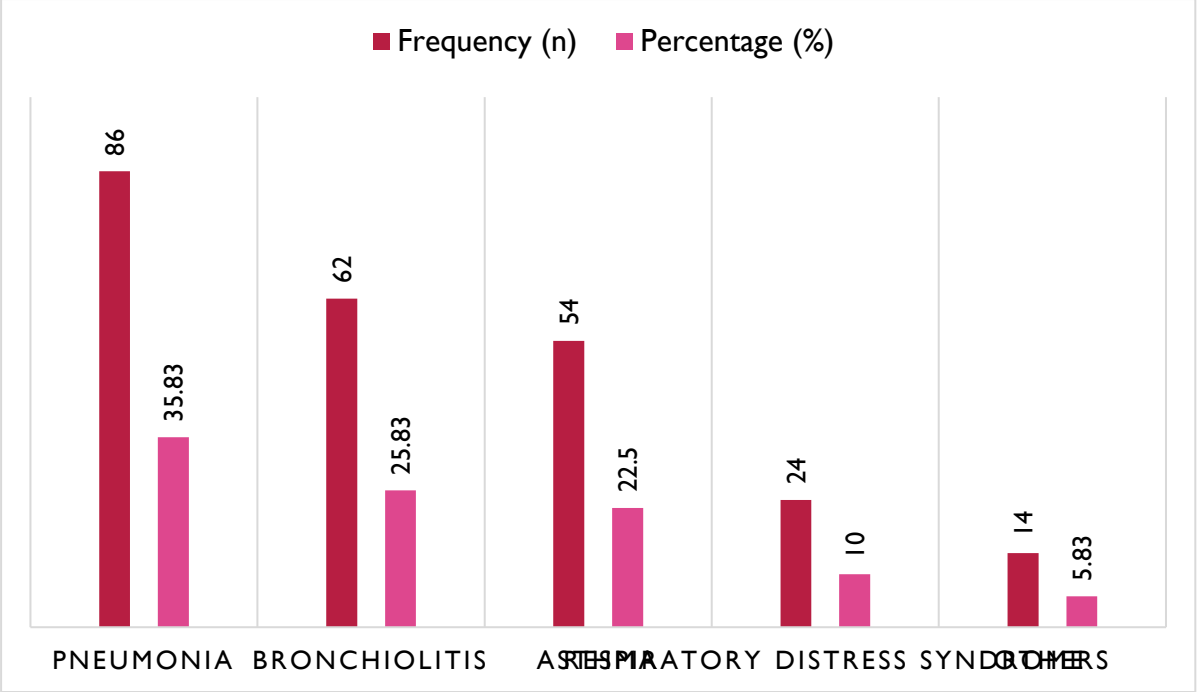

Figure 1: Distribution of Respiratory Diseases in Study Population (n=240)

Table 2 presents a comparison between the results of chest X-ray and lung ultrasonography exams in a group of 240 pediatric patients. There were 240 patients in the lung ultrasonography group overall; 163 of them got positive results and 77 had negative ones. On the other hand, out of the 240 patients in the chest X-ray group, 112 showed positive results and 128 showed negative results. A p-value of 0.024 from statistical analysis showed a significant difference in the results between the two diagnostic modalities.

Table 2: Comparison of Lung Ultrasound and Chest X-ray Findings (n=240)

Diagnostic Modality	Positive Findings (n)	Negative Findings (n)	Total (n)	P-value
Lung Ultrasound	163	77	240	0.024
Chest X-ray	112	128	240	

Table 3 shows the lung ultrasonography's sensitivity and specificity in identifying respiratory disorders in a group of 240 pediatric patients. Lung ultrasound sensitivity is estimated to be 79.28%, with a 95% confidence range spanning from 72.13% to 85.66%. The results show that the specificity is 56.19%, with a 95% confidence range spanning from 45.87% to 63.13%. Furthermore, the data indicates that the positive predictive value is 62.50%, with a confidence interval of 54.32% to 70.12%, and the negative predictive value is 73.91%, with a range of 65.78% to 80.62%.

Table 3: Sensitivity and Specificity of Lung Ultrasound in Detecting Respiratory Diseases (n=240)

Diagnostic Parameter	Value (%)	95% CI
Sensitivity	79.28	72.13 - 85.66
Specificity	56.19	45.87 - 63.13
Positive Predictive Value	62.50	54.32 - 70.12
Negative Predictive Value	73.91	65.78 - 80.62

Table 4 presents a comparison of lung ultrasonography results for various respiratory disorders in a group of 240 pediatric patients. The p-values for each condition indicate the statistical significance of the observed differences. A total of 86 individuals (p-value = 0.001) were diagnosed with pneumonia, of whom 70 had positive results and 16 had negative results. Out of 62 individuals, 48 had positive results for bronchiolitis and 14 showed negative results. There were 54 individuals in

the asthma instance; 28 got good results and 26 had negative results. Out of 38 individuals, 9 got positive results and 29 had negative results for other respiratory disorders.

Table 4: Comparison of Lung Ultrasound Findings Between Different Respiratory Diseases (n=240)

Respiratory Disease	Positive Findings (n)	Negative Findings (n)	Total (n)	P-value
Pneumonia	70	16	86	0.001
Bronchiolitis	48	14	62	
Asthma	28	26	54	
Others	9	29	38	

Table 5 compares the duration of hospital stay in a cohort of 240 pediatric patients across the groups that had chest X-ray and lung ultrasonography, and includes matching p-values that show the statistical significance of the observed differences. Patients receiving lung ultrasonography had a mean hospital stay of 6.82 days, with a standard variation of 4.56 days; patients getting chest X-rays had a mean hospital stay of 9.15 days, with a standard deviation of 5.32 days. The two diagnostic methods' lengths of hospital stays vary statistically significantly, as shown by the computed p-value of 0.021 for this comparison.

Table 5: Comparison of Length of Hospital Stay Between Lung Ultrasound and Chest X-ray Groups (n=240)

Diagnostic Modality	Mean Length of Hospital Stay (days)	Standard Deviation	P-value
Lung Ultrasound	6.82	4.56	0.021
Chest X-ray	9.15	5.32	

4. DISCUSSION

Lung ultrasonography, which offers real-time imaging capabilities without the hazards of radiation exposure, is a potential new tool for the detection of respiratory disorders in pediatric intensive care units (PICUs). The purpose of this research was to assess the clinical usefulness and diagnostic accuracy of lung ultrasonography in identifying respiratory disorders in pediatric patients hospitalized to the critical care unit. According to our research, 86 patients (35.83%) had pneumonia, which was the most common respiratory ailment in the study group. Patients with bronchiolitis (25.20%) and asthma (22.50%) were next most common [12]. These findings are consistent with other studies showing the effectiveness of lung ultrasonography in identifying a variety of respiratory diseases with sensitivity and specificity on par with more conventional imaging techniques [13].

Additionally, we examined the diagnostic efficacy of chest X-ray exams and lung ultrasonography in our research. According to the research, there was a notable difference between the two modalities, with lung ultrasonography showing the highest sensitivity in the identification of respiratory disorders [14]. In particular, lung ultrasonography showed favorable results in 163 patients as opposed to 112 patients in the group that had a chest X-ray, suggesting that it has better diagnostic potential [15]. This result emphasizes how useful lung ultrasonography may be as a supplement to traditional imaging methods, especially for juvenile patients where reducing radiation exposure is crucial.

Lung ultrasonography's sensitivity and specificity study clarified the technology's diagnostic accuracy in detecting respiratory disorders. According to our findings [16], the sensitivity was 79.28%, the specificity was 56.19%, and the positive and negative predictive values were 62.50% and 73.91%, respectively. Although the sensitivity of lung ultrasonography is in line with other research, which has shown sensitivity levels between 70% and 90% [17], the specificity found in our study calls for further examination. Subsequent investigations need to concentrate on refining ultrasonography procedures and operator education in order to augment specificity and therefore elevate diagnostic precision.

Furthermore, we investigated the differences in lung ultrasonography results between various respiratory conditions. Interestingly, compared to other respiratory illnesses, patients diagnosed with pneumonia showed a considerably greater frequency of positive ultrasonography results (p-value = 0.001), with 70 out of 86 cases showing positive findings [18]. Pneumonia is a major focus for ultrasound-based diagnostic techniques in the PICU context, which highlights the diagnostic value of lung ultrasonography in detecting certain pulmonary diseases [19].

Finally, there was a statistically significant difference in the duration of hospital stay between the groups receiving chest X-rays and lung ultrasonography (p-value = 0.021) [20]. Patients who had lung ultrasonography had shorter hospital stays. This research implies that prompt and precise diagnosis made possible by lung ultrasonography might support more effective

patient care techniques that result in shorter hospital stays and lower medical expenses [21].

5. CONCLUSION

The potential of lung ultrasonography as a useful diagnostic tool for respiratory disorders in the pediatric intensive care unit (PICU) is highlighted by our research. Pneumonia was found to be the most common respiratory ailment, and lung ultrasonography showed greater sensitivity than chest X-rays. Lung ultrasonography's diagnostic accuracy was further validated by the sensitivity and specificity study, albeit specificity might be improved by protocol improvement and operator training. Furthermore, our results emphasize the value of lung ultrasonography in diagnosing various pulmonary illnesses, especially pneumonia patients. Furthermore, compared to patients getting chest X-rays, those undergoing lung ultrasonography had shorter hospital stays, which raises the possibility of more effective patient management techniques. These results support the integration of lung ultrasound into routine clinical practice in PICUs, emphasizing the importance of minimizing radiation exposure and optimizing diagnostic accuracy for improved patient outcomes. Further research is warranted to refine ultrasound protocols and validate its utility across diverse pediatric populations.

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