Paediatrica Indonesiana

VOLUME 43 November - December • 2003 NUMBER 11-12

Original Article

Comparison of oxygen saturation measured by pulse oximetry and arterial blood gas analysis in neonates

Srie Yanda, MD; Munar Lubis, MD; Yoyoh Yusroh, MD

ABSTRACT

Background Arterial blood gas is usually beneficial to discern the nature of gas exchange disturbances, the effectiveness of compensation, and is required for adequate management. Although PaO_2 is the standard measurement of blood oxygenation, oxygen saturation measured by pulse oximetry ($SapO_2$) is now a customary noninvasive assessment of blood oxygenation in newborn infants.

Objective To compare oxygen saturation measured by pulse oximetry ($SapO_2$) and arterial blood gas (SaO_2), its correlation with other variables, and to predict arterial partial pressure of oxygen (PaO_2) based on $SapO_2$ values.

Methods A cross sectional study was conducted on all neonates admitted to Pediatric Intensive Care Unit (PICU) during February 2001 to May 2002. Neonates were excluded if they had impaired peripheral perfusion and/or congenital heart defects. Paired t-test was used to compare $SapO_2$ with SaO_2. Correlation between two quantitative data was performed using Pearson's correlation. Regression analysis was used to predict PaO_2 based on $SapO_2$ values.

Results Thirty neonates were included in this study. The difference between SaO_2 and $SapO_2$ was significant. There were significant positive correlations between heart rate /pulse rate and TCO_2, HCO_3; respiratory rate and TCO_2, HCO_3, base excess (BE); core temperature and HCO_3, BE; surface temperature and pH, TCO_2, HCO_3, BE; $SapO_2$ and pH, PaO_2; and significant negative correlation between $SapO_2$ and $PaCO_2$; the correlations were weak. The linear regression equation to predict PaO_2 based on $SapO_2$ values was $PaO_2 = -79.828 + 1.912\ SapO_2$.

Conclusion Pulse oximetry could not be used in place of arterial blood gas analysis available for clinical purpose **[Paediatr Indones 2003;43:211-215].**

Keywords: *arterial oxygen saturation, pulse oximetry, arterial blood gas analysis, neonates*

Rapid changes in arterial blood gas values are common in critically ill patients.[1] Arterial blood gas is usually beneficial to discern the nature of gas exchange disturbances, the effectiveness of compensation,[2,3] and is required for adequate management.[4] Blood gas provides information on oxygenation, carbon dioxide homeostasis, and acid-base balance, and therefore is the most important tool utilized in evaluating the adequacy of pulmonary function.[5] Although arterial partial pressure of oxygen (PaO_2) is the standard measurement of blood oxygenation, the oxygen saturation measured by pulse oximetry ($SapO_2$) is now a customary noninvasive assessment of blood oxygenation in newborn infants.[6] Pulse oximetry is a noninvasive and reliable method to detect hypoxemia.[1] Using pulse oximetry, oxygen saturation can easily be monitored continuously at the bedside.[3] Comparison of oxygen saturation by pulse oximetry and arterial blood gas analysis has been reported by several authors.[7-9] They found different values between SaO_2 and $SapO_2$.

From the Department of Child Health, Medical School, University of Sumatera Utara, Medan, Indonesia.

Reprint requests to: Sri Yanda, MD, Department of Child Health, Medical School, University of Sumatera Utara, Medan, Indonesia; Tel. 62-61-8361721, Fax. 62-61-8360255.

The purposes of this study were to compare the oxygen saturation measured by pulse oximetry ($SapO_2$) and arterial blood gas analysis (SaO_2) on neonates in Pediatric Intensive Care Unit (PICU), to find out correlation with other variables, and to predict PaO_2 based on $SapO_2$ values.

Methods

This cross-sectional study was conducted in Pediatric Intensive Care Unit (PICU) Adam Malik Hospital, Medan from February 2001 to May 2002. We included neonates (0 – 28 days of age). Informed consent was obtained from their parents. Neonates were excluded if they had impaired peripheral perfusion and/or congenital heart defects. This study was approved by the ethics committee of the hospital.

We used pulse oximetry (Ohmeda Biox 3740, BOC Health Care, USA) and arterial blood gas analysis (Ciba Corning 280) to measure the oxygen saturation. Pulse oximeter probe was placed on the neonate's thumb or toe to record the oxygen saturation, and at the same time blood sampling was taken from femoral artery to examine arterial blood gas analysis. We also recorded their blood pressure (BP), heart rate (HR), pulse rate (PR), core (Tc) and surface (Ts) temperature, and hemoglobin (Hb) concentration. Identity of the patients were obtained from medical records including their primary diagnosis.

Data were analyzed by means of computer using SPSS for Windows version 10.5. Paired t-test was used to compare $SapO_2$ with SaO_2. The correlations between vital signs and arterial blood gas parameters,

Table 1. Characteristics of the subjects

Characteristics	Mean (SD)	Range
Age (hour)	143.8 (199.40)	2 – 672
Body weight (gram)	2990.0 (641.44)	1700 – 4700
BPs (mmHg)	63.6 (3.58)	58 – 72
HR (bpm)	135.1 (21.61)	102 – 200
PR (bpm)	134.8 (21.85)	102 – 200
RR (bpm)*	51.3 (18.43)	20 – 82
Tr (^{0}C)	36.81 (0.942)	35.0 – 38.5
Ts (^{0}C)	36.56 (0.723)	35.0 – 37.9
Hb (g / dL)	14.52 (3.180)	9.4 – 21.1

* Only in samples with spontaneous breathing (n = 15)
bpm = beat per minute

Table 2. Correlations between vital signs, hemoglobin and arterial blood gas analysis (BGA) parameters and arterial pulse oxygen saturation ($SapO_2$)

BGA & $SapO_2$		Vital signs						
		BPs	HR	PR	RR	Tc	Ts	Hb
PH	r	0.061	-0.055	-0.065	0.285	0.277	0.444*	-0.200
	p	0.749	0.771	0.733	0.126	0.138	0.014	0.290
$PaCO_2$	r	-0.321	0.185	0.191	-0.100	-0.168	-0.234	0.217
	p	0.084	0.328	0.311	0.601	0.376	0.214	0.249
PaO_2	r	0.300	-0.237	-0.228	-0.294	-0.117	0.047	-0.016
	p	0.107	0.208	0.226	0.114	0.536	0.804	0.933
TCO_2	r	-0.306	0.365*	0.362*	0.443*	0.344	0.401*	-0.091
	p	0.100	0.047	0.049	0.014	0.062	0.028	0.633
HCO_3	r	-0.277	0.387*	0.383*	0.480**	0.388*	0.458*	-0.119
	p	0.138	0.035	0.037	0.007	0.034	0.011	0.532
BE	r	-0.117	0.222	0.215	0.466**	0.432*	0.575**	-0.189
	p	0.537	0.237	0.254	0.010	0.017	0.001	0.316
SaO_2	r	0.238	-0.189	-0.192	0.078	-0.103	-0.083	-0.307
	p	0.206	0.318	0.309	0.682	0.588	0.662	0.099
$SapO_2$	r	0.252	-0.205	-0.205	0.067	0.052	0.032	-0.196
	p	0.179	0.277	0.278	0.726	0.787	0.868	0.299

** Correlation is significant at the p = 0.01 (*2-tailed*)
* Correlation is significant at the p = 0.05 (*2-tailed*)

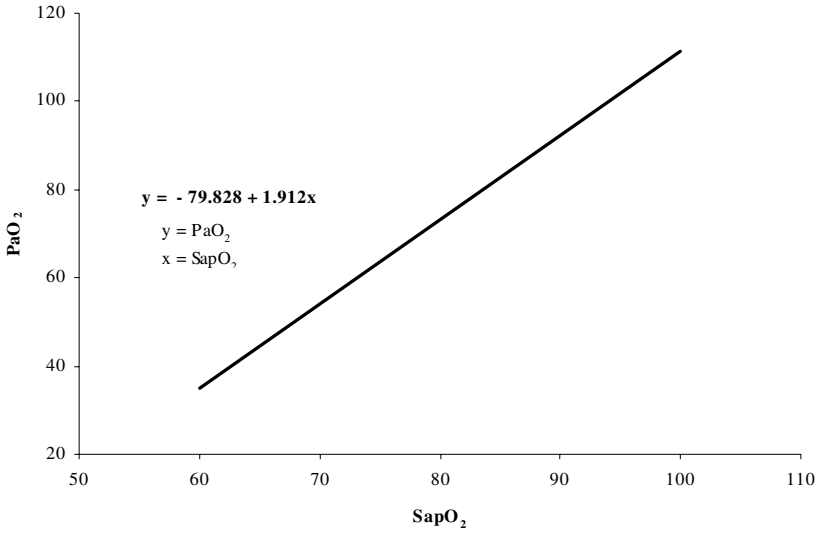

Figure 1. Prediction of arterial partial pressure of oxygen (PaO_2) based on arterial pulse oxygen saturation ($SapO_2$) results

vital signs and $SapO_2$, hemoglobin concentration and arterial blood gas parameters, hemoglobin concentration and $SapO_2$, arterial blood gas parameters and $SapO_2$, were performed using Pearson's correlation. Regression analysis was used to predict PaO_2 based on $SapO_2$ values. To determine the importance of pulse oximetry, we calculated sensitivity, specificity, likelihood ratio for a positive and negative test results, positive predictive value, negative predictive value, accuracy, pre-test probability (prevalence) and pre-test odds with arterial blood gas analysis as the gold standard. The oxygen saturation cut-off point to determine hypoxemia was 90%. A value of $p<0.05$ (2-tailed) was considered as significant.

Results

During the study, 30 neonates were admitted to PICU Adam Malik hospital, consisted of 20 boys and 10 girls. The mean age was 143.8 (SD 199.40) hours and mean of body weight was 2990.0 (641.44) grams (**Table 1**).

We found a significant difference between SaO_2 and $SapO_2$ ($p<0.05$) with the limit of agreement of –7.502% and 11.042%. Pearson's correlation pointed out significant but weak positive correlations between heart rate (HR)/pulse rate (PR) and TCO2, HCO3; respiratory rate (RR) and TCO2, HCO3, BE (base excess); core temperature (Tc) and HCO3, BE; surface temperature (Ts) and pH, TCO2, HCO3, BE. (**Table 2**).

TABLE 3. CORRELATIONS BETWEEN ARTERIAL BLOOD GAS ANALYSIS (BGA) PARAMETERS AND ARTERIAL PULSE OXYGEN SATURATION ($SapO_2$)

BGA	$SapO_2$	
	r	p
pH	0.406*	0.026
$PaCO_2$	-0.446*	0.014
PaO_2	0.403*	0.027
TCO_2	0.135	0.479
HCO_3	0.160	0.399
BE	0.352	0.056

*Correlation is significant at the p = 0.05 (*2-tailed*)

TABLE 4. COMPARISON OF THE OXYGEN SATURATION RESULTS BETWEEN ARTERIAL BLOOD GAS ANALYSIS (SaO_2) AND PULSE OXIMETRY ($SapO_2$).

		SaO_2		Total
		Normal	Abnormal	
$SapO_2$	Normal	18	3	21
	Abnormal	3	6	9
Total		21	9	30

$x^2 = 8.321$, df = 1, p = 0.008, cut-off point: 90%

Arterial pulse oxygen saturation ($SapO_2$) correlated positively with pH (r = 0.41; p<0.05) and PaO_2 (r = 0.40; p<0.05), but $SapO_2$ correlated negatively with $PaCO_2$ (r = -0.45; p<0.05) (**Table 3**).

The linear regression equation to predict PaO_2 (y) based on $SapO_2$ (x) values was y = - 79.828 + 1.912 x (**Figure 1**).

By using cut-off point of 90%, diagnostic test showed that the sensitivity of Ohmeda Biox 3740 pulse oximetry was 85.7%; specificity was 66.7%; positive likelihood ratio was 2.57; negative likelihood ratio was 0.21; positive predictive value was 85.7%; negative predictive value was 66.7%; accuracy was 80.0%; pre-test probability (prevalence) was 70.0%; and pre-test odds was 2.33 (**Table 4**).

Discussion

Fanconi *et al*[7] who evaluated 40 critically ill children with mean age of 3.9 years (range 1 day to 19 years) found the mean difference of SaO_2 (IL 182 co-oximeter, Instrumentation Laboratory, Inc., Lexington, Mass) and $SapO_2$ (Nellcor, Hayward, Calif.) was 1.5% (SD 3.5%; range –7.5% to + 9%).

Southall *et al*[8] reported the mean (SD) absolute difference between $SapO_2$ using Nellcor pulse oximeter and SaO_2 using the blood gas analysis with Corning 178 and Radiometer ABL was 2.6 (2.4) % in 24 infants <5 months and 1.8 (2.1) % in 19 infants and children ≥5 months old.

Russel *et al*[9] who studied 24 hemodynamically stable patients, aged between 1 month and 13 years, (median 1.9 years) found that the difference (SD) between $SapO_2$ and SaO_2 were –0.77 (3.23) for the Nellcor and –2.90 (2.19) for the Biox with blood gas analysis by ABL2 Radiometer, Copenhagen, Denmark with hemoximeter (OSM2 Radiometer).

Rajadurai *et al*[10] reported the mean $SapO_2$ and SaO_2 difference of 1.3% (SD 2.5%; p<0.001) in 22 preterm infants (mean 31 weeks, range 25–36 weeks gestation) between 1 hour and 73 days of age. Oxygen saturation obtained by a Nellcor N-200 pulse oximeter ($SapO_2$) was compared to arterial values (SaO_2) measured by a Radiometer OSM3 Hemoximeter.

Those previous studies determined the correlation between $SapO_2$ and SaO_2 as well as linear regression equation between $SapO_2$ and SaO_2.

In this study, we found a significant difference between SaO_2 and $SapO_2$ (p<0.05) with the limit of agreement of –7.502% and 11.042%. The limits of agreement of –2.0 and 2.8 are small enough for us to be confident that the new method can be used in place of the old for clinical purposes.[11]

We found a different result compared to previous studies. It maybe caused by different samples and the instruments used.

There were significant but weak positive correlations between heart rate (HR)/pulse rate (PR) and TCO_2, HCO_3; respiratory rate (RR) and TCO_2, HCO_3, BE; core temperature (Tc) and HCO_3, BE; surface temperature (Ts) and pH, TCO_2, HCO_3, BE. $SapO_2$ correlated positively to pH (r = 0.41; p<0.05), and PaO_2 (r = 0.40; p<0.05); and negatively to $PaCO_2$ (r = -0.45; p<0.05). Brockway *et al*[6] reported PaO_2 correlated positively to $SapO_2$. Fanconi *et al*[7] also found a good agreement between $SapO_2$ and PaO_2 (r = 0.98).

To predict PaO_2 (y) based on $SapO_2$ (x) values, we found the linear regression equation was y = - 79.828 + 1.912 x. While Brockway *et al*[6] reported that the regression equation with nonlinear mixed effects regression analysis was $PaO_2 = (0.03)\ e^{0.08\ (SapO2)}$ (e = subjects regressions was 32.5).

In conclusion, the mean (SD) difference between SaO_2 and $SapO_2$ was 1.77% (4.636%) with the limit of agreement was –7.502% and 11.042%. There were significant positive correlations between HR/PR and TCO_2, HCO_3; RR and TCO_2, HCO_3, BE; Tc and HCO_3, BE; Ts and pH, TCO_2, HCO_3, BE; $SapO_2$ and pH, PaO_2; and significant negative correlations between $SapO_2$ and $PaCO_2$; but the correlations above were weak. The linear regression equation to predict PaO_2 based on $SapO_2$ values was PaO_2= -79.828 + 1.912 $SapO_2$. It seemed that, pulse oximetry could not be used in place of arterial blood gas analysis available for clinical purpose.

References

1. Haller M, Kilger E, Briegel J, Forst H, Peter K. Continuous intra-arterial blood gas and pH monitoring in critically ill patients with severe respiratory failure: a prospective, criterion standard study. Crit Care Med 1994;22:580-7.

2. Lister G, Fontan JJP. Pediatric critical care. In: Nelson WE, Behrman RE, Kliegman RM, Arvin AM, editors. Nelson textbook of pediatrics. 15th ed. Philadelphia: Saunders; 1996. p. 239-45.
3. Durand DJ, Phillips BL. Blood gases: technical aspects and interpretation. In: Goldsmith JP, Karotkin EH, editors. Assisted ventilation of the neonate. 3rd ed. Philadelphia: Saunders; 1996. p. 257-71.
4. Gomella TC, Cunningham MD, Eyal FG. Neonatology: management, procedures, on-call problems, diseases and drugs. 3rd ed. USA: Appleton & Lange; 1994. p. 43-69, 226-9, 243-4.
5. Burton GG, Hodgkin JE. Respiratory care: a guide to clinical practice. 2nd ed. Philadelphia: Lippincott; 1984. Cited from: Kornhauser MS. Blood gas interpretation. In: Spitzer AR, editor. Intensive care of the fetus and neonate. St. Louis: Mosby; 1996. p. 440-57.
6. Brockway J, Hay WW. Prediction of arterial partial pressure of oxygen with pulse oxygen saturation measurements. J Pediatr 1998;133:63-6.
7. Fanconi S, Doherty P, Edmonds JF, Barker GA, Bohn DJ. Pulse oximetry in pediatric intensive care: comparison with measured saturations and transcutaneous oxygen tension. J Pediatr 1985;107:362-6.
8. Southall DP, Bignall S, Stebbens VA, Alexander JR, Rivers RPA, Lissauer T. Pulse oximeter and transcutaneous arterial oxygen measurements in neonatal and pediatric intensive care. Arch Dis Child 1987;62:882-8.
9. Russell RIR, Helms PJ. Comparative accuracy of pulse oximetry and transcutaneous oxygen in assessing arterial saturation in pediatric intensive care. Crit Care Med 1990;18:725-7.
10. Rajadurai VS, Walker AM, Yu VYH, Oates A. Effect of fetal haemoglobin on the accuracy of pulse oximetry in preterm infants. J Pediatr Child Health 1992;28:43-6.
11. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Available from: URL: http://www.sghms.ac.uk/depts/phs/staff/jmb/ba.htm.