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Oxygen Saturation Reference Values Using Percutaneous Pulse Oximetry in Apparently Healthy Neonates within the First 24 Hours of Life

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Abstract

Standard reference values for pre- and post-ductal oxygen saturation within the 1st 24 hours of life are essential for comparison and early detection of deviations from the norm. Such data is sparse in Nigeria. We determined the reference values for pre-ductal and post-ductal oxygen saturation by pulse oximetry during the first 24 hours of life in apparently healthy term infants in Makurdi, a city at an altitude of 113 m above sea level in North Central Nigeria. This study was cross-sectional and eligible neonates with birth weights ≥ 1500 g were consecutively enrolled. Pre- and post-ductal pulse oximetry readings were obtained using a Lifebox oximeter®. Four hundred and six neonates (91% normal weight, 6% LBW, and 3% macrosomic) were studied. Although the mean pre- and post-ductal oxygen saturation were found to differ significantly; 97.41% ± 1.52% and 96.66% ± 1.95% respectively (paired sample $t = 8.359$, $p < 0.001$) and these progressively increased with both increases in weight and age in hours although not statistically significant.

Keywords

Oxygen Saturation, Pulse Oximeter, Newborn, Pre-Ductal, Post Ductal

1. Introduction

Oxygen saturation is a measure of the amount of hemoglobin that is bound to oxygen as compared to the unbound hemoglobin. [1] During the transport of oxygen

in the body, hemoglobin is capable of carrying up to 4 molecules of oxygen. It is therefore essential to monitor oxygen saturation especially since there are critical body tissues that are solely dependent on oxygen, and this is frequently done using a pulse oximeter, which is a non-invasive device that measures the ratio of current levels of oxygenated hemoglobin to deoxygenated hemoglobin and reports findings in percentages. [1]

Pulse oximetry is reliable, vital, widely used, and acceptable. [2]-[5] It works on the principle that oxygenated hemoglobin and deoxygenated hemoglobin have different absorbance of red and near-infrared light. In newborns, the monitoring of oxygen saturation takes on more significance due to the transition from the low-resistance fetal circulation to the high-resistance neonatal circulation. This transition is responsible for the time lag it takes to achieve optimum oxygen saturation. [2]-[5]

Previous studies have demonstrated that it takes an average of 10 minutes for newborns to attain a SpO_2 of ≥90%. [6]-[8] In a study to determine reference range of SpO_2 in the first 10 minutes of life among newborns who received no medical intervention in the delivery room, Dawson *et al.* [9] found that SpO_2 values ranged between 29% and 92% and these values corresponded to the 3rd and 97th percentile respectively of newborns studied. The study also revealed that it took a median time of 7.9 minutes for newborns to attain a SpO_2 of >90%. In another study by O'Brien *et al.* [10] that involved long-term recordings of SpO_2 values in 90 newborns within the first 24 hours of life, a median SpO_2 value of 98.3% was found (with a range of 88.7% - 100%). Shiao *et al.* [11] who studied 78 neonates, monitored their oxygen saturation and validated the same with analyses of blood samples of such neonates. They observed that the safety limits for pulse oximeters were higher and narrower in neonates than in adults and recommended that SpO_2 in neonates should be maintained at ≥95%. [11]

Oxygen saturation via the use of a pulse oximeter has also been used as a screening tool for certain childhood diseases. The pre- and post-ductal saturations are both arterial saturations and refer to arterial oxygen saturations in vessels originating from the aorta both before and after the ductus arteriosus. Post-ductal saturations become lower than pre-ductal saturation when there is a mixing of blood through the duct in congenital heart diseases. In a study by Patriciu *et al.* [12] that involved over 5000 infants, pulse oximetry was used to screen for and identify 14 infants with critical congenital heart disease. The study also revealed that pulse oximetry had sensitivity and specificity rates of 87.5% and 95.5% at 1 hour, respectively, as well as 92.5% and 97.4% at 24 hours, respectively, for the diagnosis of congenital heart disease.

Murkeji *et al.* [13] also demonstrated in a study in Canada that pulse oximetry screening of newborns within the first 24 hours of life was a cost-effective means of detecting critical congenital heart defects and in fact, it could potentially detect 51 cases of critical congenital heart defects annually if routine screening is implemented.

To the best of the authors' knowledge, reference values of oxygen saturation in neonates have been obtained mainly from Caucasians; data from African newborns are largely lacking, hence the need to carry out this research.

This study was designed to determine reference values for pre-ductal and post-ductal oxygen saturation by pulse oximetry during the first 24 hours of life in apparently healthy term infants in Makurdi, a city at an altitude of 113 m above sea level in North Central Nigeria. The present study evaluated the differences in pre- and post-ductal oxygen saturation as these are significant in newborn screening for critical congenital heart defects. On the right arm and on any foot, the pre- and post-ductal oxygen saturations respectively were obtained, reflecting oxygen levels from the areas supplied by the right subclavian artery versus the descending aorta.

2. Methods

The study was a cross-sectional study that was conducted over a period of four months in the labour and post-natal wards of Federal Medical Center (FMC), Makurdi, Nigeria. Consecutive apparently healthy newborn babies aged 0 - 24 hours, weighing ≥ 1500 g at birth, and whose parents gave informed consent were recruited. For this study, neonates were adjudged to be apparently healthy if they were not obviously ill at birth, did not require supplemental oxygen after delivery and had APGAR scores of 5 - 10 and 7 - 10 in the 1st and 5th minutes of life respectively. Newborns who required resuscitative measures that included ventilation and oxygenation at delivery, respiratory distress, severe congenital malformations or other signs of illness were excluded from the study and no baby was enrolled more than once during the study.

A sample size of 406 subjects was calculated for this study based on Wayne's formula. [14]

$$n = Z^2 s^2 / B^2$$

where n = the minimum sample size for the study; Z = the standard normal coefficient; s = the standard deviation of SpO_2; B = the desired precision level. Thus, at 95% confidence interval, Z = 1.96.

With s = 3.6 (mean 96.6%) [14]; B = 0.95 (at desired confidence interval of 5%)

$$n = (1.96)^2 (3.6)^2 / (0.95)^2 = 55.2$$

However the sample size was further increased to 406 from the minimum calculated, to take care of attrition, and better represent study population.

Oxygen saturation was recorded (under standardized room temperature with the infant as calm as possible) once within the 24 hours of life using the Lifebox oximeter®, which was developed for low-resource settings by WHO and World Federation of Societies for Anesthesiologists (Acare Technology, New Taipei City, Taiwan region). The pulse oximeter was attached to the right thumb and measurement was recorded when there was a good waveform for ≥15 seconds and SpO_2 remained stable over that period. A post-ductal pulse oximetry reading was obtained

immediately with the sensor applied to the foot on the same subject. Pulse oximetry was carried out under normal temperatures and babies were allowed at least 10 minutes after delivery to undergo post-natal transition before applying probes as there are age-related differences (in minutes) in normal target values of oxygen saturation. [15]

Data was analyzed using the Statistical Package for Social Sciences (SPSS) software, version 22 (IBM, Armonk, NY, USA). Categorical data were described as frequencies and percentages and displayed as pie charts, bar charts and line graphs. Descriptive statistics including mean (standard deviation) were used to summarize data that are continuous and normally distributed. A paired sample t-test was used to compare pre- and post-ductal SpO_2 values while a one-way ANOVA test was used to compare pre- and post-ductal oximetry readings across birthweight and age categories. A p-value < 0.05 was considered statistically significant.

3. Results

Four hundred and six neonates aged 0 - 24 hours of life who met the inclusion criteria with a mean gestational age 39.01 ± 0.39 weeks were enrolled in this study. There were 222 male and 184 female neonates, with M:F ratio of 1.2:1.

Subjects' age and weight categorization are shown in Figure 1 and Figure 2 below.

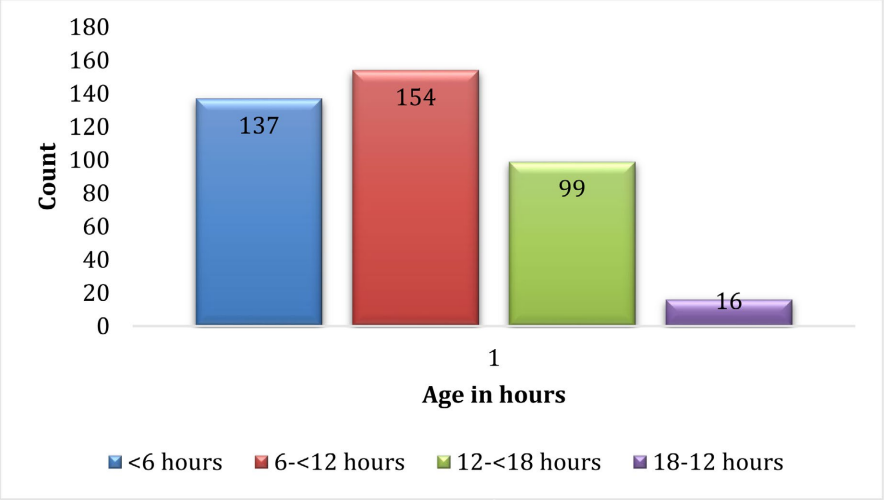

Figure 1. Bar chart showing age distribution of subjects in hours.

Mode of delivery was via SVD in 266 (65.5%) and Caesarean section in 140 (34.5%) of them, with a mean weight at birth of 3.25 ± 0.46 kg. The mean maternal age of subjects was 28.85 ± 5.06 years, and frequency of maternal medical condition is as depicted in Table 1.

Mean pre- and post-ductal oxygen saturation was found to be 97.41% ± 1.52% and 96.66% ± 1.95% respectively (paired sample t = 8.359, p < 0.001), and a comparison of these across weight categories reveals that saturation was highest and lowest in the macrosomic and LBW babies respectively (Figure 3), although this difference was not statistically significant (Table 2).

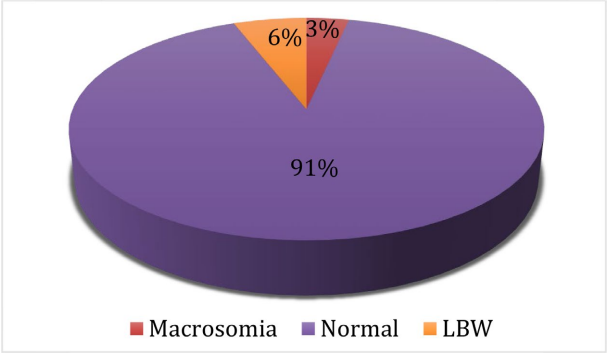

Figure 2. Pie chart showing birth weight distribution of subjects.

Table 1. Table showing frequency of maternal medical condition.

Maternal medical conditions	Frequency (N = 406)	%
None	389	95.8
HTN	4	1.0
DM	3	0.7
HIV	8	2.0
Others	2	0.5

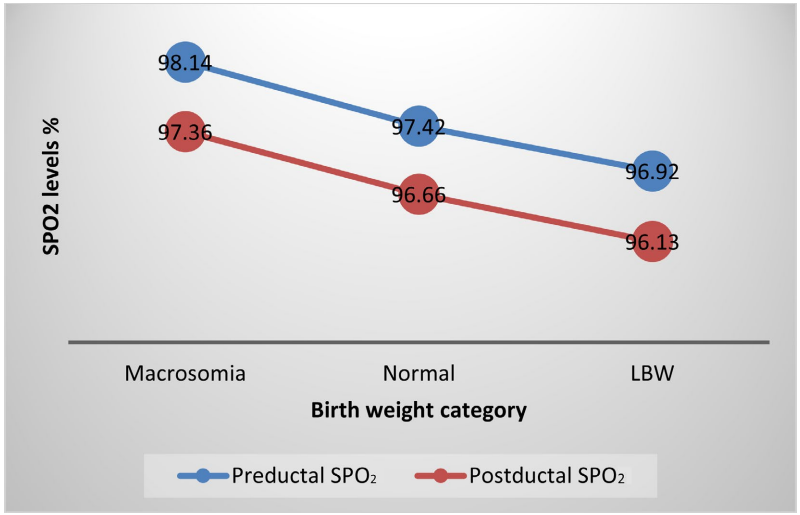

Figure 3. Line graph comparing pre-ductal and post-ductal SpO_2 across birth weight categories.

Table 2. Comparison of pre-ductal and post-ductal SpO_2 across birth weight categories by one-way ANOVA test.

Parameters Mean (SD)	Macrosomia (n = 14)	Normal weight (n = 368)	Low birth weight (n = 24)	p-value
Preductal SpO_2	98.14 (0.95)	97.42 (1.4)	96.92 (2.1)	0.05
Postductal SpO_2	97.36 (1.08)	96.66 (1.95)	96.13 (2.29)	0.17

Differences across groups not statistically significant.

Although pre- and post-ductal oxygen saturation was appreciated with age in hours after delivery (Figure 4), this difference was not statistically significant (Table 3).

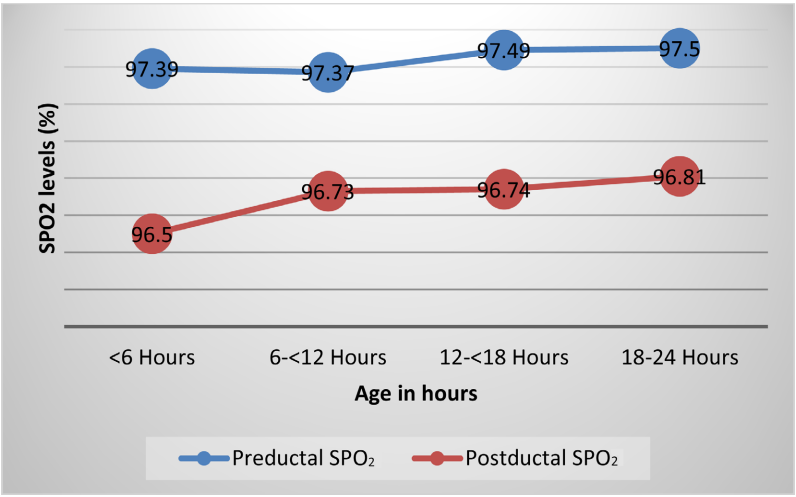

Figure 4. Line graph comparing pre-ductal and post-ductal SpO_2 age categories.

Table 3. Comparison of pre-ductal and post-ductal SpO_2 across age categories by one-way ANOVA test.

Parameters Mean (SD)	<6 (n = 137)	6 - <12 (n = 154)	12 - <18 (n = 99)	18 - 24 (n = 16)	p-value
Pre-ductal SpO_2	97.39 (1.58)	97.37 (1.62)	97.49 (1.3)	97.50 (0.89)	0.92
Post-ductal SpO_2	96.50 (1.89)	96.73 (2.06)	96.74 (1.99)	96.81 (1.22)	0.70

Differences across groups not statistically significant.

4. Discussion

The present study has determined the reference value of SpO_2 for apparently healthy neonates aged 0 - 24 hours of life to be 97.41% ± 1.52%, which represents the mean pre-ductal SpO_2 for study population. Our value is similar to the 97.8% reported by O'Brien *et al.* [10] but higher than the reference value of SpO_2 of 96.1% reported by Ezeanosike *et al.* [16] in Enugu, Nigeria, and 95.9% by Odudu *et al.* [17] in Lagos, Nigeria. The observed difference may be attributable to several factors; Enugu is at a higher altitude above sea level, and at higher altitudes, there is a reduction in atmospheric oxygen tension with a resultant drop in arterial oxygen saturation due to the diminution of barometric pressure at high altitude. [18] As for the Lagos study with a lower oximetry value, significant differences exist, not only in their sample size which is more than 6 times less than ours', but also the difference in subjects' selection as theirs were low birth weight neonates, a subset of our study population that had the lowest pre-ductal SpO_2 values.

We observed that the post-ductal SpO_2 values were consistently lower than the preductal readings, and this observed difference was statistically significant. Our

findings are in tandem with those of other authors who conducted similar studies. [19] [20] It is thought that the higher blood pressure and better perfusion of the upper limbs by the pre-ductal vessels account for the concomitant better oxygenation when compared with the post-ductal supply. [21] However, a difference of >3% between pre- and post-ductal oxygen saturation taken simultaneously should arouse the suspicion of a critical congenital cardiac lesion, and echocardiography will be needed to establish or dismiss such suspicion. The difference in our mean pre- and post-ductal oximetry reading was less than 3%.

Comparing pre- and post-ductal oximetry readings across birth weight categories, we observed that neonates with higher birth weights had higher values of SpO_2. The higher weights may be related to the better development of the alveolar phase of their respiratory embryology. Our low-birth-weight group which had the lowest oximetry reading is similar to the value reported by Odudu *et al.* [17]

The observed physiologic increase in oxygen saturation with increasing age in hours is relevant in choice of optimal time to measure SpO_2 after birth, when screening for critical congenital heart lesions that will be most effective of the time value. Close monitoring of newborns in the first 24 hours of life with pulse oximetry will be a valuable screening tool for cardiopulmonary problems that may arise.

5. Conclusion

We have established the reference value for apparently healthy neonates born in North-Central Nigeria to be 97.41% ± 1.52% and 96.66% ± 1.95% (pre- and post-ductal) respectively within the first 24 hours of their life. We also established values for birth weight categories; hence, when SpO_2 values are compared with our established normative values, lower readings should prompt further evaluations like echocardiography for early detection of congenital cardiac lesions.

Our study is limited by the single-center design and carried out under normal room temperatures; however, we deliberately enrolled more subjects than the calculated minimum sample size to better represent the study population. There was no control for humidity in the labour room. Our study was set out to deliberately exclude ill neonates as we desired to establish normative oximetry values for healthy neonates; hence, while this exclusion might have introduced a bias in study participant selection, this was so to achieve our study aim.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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