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PULMONARY ULTRASOUND AND PULSE OXIMETRY VERSUS CHEST RADIOGRAPHY AND ARTERIAL BLOOD GAS ANALYSIS FOR THE DIAGNOSIS OF ACUTE RESPIRATORY DISTRESS SYNDROME IN PEDIATRICS

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ABSTRACT

Background: In low-resource settings it is not always possible to acquire the information required to diagnose acute respiratory distress syndrome (ARDS). Ultrasound and pulse oximetry, however, may be available in these settings. This study was designed to test whether pulmonary ultrasound and pulse oximetry could be used in place of traditional radiographic and oxygenation evaluation for ARDS. **Aim of study:** To evaluate the useful of non-invasive bed-side pulmonary U/S and pulse oximetry in the diagnosis and assessment of ARDS in pediatrics. **Methods:** This a prospective study has been conducted on (100) samples of children between 2 to 14 years old, under mechanical ventilation, who are admitted to PICU of child welfare teaching hospital in medical city. Bedside pulmonary ultrasound was performed. Pulse oximetric oxygen saturation (SpO_2), partial pressure of oxygen (PaO_2), fraction of inspired oxygen (FiO_2), provider diagnoses, and chest radiograph closest to time of ultrasound were recorded or interpreted. Corresponding measurements, as well as demographic and diagnostic information, were included in the database. **Results:** There is a moderate level of agreement between bilateral lung infiltration of x-ray and U/S, and this agreement was statistically significant (kappa= 0.514, P=0.001). Perfect positive correlation was seen between S/F and P/F ratios (r= 0.907, P= 0.001). **Conclusion:** This study clearly demonstrates that lung U/S and pulse oximeter are a safe and validated tools, which can use through assessment in the diagnosis of ARDS.

KEYWARDS: Ultrasound imaging; respiratory distress syndrome; pulse oximetry; arterial blood gases.

INTRODUCTION

The recent Berlin definition of ARDS includes :1) onset within a week of a known clinical insult or new respiratory symptoms, 2) bilateral opacities on chest radiograph or computed tomography scan, 3) respiratory failure not fully explained by cardiac failure or fluid overload, and 4) impaired oxygenation defined as partial pressure of oxygen (PaO_2)/fraction of inspired oxygen (FiO_2) ≤300 on positive end-expiratory pressure (PEEP) or continuous positive airway pressure (CPAP) ≥5 cmH_2O], which requires chest radiography or computed tomography for determination of bilateral pulmonary infiltrates.[1]

However, P/F ratio (PaO_2/ FiO_2) criteria require arterial blood sampling, which included concerns about anemia due to repeated blood sampling, risk of infection and sepsis, painful procedure and also difficulty finding a vessel in the child.[2] Traditionally chest radiography or computerized tomography have been used. However, these carry the limitations of exposure to ionizing radiation, need to transfer the critically unwell child, lag-time with clinical correlation and lack of immediate results.

Lung ultrasound (LUS) is an attractive alternative to CXRs and CT scans. Point-of-care or bedside LUS has several unique advantages, including immediate availability of findings to guide clinical decision-making, availability of portable ultrasound devices in austere settings such as field hospitals, repeatability to monitor patients serially, and ease of machine decontamination.[3]

In much of the world where medical resources are limited, blood gas analysis and imaging technologies may not be available, impairing the ability to make the diagnosis of ARDS Consequently, there is a tendency to implement less invasive diagnosis approaches.[2]

The pulse oximetric saturation to inspired oxygen ratio (SpO_2/ FiO_2) has been correlated with the PaO_2/ FiO_2 ratio in ARDS.[4] Pulmonary ultrasound is a rapidly developing technology in which the diagnosis of lung disease is being explored in diverse settings, and new diagnostic criteria are being developed for multiple pulmonary processes.[5]

In most PICU, daily arterial blood sampling to calculate the PF ratio often is impossible, then calculation of SF ratio and replacement it to PF ratio for diagnosis of ARDS or ALI is noninvasive and affordable.[6] Using SF ratio determine the degree of hypoxemia non-invasively and without the need for arterial blood sampling.[7]

PaO2/FiO2 $\leq$ 200 was considered at least moderately impaired oxygenation. For each study assessment the SpO_2/ FiO_2 ratio was calculated using $SpO_2$and FiO_2 recorded at the time of the ABG. Based on the relationship between SpO_2/ FiO_2 and PaO_2/ FiO_2in ARDS patients,[8] SpO_2/ $FiO_2 \leq 315$ was considered impaired oxygenation and SpO_2/ $FiO_2 \leq 235$ at least moderately impaired oxygenation.

Pulmonary ultrasound is a rapidly developing technology in which the diagnosis of lung disease is being explored in diverse settings, and new diagnostic criteria are being developed for multiple pulmonary processes.[5]

PATIENT AND METHOD

After obtaining the Iraqi council of anesthesia and intensive care approval, a descriptive predictive study was carried out in pediatric intensive care unit (PICU) of Child Welfare Teaching Hospital, during the period from 1st of January to 31th of August 2023.

A 100 patient enrolled in the study who was intubated for different causes, written informed consent was obtained from all patient relatives before enrolling them in the study.

No attempts were made to determine the etiology or management of respiratory failure before enrollment.

Mechanically ventilated patients in the ICUs were identified early each morning. Patients were screened for study eligibility based on inclusion and exclusion criteria.

Any patient who is intubated in PICU for any cause with age between 2 years to 14 years.

Exclusion Criteria

- Patient relative refusal,
- Un-intubated patient or only those admitted for simple O_2 therapy interventions as simple O_2 face mask.
- burns over the chest, flail chest, active hemodynamic instability or declination by the patient’s nurse, receiving palliative care, prone positioning, planned extubation the morning of study, or lack of identifying personal information.

After taking a history and examining the patient who is already on ETT and connected to mechanical ventilator, the demographic data were collected which include:

- age,
- gender
- weight
- height
- Type of the disease or the cause of admission.

For patients who met the eligibility criteria, the ultrasound examination before reviewing medical records or other imaging studies.

Six-second video images of the lungs were captured at three locations on each side of the chest using a Samsung-ICU ultrasound machine equipped with a p21x 5-1 MHz phased array probe. In particular, six "blue" points were checked for the presence of B-lines. Ultrasound imaging consistent with ARDS was confirmed by the presence of bilateral B-lines.

Scanning time is not allowed to exceed 5 minutes, including device startup time and video recording time.

Record $FiO_2$and SpO_2 values at the time of ultrasound examination. The procedure was performed around 06:30 am whenever possible to shorten the time between the ICU ultrasound and the early morning chest X-ray and ABG measurement.

Subsequently, the chest X-ray and arterial blood gas analysis closest to the time of the ultrasound examination were retrieved from the medical records. $FiO_2$and SpO2 values recorded during blood gas measurements were also recorded.

Other data calculated based on the above data include:

- PaO_2/ FiO_2
- SpO_2/ FiO_2

The data analyzed using Statistical Package for Social Sciences (SPSS) version 26. The data presented as mean, standard deviation and ranges. Categorical data presented by frequencies and percentages. Independent t-test (two tailed) was used to compare continuous variables accordingly. Pearson’s correlation test (r) was used to assess correlation between S/F and P/F ratios. A level of P – value less than 0.05 was considered significant.

RESULTS

The total number of study patients was 100. All of them were children diagnosed with acute lung injury.

The distribution of study patients by age and gender is shown in figures (1 and 2). Study patients' age was ranging from 2 to 14 years with a mean of 6.56 years and standard deviation (SD) of ± 3.81 years. The highest proportion of study patients was aged < 5 years (40%).

Regarding gender, proportion of males was higher than females (57% versus 43%) with a male to female ratio of 1.32:1

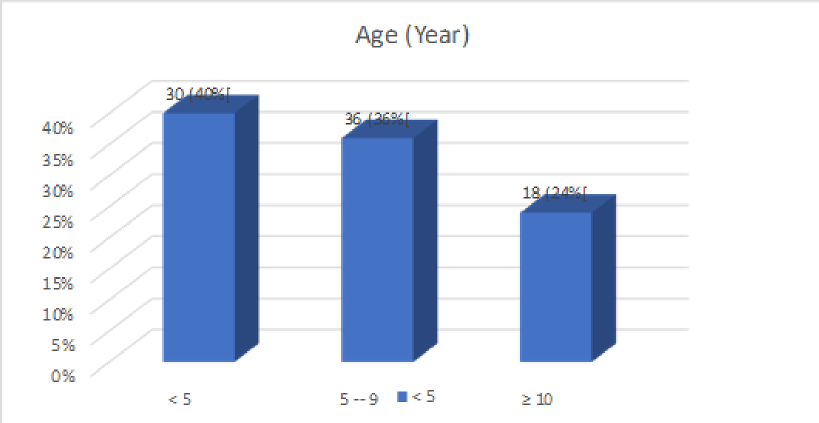

Figure 1: Distribution of study patients by age.

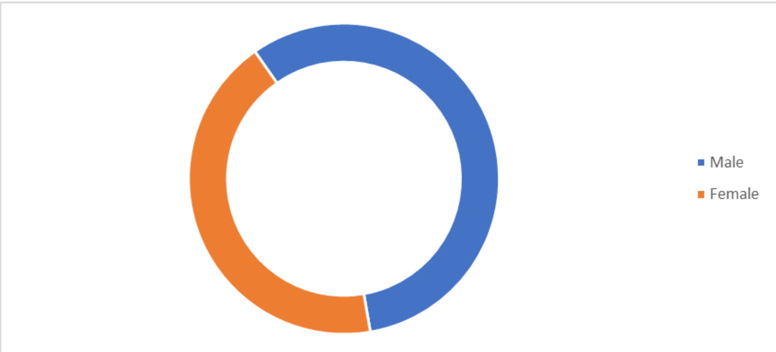

Figure 2: Distribution of study patients by gender.

Table 1 shows the distribution of study patients by BSA. The highest proportion of study patients had BSA between 0.5 – 1.0 m2 (75%).

Table 1: Distribution of study patients by BSA.

BSA (m^2)	No. (n= 100)	Percentage (%)
< 0.5	6	6.0
0.5 – 1.0	75	75.0
> 1.0	19	19.0

Table 2 shows the distribution of study patients by diagnosis according X-ray and U/S. We noticed that U/S was positive in 60% of patients while x-ray was positive in 43%.

Table 2: Distribution of study patients by diagnosis according X-ray and U/S.

Diagnosis	No. (n= 100)	Percentage (%)
U/S finding		
Positive	60	60.0
Negative	40	40.0
X-ray finding		
Positive	43	43.0
Negative	57	57.0

Table 3 shows the agreement level in bilateral lung infiltration finding between x-ray and U/S. U/S detected 60 patients with bilateral lung infiltration; 39 of them were confirmed by x-ray.

In conclusion, there was a moderate level of agreement between bilateral lung infiltration of x-ray and U/S, and this agreement was statistically significant (kappa= 0.514, P=0.001).

Table 3: Agreement in bilateral lung infiltration finding between x-ray and U/S.

X-ray Finding	U/S Finding		Total	Kappa value	P- value
	Positive	Negative			
Positive	39	4	43	**0.514**	**0.001**
Negative	21	36	57		
Total	60	40	100		

Table 4 shows the comparison in clinical parameters according U/S findings. Means of SpO_2, PaO2, S/F ratio, and P/F ratio were significantly lower; while FiO2 was significantly higher ($P < 0.05$) in patients with positive U/S findings than that in those with negative findings.

Table 4: Comparison in clinical parameter according U/S findings.

Clinical parameter	U/S Finding		P – Value
	Positive Mean ± SD	Negative Mean ± SD	
SpO_2 (%)	93.95 ± 3.2	96.27 ± 1.8	**0.001**
PaO_2 (mmHg)	109.18 ± 27.1	126.2 ± 15.3	**0.001**
FiO_2 (mmHg)	79.75 ± 18.2	61.37 ± 14.0	**0.001**
S/F ratio	125.77 ± 36.8	165.07 ± 39.2	**0.001**
P/F ratio	151.12 ± 68.8	213.82 ± 45.4	**0.001**

Table 5 shows the comparison in clinical parameters according x-ray findings. Means of SpO_2, PaO2, S/F ratio, and P/F ratio were significantly lower; while FiO_2 was significantly higher ($P < 0.05$) in patients with positive x-ray findings than that in those with negative findings.

Table 5: Comparison in clinical parameter according X-ray findings.

Clinical parameter	U/S Finding		P – Value
	Positive Mean ± SD	Negative Mean ± SD	
SPO_2 (%)	92.95 ± 3.1	96.33 ± 1.9	**0.001**
PaO_2 (mmHg)	100.43 ± 25.9	127.71 ± 15.1	**0.001**
FiO_2 (mmHg)	84.53 ± 15.8	63.24 ± 15.7	**0.001**
S/F ratio	114.72 ± 26.9	161.69 ± 40.6	**0.001**
P/F ratio	127.6 ± 55.5	212.86 ± 51.1	**0.001**

Correlation between S/F and P/F ratios is shown in table (6) and figure (3). Perfect positive correlation was seen between S/F and P/F ratios (r= 0.907, P= 0.001).

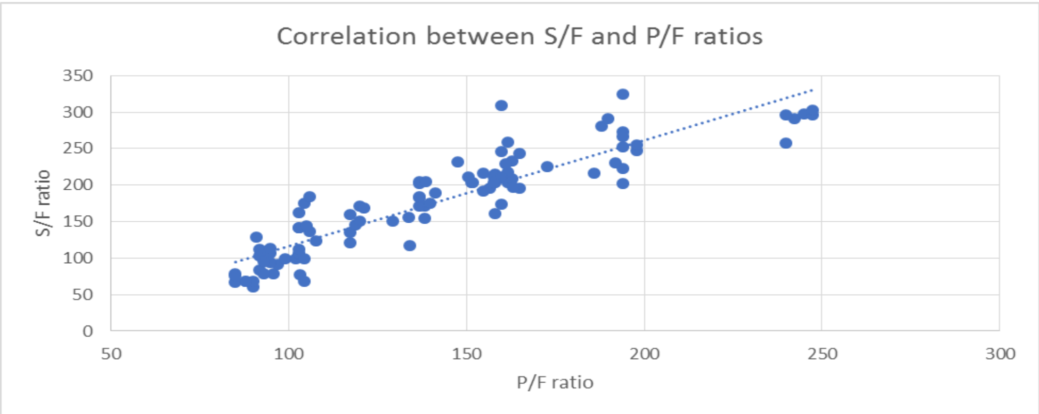

Figure 3: Correlation between S/F and P/F ratios.

Table 6: Correlation Between S/F and P/F Ratios.

P/F ratio (mmHg)	S/F ratio (mmHg)	
	r	**P - Value**
	0.907	**0.001**

DISCUSSION

ARDS is a major contributor to morbidity and mortality among children admitted to PICU. It has sophisticated diagnostic criteria that require an invasive blood gas analysis, which included concerns about anemia due to repeated blood sampling, risk of infection and sepsis, painful procedure and also difficulty finding a vessel in the child.[9,10,11]

Traditionally chest radiography or computerised tomography have been used. However, these carry the limitations of exposure to ionizing radiation, need to transfer the critically unwell child, lag-time with clinical correlation and lack of immediate results.

In much of the world where medical resources are limited, blood gas analysis and imaging technologies may not be available, impairing the ability to make the diagnosis of ARDS. Consequently, there is a tendency to implement less invasive diagnosis approaches.[3]

However, both pulse oximetry and ultrasound are becoming increasingly accessible worldwide.[12] The pulse oximetric saturation to inspired oxygen ratio (SpO_2/ FiO_2) has been correlated with the PaO2/ FiO_2ratio in ARDS.[4] Pulmonary ultrasound is a rapidly developing technology in which the diagnosis of lung disease is being explored in diverse settings, and new diagnostic criteria are being developed for multiple pulmonary processes.[5]

The present study aimed to evaluate the role of non-invasive bed-side pulmonary US and pulse oximetry in the diagnosis of ARDS in pediatrics.

According to the result of the study the combination of Pulse oximetry and pulmonary ultrasound may be useful tools to screen for, or rule out, impaired oxygenation or lung abnormalities consistent with ARDS in under-resourced settings where arterial blood gas testing and chest radiography are not readily available.

These results are in accordance with many previous studies worldwide.

In our study, The total number of study patients was 100. All of them were children diagnosed with acute lung injury.

Study patients' age was ranging from 2 to 14 years with a mean of 6.56 years and standard deviation (SD) of ± 3.81 years. The highest proportion of study patients was aged < 5 years (40%).

Regarding gender, proportion of males was higher than females (57% versus 43%) with a male to female ratio of 1.32:1.

In our study we noticed that U/S was positive in 60% of patients while x-ray was positive in 43%.

U/S detected 60 patients with bilateral lung infiltration; 39 of them were confirmed by x-ray. In conclusion, there was a moderate level of agreement between bilateral lung infiltration of x-ray and U/S, and this agreement was statistically significant (kappa= 0.514, P=0.001).

Almost the same findings were observed in Spanish study by Maria et al.[13], Ninety-six patients with a clinical diagnosis of COVID-19 underwent an LUS exam and CXR upon presentation. LUS detected unilateral or bilateral pulmonary infiltrates in 55% of subjects with a normal CXR. Substantial agreement was demonstrated between LUS and CXR for normal, unilateral or bilateral findings (K = 0.48). They found that LUS findings correlated well with those of CXR in patients with suspected or confirmed COVID-19.

In another study by Plantinga[14], a total of 116 patients were included LUS, detected bilateral abnormalities more often than chest radiography (in 86.2% versus 60.3% of the patients; p < 0.001). Lung ultrasound was able to detect pulmonary infiltrates in more than half of patients with a normal CXR.

In our study, Means of SPO2, PaO2, S/F ratio, and P/F ratio were significantly lower; while FiO2 was significantly higher (P < 0.05) in patients with positive U/S findings than that in those with negative findings.

Means of SPO2, PaO2, S/F ratio, and P/F ratio were significantly lower; while FiO2 was significantly higher (P < 0.05) in patients with positive x-ray findings than that in those with negative findings.

Perfect positive correlation was seen between S/F and P/F ratios (r= 0.907, P= 0.001).

In another similar study by Lohano et al.[15], a total of 120 children were included, the mean age was 40.58±38.88 months and 67 (55.8%) were males. The mean FiO2 was 76.33%, the mean PaO2 and SpO2 were 100.35 mmHg and 94.37%, respectively. The mean PF ratio was 156.34, and the mean SF ratio was 156.45. There was a strong correlation between the SF ratio and the PF ratio (r=0.688; p=0.001).In another similar study by Khemani et al.[4], a moderate correlation was found between SF and PF (r=0.47) among 383 children with ARDS.

So, the SF ratio can be reliably used for early detection and risk assessment of ARDS in children.

CONCLUSION

Pulse oximetry and pulmonary ultrasound may be useful tools to screen for, or rule out, impaired oxygenation or lung abnormalities consistent with ARDS in under-resourced settings where arterial blood gas testing and chest radiography are not readily available.

RECOMMENDATIONS

1. We recommend the use of non-invasive bed-side pulmonary US and pulse oximeter device rather than invasive ABG and CXR in PICU for evaluation of patients with PARDS.
2. Future studies are needed to evaluate the use of a standardized LUS protocol on triage decisions and health services of patients with suspected ARDS.

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