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Reliability of Pulse-Oximetry for Oxygen Saturation Monitoring in Sick Neonates

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Abstract **Original Research Article**

Pulse oximetry is a non-invasive continuous method for monitoring oxygen saturation in sick neonates. Its advantages include early detection of hypoxia and less frequent need of blood sampling for blood gas analysis. So, this study was designed to find out the reliability of assessment of oxygenation status by pulse oximeter in sick neonates. In this cross-sectional study, 291 ABG and their corresponding values of oxygen saturation (SpO_2) by pulse oximeter have been analyzed. Linear relations between differences in two successive measurements of SPO_2 and SaO_2, SPO_2 and PaO_2 were analyzed using Pearson correlation coefficient (r) and linear regression tests. Neonates with a mean age 4.5±5.1 days admitted in NICU with different diagnoses over a period of 9 months have been included in the study. SpO_2 in pulse oximeter was ranging from 51% to 100.0% and SaO_2 ranging from 40.4% to 99.7% and PaO_2 ranging from 23.5 mmHg to 118.0 mmHg in ABG of study patients. Linear regression analysis revealed a strong positive correlation between simultaneous pulse oximeter SpO_2 and directly measured SaO_2 values (r=0.865, n = 291, p = 0.000), also simultaneous SpO_2 and PaO_2 (r=.744, n=291, p= 0.000) values. This study concludes that pulse oximetry is a reliable non-invasive procedure for measuring oxygen saturation.

Keywords: Neonate, Oxygen saturation, Pulse oximetry, Partial pressure of oxygen.

INTRODUCTION

Most of the critically ill neonates are supplemented with oxygen. There are adverse effects of hypo and hyperoxemia in neonates due to disease states and too low or too high oxygen administration. So, continuous and precise monitoring of blood oxygenation is vital in the management of sick neonates [1]. Partial pressure of oxygen in arterial blood named as PaO_2, and percentage of oxygen saturation attached to haemoglobin (Hb) named as SaO_2, and when this value is measured with Pulse-Oximeter, called as SpO_2 [2].

Arterial blood gas analysis (ABG) is a reliable way to provide information of oxygenation status to the neonatologist. But problems exist with this procedure as it is an invasive procedure, done intermittently; may miss sudden changes and has complications [3]. Therefore, an alternate non-invasive method in monitoring oxygen status continuously in NICU is needed. Transcutaneous oxygen tension (TcPO2) was widely used but had serious limitations [4], which has been replaced by Pulse oximetry [5].

Pulse oximetry is a non-invasive mean of obtaining information regarding oxygen saturation [6], used in the management of critically ill patients in the intensive care units [7]. Pulse oximetry is the combination of two technologies, plethysmography and spectrometry, that provides non-invasive measurements of pulse rate and haemoglobin saturation respectively. A pulse oximeter measures the functional saturation of haemoglobin, i.e., percent of the oxyhaemoglobin in relation to the sum of oxyhaemoglobin and deoxygenated haemoglobin [8-10]. Pulse oximeter is used to detect hypoxia, to avoid hyperoxia, to reduce the frequency of arterial blood gas analysis, to determine the required fraction of inspiratory O_2 and to wean from mechanical ventilation [7, 11-13]. Advantages of monitoring oxygen saturation by pulse

oximetry over transcutaneous oxygen saturation monitoring and ABG, including no need of repeated blood sampling [12], rapid response time, no risk of skin burn and self-calibrations [10].

Critical care facilities as well as use of electronic gadgets to take care of critically ill neonates are not old enough and are limited in Bangladesh. So, this cross-sectional observational study was designed to assess the reliability of pulse oximetry to monitor oxygenation and to evaluate whether and how SpO_2 correlates with SaO_2 and PaO_2 in a heterogeneous group of critically ill neonates.

MATERIALS AND METHODS

This cross-sectional study was conducted in NICU of Dhaka Shishu (Children) Hospital from April to December 2018. Out of the 343 admitted neonates, 246 neonates with different clinical diagnoses who needed simultaneous blood sampling for ABG and pulse oximetry during their treatment were enrolled during the study period. After enrollment baseline data including gender, weight, gestational age, vital parameters and clinical diagnosis were recorded in a questionnaire.

In each neonate, arterial blood was drawn from radial or brachial artery, by using heparinized butterfly needle and syringe. ABG were analyzed in a standard manner within 10 minutes of sampling by GASTAT-600 blood gas analyzer (Techno Medica Co. Ltd, Japan). Pulse oximetry was done simultaneously by placing a probe use for neonates on the site that gave the best trace, either palm or sole. The Oxcyon II Pulse Oximeter (Infinium Medical, Florida, USA) was used in this study. A trained nurse recorded the pulse oximeter reading and drew the blood for ABG. Data of SpO_2, PaO_2 and SaO_2 were also recorded.

During ICU stay all enrolled neonates were managed according to the primary diagnosis. The neonates were either being supplemented with oxygen or were under mechanical ventilation. As only those neonates who underwent simultaneous blood sampling for ABG analysis and pulse oximetry for their treatment were enrolled, there was no additional cost to bear by parents or no unnecessary blood sampling was done and for that only verbal consent was taken from the parents.

Out of 246 neonates, ABG was done single time from 192 neonates, 2 times from 42 neonates and 3 times from 12 neonates. So, from 246 neonates in total 312 ABG was done. Among 312 ABG, due to abnormal report suggestive of technical error, 21 ABG reports from 10 neonates were discarded. Therefore, finally 291 ABG reports with simultaneous pulse oximetry readings from 236 neonates were analyzed. Data were analyzed by using SPSS version 25. All categorical variables were expressed as percent (%) and continuous variables were expressed as mean±sd. The linear relations between differences in two successive measurements of SpO_2 and SaO_2, SpO_2 and PaO_2 were analyzed using Pearson correlation coefficient (r) and linear regression tests.

RESULTS

Amongst 236 newborns, mean age was 4.5±5.1 days with a range 6 hours to 24 days and 37.3% neonates reached to the hospital within first 24 hours of birth. Male outnumbered the female neonates with a ratio of 1.7:1. Mean gestational age was 34.8±5.3 week and out of them 56.4% were term babies. Mean admission weight was 2417±747 gm and about half (52.5%) of them had normal birth weight (Table-1). The diagnoses of the studied neonates were Perinatal asphyxia (36.4%) followed by Preterm low birth weight (33.5%) and Neonatal sepsis (20.8%) (Table-2).

Out of 291 simultaneous pulse oximeter readings and arterial blood gas analysis, the mean value of SpO_2, SaO_2 and PaO_2 were 84.1±13.1%, 80.7±14.6% and 65.9±20.9 mm of Hg respectively (Table 3). From 291 paired data, the linear regression equation comparing SpO_2 with SaO_2 was $y=21.78+0.771x$ ($r=0.865$, $r^2=0.749$, $p= 0.000$) (Fig-1), which indicates SpO_2 measured by pulse oximeter can estimate actual changes in SaO_2 of arterial blood. Regression analysis was also done between SpO_2 and arterial PaO_2 which revealed SpO_2 has significant positive correlation with PaO_2 ($y=53.47+0.46x$, $r=0.744$, $r^2=0.553$, $p= 0.000$) (Fig-2).

Table-1: Baseline data of the study population (n=236)

Baseline characteristics		N	%
Gender	Male	147	62.3
	Female	89	37.7
Age on admission (day)	≤1	88	37.3
	2-7	100	42.4
	>7	48	20.3
Gestation	Preterm	103	43.6
	Term	133	56.4
Admission weight (gm)	<1500	30	12.7
	1500-<2500	82	34.8
	≥2500	124	52.5

Table-2: Diagnoses of study population (n=236)

Diagnosis	N	%
Perinatal asphyxia	86	36.4
Preterm low birth weight	79	33.5
Neonatal sepsis	49	20.8
Others	22	9.3

Table-3: Simultaneous reading of Pulse oximetry and ABG (n=291)

Variable	Mean ±SD	Range
Pulse oximetry SpO_2 (%)	84.1±13.1	51.0 - 100.0
ABG SaO_2 (%)	80.7±14.6	40.4 - 99.7
ABG PaO_2 (mm of Hg)	65.9±20.9	23.5 - 118.0

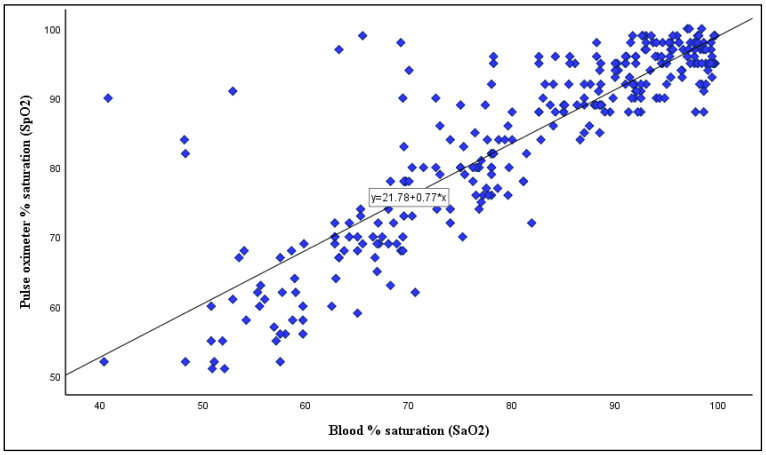

Fig-1: Comparison of pulse oximetry oxygen saturation (SpO_2) with arterial oxygen saturation (SaO_2)

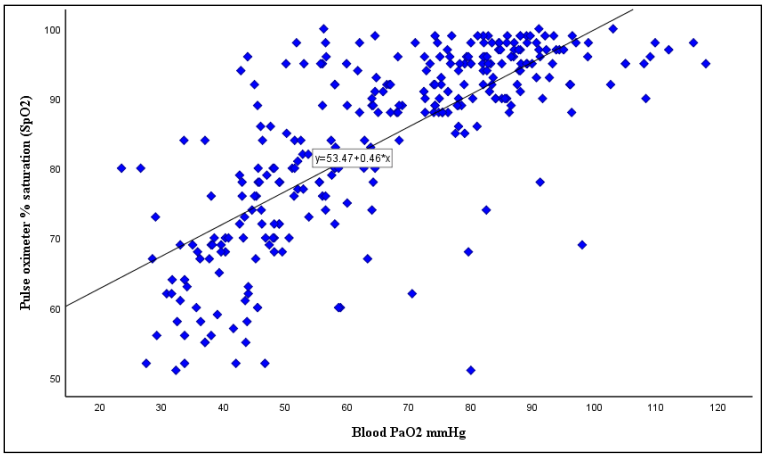

Fig-2: Comparison of pulse oximetry oxygen saturation (SpO_2) with arterial partial pressure of oxygen (PaO_2)

DISCUSSION

Significant improvements in arterial oxygen monitoring have occurred over several decades due to advanced technology and better understanding of pathophysiology of underlying disease conditions. Pulse oximetry is now available in most NICU and routine use of it has led to reduce arterial blood gas measurements significantly [14], thus preventing arterial blood sampling and reduced the cost for ABG analysis.

Because pulse oximetry deals with oxygen saturation of hemoglobin, it is a valuable tool in assessing oxygenation status. Among the equipment of monitoring in NICU, pulse oximeter has proven to be very much effective [15]. This study has evaluated the reliability of pulse oximeter for monitoring of oxygen saturation in neonates. Deckardt and Steward [16] found pulse oximetry to be a reliable method for monitoring of oxygenation in neonates.

Neonatologists have been accustomed to measuring PaO_2 as an index of oxygenation in sick neonates, and safe limits for oxygen tension have been defined. The commonest problem in critically ill neonates is hypoxia. The oxygen content of the blood in

hypoxemic infants is more sensitively expressed in terms of SaO_2 than PaO_2. Thus, in the presence of hypoxemia, SaO_2 is a better index of oxygenation than PaO_2 [17, 18]. Our study population has SaO_2 values of 40.4% to 99.7%, which would be typical in vast majority of infants in a neonatal intensive care unit. Durand and Ramanathan reported that their study population had SaO_2 values of 78% to 100%, which was higher than this study [18].

To find out the reliability of SpO_2 in predicting arterial oxygen saturation (SaO_2), this study compared SpO_2 and SaO_2 from 291 paired data. We found that there was a strong positive correlation (r=0.865) between SpO_2 and SaO_2 which indicates SpO_2 measured by pulse oximeter can estimate actual changes in SaO_2 of arterial blood. So, our findings indicate that pulse oximetry is an efficient and convenient method for evaluating arterial oxygen saturation similar to ABG analysis. Similar findings of reliable correlation between SpO_2 and SaO_2 were reported by Paky F [11], Deckardt and Steward [16], Mok *et al*., [19], Jennis and Peabody [20], Ramanathan *et al.*, [21], Southhall DP [22].

In this study we found SpO_2 was higher than PaO_2 (84.1±13.1% vs. 65.9±20.9 mmHg). Perkins et al also reported that SpO_2 measured by pulse-oximetry was higher than real PaO_2 levels [23]. Wilson *et al.*, found that SpO_2 is not an accurate marker of PaO_2 in patients with sepsis or ill patients who admitted to ICU [24]. In this study all neonates were sick and about 20.8% of them had sepsis. But when Pearson correlation coefficient was computed to assess the relationship between SpO_2 and PaO_2, we found good positive correlation (r=0.744) between SpO_2 and PaO_2. Similarly, Hay et al found considerable reliability of SpO_2 to predict PaO_2 [6].

CONCLUSION

This study found good linear correlation between simultaneous measurements of SpO_2 and SaO_2 to assess arterial oxygen saturation. So, pulse oximetry is a reliable non-invasive device for measuring oxygen saturation and may be an appropriate alternative to assess arterial oxygen saturation where ABG analysis is not possible.

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