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Original Article

Pre- and Post-ductal Oxygen Saturation among Apparently Healthy Low Birth Weight Neonates

Leo A. Odudu, Beatrice N. Ezenwa, Christopher I. Esezobor, Ekanem N. Ekure, Mathias T. C. Egri Okwaji, Chinyere V. Ezeaka, Fidelis O. Njokanma[1], Jejelola Ladele

Department of Paediatrics, Lagos University Teaching Hospital, Idi-Araba, [1]Department of Paediatrics, Lagos State University Teaching Hospital, Ikeja, Lagos, Nigeria

Abstract

Introduction: Reference values of oxygen saturation (SpO_2) to guide care of low birth weight neonates have been obtained mainly from Caucasians. Data from African newborns are lacking. To determine the pre- and post-ductal SpO_2 values of low birth weight neonates within the first 72 h of life, compare SpO_2 values of moderate–late preterm and term low birth weight neonates and determine how mode of delivery affected SpO_2 in the first 24 h of life. **Methodology:** An observational descriptive study was carried out on apparently healthy low birth weight newborns weighing 1500 to ≤2499 g. Pre and post ductal SpO_2 values were recorded at the following hours of life: 10–24 h, >24–48 h and >48–72 h using a NONIN® pulse oximeter. **Results:** The ranges of pre- and post-ductal SpO_2 in the study were similar for both preterm and term neonates in the study (89%–100%). The mean (standard deviation [SD]) pre-ductal SpO_2 was 95.9% (2.3) and the mean (SD) post-ductal SpO_2 was 95.9% (2.1). There was a significant increase in pre-ductal SpO_2 from 10 to 24 h through >48–72 h of life ($P = 0.027$). The mode of delivery did not affect SpO_2 values within 10–24 h of life. **Conclusion:** The present study documented daily single pre- and post-ductal SpO2 values for preterm and term low birth weight neonates weighing 1500 g to <2500 g during the first 72 h of life. The overall range and mean pre- and post-ductal SpO2 were similar for both categories of stable low birth weight neonates in the study. There was no significant difference between SpO_2 ranges for late preterm compared to term low birth weight neonates. The results obtained could serve as guide in assessing SpO_2 of low birth weight neonates weighing between 1500 and 2499 g in the first 72 h of life.

Keywords: Low birth weight newborn, oxygen saturation, pulse oximeter

Introduction

The use of pulse oximetry to monitor oxygen saturation (SpO_2) and judicious delivery of oxygen to low birth weight newborns has become standard practice in neonatology.[1] This is because oxygen therapy, though very useful can also be injurious especially to low birth weight neonates.[1-3] Pulse oximetry is described as the fifth vital sign in neonatal medicine and is now the primary form of monitoring the appropriate level of oxygen supply and blood oxygenation in low birth weight infants.[4] Globally, there is still variation in accepted optimum SpO_2 ranges for different categories of low birth weight neonates;[5] different levels set as alarm limits for hypoxia and hyperoxia.[6] Hypoxia can lead to pulmonary vasoconstriction and pulmonary hypertension, neurologic and other organ damage.[7] While hyperoxia can cause free radical production which may cause cellular and tissue damage as seen in preterm neonates with immature vascularisation, resulting in retinopathy of prematurity.[8]

The sub-committee of the International Liaison Committee on Resuscitation has noted the paucity of information on SpO_2 of healthy term and preterm infants during the first moments of life and has called for more data in making evidence-based recommendations.[9] Taking this cue, several researchers have attempted to determine SpO_2 immediately after birth in the delivery room,[10,11] a few minutes after birth,[12,13] within the 1st day of life,[14,15] at different altitudes[16] in an attempt to define reference ranges for newborns. However, the study populations in these studies have been essentially Caucasians. To the best of our knowledge, there is paucity of studies defining SpO_2 values to serve as reference guides for low birth weight neonates in

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Address for correspondence: Dr. Beatrice N. Ezenwa, Department of Paediatrics, Lagos University Teaching Hospital, Idi-Araba, Lagos, Nigeria.
E-mail: beatriceezenwa@yahoo.com

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Nigeria. Therefore, this study was designed to determine the pre- and post-ductal SpO_2 values of preterm and term low birth weight neonates in the newborn nursery within the first 72 h of life in our environment.

Methodology

The study was a prospective observational study conducted from April 2011 to February 2012 among apparently healthy low birth weight neonates delivered in the labour ward of Lagos University Teaching Hospital (LUTH), Lagos Nigeria. Ethical clearance for the study was obtained from the Health Research and Ethics committee of the Lagos University Teaching Hospital with ethics approval number ADM/DCST/221 given on the 9th of March 2010. Informed consent was obtained from the parents at the point of recruitment of infant.

All apparently healthy low birth weight infants delivered at LUTH were recruited into the study. Neonates were adjudged to be apparently healthy if they were not 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 min of life respectively. Neonates weighing between 1500 g and 2499 g were recruited on admission into either the newborn special baby care unit or the lying in ward within the first 24 h of life. The protocol in the hospital is that stable low birth weight neonates above 2 kg were usually admitted for 72 h with their mothers in the lying in ward. Stable neonates admitted to the special care baby unit on account of low birth weight are discharged from the newborn unit after attaining a weight of at least 1.7 kg and having ensured that mother or caregiver can cope with care at home and were booked for twice-weekly follow-up visits. Excluded were babies with gross congenital malformations, sick neonates, severe birth asphyxia, severe anaemia requiring transfusion,[17] severe jaundice, hypothermia (temperature < 36.5°C)[18] and haemodynamically significant patent ductus arteriosus.

A calculated minimum sample size of 60 participants was required for the study based on the formula by Wayne.[19]

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

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

s = 3.6 (mean 96.6%)[20]

B = 0.95 (at desired confidence interval of 5%)

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

n = 55.173 (attrition factor of 10% was assumed and rounded up to the sample size of 60).

Study procedure

Birth weight was measured by the attendant midwife using the Ultrascale MBSC-55® (Ply weigh USA), measuring to the nearest 2 g. The newborn is placed nude in the weighing scale and the weight read off. The scale was standardised every 2 days by one of the researchers using known standard weights. The weight obtained is cross-checked against the Olowe[21] intrauterine growth reference standard to classify the newborn into appropriate for gestational age, small for gestational age or large for gestational age. The crown-heel length was obtained by the principal researcher and a trained assistant using the *infa-length*® Olympic Surgical Company INC, Seattle USA). With the infant nude and placed on the tray, the head was held straight so that the ear-eye plane was vertical. Firm but gentle pressure was applied by the assistant at the infant's knees. With the infant's head touching the headboard at the zero mark, the sliding foot piece was moved to obtain firm contact with the heels and the length read off a dial built into the tray to the nearest 0.1 cm.

Gestational age was determined using the last menstrual period of the mother if known, or the Ballard score.[22] Other relevant medical data such as mode of delivery were obtained from the mother's obstetric records. SpO_2 was measured by the principal researcher using NONIN® model 2500A PalmSat pulse oximeter with alarm.[23] A neonatal flexor sensor model 8001J was attached to the NONIN pulse oximeter. To obtain pre-ductal SpO_2, with the neonate lying supine and calm, the flexiform sensor was applied from across the palm of the right hand from the ulnar side just below the fingers. For post-ductal SpO_2, the sensor was applied from the outstep of the left lower limb directly under the toes.[2] Saturation readings were recorded only when the heart rate (by auscultation) equals the heart rate recording of the oximeter for at least 20 s.[24] Single reading[25] was taken at three separate time intervals in the first 72 h of life: 10–24 h; 24–48 h and 48–72 h of life. Readings were not taken till after the 10th h of life to ensure the babies were stable in the nursery and to allow any manifestation of instability that may exclude a neonate from the study. Unstable and desaturating babies were excluded from the study and managed according to unit protocols.

Data obtained were entered into Microsoft Excel software and analysed using SPSS version 17.0.[26] Categorical variables were summarised as frequencies while continuous data were presented either as mean (standard deviation [SD]) or median (interquartile range) as appropriate. Bivariate analysis was done to determine the association between the outcome variable SpO_2 and independent variables such as birth weight and mode of delivery. Student's *t*-test was used to compare means of continuous variables; $P < 0.05$ was considered statistically significant.

Results

A total of 75 neonates weighing between 1,500 g and ≤2499 g were delivered in the labour ward of the hospital within the

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study period (April 2011 to February 2012). Sixty neonates that met the inclusion criteria were recruited and studied. Table 1 shows the mean (SD) and the range of gestational age, birth weight and birth length of the neonates. Table 2 shows the frequency distribution of the neonates according to gestational age, sex, mode of delivery and appropriateness of weight for gestational age details. There were 26 males and 34 females giving a male to female ratio of 1:1.3. The preterm to term neonate ratio was 2.3:1. Twenty-eight out of the thirty-two surgical deliveries were emergency sections with the most common indications being pregnancy-induced hypertension and antepartum haemorrhage.

The range and mean (SD) of pre-ductal SpO_2 values throughout the study were 89%–100% and 95.9 (2.3), respectively, while the post-ductal SpO_2 values were 89%–100% and 95.9% (2.1), respectively. Table 3 shows the pattern of SpO_2 readings in the first 72 h of life. Only two neonates had pre-ductal SpO_2 values below 90% within the first 10–24 h of life, while two neonates had post-ductal values below 90% within 10–24 h of life. By 24–48 h of life, only one neonate had post-ductal SpO_2 < 90%, while 45 babies had pre-ductal SpO_2 above 94% and 44 babies had post-ductal values above 94%. The number of neonates who had pre- and post-ductal SpO_2 between 95%–100% at >48–72 h of life were 48 and 46, respectively. Table 4 shows the mean (SD) of pre- and post-ductal SpO_2 values at specified time intervals. There was a steady increase in mean pre-ductal SpO_2 over the study period. This increase was statistically significant (**$F = 3.70$, $P = 0.027$**). This trend was not observed in the mean post-ductal values as after an increase at >24–48 h of life, a reduction was noticed at >48–72 h of life. There was no consistent pattern of relationship between mean pre- and post-ductal saturation. At 10–24 h of life, the mean values for both pre- and post-ductal SpO_2 values were equal; the post-ductal mean was higher at >24–48 h of life while pre-ductal was higher at >48–72 h of life. None of these differences were statistically significant.

Table 1: Baseline characteristics of the study subjects

Characteristic	Mean (SD)	Range
Gestational age (weeks)	34.9 (2.6)	30-40
Birth weight (g)	1992.8 (310.1)	1500-2490
Birth length (cm)	43.2 (4.3)	31-52
1-min APGAR score	7.0 (1)	5-9
5-min APGAR score	9.0 (1)	7-10

SD: Standard deviation

Table 2: Gestational age, sex and mode of delivery distribution of neonates

	Frequency, *n* (%) (*n*=60)
Gestational age	
Pre-term	42 (70.0)
Term	18 (30.0)
Sex	
Male	26 (44.1)
Female	34 (55.9)
Mode of delivery	
Spontaneous vertex delivery	28 (46.7)
CS	32 (53.3)
Emergency CS	28
Elective CS	4

CS: Caesarean section

Table 5 compares the pre- and post-ductal SpO_2 of neonates delivered through caesarean section with those delivered through spontaneous vertex delivery within the first 24 h of life. The mean pre-ductal SpO_2 was 0.8% higher in babies born by spontaneous vertex delivery than those born by caesarean section. On the other hand, the mean value for post-ductal SpO_2 was 0.1% higher in babies delivered by caesarean section. Neither difference was however statistically significant ($P = 0.32$ and $P = 0.89$, respectively). Table 6 compares mean SpO_2 values between preterm and term neonates. The preterm babies had consistently but not significantly higher ($P > 0.05$) pre-ductal SpO_2 than term babies at each of the time intervals. The mean post-ductal values were higher at 10–24 h of life for preterm but higher in term babies at the other time intervals. However, none of the differences was significant ($P > 0.05$) at each of the time intervals.

Discussion

The overall range and mean SpO_2 of the neonates during the study were 89%–100% and 95.9%, respectively. The values obtained were higher than the mean SpO_2 of 94% and range of 92%–96% reported by Morgan *et al*.[27] in Kenyan preterm neonates with the median gestational age of 35 weeks. Also Lee *et al*.[20] in a study of preterm neonates with comparable mean birth weight and gestational age obtained a slightly higher mean SpO_2 of 96.1% (range 96%–99%). These two studies included slightly different preterm populations from the present study. While Lee *et al*.[20] studied preterm babies of 34–36 weeks gestation, Morgan *et al*.[27] included preterm babies from

Table 3: Pattern of oxygen saturation among the neonates at specified age ranges

Time (h)	Oxygen saturation ranges					
	Pre-ductal (%)			Post-ductal (%)		
	<90%	90-94%	95-100%	<90%	90-94%	95-100%
10-24 (*n*)	2	15	43	2	19	39
>24-48 (*n*)	2	13	45	1	15	44
>48-72 (*n*)	0	12	48	0	14	46

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Table 4: Comparison of pre- and post-ductal oxygen saturation at specified time intervals

Timing of SpO_2 (h)	Mean (SD)		t	P
	Pre-ductal	Post-ductal		
10-24	95.5 (2.9)	95.5 (2.8)	0.0	1.000
>24-48	96.0 (2.8)	97.0 (2.5)	0.1	0.950
>48-72	96.3 (2.1)	96.1 (2.3)	0.8	0.420

SD: Standard deviation

Table 5: Mode of delivery versus mean (standard deviation) SpO_2 readings in the first 24 h

Characteristics	Pre-ductal (SD)	Post-ductal (SD)
Spontaneous vertex delivery (*n*=28)	95.9% (2.7)	95.4% (3.3)
CS (*n*=32)	95.1% (3.4)	95.5% (2.5)
t	1.0	0.1
P	0.32	0.89

CS: Caesarean section, SD: Standard deviation

Table 6: Comparison of pre- and post-ductal mean oxygen saturation values of moderate/late pre-term and term neonates at specified time intervals

Oxygen saturation	Time (h)	Mean (SD)		t	P
		Pre-term (*n*=42)	Term (*n*=18)		
Pre-ductal	10-24	96.0 (2.9)	95.0 (3.0)	0.9	0.36
	>24-48	96.2 (2.6)	95.7 (3.2)	0.6	0.57
	>48-72	96.6 (2.0)	94.8 (2.7)	1.4	0.16
Post-ductal	10-24	95.8 (2.8)	94.8 (2.8)	1.2	0.24
	>24-48	95.9 (2.7)	96.4 (2.2)	0.8	0.43
	>48-72	96.1 (2.3)	96.2 (2.3)	0.1	0.91

27 to 36 weeks' gestation. This may have contributed to the heterogeneity of results seen. There is surprisingly a paucity of data on SpO_2 values for neonates within the weight range of neonates in the present study as compared to values suggested for neonates weighing <1500 g[28] and those above 2500 g.[25,29] Therefore, direct comparisons with other studies on the basis of weight range was difficult. In the present study, pre- and post-ductal oxygen SpO_2 were measured once at the specified time intervals, while Lee *et al*.[20] measured continuous readings at six-hourly intervals. Our study was similar to that of Morgan *et al*.[27] who also measured one SpO_2 reading in 24 h and concluded that the study provided important evidence for pulse oximeter readings of newborns in the first 24 h of life.

Other possible reasons for the difference in SpO_2 values observed above could also be due to different study protocols as well as different types of oximeters used. It is known that different oximeters employ different algorithms for calculating SpO_2 curve and a variation of about 2% has been noted among new generation pulse oximeters with motion resistant technology.[30] Thus, interpretation of SpO_2 should also take into cognisance the type of oximeter used. A study in Enugu State in Nigeria at a higher altitude, 232.6 m above sea level, obtained similar mean pre-ductal SpO_2 of 96% but a slightly lower post-ductal of 95% in newborns, with birth weight range of 2.1–4.4 kg within the first week of life. Only 24 (4.4%) of the study population were preterm with minimum gestational age of 34 weeks similar to the mean gestational age of the newborns in the present study.[31] The weight range of the preterm neonates in the study from Enugu was not stated. Nonetheless, the mean pre- and post-ductal SpO_2 observed in the present study were in conformity with findings that during normal breathing, 95% of term and preterm infants maintain a saturation value at and above 95%.[32]

The significant consistent increase in pre-ductal SpO_2 values from >10–24 h to >48–72 h of life is in consonance with findings in other studies which showed that SpO_2 increased by about 0.17% per 24 h in the nursery.[15,25] The reason for the slight decrease of 0.9% in post-ductal values between >24–48 h of life and >48–72 h of life is not conclusively known. However, the decrease was not statistically significant. It is known that various activities, such as feeding, crying and agitation may influence saturation momentarily. Transient minor decline in SpO_2 was also observed in the studies by Morgan *et al*. and O'Brien *et al*. and were accepted as normal as they were momentary and non-statistically significant.[15] The similarity between pre- and post-ductal SpO_2 values underscores the fact that the neonates in the study were apparently stable newborns. Differences between pre- and post-ductal SpO_2 values immediately after birth have been attributed to high pulmonary pressure and left-to-right shunt through the ductus arteriosus. As soon as the ductus arteriosus closes in stable newborns without any duct dependent congenital heart defect, pre- and post-ductal SpO_2 readings are expected to be similar. The difference between pre- and post-ductal values at all-time intervals in the present study was <3% (which is the cutoff at which duct dependent congenital heart defect would be suspected.)[33]

An important factor known to influence SpO_2 levels immediately after birth is mode of delivery. Neonates born by spontaneous vertex delivery have been noted to have a higher saturation reading than those delivered by caesarean section.[34] Although not statistically significant, the neonates delivered vaginally in the present study had higher mean SpO_2 compared to those delivered by caesarean section. Kamlin *et al*.[11] observed that it took a longer time for babies delivered by caesarean section to achieve a predetermined SpO_2 of >90% when compared with children delivered by spontaneous vertex delivery. The delay in absorption of lung fluids in children born by caesarean section has been cited as being responsible for the lower SpO_2 value immediately after birth.[11] It is documented that after the first few minutes of life, mode of delivery does not significantly affect SpO_2.[34,35] This is noted in our cohorts. The earliest time readings were obtained in the present study was 10–24 h of life by which time most of the fluid in the lungs that might have contributed

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to low saturation in neonates delivered by caesarean section would have been absorbed.[34,35] The mean pre-ductal SpO_2 values were marginally higher in preterm neonates compared to term neonates. With respect to post-ductal values, apart from the first 10–24 h of life, SpO_2 was higher in term neonates. The reason for this is not quite clear. The reason for the reversal in post-ductal values is also not known. However, it had been documented that SpO_2 rises more slowly in preterm than in term neonates.[12] The underdevelopment of the lungs in the preterm babies had been cited as a possible reason for this trend.[11] Despite slight differences at various intervals, the values of pre- and post-ductal values were comparable within the two groups.

Conclusion

Single readings obtained at specified time intervals show that the range and mean pre- and post-ductal SpO_2 were similar for apparently stable low birth weight term and preterm neonates in the present study and that in the administration of oxygen therapy to low birth weight neonates with weights between 1500 and 2499 g in the first 72 h of life, irrespective of gestational age, a mean SPO2 value of 95.9% could be considered as within acceptable norms.

The study was not without limitations. The fact that SpO_2 values in the first 10 h of life were not obtained could have affected the interpretation of the results. Furthermore, SpO_2 readings were obtained once during the various time intervals when the neonates were calm, rather than continuously over several hours at different states: when asleep, awake, feeding or crying. Continuous readings at different states may allow wider interpretation of the SpO_2 readings of the neonates. Despite these drawbacks, the result has shown that there are similarities in SpO_2 between moderate to late preterm and low birth weight term neonates. The results obtained could serve as guide in assessing SpO_2 of low birth weight neonates weighing between 1500 and 2499 g in the first 72 h of life.

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Conflicts of interest

There are no conflicts of interest.

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