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Original Article

Detection of hypoxemia and hyperoxemia by pulse oximetry in neonates and children

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Abstract

Objective To assess the validity of pulse oximetry for detecting hypoxemia and hyperoxemia in neonates and children.

Methods This was a diagnostic test study conducted in Neonatal Intensive Care Unit (NICU). The subjects of the study were neonates of 0-28 days and children aged one month to 14 years in Pediatric Intensive Care Unit (PICU) of Sardjito Hospital. Hypoxemia and hyperoxemia were obtained by using Nellcor^{R} pulse oximetry, at the same time as blood gas analysis was obtained as a gold standard.

Results There were 240 neonates and 268 children enrolled in this study. Pulse oximetry test with cut-off point 91% (neonates) and 90% (children) for detecting hypoxemia had sensitivity of 81% and 80%, specificity of 79% and 95% positive predictive value of 54% and 82% negative predictive value of 93% and 93% positive likelihood ratio of 3.79 and 14.20 and negative likelihood ratio of 0.25 and 0.24. Pulse oximetry test with cut-off point 95% (neonates) and 97% (children) for detecting hyperoxemia had sensitivity of 78% and 81% specificity of 66% and 79%, positive predictive value of 77% and 76% negative predictive value of 66% and 83% positive likelihood ratio of 2.26 and 3.84 and negative likelihood ratio of 0.34 and 0.24.

Conclusion Pulse oximetry has a fairly good validity in detecting hypoxemia in neonates and children and in detecting hyperoxemia in children to however, it is not good enough to be used to detect hyperoxemia in neonates. **[Paediatr Indones. 2008;48:346-9]**.

Keywords: *blood gas analysis, pulse oximetry, oxygen saturation, hypoxemia, hyperoxemia, diagnostic test*

Hypoxemia is one of the causes that can increase the risk of mortality while hyperoxemia can be toxic leading to a condition that damages tissues. Blood gas analysis (BGA) is the gold standard of examination but since it is invasive, it causes risk and complications due to needle pricks.

Pulse oximetry is a non-invasive tool to measure oxygen saturation and is frequently used to replace BGA examination. It is inaccurate to be used in low saturation because it may give high biases; on the contrary, high saturation will give saturation measurement by pulse oximetry that exceeds from the actual result.[1] The results of the correlation between BGA and pulse oximetry vary with r = 0.4 which compared BGA with pulse oximetry in neonates,[2] while pulse oximetry gives a high correlation result (r = 0.95) in a study by Razi and Akbari.[3] Those illustrated conditions become the background of this study to investigate the diagnostic value of pulse oximetry in assessing oxygen saturation.

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Methods

We conducted a diagnostic test study to investigate the diagnostic value of pulse oximetry with Nellcor^R in detecting hypoxemia and hyperoxemia in neonates and children. Capillary BGA was the gold standard for neonates and arterial BGA was for children.

We recruited consecutively neonates aged 0–28 days admitted to Neonatal Intensive Care Unit (NICU) and children of one month to 14 years old admitted to Pediatrics Intensive Care Unit (PICU) of Dr. Sardjito Hospital in need of BGA examination from April 2006 to June 2007. We excluded patients with shock, hypotension or peripheral vasoconstriction, congenital heart disorder, wound or phlebitis on the skin where probe was put, anemia <5 g/dl, or those who declined to join the study.

Before the study was conducted, the field attendants (residents) were trained on how to use pulse oximetry, place probe, and write note in recording forms. They did not receive any explanation about the definition of hypoxemia or hyperoxemia intended by the investigators. The results were read and noted by other attendants. The neonates and children who needed BGA examination also underwent the assessment of oxygen saturation with pulse oximetry at the same time. Hypoxemia in neonate was defined as PaO_2 capillary was <35 mmHg[4] and in children when PaO_2 from arterial BGA was <60 mmHg.[5] Hyperoxemia was defined as PaO_2 from capillary BGA of >50 mmHg[3] to whereas in children when arterial PaO_2 was >100 mmHg.[7] By using Receiver Operator Curve (ROC), the cut-off point of hypoxemia and hyperoxemia detection to get the best diagnostic was determined.

Results

During the period of April 1st – June 30th 2007, 240 specimens of neonates capillary BGA and 268 specimens of children's arterial BGA were collected. **Table 1** shows the characteristics of the neonate group. Of 240 subjects, 152 (63.3%) were male with mean of age was seven days, and the greatest number of term gestational age (37 - ≤42 weeks) was 126 (58.3%).

Table 1. Characteristics of the neonates

Characteristics	
Sex (n/%)	
Male	152 (63.3)
Female	88 (36.7)
Age, days, mean (range)	7 (0-62)
Gestational age (n/%)	
< 28 weeks	17 (7.1)
28 - < 37 weeks	69 (28.8)
37 – ≤ 42 weeks	140 (58.3)
>42 weeks	14 (5.8)
Pulse rate, per minute, mean (range)	146 (100-213)
Respiratory rate, per min., mean (range)	53 (30-98)
Temperature, °C, mean (range)	37 (36.5-40)
Hemoglobin, g/dl, mean (range)	15.2 (10-21.6)
Diagnosis, n (%)	
Asphyxia	106 (44)
Meconium aspiration syndrome	36 (15)
Pneumonia	37 (15.4)
HMD (hyaline membrane disease)	29 (12.1)
Apnea of prematurity	15 (6.2)
ARDS (acute respiratory distress syndrome)	13 (5.4)
Hydrocephalus	2 (0.8)
Aspiration	2 (0.8)

The characteristics of children group are shown in **Table 2**. Of 268 subjects, 176 (65.7%) were male with mean age of 31.6 months. The most prevalent underlying disease was pneumonia (24.2%).

From hypoxemia prediction variant, saturation of 91% and 92% gave fairly good sensitivity and specificity as the lowest cut-off points in determining

Table 2. Basic characteristics of the children

Characteristics	
Sex, n (%)	
Male	176 (65.7)
Female	92 (33.3)
Age, mo, mean (range)	31.6 (1.5-156)
Heart rate per minute, mean (range)	153 (92-205)
Resp. rate per minute, mean (range)	42 (20-80)
Temperature, °C, mean (range)	37.6 (36.5-40)
Systolic blood pressure, mmHg, mean (range)	113 (80-160)
Diastolic blood pressure, mmHg, mean (range)	66 (40-114)
Mean arterial pressure, mmHg, mean (range)	82 (52-126)
Hemoglobin, g/dl, mean (range)	11 (9-20)
Diagnosis, n (%)	
Pneumonia	58 (24.2)
Bronchial asthma	43 (16)
ARDS (acute resp. distress syndrome)	33 (12.3)
Encephalitis	40 (16.7)
CLD (chronic lung disease)	26 (9.7)
Meningoencephalitis	19 (7.1)
Wheezy infant	15 (5.6)
Intracranial bleeding	14 (5.8)
Bronchiolitis	12 (4.5)
Renal failure	6 (2.3)
Pleural effusion	2 (0.7)

hypoxemia in neonates, and saturation of 95% and 96% gave better sensitivity and specificity as the highest cut-off points in determining hyperoxemia in neonates. The sensitivity and specificity in neonates are shown in **Table 3.**

Table 3. Prediction of hypoxemia and hyperoxemia in neonates*

Lowest cut-off point SpO2 (%)	Sensitivity (%)	95% Confidence Interval (%)	Specificity (%)	95% Confidence Interval (%)
90	70	58 to 82	81	75 to 87
91	81	70 to 91	79	73 to 85
92	84	70 to 91	77	73 to 85
Highest cut-off point SpO2 (%)				
94	64	56 to 72	82	75 to 90
95	78	71 to 95	66	56 to 75
96	82	76 to 88	63	53 to 72
97	88	82 to 93	59	50 to 69

* Capillary BGA was used as reference

In children, saturation of 90% and 91% presented fairly good sensitivity and specificity as the lowest cut-off point in determining hypoxemia, and saturation 97% and 98% exhibited better sensitivity and specificity as the highest cut-off point in determining hyperoxemia. These can be seen in **Table 4.**

Table 4. Prediction of hypoxemia and hyperoxemia in children*

Lowest cut-off point SpO2 (%)	Sensitivity (%)	95% Confidence Interval (%)	Specificity (%)	95% Confidence Interval (%)
89	69	58 to 80	96	93 to 99
90	80	58 to 80	95	93 to 99
91	77	67 to 87	95	91 to 98
Highest cut-off point SpO2 (%)				
96	73	65 to 81	88	82 to 93
97	81	74 to 88	79	72 to 86
98	89	84 to 95	67	59 to 74

* Arterial BGA as gold standard

Discussion

To prevent potential morbidity in infants and children, associated with episodes of chronic hypoxemia and/or hyperoxemia, we studied the validity of pulse oximetry for detecting hypoxemia and hyperoxemia. Theoretically, because of relations between PaO_2 and arterial oxyhaemoglobin saturation (SaO_2) in sick infants and children vary, recalculating the shape of the oxyhemoglobine dissociation curve (OHDC) in each infant and children after a blood gas analysis result we should take into account some of the factors which alter its shape, such as temperature, acid-base state, Hb, fetalHb, MetHb, COHb, amount of CO_2 and 2,3-DPG. The position of the OHDC may move frequently in an individual infant and child because of those factors, for example, some of the infants in the study would have received red cell transfusion. Therefore this may have affected the position of the OHDC by altering the amount of circulating hemoglobin F. Although this theoretically affects the OHDC, it has not been shown to have a major effect clinically, and is unlikely to have affected our results.

The magnitude of sensitivity and specificity to detect hypoxemia and hyperoxemia tended to be lower in neonates in our study. This might be because the gold standard that was used was not from the analysis of arterial blood gas that described the actual level of PaO_2 in blood, but from the analysis of capillary blood gas while it was known that the correlation between artery and capillary varied for PaO2 $r = 0.657$,[11] $r = 0.92$,[2] and $r = 0.65$.[4]

In conclusion, pulse oximetry has a fairly good validity in detecting hypoxemia in neonates and children, and in detecting hyperoxemia in children; however, it is not good enough to be used to detect hyperoxemia in neonates.

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