ORIGINAL ARTICLE

Evaluation of Oxygenation Index Compared With Oxygen Saturation Index Among Neonates Admitted to the NICU

Masoud Zadkarami, Nahid Sadat-Mirdamadi, Amirkamal Hardani, Mohammadreza Mirkarimi, Mohsen Alisamir, Solmaz Heidari, Shahriar Barouti, Shooka Mohammadi

Department of Pediatrics, Faculty of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran

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Abstract- Oxygenation index (OI) based on arterial blood gas (ABG) test is an invasive procedure and requires indwelling arterial lines. However, the oxygen saturation index (OSI) assessed by the pulse oximetry method is simple and noninvasive for monitoring oxygenation saturation in newborn neonates with chronic lung disease. This study aimed to evaluate and compare OI and OSI among neonates in NICU who underwent mechanical ventilation. A cross-sectional study was carried out among fifty neonates (term and preterm) who were admitted to the NICU of Abuzar Hospital in Ahvaz, Iran. All neonates were examined by both ABG and pulse oximetry methods. Approximately 2 cc of arterial blood sample was taken and sent to the laboratory to determine blood gases. At the same time, the level of peripheral capillary oxygen saturation (SpO) was recorded using a pulse oximeter. OI and OSI were calculated according to their formula. Spearman's correlation, linear regression, and Bland-Altman scatter plot were used to determine the correlation, association, and agreement between OI and OSI, respectively. Of the total 50 neonates, 26 were female. The mean (range) gestational age was 35.28±3.01 (28-39) weeks, and post-neonatal age was 6.05±7.04 (1-25) weeks. There was a linear and significant association and correlation between OI and oxygen OSI (*P*<0.001), while the Bland-Altman scatter plot confirmed the agreement between them in mean values. Therefore, OSI utilizing pulse oximetry as a noninvasive method can be a substitute for OI in neonates with respiratory failure. It can also reduce workloads and costs.

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Keywords: Oxygenation index (OI); Oxygen saturation index (OSI); Neonates; Neonatal intensive care unit (NICU); Arterial blood gas (ABG); Pulse oximetry

Introduction

Neonatal mortality rate (NMR) is considered as one of the important indicators that reflects the quality of the healthcare delivery system and the development of the country (1). The global NMR was 18 deaths per 1000 live births in 2017, and it was estimated that without any improvement in neonatal mortality, around 27·8 million neonates would die between 2018 and 2030 (2). It has been reported in a recent meta-analysis that the NMR is around 11.4% in Iran as a developing country (3). The Neonatal Intensive Care Units (NICUs) are the most effective places to reduce a country's newborn mortality. Improvements in perinatal and neonatal care, as well as technology, have significantly decreased neonatal mortality rates (4,5).

Approximately one in 10 newborns need support to commence breathing at birth (6); thus, supplemental oxygen is the most routine therapeutic agent utilized in neonatal care worldwide as a part of respiratory support (5). However, optimal oxygen management remains uncertain (7).

Neonates in the NICU need specific oxygenation and gas exchange monitoring (8). They are at risk for a variety of serious conditions and related complications. Therefore, monitoring of oxygen indicators is essential for them (9,10). For the treating of respiratory insufficiency, the necessity for a good result is a reliable

Corresponding Author: N. Sadat-Mirdamadi
Department of Pediatrics, Faculty of Medicine, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
Tel: +98 6135715794, Fax: +98 6134443051, E-mail address: ns.mirdamadi@yahoo.com

estimation technique for the functional state of the respiratory system, as well as monitoring the special effects of treatment. Neonates with respiratory insufficiency require constant expansion pressure to manage proper functional residual capacity (11).

Several methods for oxygen monitoring are available and several studies compared invasive (e.g., Arterial blood gas (ABG)) and noninvasive methods (e.g., Pulse oximetry ((SpO_2)) (12-14). The ABG has recognized the gold standard, but there is 10-25% failure to place an arterial catheter, and severe complications (e.g., limb ischemia, necrosis) can happen (13,15).

Oxygenation index (OI) based on Arterial blood gas (ABG) test requires indwelling arterial lines (16). It has been used as an indicator in clinical trials and clinical management to initiate treatments (17,18). OI has also been suggested as a predictive marker for neonatal mortality and outcomes (19). However, OI for frequent sampling and intermittent measurement of oxygenation status by nature requires an indwelling arterial catheter, which is an invasive operation.

Pulse oximetry (Spo_2) is a simple and reliable method in the NICU for the constant, noninvasive observation of oxygenation saturation in neonates with chronic lung disease. However, oxygen saturation can be overestimated by pulse oximetry and is imprecise at oxygen saturation levels <70% and in hyperoxia >95% (20,21). The other disadvantages of this method are the movement of artifacts and low perfusion quality relying on the probe site placement (20). Oxygen saturation index (OSI) is measured by pulse oximetry. OSI in the NICU is recognized as a valid and reliable indicator for evaluating the severity of lung damage and respiratory failure (22,23).

Despite the common usage of oxygen supplementation in NICU, insufficient knowledge of neonatal oxygenation (24) and uncertainty about optimal oxygen saturation (24,25) have been stated among neonatal healthcare specialists. Balancing the oxygen requirements of neonates is vital to avoid damage from too much or too little oxygen (26). Besides, to our knowledge, the conducted studies to compare the OI (ABG method) and OSI (pulse oximetry method) indicators are limited (12,27). By considering the invasive nature of ABG compared with pulse oximetry to measure oxygen in these neonates, this study aimed to evaluate and compare OI and OSI among neonates in NICU who underwent mechanical ventilation. We have used indwelling arterial catheters and continuous pulse oximetry monitoring for the subjects. If the two indicators have similar diagnostic efficiency, we will use pulse oximetry as a noninvasive method instead of ABG.

Materials and Methods

A cross-sectional study was carried out among fifty neonates admitted to the NICU of Abuzar Hospital in Ahvaz, Iran, for three months in 2019. All neonates in NICU (term and preterm) requiring invasive mechanical ventilation (SpO_2 level between 85 and 98%) were enrolled in this study. Those with SpO_2 above 98%, congenital heart disease, bronchopulmonary dysplasia (BPD), and hypothermia were excluded from the study.

Demographic data of neonates (e.g., gender, gestational age, and birth weight) and prenatal data were collected from medical records. All neonates were examined by both ABG and pulse oximetry methods. Laboratory results and information related to pulse oximeters were recorded. The ABG sample was taken by the nurses, and the settings for the ventilator were recorded in the nursing sheets. Approximately 2 cc of arterial blood was drawn, labeled, and sent to the laboratory for defining blood gases. At the same time with blood sampling, the level of SpO_2 (peripheral capillary oxygen saturation) was recorded using a pulse oximeter monitor (Masimo set, Alborz B9, Saadat CO-Iran). The SpO_2 assessed by pulse oximetry of the right hand differs from other extremities. Arterial blood gases were measured 30 seconds after post-ductal fixed SpO_2 recording. The average value of SPO_2 was assessed from the right hand after stabilization of the neonate condition. The OI and OSI were calculated using PaO_2 and SpO_2, respectively, during arterial blood sampling.

OI is calculated as $OI=MAP \times FiO_2 \times 100/PaO_2$, where MAP specifies the mean airway pressure and FiO_2 is the fraction of inspired oxygen. OSI replaces PaO_2 with oxygen saturation as measured by pulse oximetry (SpO_2) in the OSI equation and is calculated as $OSI=MAP \times FiO_2 \times 100/SpO_2$ (22,23) where the MAP is the average airway pressure indicates to the mean pressure applied during positive-pressure mechanical ventilation.

Sample size estimation

Based on a previous study (28) and using a power of 88% and an alpha error of 0.05, the sample size was considered 50 neonates.

Primary and secondary outcomes

The primary aim of this study was to compare OI and OSI among neonates in NICU. The secondary objective was confirmation of optimal use of pulse oximetry compared to ABG test and provided solutions to reduce aggressive diagnostic methods among neonates in NICU.

Statistical analysis

All data were analyzed utilizing the Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics comprising the median, interquartile range (IQR), mean, standard deviation (SD), range, and percentage were applied to describe the neonate's demographic information. The normality of the data was assessed by the Shapiro-Wilk test. Comparisons between the two groups were implemented using the Mann–Whitney U test. Spearman's correlation, linear regression, and Bland-Altman scatter plot were used to determine correlation, association, and agreement between OSI and OI, respectively. The $P<0.05$ was considered as the level of significance.

Results

The findings of the study indicated that 50 neonates were involved during the study period, and 26 (52%) neonates were female. The mean (range) gestational age was 35.28±3.01 (28-39) weeks, and post-neonatal age was 6.50±7.04 (1-25) weeks with the mean (SD) birth weight of 2165.90±624.861 g (800-3300 g). The medians (IQR) of OSI and OI in neonates were 8.15 (2.25) and 7.50 (3.4), respectively. There was no significant difference between the median of both OSI and OI based on birth weight, gestational age, hospitalization causes ($P>0.05$). The median OI and OSI indices are presented based on the gender of the neonates in Table 1. The median of OSI and OI was higher in boys than in girls, but this median difference was only significant for OI ($P=0.049$). The reason for admission to the ward for almost 21 (42%) of the subjects was sepsis, for 16 (32%) was respiratory distress syndrome (RDS), while 14% and 12% of subjects had asphyxia and hernia, respectively.

The correlation between OI and OSI with different variables is presented in Table 2. The OI index was not significantly correlated with gestational age, birth weight, pH, and PCO_2 ($P<0.05$) but indicated a significant correlation with other variables ($P<0.001$). However, the OSI was significantly associated with SpO_2 and MAP ($P<0.001$).

Table 1. The Median differences between OI and OSI based on the gender of neonates (n=50)

Variable	Boys	Girls	*P*
OSI	9 (2.85)	7.95(1.19)	0.098
OI	8 (4.53)	7(2.35)	0.049*

Data are reported as the median (IQR); Mann Whitney U test, *Statistical differences ($P<0.05$)

Table 2. Correlation between OSI and OI with other variables in neonates (n=50)

Variables	OI		OSI	
	r	*P*	r	*P*
Gestational age	0.070	0.630	0.254	0.۰75*
Birth weight	-0.092	0.527	-0.012	0.۹32
pH	0.148	0.304	0.215	0.134
PCO_2	0.113	0.434	-0.151	0.296
PO_2	-0.433	0.000**	-0.199	0.165
HCO_3	0.345	0.014*	0.128	0.374
PaO_2	-0.612	0.000**	-0.187	0.195
SpO_2	-0.465	0.000**	-0.319	0.024*
MAP	0.646	0.000**	0.820	0.000**

Values have resulted from Spearman test; OI: Oxygenation index; OSI: Oxygen saturation index; MAP: Mean airway pressure; PaO_2: Oxygen saturation *Significant differences ($P<0.05$); **Significant differences ($P<0.001$)

The results indicated that there is a significant and positive correlation between OI and oxygen OSI among neonates in NICU (r=0.702; $P<0.001$). There was a significant association between OI and OSI in neonates applying linear regression (β=4.92; $P<0.001$). The Bland-Altman scatter plot is shown in Figure 1 for the agreement between OI and OSI in mean values. The mean (SD) of the difference between the OI and OSI was 0.35 (1.50).

The Bland-Altman scatter plot showed agreement between OSI and OI in the average values and the difference between the two indicators for extreme values.

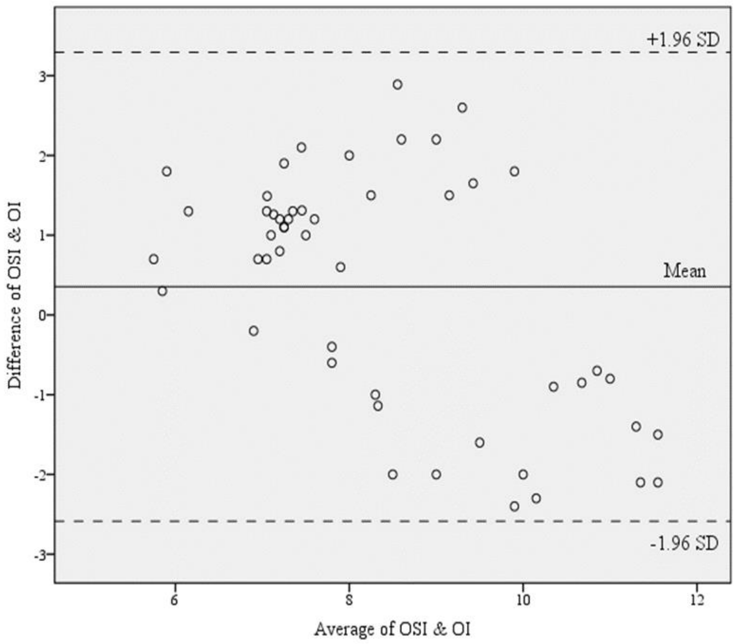

Figure 1. Bland-Altman plot for assessing the agreement between oxygen saturation index (OSI) and oxygenation index (OI)

Discussion

The current study was to evaluate and compare the OI and OSI among neonates in NICU who underwent mechanical ventilation. The results indicated that there was a significant association and correlation between OI and OSI in 50 neonates (term and preterm) (P<0.001). The Bland-Altman plot confirmed the agreement between OSI and OI in average values and identified the differences between the two indicators for extreme values. A similar result was reported in a retrospective cohort study in Bosnia and Herzegovina, which aimed to assess the correlation between OSI and OI among 101 neonates in NICU (term and preterm) with acute respiratory failure (ARF) (11). The findings of that study showed a significant correlation between OSI and OI in infants with respiratory failure (RF) (r=0.76; P<0.0001). Bland-Altman plot confirmed the agreement between OI and OSI in mean values, recognizing the difference between the two indices for extreme values. They concluded that the noninvasive technique of oxygenation assessment using pulse oximetry could be applied to evaluate mortality risk and the severity of ARF in neonates. The study suggested that OSI could be reliable in the medium values for the factor of assessment, while it is not highly reliable for limit values (11).

The findings of the current study also indicated that there was no significant difference between the median of both OSI and OI based on birth weight, gestational age, hospitalization causes. However, the median of OSI and OI was higher in boys than in girls, but these median differences were significant only related to OI.

In a prospective study that was conducted among 51 neonates (preterm and term) in India, OSI showed a high correlation with OI. They concluded that OSI was correlated with OI in neonates with hypoxemic respiratory failure, and it had the potential to be applied in research and clinical management for assessing the severity of lung disease (27), which was in accordance with our findings. A few other retrospective studies have reported a high correlation between OI and OSI in neonates hospitalized in NICU (23,29).

A Cross-sectional study in Iran among 95 preterm neonates in NICU with distress syndrome (RDS) aimed to assess the precision of OSI in defining the severity of RF. The results showed good Kappa agreement between OI and OSI. In addition, OSI with high specificity and sensitivity values could estimate the severity of RF in preterm neonates with RDS. In addition, similar to our study, the mean OSI in boys was higher than in girls, but there were not any significant mean differences (30).

A similar epidemiologic-analytic study in Iran was conducted to compare OSI and OI among 74 intubated patients admitted in the pediatric intensive care unit (PICU) of Abuzar Hospital in Ahvaz. They were divided into the non-pulmonary and pulmonary groups. There was a significant correlation between OSI and OI ($P<0.001$), which had a lower correlation coefficient in non-pulmonary patients than in patients with pulmonary disease. The study reported that the OSI with a specificity of 83% and sensitivity of 78% in patients without acute pulmonary distress syndrome (ARDS) can be used to estimate the status of patients and is a suitable indicator instead of OI (31).

Similar to our findings, a retrospective cohort study in the US aimed to assess the correlation of OSI with OI and develop and validate predictive OI from noninvasive OSI assessments for clinically relevant OI values. It was conducted among 220 neonates (term and preterm) under invasive mechanical ventilation for hypoxic RF. The results showed a strong and significant correlation between OI and OSI. The correlation was stronger in preterm infants and within an oxygen saturation range of 85% to 95%. Derived OI from OSI was in good agreement and intensely predictive of clinically relevant OI cut-offs from five to 25. It was suggested that OSI derived from noninvasive sources might be suitable to reliably measure the severity of RF (12).

Our results indicated that OSI measured by pulse oximetry as a noninvasive method had a linear association and positive correlation with OI. It could also be used instead of OI in neonates hospitalized due to respiratory disease. OI, an invasive measurement, is regularly used as an indicator of the severity of hypoxemic respiratory failure in neonates (32). However, this index based on the ABG method requires painful arterial puncture (16,33). OSI is a noninvasive measurement, and it was suggested as a reliable alternative indicator of OI in adults and children with RF (1). Therefore, noninvasive OSI can be used instead of OI. To the best of our knowledge, the current study is among few prospective studies conducted to compare OSI and OI among neonates in NICU. In addition, the admission of neonates to the NICU was due to different causes. It also examined neonates with a wide range of gestational age (28 to 39 weeks), so it is possible to generalize the results to different respiratory failure conditions.

Limitations

It should be mentioned that this study had an observational study design with a small sample size; it can over-estimate the magnitude of the correlation or may have impact on statistical significance (34). The major limitation of the current study was related to pulse oximetry in which the changes in O_2 saturation levels in PaO_2 more than 60 mmHg are minor. In addition, the change of correlation between PaO_2 and SpO_2 by the type of hemoglobin, temperature, PH, and oxygen dissociation curve may be another limitation of this method. Nevertheless, other factors, such as mode of ventilation, the effect of blood transfusion, hypothermia, 2,3-diphosphoglycerate levels, and use of inhaled nitric oxide, were not considered, which might have impact on our findings. These limitations could have an impact on our compared indices like OI.

The study could evaluate and compare OI and OSI among neonates in NICU with respiratory failure who underwent mechanical ventilation support. It showed that OSI correlated significantly with OI. Due to this close correlation, this study suggests that the noninvasive OSI measured by pulse oximeter can be calculated and used as a substitute for assessment of RF in neonates instead of invasive OI measured by the partial pressure of oxygen through the arterial puncture. OSI has the potential to reduce cost, workload, and invasive procedures. Further studies with a larger sample size with a better design are strongly suggested.

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MZ and NSM conceived and designed the protocol. SM prepared the initial draft of the manuscript and analyzed the data. MZ, NSM, AH, MM, MA, SH, SB, and SM contributed to the manuscript preparation and provided valuable input. All authors critically reviewed the draft of the manuscript and approved the final version.

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