IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)
e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 23, Issue 1 Ser.2 (January. 2024), PP 80-87
www.iosrjournals.org

A Comparative Study of Oxygen Saturation Measured by Pulse Oximetry and Arterial Blood Gas Analysis in Neonates with Respiratory Distress in a Tertiary Care Hospital

[1]Dr. Ishrat Jahan, *Assistant Professor, Department of Paediatrics, Ad-din Barrister Rafique-ul-Huq, Hospital, Jurain, Dhaka, Bangladesh.*
[2]Dr. SyedaNafisJubaida, *Assistant Professor, Department of Pediatrics, Central Medical College and Hospital, Cumilla, Bangladesh.*
[3]Dr. Amrin Sultana, *Assistant Professor, Department of Paediatrics, Ad-din Barrister Rafique-ul-Huq, Hospital, Jurain, Dhaka, Bangladesh.*
[4]Dr. Urbasree Devi, *Assistant Professor, Department of Paediatrics, Ad-din Barrister Rafique-ul-Huq Hospital, Dhaka, Bangladesh.*
[5]Dr. Sabrina Akter, *Assistant Professor, Department of Paediatrics, Ad-din Sakina Women's Medical College and Hospital, Jashore, Bangladesh.*
[6]Dr. Md. Towhidul Islam, *Consultant, Department of Orthopaedics, National Institute of Traumatology and Orthopedic Rehabilitation (NITOR), Dhaka, Bangladesh.*
[7]Dr. AHM Saik Rahman, *Assistant Professor, Department of Transfusion Medicine, Ad-din Barrister Rafique-ul-Huq, Hospital, Jurain, Dhaka, Bangladesh.*
Corresponding Author: *Dr. Ishrat Jahan, Assistant Professor, Department of Pediatrics, Ad-din Barrister Rafique-ul-Huq, Hospital, Jurain, Dhaka, Bangladesh. Email: ishrat.cmc@gmail.com*

ABSTRACT
Background:*Respiratory distress is a common problem in neonates necessitating hospital admission. Monitoring of oxygen saturation in case of neonatal respiratory distress is essential. Arterial blood gas (ABG) analysis is the gold standard method for determination of oxygen saturation but is not available in all hospital in our country. On the other hand, pulse oximetry which is noninvasive, portable and inexpensive and it can monitor oxygen saturation at any time at any place.*
Objectives: *The aim of the study was to compare the oxygen saturation measured by pulse oximetry (SpO_2) and arterial blood gas analysis (SaO_2) on neonates with respiratory distress in a tertiary care hospital.****Methods:****This cross-sectional study was conducted on 100 neonates presented with respiratory distress from June 2018 to June 2020 at Dhaka Shishu hospital, Dhaka. Pulse oximetry and arterial blood gas analysis was done at the same time to measure the oxygen saturation of enrolled neonates with respiratory distress. Paired t-test was used to compare SpO_2 with SaO_2. Correlation between two quantitative data was performed using Pearson's correlation. Statistical analyses of the results were be obtained by using window-based Microsoft Excel and Statistical Packages for Social Sciences (SPSS-24).*
Results:*Average gestational ages of the patients were 38 (±1.29) weeks. Fifty-seven percent neonates were males and 43% were females. Mean birth weight was 2.9 kg. Most common diagnosis among the study population was transient tachypnea of the newborn (TTN) (29%). Average oxygen saturation measured by ABG was 92% (±7.8) and by pulse oximetry was 87% (±6.5). This study found significant positive correlation between the result of pulse oximetry oxygen saturation (SpO_2) and arterial oxygen saturation (SaO_2) (r =.883) and also between pulse oximetry oxygen saturation (SpO_2) and partial pressure of oxygen (PO_2) (r =.582).****Conclusion:****This study found significant positive correlation between the oxygen saturation measured by ABG and pulse oximetry. So, pulse oximetry could be a reliable and accurate noninvasive device for measuring oxygen saturation, which because of its rapid response time may be an important advance in monitoring changes in oxygenation and guiding oxygen therapy.*
Key words:*Pulse oximetry, Arterial blood gas analysis, Neonate, Respiratory distress.*

I. INTRODUCTION

Respiratory distress is one of the commonest disorders encountered frequently in newborns. [1] It occurs in approximately 7% of babies during the neonatal period and resulting in significant numbers of term-born infants being admitted to neonatal units. [2, 3] According to the American Academy of Pediatrics, approximately 10% of neonates need some assistance to begin breathing at birth, with up to 1% requiring extensive resuscitation. [4] In fact, neonates with respiratory distress are 2–4 times more likely to die than neonates without respiratory distress. [5] If respiratory distress is prolonged it results in hypoxaemia, hypercarbia and acidosis which ultimately leads to multi system organ dysfunction. [6] So that newborns in respiratory distress must be evaluated promptly, accurately and occasionally it is life-threatening which requires immediate intervention. [7]

Oxygen is the most widely used therapeutic agent in neonatal care. [8] The therapeutic use of oxygen in neonatal period is considered as double-edged sword because of its beneficial and toxic effects. If supplementation of oxygen is inappropriate there is chance of development of either hypoxia or hyperoxia. [9] Hypoxia may lead to pulmonary vasoconstriction, pulmonary hypertension, and neurological and other organ damage. On the other hand, hyperoxia produces free radical mediated cellular damage. A number of diseases in the newborn may occur as consequences of oxygen free radicals e.g. retinopathy of prematurity, bronchopulmonary dysplasia, necrotizing enterocolitis and patent ductus arteriosus etc. [10]

Oxygen saturation is the percentage of haemoglobin molecules bound with oxygen molecules. [11] Oxygen saturation monitors were designed to detect hypoxemia and potential hypoxia. It is important to the newborns receiving supplemental oxygen so to decrease the incidence of exposure to hyperoxemia and the risk of potential deleterious effects of radical oxygen species. [12] During supplementation of oxygen a good monitoring system is required. There are many monitoring systems of oxygen saturation in newborn infants. In our perspective, where facilities are inadequate, a convenient, user friendly but reliable monitoring system is prioritized. [13]

The information provided by blood gas measurements and noninvasive monitoring techniques should allow the clinician to provide information essential to patient assessment, therapeutic decision making, and prognostication. [14] Blood gas measurements are important for ill newborns. In case of neonate there is rapidly changing physiology, difficult access to arterial and mixed venous sampling sites and small blood volumes presents unique challenges. [15] Arterial blood gas analysis and pulse oximetry provide important information about oxygenation. The general goals of oxygen therapy in the neonate are to maintain adequate arterial oxygenation and to minimize cardiac work and the work of breathing. During admission of neonate with respiratory distress blood gas analysis is one of the commonest routine investigations which provide the information of acid-base status and to decide about the need for intervention. [16]

Blood gas analysis is technically difficult to obtain, more painful, more expensive and often an extra needle sticks so its use should be minimal. [17] ABG sample contaminates with bubbles and venous blood. If the sample takes too long to transport, blood cell metabolism changes the gas concentration. The sample is transported to the lab by a pressurized pneumatic system which has the tendency to amplify errors caused by gas bubbles. [18] Storage of blood samples leads to changes in partial pressures of oxygen and carbon dioxide owing to metabolism and diffusion. Samples should be transported on ice. [19]

Pulse oximetry is often attached to a medical monitor so staff can see a patient's oxygenation at all times. Most monitors also display the heart rate. Portable, battery-operated pulse oximeters are also available for home blood-oxygen monitoring. [20] Monitoring of peripheral oxygen saturation (SpO_2) by pulse oximetry can be done either continuously or intermittently (spot check) depending on the clinical status of the patient. [21] Several factors can disrupt the performance of the pulse oximeter such as poor peripheral perfusion, peripheral vasoconstriction, hypotension, low pulse pressure and patient's motion. [22]

II. METHODOLOGY

This cross-sectional study was carried out in the Department ofGeneral Pediatrics, Bangladesh Institute of Child Health (BICH)Dhaka Shishu (Children) HospitalSher-e-Bangla Nagar, Dhaka. This study was conducted on 100 neonates presented with respiratory distress from June 2018 to June 2020 at Dhaka Shishu hospital, Dhaka. Pulse oximetry and arterial blood gas analysis was done at the same time to measure the oxygen saturation of enrolled neonates with respiratory distress. Paired t-test was used to compare SpO_2 with SaO_2. Correlation between two quantitative data was performed using Pearson's correlation. After taking consent and matching eligibility criteria, data were collected from patients on variables of interest using the predesigned structured questionnaire by interview, observation. Statistical analyses of the results were be obtained by using window-based Microsoft Excel and Statistical Packages for Social Sciences (SPSS-24).

III. RESULTS

Table-I: Distribution of neonates by their age of the study subject. (n=100)

Age group (Days)	Frequency	
	Number	Percentage
<3	82	82
3-10	11	11
>10	7	7
Total	100	100
Mean (±SD)	2.67±4.85	

Values are presented as frequency, mean or percentage, SD: Standard Deviation.
Table I shows distribution of the neonates by their age, average age of the patients is 2.67 days, 82% patients were in the age group of < 3 days.

Table II: Gestational age of the study subjects (n=100)

Gestational age (weeks)	Frequency	
	Number	Percentage
35 wks.	1	01
36 wks.	11	11
37 wks.	13	13
38 wks.	29	29
39 wks.	25	25
40 wks.	21	21
Total	100	100
Mean (±SD)	38.29±1.29	

Table II shows average gestational age of cases was 38 weeks.

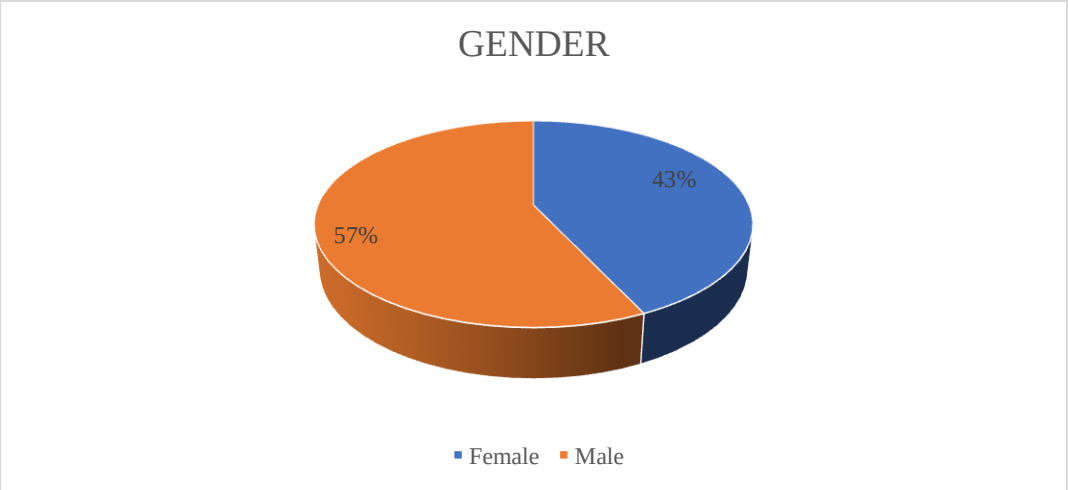

Figure I: Pie diagram showing the distribution of gender in the study subjects.
Figure I show that 57% of the patients were male and 43% female; male female ratio of 1:1.3.

Table III: Clinical measurements of the subjects (n=100).

Variables	Min-Max	Mean±SD
Weight (gm)	2100.0-4100.0	2937.7±374.6
Length (cm)	43.00-52.00	48.5±1.7
OFC (cm)	32.00-35.00	34.1±6.5
Temperature (^{0}F)	97.90-101.00	99.2±0.8
Heart rate (beats/min)	120.00-177.00	153.0±9.1
Respiratory rate (min)	30.00-100.00	75.1±9.7

Table III shows that average body weight was 2937 gm, average length 48.5 cm, and average respiratory rate was 75.1/min.

Table IV: Maternal obstetrical history in the study group. (n=100)

Maternal history	Frequency	
	n	%
Bad obstetrical history	39	39
Antenatal checkup	62	62
Drugs in 1st trimester	2	2
Illness in 1st trimester	6	6
Fever with rashes	2	2
Oedema	2	2
Hypertension	3	3
DM/APH/ other illness	20	20
H/O Prolong labor	25	25
H/O Obstructed labor	8	8
Total	100	100

Table IV shows that 39% mother had bad obstetrical history, 38% mother fail to do antenatal checkup. 20% suffer with gestational DM, APH and other illness and about 25% mother experienced prolong labour.

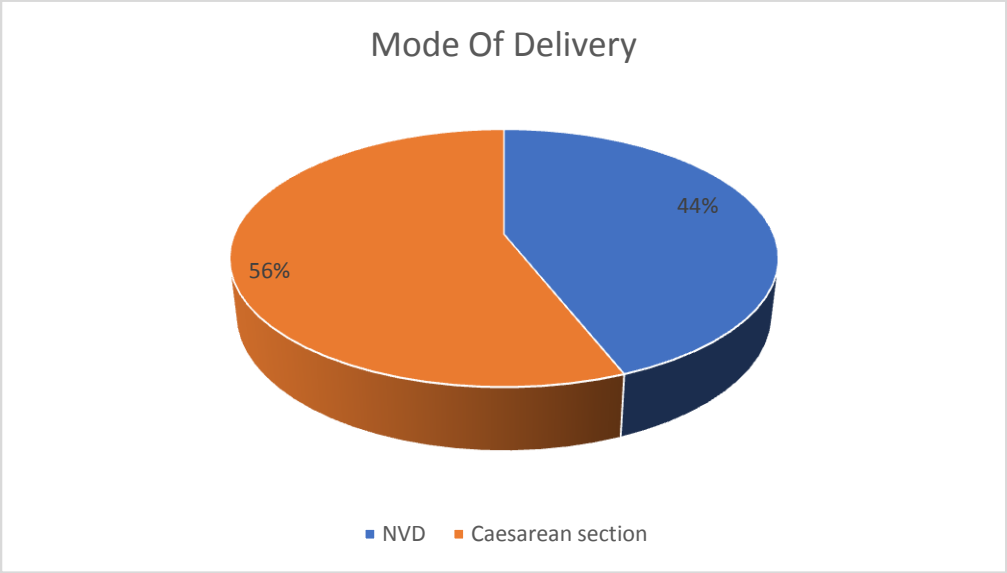

Figure II: Pie diagram showing the distribution of mode of delivery in the study subjects.

Figure II shows 44% mother experienced NVD but 56% case mode of delivery was caesarean section.

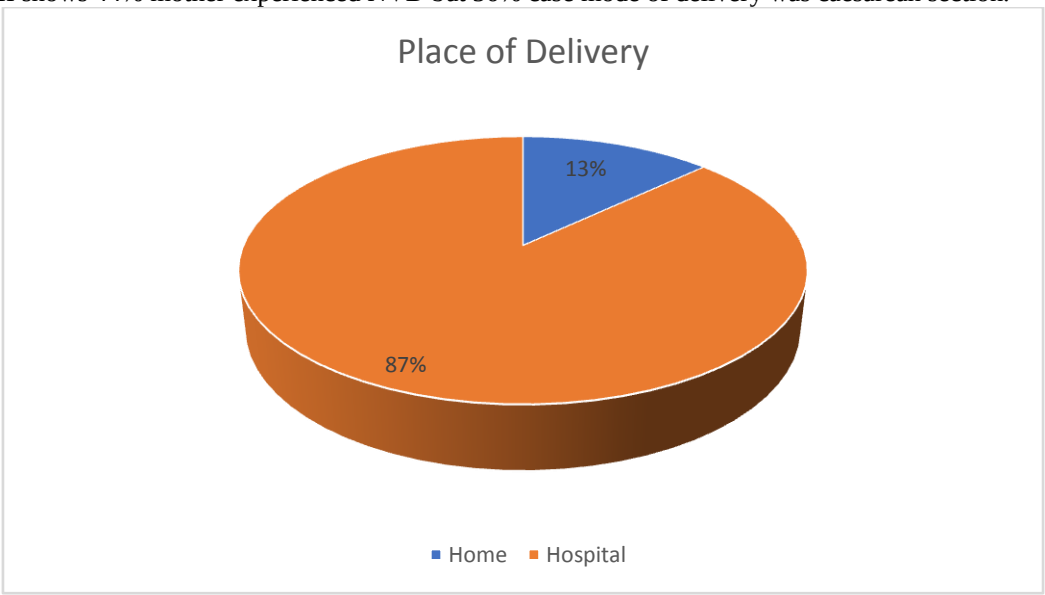

Figure III: Pie diagram showing the place of delivery of the study subjects.

Figure III shows majority of delivery conducted at hospital settings (87%).

Table V: Clinical features of the study subjects (n=100)

Clinical features	Frequency	
	n	%
Respiratory distress	100	100
Apnoea	01	01
Nasal flaring	83	83
Head nodding	34	34
Grunting	38	38
Chest indrawing	96	96
Cyanosis	18	18
Total	100	100

Table V demonstrate that all patient present with respiratory distress among them 83% present with nasal flaring, 96% present with chest indrawing, 34% present with head nodding, 38% present with grunting, 18% were cyanosed.

Table VI: Clinical diagnosis of the study subjects (n=100)

Clinical features	Frequency	
	n	%
TTN	29	29
Birth asphyxia	28	28
MAS	8	8
Neonatal sepsis	20	20
Neonatal pneumonia	10	10
RDS	5	5
Total	**100**	**100**

This table demonstrates that most common diagnosis among the study population was transient tachypnea of the newborn (TTN) which was 29%, followed by birth asphyxia (28%).

Table VII: Descriptive analysis of ABG among the study subjects (n=100)

ABG	Minimum	Maximum	Mean	SD
pH	7.14	7.53	7.34	0.08
PCO_2	10.00	42.80	24.04	8.04
PO_2	37.30	293.00	116.90	52.78
HCO_3	4.40	26.70	15.21	4.42
Base Excess	-19.70	2.50	-8.03	5.11
O_2 Saturation	65.00	99.80	92.85	7.83

Table VII shows arterial blood gas analysis among the study subjects. Average Oxygensaturation was 92% and average PO_2 was 116.90.

Table VIII: Oxygen saturation measured by pulse oximetry (SpO_2) in study subjects (n=100).

Pulse oximetry	Minimum	Maximum	Mean	SD
Oxygen saturation (SpO_2)	60.00	95.00	87.28	6.53

This table shows average oxygen saturation measured by pulse oximetry was 87.28%.

Table IX: Comparison of oxygen saturation measured by ABG and Pulse oximetry.

O_2 saturation	Frequency		Mean±SD	P value
	Number	**Percentage**		
ABG			92.85±7.8	
Normal (>90%)	54	54.0		87.28±6.5
Abnormal (<90%)	46	46.0		
Pulse oximetry			87.28±6.5	
Normal (>90%)	51	51.0		
Abnormal (<90%)	49	49.0		

S=significant, P-value reached from paired t test

Table IX shows 54% of oxygen saturation measured by ABG was normal that mean saturation was more than 90%. In case of pulse oximetry this value is about 51%. On the other hand, 46% of ABG oxygen saturation was found less than 90%.

Table X: Statistical difference between the oxygen saturation measured by ABG and Pulse oximetry.

O_2 saturation	ABG(n=100)	Pulse oximetry (n=100)	P value
Normal	54	51	0.671^{ns}
Abnormal	46	49	
Total	100	100	
Mean±SD	92.85±7.8	87.28±6.5	

P-value reached from Chi-square test, ns= not significant

Table X shows $\chi 2$ test found no significant difference between oxygen saturation measured by ABG and Pulse oximetry (p = 0.671).

Table XI: Relationship between the oxygen saturation measured by ABG and Pulse oximetry.

Correlations			
		Pulse oximetry oxygen saturation (SpO_2)	ABG oxygen saturation (SaO_2)
Pulse oximetry oxygen saturation (SpO_2)	Pearson Correlation	1	$.883^{**}$
	Sig. (2-tailed)		.000
	Number	100	100
ABG oxygen saturation (SaO_2)	Pearson Correlation	$.883^{**}$	1
	Sig. (2-tailed)	.000	
	Number	100	100

Correlation is significant at the 0.01 level (2-tailed)

Table XI demonstrates significant positive correlation between the oxygen saturation measured by ABG and Pulse oximetry.

Table XII: Relationship between pulse oximetry oxygen saturation (SpO_2) and Partial pressure of oxygen (PO_2) in the study subject.

Correlations			
		Pulse oximetry oxygen saturation (SpO_2)	ABG oxygen saturation (SaO_2)
Pulse oximetry oxygen saturation (SpO_2)	Pearson Correlation	1	$.582^{**}$
	Sig. (2-tailed)		.000
	Number	100	100
ABG oxygen saturation (SaO_2)	Pearson Correlation	$.582^{**}$	1
	Sig. (2-tailed)	.000	
	Number	100	100

Correlation is significant at the 0.01 level (2-tailed)

Table XII demonstrates significant positive correlation between SpO_2 and PO_2.

IV. DISCUSSION

Significant improvements in oxygen monitoring system have occurred over the last decade based on both technologic advances and a better understanding of the pathophysiologic characteristics of respiratory distress. Pulse oximetry arterial oxygen saturation (SpO_2) becomes the fifth vital sign in the examination of every newborn and infant with respiratory system presentation. Pulse oximetry is now available in all hospital setting and routine use of it has led to reduce Arterial Blood Gas (ABG) measurements. This study was conducted on 100 neonates presented with respiratory distress admitted to neonatal unit, Dhaka Shishu hospital, Dhaka within the first four weeks of life. The purposes of this study were to compare the oxygen saturation measured by pulse oximetry (SpO_2) and arterial blood gas analysis (SaO_2) on neonates with Respiratory Distress in a Tertiary Care Hospital.

In this study it was observed that mean age of the neonate was 2.7 days that mean 64 hours. A study done in Aga Khan University, Karachi, Pakistan found mean age of the neonate was 70 hours. [1] Results of this study are almost similar to our study. But another study found mean age was 143 hours. [23] One important reason behind this difference might be small sample size (30). In this study mean gestational age at birth was 38.29±1.29 weeks. A study in departments of pediatrics, Cairo University, Egypt found mean gestational age was 35±3.6 weeks, results of this study is similar to our study. [24] Another prospective study done in Afzalipur Medical Centre; Iran found average gestational age was 31 weeks. [25] Possible reason behind this difference might be that their study was done among the preterm infants. There were 57% of neonates were male and 43% were female in our study which states of male predominance.

Regarding the characteristics of the study population, mean body weight was 2937.7 gm. A cross sectional study done in Indonesia found similar body weight that was 2990.0 grams. [23] Average respiratory rate of our study was 75.1/min. A study found respiratory rate was more than 60/min among all study population. [1]

Regarding the maternal history we found 61% mother had no bad obstetrical history. In this study 20% mother suffer with gestational DM, APH and other illness and about 25% mother experienced prolong labour. A study found most of cases were without history of maternal illness which is about 75% while history of Pre-eclampsia was observed in (10%) of neonates with respiratory distress, PROM was (6.3%) and ante partum hemorrhage was (3.7%). [24] As regards the mode of delivery we found that Caesarean section in neonates with respiratory distress were (56%) of cases, compared to normal vaginal delivery (NVD) were (44%) of cases and majority of delivery done in hospital settings which was about 87%. A review article also found predominant mode of delivery was caesarean section. [24]

Regarding the sign symptom of respiratory distress, average respiratory rate in our study was 75/min, while 83% present with nasal flaring, 96% present with chest indrawing, 34% present with head nodding, 38% present with grunting, 18% were cyanosed. A descriptive clinical analysis of 205 patients found respiratory rate was 60/min, while 100% present with nasal flaring, 100% present with chest indrawing, 60% present with grunting, 39% were cyanosed. [1] Possible reason behind this difference might be large sample size (205).

In our study most common diagnosis among the study population was Transient tachypnea of the newborn (TTN) which was about 29% followed by birth asphyxia which was about 28%. A prospective study done in India also found common diagnosis of respiratory distress on term newborn was Transient tachypnea of the newborn (TTN). [26] On the other hand, in Egypt found RDS was the most common diagnosis. [24]

Regarding arterial blood gas analysis among the study population shows the mean pH of neonates included in our study it was (7.34 ± 0.08) with a minimum of (7.14) and a maximum of (7.53). Another study found mean pH of neonates was (7.4 ± 0.1) with a minimum of (7.2) and a maximum of (7.6). [24] This result is almost similar in compare to our study. In our study average arterial oxygen saturation was (92%±7.8).Jose found arterial SaO_2 was (94.4±4.9) which was similar to our study. [27]

In our study found, Average O_2 saturation measured by pulse oximetry was (87.28%±6.5) with a minimum (60%) and a maximum of (95%). A study done in Cairo University; Egypt found mean O_2 saturation measured by pulse oximetry was (90.7%±7.1). Similar results also found in studies by Castillo. [28]

In this study found significant positive correlation between SpO_2 and PO_2. This was also in agreement with the results obtained by Doss et al., (2011) who also found there is relationship between SpO_2 and PO_2. The current study found significant positive correlation between the oxygen saturation measured by ABG and Pulse oximetry. A similar result was reported by Josefound there was good correlation with SpO_2 from pulse oximeters and arterial SaO_2. Kugelman also found relationship SpO_2 and SaO_2.

Limitations of the study

The present study was conducted in a very short period due to time constraints and funding limitations. The small sample size was also a limitation of the present study.

V. CONCLUSION

We conclude that pulse oximetry is a reliable and accurate noninvasive device for measuring oxygen saturation, which because of its rapid response time may be an important advance in monitoring changes in oxygenation and guiding oxygen therapy. Routine use of it has led to reduce arterial blood gas measurement in case of neonatal respiratory distress.

VI. RECOMMENDATION

This study can serve as a pilot to much larger research involving multiple centers that can provide a nationwide picture, validate regression models proposed in this study for future use and emphasize points to ensure better management and adherence.

ACKNOWLEDGEMENTS

The wide range of disciplines involved in compare to compare the oxygen saturation measured by pulse oximetry (SpO_2) and arterial blood gas analysis (SaO_2) on neonates with respiratory distress in a tertiary care hospitalresearch means that editors need much assistance from referees in the evaluation of papers submitted for publication. I would also like to be grateful to my colleagues and family who supported me and offered deep insight into the study.

REFERENCE

[1]. Parkash A, Haider N, Khoso ZA, Shaikh AS. Frequency, causes and outcome of neonates with respiratory distress admitted to Neonatal Intensive Care Unit, National Institute of Child Health, Karachi. J Pak Med Assoc. 2015 Jul 1;65(7):771-5.

[2]. Sweet LR, Keech C, Klein NP, Marshall HS, Tagbo BN, Quine D, Kaur P, Tikhonov I, Nisar MI, Kochhar S, Muñoz FM. Respiratory distress in the neonate: Case definition & guidelines for data collection, analysis, and presentation of maternal immunization safety data. Vaccine. 2017 Dec 12;35(48Part A):6506.

[3]. Hermansen CL, Lorah KN. Respiratory distress in the newborn. American family physician. 2007 Oct 1;76(7):987-94.

[4]. Kattwinkel J, Perlman JM, Aziz K, Colby C, Fairchild K, Gallagher J, Hazinski MF, Halamek LP, Kumar P, Little G, McGowan JE. Part 15: neonatal resuscitation: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation. 2010 Nov 2;122(18_suppl_3): S909-19.

[5]. Swarnkar K, Swarnkar M. Neonatal respiratory distress in early neonatal period and its outcome. Int J Biomed Adv Res. 2015;6(9):643-7.

[6]. Doss WS, Mosallam DS, Ali EA, Moro MM. Pulse Oximetry in Comparison to Arterial Blood Oxygen Saturation in Respiratory Distress in Neonates. Alexandria Journal of Pediatrics. 2011 Jul;25(2):77-83.

[7]. Aly H. Respiratory disorders in the newborn: identification and diagnosis. Pediatrics in Review. 2004 Jun 1;25(6):201-8.

[8]. Sola A, Saldeno YP, Favareto V. Clinical practices in neonatal oxygenation: where have we failed? What can we do? Journal of Perinatology. 2008 May;28(1): S28-34.

[9]. Behera N, Behera JP. Reduction of Inappropriate Use of Oxygen by Standardizing Initiation of Simple Check List among Neonates Admitted in Newborn Care Unit: A Quality Improvement Initiative.

[10]. Das JC. Pulse Oximetry: The Fifth Vital Sign of Neonates. Journal of Bangladesh College of Physicians & Surgeons. 2011 Jul 1;29(3):158.

[11]. Chauhan K, Inamdar P, Thakker M. Pulse Oximeter Using Arduino and Pulse Rate Measurement Device. Advisory Committee.:22.

[12]. Castillo A, Sola A, Baquero H, Neira F, Alvis R, Deulofeut R, Critz A. Pulse oxygen saturation levels and arterial oxygen tension values in newborns receiving oxygen therapy in the neonatal intensive care unit: is 85% to 93% an acceptable range? Pediatrics. 2008 May 1;121(5):882-9.

[13]. Das JC. Pulse Oximetry: The Fifth Vital Sign of Neonates. Journal of Bangladesh College of Physicians & Surgeons. 2011 Jul 1;29(3):158.

[14]. Brouillette RT, Waxman DH. Evaluation of the newborn's blood gas status. Clinical Chemistry. 1997 Jan 1;43(1):215-21.

[15]. Yanda S, Lubis M, Yusroh Y. Comparison of oxygen saturation measured by pulse oximetry and arterial blood gas analysis in neonates. PaediatricaIndonesiana. 2003;43(6):211-5.

[16]. Manzar S. Appropriateness of blood gas analysis in newborns with respiratory distress. Pakistan Journal of Medical Sciences. 2004;20(1):33-5.

[17]. Zeserson E, Goodgame B, Hess JD, Schultz K, Hoon C, Lamb K, Maheshwari V, Johnson S, Papas M, Reed J, Breyer M. Correlation of venous blood gas and pulse oximetry with arterial blood gas in the undifferentiated critically ill patient. Journal of intensive care medicine. 2018 Mar;33(3):176-81.

[18]. Biswas CK, Ramos JM, Agroyannis B, Kerr DN. Blood gas analysis: effect of air bubbles in syringe and delay in estimation. Br Med J (Clin Res Ed). 1982 Mar 27;284(6320):923-7.

[19]. Woolley A, Hickling K. Errors in measuring blood gases in the intensive care unit: effect of delay in estimation. Journal of critical care. 2003 Mar 1;18(1):31-7.

[20]. Chauhan K, Inamdar P, Thakker M. Pulse Oximeter Using Arduino and Pulse Rate Measurement Device. Advisory Committee.:22.

[21]. Bilan N, Behbahan AG, Abdinia B, Mahallei M. Validity of pulse oximetry in detection of hypoxaemia in children: comparison of ear, thumb and toe probe placements. EMHJ-Eastern Mediterranean Health Journal, 16 (2), 218-222, 2010. 2010.

[22]. Tajkia G, Shirin M, Hossain MM, Al Mamun MA. Accuracy of SpO2 measurements by placing probes on newborns' wrist and ankle. Bangladesh Medical Research Council Bulletin. 2019 Dec 30;45(3):191-6.

[23]. Yanda S, Lubis M, Yusroh Y. Comparison of oxygen saturation measured by pulse oximetry and arterial blood gas analysis in neonates. PaediatricaIndonesiana. 2003;43(6):211-5.

[24]. Doss WS, Mosallam DS, Ali EA, Moro MM. Pulse Oximetry in Comparison to Arterial Blood Oxygen Saturation in Respiratory Distress in Neonates. Alexandria Journal of Pediatrics. 2011 Jul;25(2):77-83.

[25]. Niknafs P, Norouzi E, Bijari BB, Baneshi MR. Can we replace arterial blood gas analysis by pulse oximetry in neonates with respiratory distress syndrome, who are treated according to INSURE protocol? Iranian journal of medical sciences. 2015 May;40(3):264

[26]. Swarnkar K, Swarnkar M. Neonatal respiratory distress in early neonatal period and its outcome. Int J Biomed Adv Res. 2015;6(9):643-7.

[27]. Jose B, Lodha R, Kabra SK. Comparison of two new generation pulse oximeters with arterial oxygen saturation in critically ill children. The Indian Journal of Pediatrics. 2014 Dec; 81:1297-301.

[28]. Castillo A, Sola A, Baquero H, Neira F, Alvis R, Deulofeut R, Critz A. Pulse oxygen saturation levels and arterial oxygen tension values in newborns receiving oxygen therapy in the neonatal intensive care unit: is 85% to 93% an acceptable range? Pediatrics. 2008 May 1;121(5):882-9.