Normal Values of Pulse Oximetry in Newborns at High Altitude

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Summary

The aim of the study was to establish normal values of pulse oximetry saturation, respiratory rate, heart rate, and blood pressure in healthy newborns at high altitude. Vital signs and oximetry saturation readings were collected from healthy term newborns at birth, at 1 h, and at 24 h of life. These were analyzed and compared with reference ranges at sea level. This study was carried out at altitudes of 1640 m above sea level in Taif city, Saudi Arabia. A total of 6011 term newborns were examined at birth and 1 h and 4274 were examined at 24 h of life. At birth, the mean SpO_2 was 68.6 per cent and 60.3 per cent from the right upper and lower limbs, respectively. Mean SpO_2 was 94.3 per cent and 95.4 per cent at the age of 1 and 24 h, respectively. These values were significantly lower than those reported at sea level. The mean respiratory rate, heart rate, and mean blood pressure at 24 h were 45.7/min, 149.7/min, and 46.9 mmHg, respectively. It is concluded that pulse oximetry saturation for newborn babies is lower at higher altitudes than at sea level. This effect is observable at altitudes of 1600 m above sea level. Cut-off levels lower than those used at sea level should be adopted when dealing with newborns living at high altitudes.

Introduction

Pulse oximetry has become a vital instrument in the medical care of sick children as many clinicians have recognized how valuable the assessment of the patient's oxygenation in real time can be. This appreciation has propelled the use of pulse oximeters into many clinical fields in pediatrics and neonatology. Pulse oximetry has been shown to reduce the number of arterial blood gas samples taken in various populations, as well as reducing cost and improving quality of care.[1,2] Whether pulse oximetry has had a significant impact on the outcomes has yet to be substantially determined in the literature.[2]

It is difficult to obtain a generalized statement about the accuracy of pulse oximeters, but it has generally been found to be acceptably accurate in most patient populations under most conditions.[3,4] However, the reliability, accuracy, and clinical interpretation depend extensively on our understanding of normal values in different age groups and in different clinical settings. Normal values of pulse oximetry saturation (POS) are generally assumed to be identical to that of arterial oxygen saturation in view of the fact that the confidence limit is ±2–4 per cent of the actual level.[5,6] The normal values for pulse oximetry saturation in healthy newborn infants at sea level have been studied.[7] However, few previous studies have evaluated the oxygen saturation status for children living at high altitude. A wide disparity is noticed when attempts are made to define the normal values of oxygen saturation at high altitudes in different pediatric age groups.[8–12] In this study, our objective was to determine the reference values of pulse oximetry saturation in a large sample of healthy term neonates born in Taif, a city that lies at 1640 m above sea level.

Material and Methods

This study was carried out in the neonatology department of King Abdel-Aziz Specialist Hospital (KAASH), Taif, Saudi Arabia, at an altitude of 1640 m above sea level. The study was approved by the ethical committee of the hospital. KAASH is the main maternity hospital and has the largest newborn unit in the area (an average of 12 000 deliveries/year). The study was designed to collect data reflecting POS, respiratory rate, and heart rate from healthy full term newborns at birth, at 1 h, and at 24 h of life. Blood pressure was measured at the age of 1 h. A cord blood sample was collected to measure pH and hemoglobin. POS readings at birth were taken

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from right upper and lower limbs. All products of high-risk pregnancies together with preterm newborns, those with congenital anomalies, and those who needed oxygen for resuscitation were excluded. Newborns who were admitted to the NICU before discharge were also excluded.

Data were collected during the study period by the same team of pediatricians and nurses. The assigned staff received training about the proper use of the equipment before starting the study. Informed consent from the parents was obtained before the examination. Pulse oximetry readings were obtained for each newborn using General Electric DASH 3000 monitor (General Electric Systems, Milwaukee, USA). The readings were taken in a quiet setting. Oxygen saturation was taken from right upper and lower limbs at birth and from the right upper limb later on. The saturation probes were cleaned with alcohol swabs before each use. The oximetry reading was recorded after stabilization for 1 min, according to the manufacturer.

Collected data were entered in a database and a descriptive statistical analysis was performed. Data were also compared with neonatal reference values at sea level, whenever applicable. A confidence interval of 95 per cent was defined and p values <0.05 were considered statistically significant.

Results

The study lasted for 7 months from January to July 2004. During the study period, 6706 babies were born in the hospital. Out of these, 617 were admitted to the NICU at birth, and 16 were re-admitted to the NICU from the nursery. These together with 35 preterms were excluded from the study. Because of technical errors, results were not recorded in 27 cases at birth. POS readings were recorded for 6011 newborns at birth and 1 h. Because of early discharge, readings were taken from 4274 babies at 24 h of life.

The mean gestational age was 39.4 ± 0.78 weeks (range 38–41). The mean birth weight was 3.12 ± 0.32 kg (range 2.6–4.1 kg). Mean and median values were calculated for oxygen saturation, heart rate and respiratory rate at birth, 1 h and 24 h of life. Blood pressure values at the age 1 h and cord blood pH and hemoglobin results were also measured. Table I summarizes the values obtained from the study.

Discussion

Pulse oximetry has become a routine aid to physicians caring for newborn babies.[13] Not only is pulse oximetry helpful in monitoring sick babies but it is also used to screen healthy newborns for congenital heart disease.[14,15] Using it to monitor transition to extrauterine life and closure of ductus arterisous is currently under research.[16] From here came the need to define reference values and cut-off levels.[17–21]

Reference values at sea level are well studied.[3,13] However, studying and reporting pulse oximetry reference values at high altitudes is not consistent. Few studies have dealt with children and even fewer have looked at newborns. Those who studied the neonatal period did not concentrate on the early hours of life, which are more important as they reflect the non-acclimatization state. The definition of high altitude was not usually clear and a wide disparity in the studied altitudes was noticed. The size of the studied sample was usually small, a feature which is not ideal when the aim is to infer reference values. Furthermore, most of these studies did not look into or correlate the arterial oxygen saturation with vital signs of the studied newborns.[17–21]

Our study reflects data collected from nearly 6000 newborn babies. The mean SpO_2 at birth was found to be 68.6 per cent and 60.3 per cent taken from the right upper and lower limbs, respectively. In a study carried-out by Toth, *et al.*,[16] pre- and postductal arterial oxygen saturation was measured in 50 healthy newborn infants immediately after birth. They reported mean values of 73 per cent and 67 per cent for the pre- and postductal SpO_2, respectively, values which are significantly higher than those reported in our study. In another study by Dimich, *et al.*,[22] the mean SpO_2 recorded from the right hand was 71.9 per cent and that from lower extremities was 63.4 per cent.

In our study, the mean SpO_2 at 1 h was 94.3 per cent and at 24 h it was 95.4 per cent. The study of Toth, *et al.* found the SpO_2 to reach more than 95 per cent in less than 1 h.[16] In a study on 90 newborn infants, O'Brien, *et al.*[23] reported the baseline mean SpO_2 to be around 98.3 per cent during the first 24 h of life. This is significantly higher than the value we reported at 24 h of life.

Pulse oximetry saturation is used to monitor sick newborns and to screen healthy ones. Previous studies have already determined the normal values of oxygen saturation in neonates at sea level and suggested a cut-off level of $\geq$94 per cent to be considered as normal.[24–26] Our results showed that the mean SpO_2 in the first hours of life were always significantly lower in neonates born at high altitude than those born at sea level. This is a good rationale to presume that the neonatal SpO_2 cut-off level should be lower than that considered normal for sea level ($\geq$94 per cent).

The mean respiratory rate was 64, 55, and 45/min as measured at birth, 1 h and 24 h, respectively. Figures for heart rate were 169, 149, and 115/min in the same order. In the literature, many articles looked into heart rate variability patterns in the newborn,[27–29] but only a few tried to set normal reference values for neonates during their transitioning.[30]

TABLE 1
Vital signs, POS and cord blood pH and hemoglobin for studied newborns

	Mean[a]	SD	Range	Median[a]	Mode	SEM[a]
Saturation						
At birth						
Upper limb[b]	68.6	9.09	51–80	69	58	0.12
Lower limb[b]	60.3	13.81	40–77	65	40	0.18
At 1 h	94.3	6.71	85–97	94	94	0.09
At 24 h	95.4	3.32	91–98	95	95	0.05
Respiratory rate						
Birth	64.8	5.54	56–80	65	62	0.07
1 h	55.4	5.08	40–62	56	56	0.07
24 h	45.7	6.02	38–56	44	43	0.09
Heart rate						
Birth	169.4	15.39	140–200	170	178	0.20
1 h	149.7	10.63	123–168	152	144	0.14
24 h	115.2	11.30	97–126	118	115	0.17
Blood pressure (at 1 h)						
Systolic	62.22	6.82	48–73	63	63	0.09
Diastolic	35.22	4.91	26–48	36	32	0.06
Mean	46.89	7.84	34–63	45.50	45	0.10
Cord blood pH	7.31	0.04	7.23–7.37	7.32	7.33	0.0005
Cord blood hemoglobin (g/dl)	15.85	1.88	12.7–19.4	15.85	15.90	0.02

[a] Approximations were made.
$n = 6011$ at birth and 1 h, $n = 4274$ at 24 h.

For blood pressure, the average mean value at 1 h of life was 47 mmHg in our study. A study by Contis and Lind[31] assessed the blood pressure, heart rate, and body temperature of normal newborns during the first week of life. We reported the mean cord blood pH to be 7.31 and the cord blood hemoglobin to be 15.9 g/dl. These results are consistent with newborn values at sea level.[32]

Studies that looked into pulse oximetry saturation at high altitudes reported that younger children tend to have a lower mean SpO_2 than older children, suggesting physiological adaptation to high altitude over time. In addition, sleep had a lowering effect on SpO_2.[12] Nicholas, *et al.* reported that SpO_2 levels are significantly lower in newborns and infants living at moderate altitude (2800 m).[10] In a study on 189 children aged 5 days to 24 months living in Bogota (2640 m above sea level), Lozano, *et al.* found that the SpO_2 values in the studied children were lower than those reported from children living at sea level. They suggested using these estimates for interpreting SpO_2 results in children from Bogota and other cities located at a similar altitude.[9]

Three studies were carried out at altitudes comparable to that of Taif (1600 m).[18–20] The study by Saleu, *et al.*[18] was performed on 302 children aged ≤3 months. The overall mean SpO_2 was 96 per cent and it was significantly lower in the first month of life than later. About 6 per cent of the values were ≤92 per cent, which was considered a practical cut-off for normal children aged ≤3 months living in this area. Beebe, *et al.*[19] performed their study on 80 well and 74 sick children with upper respiratory tract infections (URI) (age 2–23 months). Mean oxygen saturation for well children corresponded to reported values at sea level. Oxygen saturations of children with URI were significantly lower. They presumed that URI cannot be considered the cause of clinically significant oxygen desaturation in previously healthy children at moderate altitude. It is to be noted that the age is far beyond the neonatal period, a factor which allows acclimatization to be established. In the third study,[20] serial pulse oximetry studies were performed on 150 term healthy infants. The mean SpO_2 at 24–48 h of age were reported to be 92–93 per cent. With increasing postnatal age, there was a tendency for increased oxygen saturation during the awake states to 93–94 per cent, while oxygen saturation during sleep remains the same or even decreases slightly.

We concluded that pulse oximetry saturation for newborn babies is lower at higher altitudes than at sea level. This effect is observable at altitudes of 1600 m above sea level. The effect is more pronounced in the early neonatal period and probably decreases with time as acclimatization occurs. Cut-off levels lower than those used at sea level should be adopted when dealing with newborns living at

high altitudes. Decreased oxygen saturation at high altitudes reflects on the vital signs.

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