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Research Article

Association of Oxygen Saturation Index with Oxygenation Index in Neonates with Hypoxemic Respiratory Failure

Amlendra Kumar Yadav[1]*, Mohammad Kamrul Hassan Shabuj[2], Tareq Rahman[3], Chit Narayan Sah[1], Ismat Jahan[3], Sadeka Choudhury Moni[4], Sanjoy Kumer Dey[5], Mohammod Shahidullah[6] and MA Mannan[5]

[1]*Neonatologist, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh*
[2]*Associate Professor, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh*
[3]*Assistant Professor, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh*
[4]*Associate Professor, Department of Pediatrics, Mugda Medical College and Hospital, Dhaka, Bangladesh*
[5]*Professor, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh*
[6]*Professor and Chairman, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbagh, Dhaka, Bangladesh*

***Corresponding Author:** Amlendra Kumar Yadav, Neonatologist, Department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka, Bangladesh.

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Abstract

Background: Hypoxemic respiratory failure is a deficiency of oxygenation associated with insufficient ventilation. Oxygenation index describes the severity of this condition. However, it requires invasive and expert hand required for arterial access. Oxygen saturation index is non-invasive and allows continuous monitoring of oxygenation status with pulse oximeter and no expert hand required.

Objectives: To determine the association between oxygenation index (OI) with oxygen saturation index (OSI).

Methodology: This cross-sectional study was conducted from September 2019 to February 2020 at department of Neonatology, Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh.

Results: A total of 103 OI and OSI measurements were calculated from 33 neonates (26 Preterm and 7 Term) with 21.2% appropriate for gestational age and 78.2% low birth weight were recorded during the study. OI and OSI showed a significant correlation (r = 0.69). The predictive derivative equation had a significant linear association between measured OI and derived OI, AUC 0.94 with 94% sensitivity and 81% sensitivity over cutoff value ≥ 5 between measured OI and derived OI. Comparison between the mean of measured OI and derived OI with the difference between measured OI and derived OI showed good agreement with mean value 0.49 and limits of agreement between 6.33 and -5.33.

Conclusion: This study showed a significant correlation of oxygenation index with oxygen saturation index. OSI may be used to assess the severity of hypoxemic respiratory failure in neonates without arterial access.

Keywords: *Oxygenation index; Oxygen Saturation Index; Hypoxemic Respiratory Failure*

Introduction

Hypoxemic respiratory failure (HRF) is the one of the common causes of neonatal admission in NICU. Estimated incidence of neonates with respiratory failure requiring mechanical ventilation is approximately 18 per 1000 live births [1]. Hypoxemic respiratory failure is associated with high risk of mortality, morbidity and Adverse neurodevelopmental outcomes [2]. HRF is a deficiency of oxygenation associated with insufficient ventilation and can occur due to a variety of pathologies [3]. HRF can result when pulmonary vascular resistance (PVR) fails to decrease at birth, leading to persistent pulmonary hypertension of newborn (PPHN), or as a result of various lung disorders including congenital abnormalities such as diaphragmatic hernia and disorders of transition such as respiratory distress syndrome, transient tachypnea of newborn, perinatal asphyxia and cardiogenic pulmonary edema [4]. OI is commonly used to assess the severity of HRF in neonatal intensive care units (NICU). OI is routinely used as an indicator of severity of HRF in neonates, with an arbitrary cutoff 15 or less for mild HRF, between 16 and 25 for moderate HRF, between 26 and 40 for severe HRF, and more than 40 for very severe HRF [5]. Existing clinical practice guidelines and research trials evaluating the use of therapies for HRF have adopted OI to define entry criteria and assess outcome [6]. This index is considered a better indicator of respiratory failure compared to the PaO_2/FiO_2 ratio as it includes mean airway pressure (MAP) - an important determinant of oxygenation [7]. The oxygenation index is calculated by the equation: MAP (in cm H_2O) × FiO_2 ×100/PaO_2 where MAP indicates mean airway pressure and FiO_2 indicates fraction of inspired oxygen.[6] Recent studies have suggested the use of the oxygen saturation index (OSI)[7]. OSI replaces PaO_2 with oxygen saturation as measured by pulse oximetry (SpO_2) in the OI equation and is calculated as OSI = MAP × FIO_2× 100/SpO_2 [8,9]. Oxygenation index has been used to analyze the severity of HRF. The major setback for OI is, it requires invasive and relatively costlier procedure - ABG analysis. Despite, it can provide intermittent index for HRF only. In the other hand, OSI is non-invasive and allows continuous monitoring of oxygenation status with pulse oximeter which is cost effective. The present study had determined the association of OSI with OI in preterm and term neonates having respiratory distress.

Materials and Methods

This cross-sectional study was conducted in the NICU of Bangabandhu Sheikh Mujib Medical University, Dhaka, Bangladesh during July 2019 to March 2020 after clearance from the Institutional Review Board. Participants were enrolled after written consent obtained from parents. Thirty-three neonates of hypoxemic respiratory failure were included in the study by purposive sampling technique. Patients with suspected congenital heart disease and major congenital anomalies were excluded from the study. Maternal history including drug history, antenatal, natal and post-natal history and thorough physical examination were done of each neonate. The details of each ABG - time, source of arterial blood sampling and findings were recorded. Corresponding oxygen saturation (SpO_2) level by pulse oximeter and its site (preductal - right hand and post ductal - foot) was also be recorded. ABG was done as per NICU protocol. Along ABG and pulse oximeter, corresponding surface (axillary) temperature was also recorded. Paired OI and OSI was calculated from PaO_2 and SpO_2, respectively at the time of ABG and recorded.

Data analysis: Data entry and analysis was carried out using the Statistical Package of Social Science Software program, version 20 (SPSS) by International Business Machines Corporation (IBM). Categorical variables were expressed as frequency (number) and percentage. Correlation of OI with OSI was analyzed by Pearson's correlation (r) with a significance level at $p < 0.05$. Receiver operating characteristic (ROC) curve analysis with associated area under the curve (AUC) was conducted to explore the discriminative ability of OSI in predicting severity of HRF with selection of the most suitable cut-off point with the best sensitivity, specificity and overall accuracy was calculated at derived OI more than ≥ 5, 10 and 15.

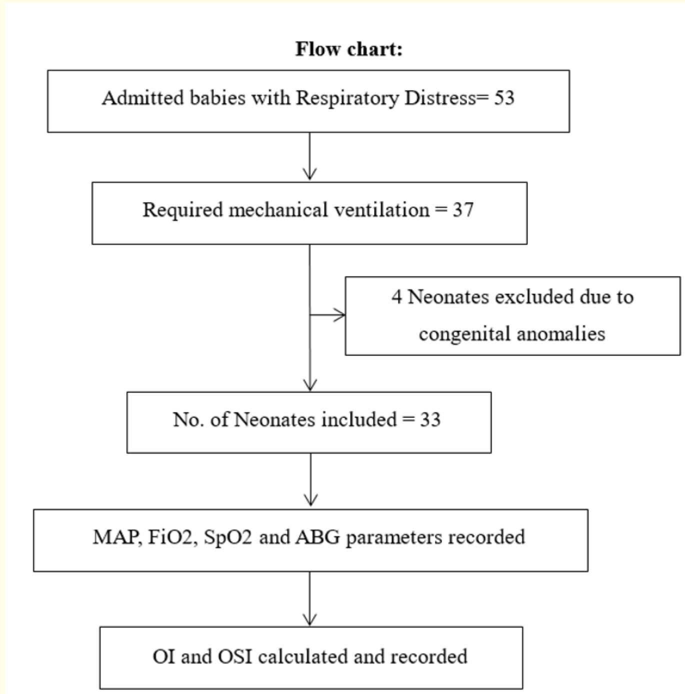

Figure 1: *Head screw size vs frequency of usage.*

Results

A total of 103 OI and OSI measurements were calculated from 33 neonates. Demographic characteristics of the neonates are presented in table 1. Gestational age of neonates between 28 - < 32 weeks was 54.5%, birth weight between 1000 - < 1500 gram was 36.3% and 51.5% was out born neonates. Figure 2 shows the sex variation of the neonates, 51.5 percent was male participants and 48.5 percent was female. Mode of delivery of the participants showed in figure 3. Approximately 94 percent was delivered by LUCS. Correlation between OI and OSI was showed in table 2. With ABG findings, MV setups and SpO_2 values, OI and OSI were calculated at different time intervals of ventilated neonates. Maximum 5 readings were recorded to calculate OI and OSI. Correlation was significant at level of P-value 0.05. Table 3 showing the correlation between OI and OSI of all observed samples. Total of 103 observed samples from 33 ventilated neonates analyzed (r = 0.69). Correlation was significant at level of P-value 0.05. Figure 4 a scatter plot showed correlation of OI and OSI with mean ± SD of all observed neonates. Linear regression equation to calculate derived OI is OI = 1.4* OSI - 0.2. Receiver operating characteristic curve showing the correlation between OI and OSI at cutoff level ≥ 5 in figure 5 (AUC = 0.94). Receiver operating characteristic curve showing the correlation between OI and OSI at cutoff level ≥ 10 in figure 6 (AUC = 0.85). Receiver operating characteristic curve showing the correlation between OI and OSI at cutoff level ≥ 15 in figure 7 (AUC = 0.78). Overall accuracy measured based on derived OI with sensitivity, specificity and area under curve at cutoff level 5, 10 and 15 showed in table 4. Bland-Altman Plot (Figure 8) showing the limit of agreement between the mean of measured OI and derived OI with the difference of measured OI and derived OI. Upper limit of agreement is +1.96*SD, lower limit of agreement is -1.96*SD and mean is 0.49.

Variables	Frequency (%)
Gestational Age	
< 28 weeks	3 (9.1)
28 - < 32 weeks	18 (54.5)
32 - < 37 weeks	5 (15.1)
> 37 weeks	7 (21.2)
Birth Weight	
< 1000g	9 (27.2)
1000 - < 1500g	12(36.3)
1500 - < 2500g	5 (15.2)
2500 - 4000 g	7 (21.2)
Place of Birth	
Inborn	(48.5)
Out born	(51.5)

Table 1: *Demographic characteristics of the participants.*

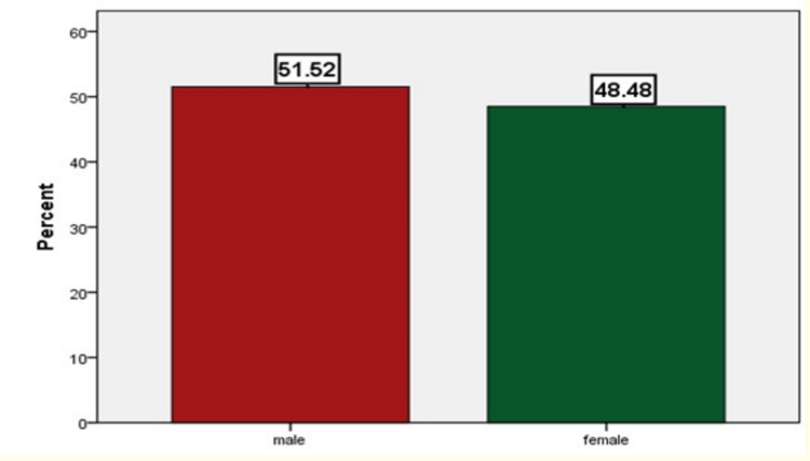

Figure 2: *Sex variation of the participants.*

Measure	No. of sample	Pearson's correlation coefficient (r)	P-value
OI 1 with OSI 1	33	0.628	0.00009
OI 2 with OSI 2	31	0.776	0.0001
OI 3 with OSI 3	24	0.760	0.0001
OI 4 with OSI 4	10	0.886	0.001
OI 5 with OSI 5	5	0.890	0.043

Table 2: *Correlation of OI with OSI.*

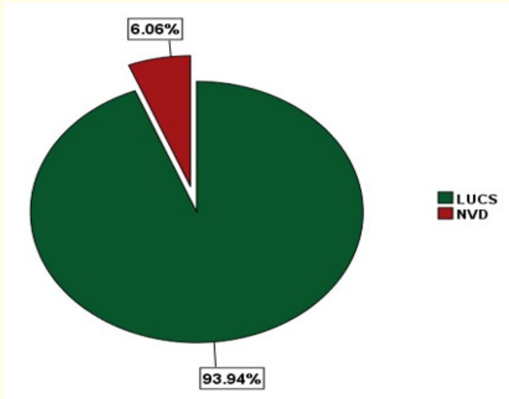

Figure 3: *Mode of delivery of the participants.*

Measure	Number	Mean ± SD	Pearson's correlation coefficient (r)	P-value
OI	103	7.3 ± 4.1	0.69	0.0001
OSI		5.0 ± 2.0		

Table 3: *Correlation between OI and OSI of all observed samples of neonates.*

Note: Correlation is significant at the 0.05 level.

OI: Oxygenation Index; OSI: Oxygen Saturation Index.

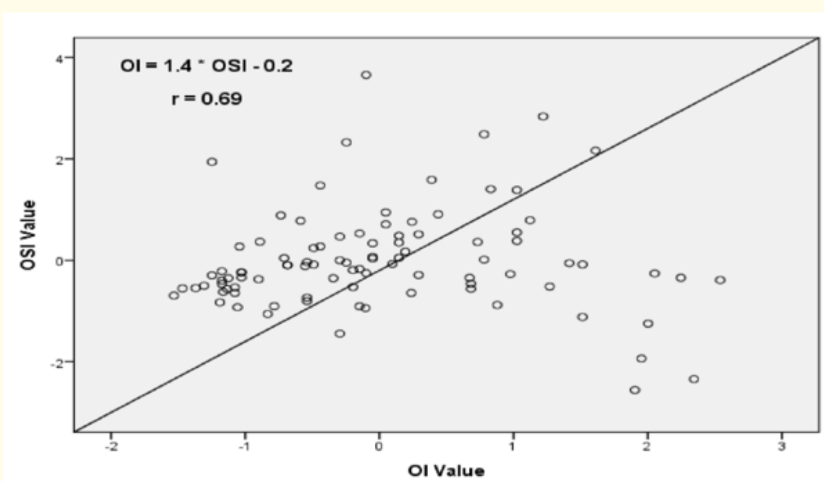

Figure 4: *Scatter plot showing the correlation of OI and OSI.*

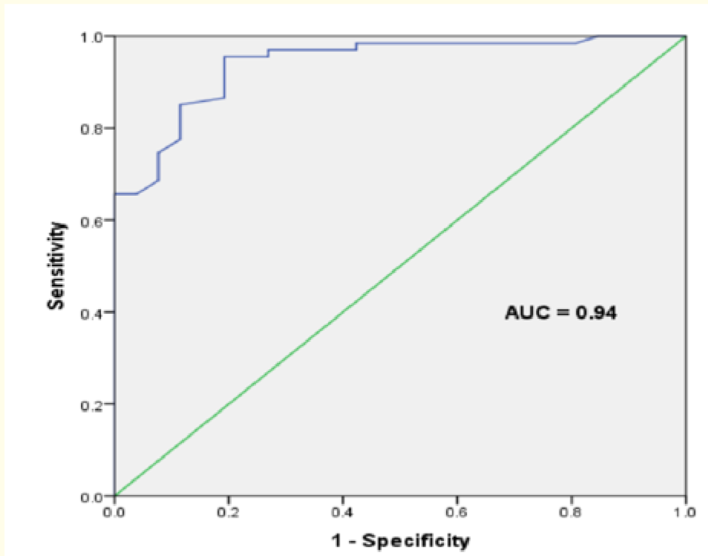

Figure 5: *ROC curve showing the comparison between OI and OSI at cutoff value ≥ 5.*

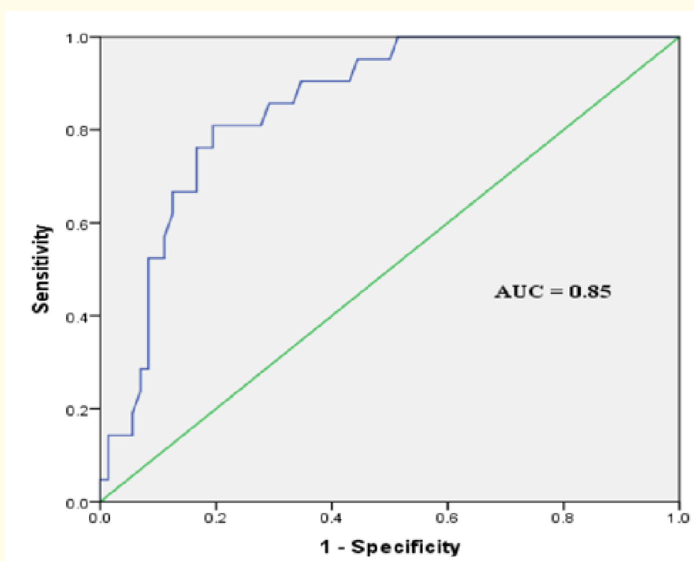

Figure 6: *ROC curve showing the comparison between OI and OSI at cutoff value ≥ 10.*

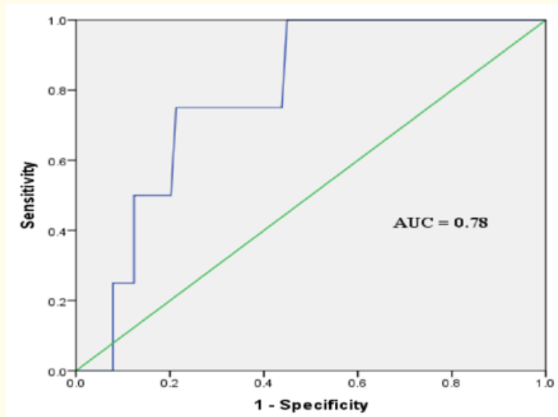

Figure 7: *ROC curve showing the comparison between OI and OSI at cutoff value ≥ 15.*

Note: OSI is derived OI.

ROC: Receiver Operating Characteristics; AUC: Area Under Curve.

Cutoff Value	Sensitivity	Specificity	AUC
OSI ≥ 5	94	81	0.94
OSI ≥ 10	85	70	0.85
OSI ≥ 15	75	78	0.78

Table 4: *Accuracy measured based on derived values of OI.*

Note: OSI is derived OI.

OI: Oxygenation Index; AUC: Area Under ROC Curve.

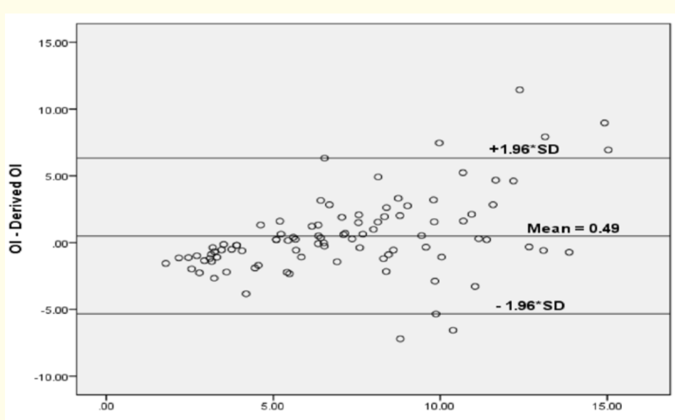

Figure 8: *Bland-Altman plot comparing derived OI and measured OI.*

Discussion

Hypoxic respiratory failure (HRF) is a deficiency of oxygenation associated with insufficient ventilation and can occur due to a variety of lung disorders such as respiratory distress syndrome (RDS), meconium aspiration syndrome (MAS), congenital pneumonia, transient tachypnea of newborn (TTN), perinatal asphyxia (PNA), persistent pulmonary hypertension of newborn (PPHN), and congenital diaphragmatic hernia (CDH). This deficiency can be reflected by progressive respiratory and metabolic acidosis and remains a challenge in the management of neonates. HRF is a clinical problem that occurs in many different settings. Our sample of 33 neonates had heterogeneous groups of gestational age, lung maturity, as well as of the underlying disease processes and postnatal intervention. Several types of dysfunction are mixed in the pathophysiology of HRF which effects on the treatment. The main goal in the treatment of HRF is the best possible oxygenation for all tissues, in order to prevent and avoid hypoxemia. The evaluation of the hypoxic infant is one of the major challenges for the neonatologist. Some recent studies suggest that ventilation with avoidance of hyperoxia and hyperventilation results in good outcomes in neonates with respiratory failure. Respiratory indices such as oxygenation index (OI), mean airway pressure (MAP), FiO_2, PaO_2, arterial oxygen saturation (SaO_2) and PaO2/FiO_2 values have been used mostly in investigating neonates with HRF. The use of the PaO_2/FiO_2 ratio and OI to assess HRF is limited exclusively to the arterial sampling ABG. With the advancements in pulse oximetry in recent years, this noninvasive tool for the measurement of oxygenation has become the fifth vital sign and has likely led to the decrease in arterial blood gas measurements. The results of our study reinforce the value of using noninvasive saturation-based methods of oxygenation assessment, utilizing pulse oximetry as a substitute for PaO_2, can be calculated and used as a substitute for assessment of respiratory failure in neonates. Furthermore, repeated blood draws in the NICU setting contribute to iatrogenic anemia, need for blood transfusions, increased risk of infection and higher cost of care. Aside from decreasing harm, saturation-based measurements are continually available in almost all NICU settings, including relatively resource-poor ones such as developing countries. Our study demonstrates a strong association of OSI, a noninvasive measurement, with OI. Our study had presented a regression equation (OI = 1.4 * OSI - 0.2) for deriving OI from OSI and report discriminative ability of our derived OI to rule in neonates within the OI cutoffs of 5 to 15, with good agreement. In this study we compared OI and OSI and we found linear correlation between OI and OSI with Pearson's correlation coefficient of (r) 0.69 and P< 0.0001. Our study showed a significant correlation, which is consistent with results of Devleta., *et al*. [10], with Pearson's correlation coefficient of (r) 0.76 and P < 0.0001 that also highlight conformity of two indices OI and OSI. Khalesi., *et al*. reports Pearson's correlation coefficient of (r) 0.91 and P < 0.001 between OI and OSI [11]. Another study conducted by Rawat., *et al*. reports linear correlation between mean of OI and OSI with correlation coefficient of 0.952 with P < 0.0001 [6]. In accordance to our findings, Doreswamy., *et al*. pointed to positive association between OI and OSI in determination of the severity of respiratory failure in neonates [12]. In this study we have calculated derived OI with the regression equation OI = 1.4 * OSI - 0.2. We compared derived OI with measured OI with receiver operating characteristics (ROC) curve which showed a strong correlation with area under curve (AUC) 0.94 with sensitivity 94% and specificity 81% over cutoff value ≥ 5, AUC 0.85 with sensitivity 85% and specificity 70% over cutoff ≥ 10 and AUC 0.78 over cutoff ≥ 15. Our study had significant correlation between derived OI and measured OI. Our study result is consistent with the results of Muniraman., *et al*. with AUC 0.88 at cutoff level ≥ 5 with sensitivity 85% and specificity 91% [13]. We also performed Bland-Altman plot analysis to show the comparison between differences of derived OI and measured OI and mean of derived OI and measured OI, our study had good agreement between these two indices and no significant systematic bias with mean value of 0.49 and limit of agreement between 6.33 upper limits and -5.33 lower limits. This result of our study is consistent with the results of Muniraman., *et al*. mean value of 0.1 and limit of agreement between (9.2 to -9.1) [13]. In this study most of the neonates were delivered by LUCS (Figure 3), since BSMMU is a tertiary center of Bangladesh so maximum complicated a critical case referred here from all part of the country. In table 2 of this study, the numbers of ABG samples were decreased further due to various reasons like as some neonates were weaned earlier from mechanical ventilation (9 neonates), in some cases there was difficulty to draw blood samples from arterial line (4 neonates), some neonates were expired during study period (8 neonates) and some neonates discontinue treatment in middle due to bad prognosis (6 neonates). Use of OSI has been increasing in neonatal intensive care unit as a marker for respiratory failure as well as lung injury. We believe our results have clinical relevance, particularly in neonates with difficult arterial access and inability to measure PaO_2 required for OI calculation. Oxygen saturation index (OSI) can be calculated readily and continuously at the bedside, without the need for invasive blood sampling, and may be useful in assessment of oxygenation in neonates with hypoxic respiratory failure. The use of OSI technique instead of OI have several benefits, for example, it is a noninvasive method that let us continuous monitoring instead of intermittent evaluation from blood gas measurement. Also, this technique does not require blood sampling thus reduce risks of infection and anemia. To the best of our knowledge, this study is among the very few studies that searched for predicting value of OSI in determination of oxygenation in mechanically ventilated neonates with HRF [14-22].

Conclusion

This study showed a significant correlation of oxygenation index with oxygen saturation index. Derived OI from oxygen saturation index strongly predictive of clinically relevant OI cutoffs 5 to 15. OI derived from a noninvasive method, such as OSI, may be used to assess the severity of HRF in neonates without arterial access.

Limitation of the Study

Single center study. Arterial blood gases were measured at the clinician's discretion. The effect of blood transfusion, hypothermia and mode of ventilation were not studied which may had an effect on our results.

Recommendation

In patients with hypoxemic respiratory failure, to minimize the invasive arterial access, this noninvasive method of oxygenation assessment with pulse oximeter can be used to access the severity of respiratory failure.

Conflict of Interest

Nil.

Source of Funding

Nil.

Author Contributions

Conceptualization: Amlendra Kumar Yadav, M. A. Mannan, Tareq Rahman, Mohammad Kamrul Hassan Shabuj, Chit Narayan Sah, Ismat Jahan, Sadeka Choudhury Moni, Sanjoy Kumar Dey, Mohammod Shahidullah.

Writing-original draft: M. A. Mannan.

Writing-review and editing: Amlendra Kumar Yadav, M. A. Mannan.

All authors contributed to the final version of the manuscript.

All authors read and approved the final manuscript.

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