

Evaluation of Non-Invasive Oxygen Saturation Index Compared With Oxygenation Index in Pulmonary and Non-Pulmonary Patients Admitted in PICU

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Received: 21 Sep. 2019; Accepted: 14 Jan. 2020

Abstract- The Oxygenation Index (OI= $[\text{MAP} \times \text{FiO}_2] / \text{PaO}_2 \times 100$), an invasive diagnostic criterion, is routinely used as a marker of severity of acute respiratory distress syndrome (ARDS). In order to determine of OI, arterial blood gas (ABG) through an invasive procedure is indispensably used to obtain PaO₂. The Oxygenation saturation Index (OSI= $[\text{MAP} \times \text{FiO}_2] / \text{SPO}_2 \times 100$), as an alternative method, can be implemented using pulse oximetry to assess SpO₂. For this epidemiologic-analytic study, 74 intubated patients admitted in a pediatric intensive care unit of Abouzar hospital of Ahvaz during the first 3-day admission were selected equally in pulmonary and non-pulmonary groups within a six months period, from January 1, 2019, to May 31, 2019. Two indexes of OI and OSI in both patients were evaluated, and eventually, the results were analyzed by linear regression using Spss. A comparison of the two OI and OSI indexes showed a meaningful relationship was found ($P < 0.001$), which has a higher correlation coefficient of 0.726 in patients with the pulmonary disease than non-pulmonary patients with 0.394. The present study demonstrates that the index of oxygen saturation (OSI) with a sensitivity of 78% and specificity of 83% in the patients without acute pulmonary distress syndrome is a suitable indicator instead of the invasive index of OI. Also, in patients with pulmonary disease that meet the medium range of Berlin criteria, with a sensitivity of 100% and specificity of 76%, the OSI index can be used to predict the status of patients.

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Acta Med Iran 2020;58(2):78-82.

Keywords: Oxygen saturation index (OSI); Oxygenation index (OI); Intubated patients; Acute respiratory distress syndrome

Introduction

Acute respiratory distress syndrome (ARDS) in the intubated patients who are admitted to the pediatric intensive care unit and its severity and prognosis in determining the patient's mortality rate has been the subject of much researches in recent years (1-5). According to the American-European consensus conference definition, the diagnosis of ADRS required arterial blood gas (ABG) sampling (6). Furthermore, the recent Berlin definition of ARDS also includes arterial PaO₂, setting three categories of ARDS based on the degree of hypoxemia: mild (200 mm Hg $< \text{PaO}_2 / \text{FIO}_2 \leq 300$ mm Hg), moderate (100 mm Hg $< \text{PaO}_2 / \text{FIO}_2 \leq 200$ mm Hg), and severe ($\text{PaO}_2 / \text{FIO}_2$ [PF] ≤ 100 mm Hg) which PaO₂ and FIO₂ are partial pressure of oxygen and fraction of inspired oxygen, respectively (7).

However, PF ratio ($\text{PaO}_2 / \text{FIO}_2$) criteria require arterial blood sampling, which included concerns about anemia due to repeated blood sampling, risk of infection and sepsis, and also difficulty finding a vessel in the child. Consequently, there is a tendency to implement less invasive diagnosis approaches (8-9). Recent researches demonstrate that the oxygen saturation index (OSI), as measured by pulse oximetry, can be used to diagnose ARDS in a non-invasive manner by defining SF ratio ($\text{SPO}_2 / \text{FIO}_2$) instead of PF ratio as long as $\text{SPO}_2 \geq 97\%$ (10-12).

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 the performance of the Berlin definition for pediatric ARDS in two

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groups of pulmonary and non-pulmonary patients by defining a new correlation between OI and OSI.

Materials and Methods

This epidemiologic-analytic study has been conducted in 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. Admitted patients were categorized into two groups; patients with pulmonary disease who have experienced trauma, pneumonia, or aspiration and those who have not a 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. Exclusion criteria were children with chronic lung disease and cyanotic heart disease and hypotension and weak pulses.

Statistical analysis

Statistical analyses were conducted using the Statistical Package for Social Sciences, version 23.0 (SPSS, Chicago, Illinois). Quantitative data were demonstrated as mean±standard deviation (SD), while qualitative data were presented as frequency and percent (%). A $P < 0.001$ was considered statistically significant. The relationship between OI and OSI for different saturation ranges were analyzed using correlation coefficients (Pearson's correlation) and calculated by the linear regression technique. Sensitivity and specificity analysis were performed of the OSI cut-off values correlating with OI in four groups of patients without acute pulmonary distress syndrome and mild, moderate, and severe ARDS.

Results

Derivation data set

Applied data sets consist of 1332 data from 74 patients, including demographics information, calculated values as input data, and results of relationships as outputs.

As demographics data set shown in table 1, in two equal groups of pulmonary and non-pulmonary patients, 64% of all patients were male with a mean age of 3.16 ± 3.64 years (minimum 0.25 and maximum 13), while remaining 36% were female with a mean age of

3.34 ± 3.58 years (minimum 0.25 and maximum 17). More detailed information is given in table 1.

Similarly, table 2 contains input data to the study obtained by pulse oximetry, arterial blood gas testing, and mechanical ventilation settings. Based on the values of the two PaO₂ and O₂sat indexes, which represent arterial oxygen pressure and arterial oxygen saturation, the mean values for the 74 studied were 137.83 and 95.89, respectively, with the minimum of 31 for PaO₂ and 52 for O₂sat. Additionally, the maximum of these two variables was 372 and 100, respectively. Also, the table shows the mean, standard deviation, and minimum and maximum values of PIP (peak inspiratory pressure), PEEP (positive end-expiratory pressure), RR (respiratory rate), FiO₂ (fraction of oxygen delivered) and Ti (inspiratory time) for 74 studied cases. Oxygen saturation (SpO₂) was obtained by pulse oximeter and recorded in the samples with the minimum values of 85 and a maximum of 97.

Table 1. Demographic data set of admitted patients in PICU

	Pulmonary Patient		Non-Pulmonary Patient	
	Female	Male	Female	Male
Sex				
Total percent	12%	38%	24%	26%
Ave. Age, y	1.41	3.88	4.31	2.12
SD.	1.16	4.07	4.80	3.03
Min.	0.25	0.25	0.25	0.25
Max.	3.5	13	17	12

Table 2. Input variables to study of patients admitted in PICU

	Ave.	SD.	Min.	Max.
PaO₂	137.83	61.68	31	372
O₂sat	95.89	7.54	52	100
PIP	18.42	3.66	12	30
PEEP	5.26	1.03	3	10
RR	24.51	5.55	12	35
FiO₂	63.51	17.37	35	100
Ti	0.8	0.13	50	1.2
SpO₂	94.95	2.60	85	97

Table 3. Output variables to study of patients admitted in PICU

	Ave.	SD.	Min.	Max.
T_{total}	2.59	0.70	1.71	5
MAP	9.54	1.91	6.25	14.92
OSI	6.42	2.22	2.80	12.30
OI	5.60	4.14	1.23	25.84
PF ratio	229.33	114.65	38.50	640
SF ratio	161.22	45.48	85	277.14

Additionally, the calculated average airway pressure (MAP) is 9.54, and the highest and lowest values are 14.92 and 6.25, respectively. The T_{total} value used to

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calculate MAP has a mean of 2.59, with a minimum of 1.71 and a maximum of 5. Also, based on calculated data and the table above for the OSI and OI indexes, the mean obtained values are 6.42 and 5.60, respectively. In these two indexes, the lowest and highest values were 2.80 and 12.30 for the oxygen saturation index and 1.23 and 25.84 for the oxygenation index, respectively. Also, the average PaO_2/FiO_2 ratio or PF ratio is 229.33, and for SpO_2/FiO_2 or SF ratio is 161.22. The minimum and maximum values for these two indexes were 38.50 and 640 for PF and also 85 and 227.14 for SF, respectively. Results of statistical analysis show that age and gender did not have a significant relationship with either OI or OSI (by $P>0.05$). Also, according to the derivation data set and Berlin definition of ARDS (7), 23% of the studied patient is not in a range of ARDS patients. Also, 34%, 34%, and 9% of all patients are in the range of mild, moderate, and severe ARDS, respectively.

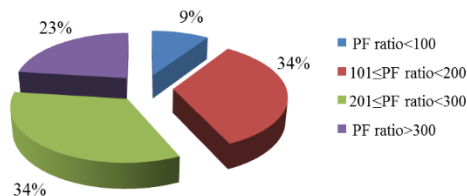


Figure 1. PF ratio and percentage of its range in patients admitted to PICU

Correlation between OI and OSI

Data were collected from 74 children admitted to PICU with or without pulmonary disease within a six months period, from January 1, 2019, to May 31, 2019. PaO_2 values were measured through arterial blood sampling and SpO_2 values measured using pulse oximetry, maximum within one hour after ABG extraction. The values of OI and OSI were calculated for each child and showed a correlation coefficient of 0.726 ($P<0.001$). The scatter plot, with all the observations, is shown in figure 2.

The mathematical relationship between OI and OSI using a linear regression model from the derivation data set represented by the following equation: $OSI=4.844+0.282 \times OI$.

Based on this equation, an OI of 4, which is the lower limit of mild ARDS according to modified Berlin criteria (13), corresponds to an OSI of 5.97. Also, an OI of 8 (lower limit of moderate ARDS (13)) is related to OSI of 7.1. In addition, an OI of 16, which is the lower limit of severe ARDS according to modified Berlin criteria (13), corresponds to an OSI of 9.35.

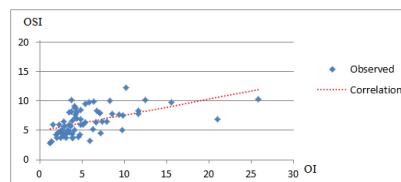


Figure 2. Scatter plot of OI vs. OSI and corresponding linear correlation

Ability to predict OI using OSI

In this study, sensitivity and specificity analysis were performed of the OSI cut-off values correlating with OI values based on the equation $OSI=4.844+0.282 \times OI$ in four groups of patients without acute pulmonary distress syndrome and mild, moderate and severe ARDS with presented in table 4.

As seen from table 4, the OSI cut off of 5.97 for patients without acute pulmonary distress syndrome had sensitivity and specificity of more than 75% for both groups of pulmonary and non-pulmonary patients. In these two groups, while the specificity value of more than 80% was gained for mild ARDS patients, no reliable value was obtained for sensitivity. Also, in the pulmonary patient group, a sensitivity test for patients with acute respiratory distress syndrome in the moderate range (OSI between 7.1 to 9.35) was obtained 100%. Similarly, The specificity of a severe range of ARDS (OSI more than 9.35) was gained 100%. As a result, the present ranges for patients with acute respiratory distress syndrome (ARDS) in moderate and severe ranges have appropriate diagnostic sensitivity and specificity. In non-pulmonary patients, while the specificity values were gained more than 80% for moderate and severe ARDS patients, sensitivity values were not obtained as well as the sensitivity values of pulmonary patients.

Table 4. Sensitivity and specificity of OSI values based on the derived correlation of OI in two groups of pulmonary and non-pulmonary patients

Patient	OI	OSI	Pulmonary Patients		Non-Pulmonary Patients	
			Sensitivity	Specificity	Sensitivity	Specificity
Non-ARDS	$OI < 4$	$OSI < 5.97$	76%	75%	80%	86%
Mild ARDS	$4 \leq OI < 8$	$5.97 \leq OSI < 7.1$	33%	90%	21%	81%
Moderate ARDS	$8 \leq OI < 16$	$7.1 \leq OSI < 9.35$	100%	76%	50%	81%
Severe ARDS	$OI \geq 16$	$OSI \geq 9.35$	87%	100%	50%	83%

Discussion

In previous studies, including Lobate *et al.*, in 2013 (14) and Khemani *et al.*, in 2015 (15), a good correlation between PaO₂ and SpO₂ 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. Major of studies have also been performed on patients with ARDS diagnosed in the neonatal age range. Based on what has been mentioned, this study aimed to evaluate these two indexes on patients admitted to the PICU of Abouzar hospital with the inclusion criteria. In addition, in this study, by dividing the statistical collection into two groups of pulmonary and non-pulmonary patients based on clinical status and chest x-ray, these two indexes were compared in order to determine the appropriateness of this replacement in each of these groups. Based on the results of this study, oxygen saturation index (OSI) and oxygenation index (OI) were significantly correlated in 74 patients studied ($P < 0.001$), which is inconsistent with previous research including Rawat *et al.*, (16) in 2015 and Doreswaamy *et al.*, (17) in 2016 that both of which were performed on infants. In addition, based on the results and comparing the correlation between these two indexes in the two groups of pulmonary and non-pulmonary patients, there was a significant relationship between the two indexes in the two groups ($OSI = 4.844 + 0.282 \times OI$), which, contrary to the initial expectation, had a higher correlation coefficient and more reliable sensitivity and specificity in the group of pulmonary patients compared to the non-pulmonary patients.

This study also faced some limitations. First, the measurement of arterial blood pressure and pulse oximetry in most samples was not exactly at the same time, which is likely to made errors in the results because of the rapid changes in PaO₂ and SpO₂ over this time gap. However, it has been attempted to record a pulse oximeter up to one hour after sampling the oxygen saturation number to reduce the error. Secondly, most of the adjustments recorded in these patients were in the first three days of their admission, that, of course, most of them have high FiO₂ levels, which, as previously mentioned, could affect the results of arterial blood oxygenation. We also had no control and influence on patients' blood acidity, body temperature, hemoglobin, and PcO₂ levels, which could affect the relationship between OI and OSI.

According to the results of this investigation, derived OI from OSI is a reliable non-invasive and readily available marker instead of oxygen saturation measured by arterial blood gas testing, especially for pulmonary patients with moderate and severe ARDS (OI cut-offs of 8 to 16). Further studies are needed to validate and correlate OSI instead of OI in children with pulmonary or non-pulmonary disease in order to determine the prognosis and severity of ARDS.

Acknowledgment

This study was performed by the credit of the approved research project no APRD-9711 in Ahvaz Jundishapur University of Medical Sciences.

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