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Evaluation of Non-Invasive Oxygen Saturation Compared to Oxygenation Index in Patients with Acute Respiratory Distress Syndrome Admitted in Pediatric Intensive Care Unit

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Abstract: Background: The Oxygenation Index (OI), an invasive diagnostic criterion, is often used as a marker of severity of acute respiratory distress syndrome (ARDS). In order to determine OI, arterial blood gas (ABG) through an invasive procedure is all-important used to obtain PaO2. The Oxygenation saturation Index (OSI), as an alternative method, can be achieved using pulse oximetry to assess SpO2 which is noninvasive & available even in remote areas. **Aim of study:** To evaluate the correlation of OI with OSI for assessment of ARDS's patient in pulmonary and non-pulmonary cases of pediatrics. **Patient and Method**: This descriptive prospective study has been conducted on children between 30 days of age to 14 years old, under mechanical ventilation, who are admitted to PICU of child welfare teaching hospital in medical city. Admitted patients were categorized into two groups; patients with pulmonary disease who have experienced trauma, pneumonia, or aspiration and those who have non pulmonary disease and admitted due to metabolic and neurologic problems or poisoning. PaO2 values were measured through arterial blood sampling and spo2 values measured using pulse oximetry, maximum within one hour after ABG extraction. Corresponding measurements, as well as demographic and diagnostic information, were included in the database. **Results**: There is significant correlation between oxygenation index (OI) and oxygen saturation index (OSI). This result permit to us to use (OSI) as screening method rather than (OI) to avoid risks of invasive procedures. Conclusion: This study showed a strong correlation of OI with OSI.

Keywords: Oxygen saturation index (OSI); Oxygenation index (OI); acute respiratory distress syndrome.

INTRODUCTION

The oxygenation index is a calculation used in intensive care unit to measure the fraction of inspired oxygen (FiO_2) and it's usage within the body. A lower oxygenation index is better- this can be inferred by the equation itself. As the oxygenation of a person improves, they will be able to achieve a higher Pao2 at a lower FiO_2. This would be reflected on the formula as a decrease in the numerator or an increase in the denominator- thus lowering the OI.[1] It can be calculated by the following equation:

$$\text{Oxygenation Index (OI)} = \frac{\text{MAP} \times \text{FiO2}}{\text{PaO2}}$$

- MAP = Mean Airway Pressure
- FiO2 = Fraction of Inspired Oxygen in Percentage
- PaO2 = Partial Pressure of Oxygen in Arterial Blood

Fig.1: Calculation of Oxygen Index.[2]

And if OI < 5 considered as normal, if > 10 there is a severe oxygenation problem, >20 an extreme oxygenation problem and if > 40 it is an indication for ECMO referal. (wikipedia.org)

As arterial blood gas sampling is an invasive procedure with the potential for crucial complications and must be performed with precedence given to the safety of the patient. Any break from the proper safety technique can cause injury to the patient, which may result in loss of form and function to the body distal to the arterial puncture site. The likelihood of complications are rises any time repeated punctures are attempted at the same site. (www.sciencedirect.com)

The complications of this procedure are a lot and will be mentioned later in this chapter.

So, OI has traditionally been the assessment tool for acute lung disease in pediatric, and the need for arterial sampling is its major limitation. OSI can overcome this limitation. Such non-invasive assessments have the potential to reduce invasive procedures, workload and cost.

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Oxygen Saturation Index (OSI) is a non-invasive method which use oxygen saturation reading on oximeter,To calculate OSI, we replace pao2 with Spo2 as measured by pulse oximetry. And is calculated as follow:

$OSI=MAPxFiO_2x100/SpO_2$

Oxygen saturation is the fraction of O_2 saturated hemoglobin relative to total hemoglobin (unsaturated + saturated) in the blood. The human body requires and regulates an extremely precise and specific balance of oxygen in the blood. Normal arterial blood oxygen saturation levels in humans are 95%–100%, if the level is below 90% it is considered low and called hypoxemia. (mayoclinic.com)

AIM OF STUDY

To evaluate the correlation of OI with OSI and to validate predictive non-invasive OSI measurements for clinically relevant OI values for assessment of ARDS patent in pediatrics.

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 2021.

68 patients 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.

Inclusion criteria:
Patients with ARDS who is intubated for any cause (pulmonary or non-pulmonary) with age between 30 days to 14 years.

Exclusion criteria:
•Patient relative refusal.
•Patients who are anemic, hypovolemic, shivering.

For this study, intubated patients who admitted in a pediatric intensive care unit divided into two groups, pulmonary and non-pulmonary groups. So, we are going to compare the OSI to OI and try to know how much the OSI is a reliable surrogate marker of oxygenation in those patients.

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.

About 60 minutes on admission and stabilization of the patient, a trolley was prepared by a professional nurse of PICU which contain a necessary equipment to draw a sample of ABG.

Under complete aseptic technique, and sterilization of area which going to take a sample from it, 2ml of blood was drawn with 2ml syringe which was already flushed with Unfractionated Heparin, and after completing the procedure the SpO_2 for the patient was obtained from the monitor and the sample sent to ABG instrument which will be obtained soon.

Another data was collected after taking the sample which include information about parameters on the ventilator machine, include:
•FiO_2.
•PEEP.
•Respiratory rate (Rr).
•PIP (positive inspiratory pressure).
•Hear rate.
•Mode of ventilation.

A PaO_2 value was taken from the result of ABG which need maximally 10 minutes to appear.

More data were calculated, based on data mentioned above according to mathematical equations remembered previously which include:
•Inspiratory time (Ti)
•OSI
•OI

STATISTICAL ANALYSES

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 and Analysis of Variance (ANOVA) (two tailed) was used to compare the continuous variables accordingly. Pearson's correlation test (r) was used to assess correlation between OI and OSI. Receiver operating characteristic (ROC) curve analysis was used for prediction of OI and OSI as diagnostic of severe ARDS. A level of P – value less than 0.05 was considered significant.

RESULTS

The total number of study patients were 68. All of them were children aged between 30 days to 14 years admitted to the pediatric intensive care unit and intubated for any cause.

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The distribution of study patients by general characteristics is shown in figure and table (1). Study patients' age was ranging from 1.5 months to 13 years with a mean of 5.59 years and a standard deviation (SD) of ± 4.7 years. The highest proportion of study patients was age > 6 years (47.1%).

Regarding gender, proportion of females was higher than males (52.9% versus 47.1%) with a male to female ratio of 1:1.12.

Study patients' BSA was ranging from 0.19 to 1.36 m2 with a mean of 0.68m^2 and SD of ± 0.32 m^2.

Table 1: gender and Body surface area distribution.

Variable	No. (n= 68)	Percentage (%)
Gender		
Male	32	47.1
Female	36	52.9
Range		Mean ± SD
BSA (m^2)	0.68 ± 0.32	0.19 – 1.36

Table 2 shows the distribution of study patients by clinical information. We noticed that 67.6% of study patients were intubated due to non-pulmonary diseases and the most common mode of ventilation was Bi-level (69.1%).

Table 2: clinical presentation and mechanical ventilation modes

Variable	No. (n= 68)	Percentage (%)
Disease		
Pulmonary	22	32.4
Non-Pulmonary	46	67.6
Mode of ventilation		
Bi-level	47	69.1
PC / AC	15	22.1
PRVG	3	4.4
PC / BiPAP	2	2.9
PC / SIMV	1	1.5

Details of mean and range of parameters of the ventilation machine are shown in table (3).

Table 3: Ventilatory parameters recorded

Variable	Mean ± SD	Range
Mean airway pressure (cm H_{2O})	9.82 ± 2.2	6.0 – 18.3
PaO_2 (cm H_{2O})	135.12 ± 53.1	60.3 – 274.0
FiO_2	82.94 ± 16.6	40.0 – 100.0
Heart rate (beats/mint.)	134.94 ± 23.3	80.0 – 182.0
PEEP (cm H_2O)	7.27 ± 1.8	4.0 – 12.0
Respiratory rate (breaths/mint.)	35.23 ± 11.5	14.0 – 66.0
PIP (cm H_2O)	17.04 ± 3.7	10.0 – 25.0

The distribution of study patients according severity of ARDS by OI, OSI, and PaO_2/FiO_2 ratio is shown in table (4). According OI and OSI, the highest proportion of study patients was diagnosed as mild ARDS (51.5% and 60.3% respectively).

By PaO_2/ FiO_2 ratio, 38.2% of study patients were diagnosed as moderate ARDS.

Table 4: Severety recorded in the study.

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Severity of ARDS	No. (n= 68)	Percentage (%)
By OI		
Severe	7	10.3
Moderate	26	38.2
Mild	35	51.5
By OSI		
Severe	7	10.3
Moderate	20	29.4
Mild	41	60.3
By PaO_2 / FiO_2 Ratio		
Severe	17	25.0
Moderate	26	38.2
Mild	25	36.8

Table 5 shows the level of agreement in severity of ARDS between OI and OSI. By OSI, severe ARDS was detected in seven patients; all of them were confirmed by OI.

In conclusion, there was a substantial agreement between the severity evaluation of OSI and OI, and this agreement was statistically significant (kappa= 0.792, P=0.001).

Table 5: Level of agreement in severity of ARDS between OI and OSI

Severity by OSI	Severity by OI			Total	Kappa value	P- value
	Severe	Moderate	Mild			
Severe	7	0	0	7	**0.792**	**0.001**
Moderate	0	19	1	20		
Mild	0	7	34	41		
Total	7	26	35	68		

Correlation between OI and OSI is shown in table (6) and figure (2). Statistically significant very strong positive correlation was detected between OI and OSI (r= 0.875, P= 0.001).

OI	OSI	
	r	P - Value
	0.875	0.001

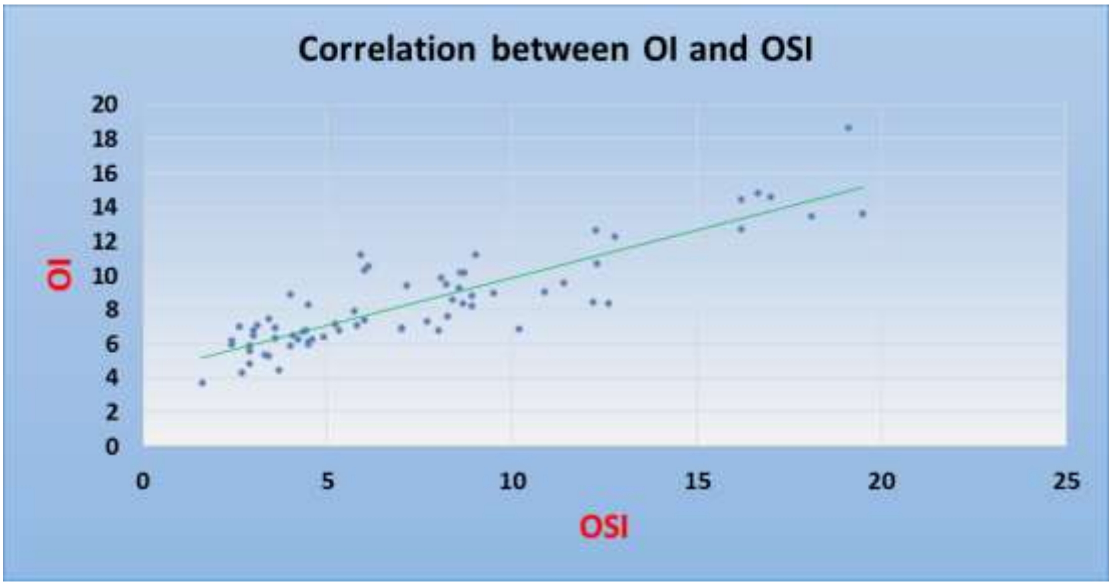

Fig.2: Correlation between OI and OSI.

Comparison in OI and OSI according severity of ARDS in pulmonary and non-pulmonary patients is shown in table (3.7). In pulmonary and non-pulmonary patients, means of OI and OSI were increasing significantly ($P < 0.05$) with more

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severe patients to reach the highest in severe ARDS.

Table 7: Comparison in OI and OSI according severity of ARDS in pulmonary and non-pulmonary patients

Parameter	Severity of ARDS by PaO_2 / FiO_2 Ratio			P - Value
	Severe Mean ± SD	Moderate Mean ± SD	Mild Mean ± SD	
Pulmonary Patients				
OI	13.33 ± 3.4	6.94 ± 1.6	3.55 ± 1.3	0.001
OSI	10.85 ± 3.4	8.78 ± 1.8	5.94 ± 1.3	0.002
Non - Pulmonary Patients				
OI	13.69 ± 4.0	7.16 ± 2.2	3.45 ± 0.74	0.001
OSI	11.51 ± 3.4	8.48 ± 2.0	6.34 ± 0.93	0.001

Receiver operating characteristic (ROC) curve analysis was constructed for OI and OSI as predictors for severe ARDS. The cut point of OI was 9.01 and of OSI was 8.33. So, OI > 9.01 and OSI > 8.33 are predictive for diagnosis of severe ARDS, as a large significant area under the curve (AUC= 97.5% and 85.9%) indicating significant association between higher scores of OI and OSI with diagnosis of ARDS.

OI was 88.2% sensitive, 98% specific, and 95.6% accurate; while OSI was 88.2%, 72.5% specific, and 76.5% accurate in predicting severe ARDS (Table 8) and (Figures 3 and 4).

Table 8: Association between study variables and OSI

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
Age	-.004	.017	-.006	-.214	.831
BSA	.044	.235	.005	.187	.852
SpO_2	-.079	.022	-.077	-3.613	.001
MAP	.840	.047	.641	17.910	.001
PaO_2	.006	.001	.113	4.701	.001
FiO_2	.091	.004	.527	22.483	.001
HR	.000	.002	.001	.082	.935
PEEP	-.017	.035	-.011	-.473	.638
RR	-.003	.005	-.014	-.702	.486
Ti	-.320	.182	-.024	-1.752	.085
PIP	-.004	.015	-.006	-.282	.779
OI	.137	.029	.216	4.793	.001

There is a statistically significant inverse association between peripheral capillary oxygen saturation (SpO_2) and oxygen saturation index (OSI) (p-value = 0.001). On the other hand, there are statistically significant positive associations between mean arterial pressure (MAP), partial pressure of oxygen (PaO_2), fraction of inspired oxygen (FiO_2), oxygenation index (OI), and OSI (p-value = .01, .01, .01, .01) respectively.

Table 9: Diagnostic accuracy of OI and OSI for prediction of severe ARDS

Variable	Cut-off value	Sensitivity	Specificity	PPV	NPV	Accuracy
OI	9.01	88.2%	98%	93.8%	96.2%	95.6%
OSI	8.33	88.2%	72.5%	51.7%	94.9%	76.5%

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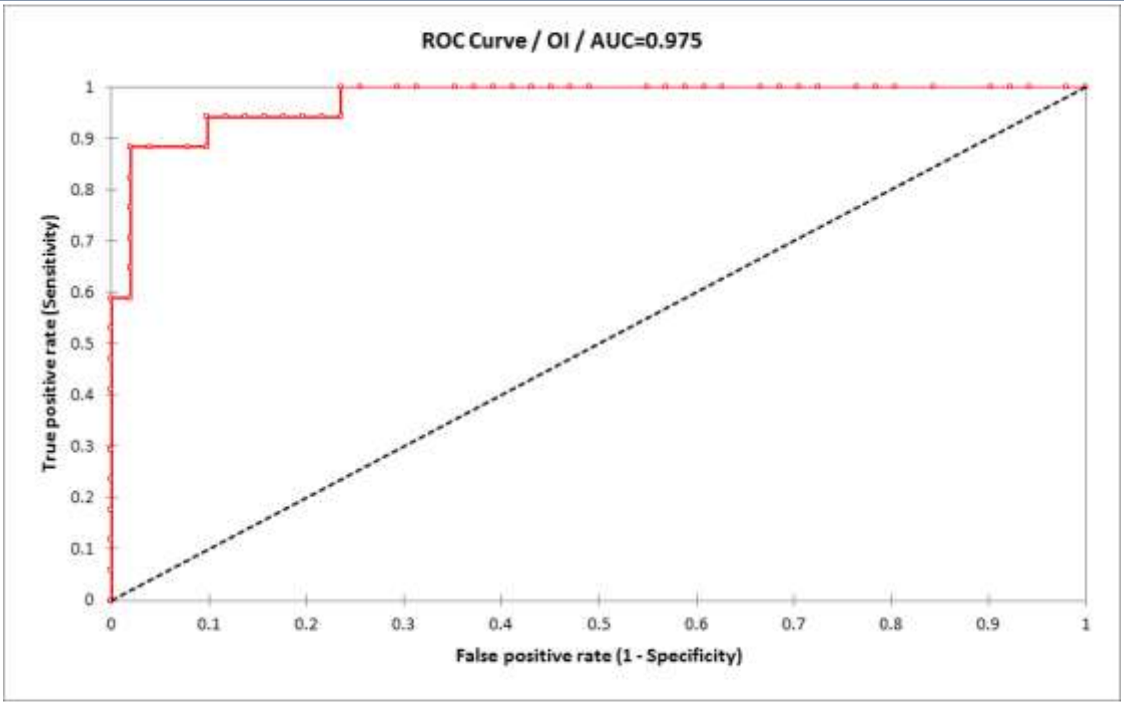

Fig.3: ROC curve for OI in predicting severe ARDS

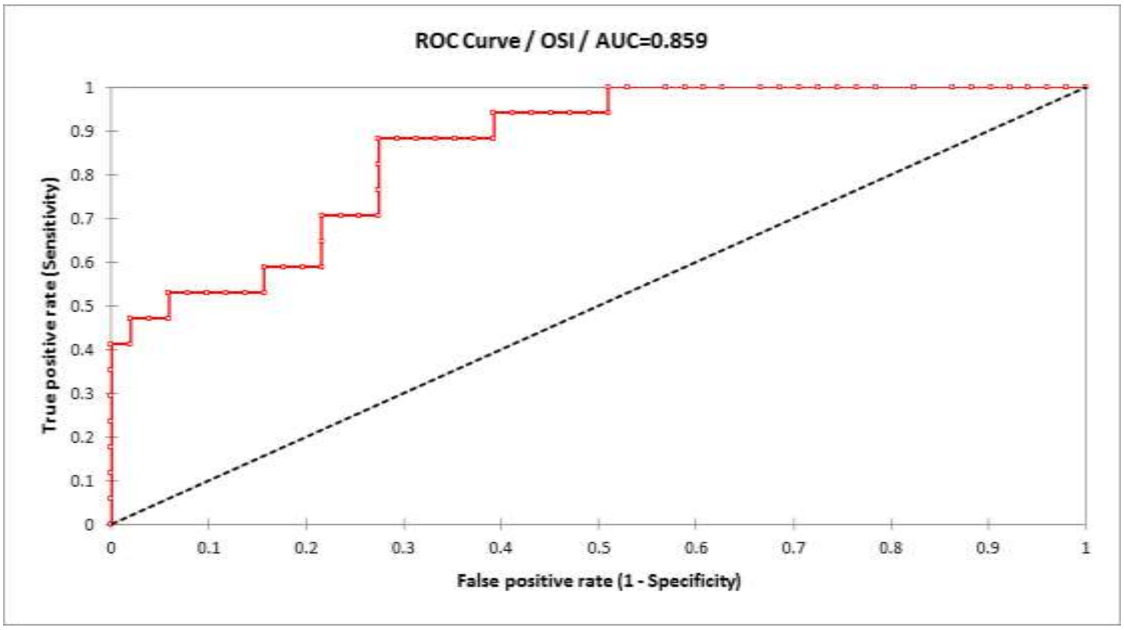

Fig 4: ROC curve for OSI in predicting severe ARDS.

Table 10 shows the comparison in OI and OSI by disease type according to severity of ARDS. No statistical significant differences detected ($P \geq 0.05$) in means of OI and OSI between pulmonary and non-pulmonary diseases in severe, moderate, and mild ARDS.

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Table 10: Comparison in OI and OSI by disease type according severity of ARDS

Severity of ARDS by PaO_2/FiO_2 Ratio	Disease		P - Value
	Pulmonary	Non-Pulmonary	
Severe			
OI	13.33 ± 3.4	13.69 ± 4.0	0.853
OSI	10.85 ± 3.4	11.51 ± 3.4	0.722
Moderate			
OI	6.94 ± 1.6	7.16 ± 2.2	0.763
OSI	8.78 ± 1.8	8.48 ± 2.0	0.385
Mild			
OI	3.55 ± 1.3	3.45 ± 0.74	0.835
OSI	5.94 ± 1.3	6.34 ± 0.93	0.446

DISCUSSION

This prospective predictive study aimed mainly to identify the association between study variables and OSI; particularly the OI and OSI. This is to help us in identifying pediatric patients with ARDS using a non-invasive instruments rather than invasive and in order to employ OSI as a monitoring parameter especially in resource-limited areas to reflect the oxygenation status in mechanically ventilated pediatric patients.

The main motivation of this paper is the feasibility study of utilization non-invasive OSI index instead of its counterpart OI in two groups of pulmonary and non-pulmonary patients admitted in PICU. The second objective of this research is evaluating and find the correlation between OI and OSI and performance in two groups of pulmonary and non-pulmonary patients.

According to study by Lobate, *et al*. A good correlation between PaO_2 and SpO_2 was identified, which has led to further studies focusing on the importance of this issue and replacing the two items in the oxygenation index and creating an oxygen saturation index instead of that to diagnose ARDS. (Lobete, C. *et al*., 2013)

Rawat, *et al*, in a retrospective study of 74 late preterm and term neonates, reported strong correlation of OSI with OI and proposed a practical equation for predicting OI from OSI (OI=2× OSI). (Rawat, M)

Our study showed there was no significant difference in both groups of pulmonary and non-pulmonary regarding OI and OSI, this is was consistent with the study of Alisamir, *et al*. which carried on 74 samples of children between 3 months to 18 years old, under mechanical ventilation, who are admitted to PICU of Abouzar children's hospital of Ahvaz 2020, he concluded that OSI can be derived from OI by mathematical equation because there was significant correlation between them in both groups. (https://acta.tums.ac)

Also Ahmed, *et al*. in his study Frequency of Pediatric Acute Respiratory Distress Syndrome Based on Oxygen Saturation Index in Pediatric Intensive Care Unit of a Developing Country, shows that by using non-invasive OSI, early diagnosis of pediatric acute respiratory distress can be made and this will help in better management and less mortality .(www.cureus.com)

Doreswamy, *et al* performed a prospective study of 54 neonates and derived predictive OSI values of OI values, with high sensitivity and specificity and correlation coefficient (0.89) which is the nearest to our study (0.875). (Doreswamy, S. M. *et al*., 2016)

Thomas, *et al*. in his study for Defining acute lung disease in children with the oxygenation saturation index demonstrate that noninvasive methods of oxygenation assessment, utilizing pulse oximetry as a substitute for PaO_2, can be calculated and used as a surrogate for the diagnosis of ALI and ARDS in children. Additionally, because mechanical ventilation can largely influence the resultant oxygenation for a delivered percentage of oxygen, the OSI likely represents a more robust measure of lung disease severity. (Curley, M. A. *et al*., 2006)

The OI and OSI are consequently an indicator for oxygenation in these individuals. Thus, the noninvasively monitored SpO_2 can be considered a good surrogate to PaO_2 in monitoring continuously the mechanically ventilated, when deemed clinically applicable.

Sonali Vadi in his study on patients aged more than 18 years to find Correlation of Oxygen Index, Oxygen Saturation Index, and PaO_2/FiO_2 Ratio in Invasive Mechanically Ventilated Adults found that the strong point in using OSI is that it includes measurements of MAP, which signals changes in

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lung compliance, aggressiveness of respiratory support, and oxygenation deficit, thus offering a better approximation of the extent of pediatric acute respiratory distress syndrome. (DesPrez, K. *et al*., 2017)

CONCLUSION

This study showed a strong correlation of OI with OSI. Oxygen saturation index as a non-invasive source, was used for ARDS diagnosis, performed as well as the OI in predicting clinical outcomes. It was simple to calculate and continuously available, and offered more prognostic information than traditional measures of ARDS severity such as PaO_2/FiO_2, while avoiding invasive arterial blood gas monitoring.

RECOMMENDATIONS

1. We recommend the use of non-invasive oxygen measurement device rather than invasive paO2 in PICU for evaluation of patients with PARDS, especially in situations where there is limited facilities.
2. Need more studies regarding correlation of OSI with PH, paCO2 and hemoglobin level.
3. Needs more studies regarding neonates and adults with ARDS and the use of OSI.

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