Oxygen Saturation In Children Living At Moderate Altitude

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Background: **Physicians caring for newborns and infants residing at or traveling to moderate altitude have little information available about the normal range for arterial oxygen saturation (SaO_2) measured by pulse oximetry. To aid clinicians in making rational decisions about the oxygen status of children at moderate altitude, we measured SaO_2 in newborns and infants who came to two family practice offices located at an altitude of 2800 meters (9000 feet) to obtain normal values for both well-child and illness visits.**

Methods: **SaO_2 measured by pulse oximetry was recorded for children younger than 2 years seen consecutively in a family practice clinic for care for any reason. The children all resided at an altitude of 2800 m (9000 ft).**

***Results*:** **The mean SaO_2 for healthy awake infants was 91.7 percent, significantly lower than the reported normal ranges for either sea level or Denver. Saturation levels in infants with minor acute illnesses did not differ from saturation levels in healthy infants, while infants with lower respiratory tract infections had significantly lower SaO_2 measurements.**

***Conclusions*:** **SaO_2 levels are significantly lower in newborns and infants living at moderate altitude. Measurement of SaO_2 at moderate altitude can be helpful in the care of both healthy and ill newborns or infants. (J Am Board Fam Pract 1993; 6:452-456.)**

In Colorado 203,000 persons live at elevations above 2100 m (7000 ft). Worldwide more than 40 million persons live permanently above such elevations.[1] Infants born at these elevations are subjected to a relatively hypoxic environment from birth onward. These infants, as do infants at any altitude, occasionally require supplemental oxygen therapy for various illnesses. Although normal values of arterial oxygen saturation (SaO_2) have been established for infants at sea level and for 1600 m (5280 ft) at Denver, Colorado, there is little information on the normal range in newborns and infants at higher elevations.[2,3] A common practice at these altitudes is to prescribe oxygen for infants to maintain SaO_2 at sea-level values. In Summit County, Colorado, 2800 m (9000 ft), with a population of 12,000 persons, an average of 5 infants each month are treated with supplemental oxygen at home, and the number doubles during an outbreak of respiratory syncytial virus. Normal values for oxygen saturation at moderate altitude are needed to help guide clinicians in the care of young children.

Our approach to determine normal values for oxygen saturation was to obtain noninvasive pulse oximeter readings in children reporting to two clinics at approximately 2800 m (9000 ft) in Summit County, Colorado. To judge the effect of common respiratory tract complaints on oxygen saturation for this altitude, we included infants with both upper and lower respiratory tract illnesses. As a control for infants with respiratory tract illness seen in a clinic setting, we measured SaO_2 of infants making visits for minor nonrespiratory tract conditions. These measurements should provide normal standards for pulse oximetry in infants and newborns at this altitude and should provide insight into the usefulness of oximetry in clinical practice.

Methods

The study was conducted during an 11-month period between May 1990 and March 1991 at the offices of the Snake River Health Services in

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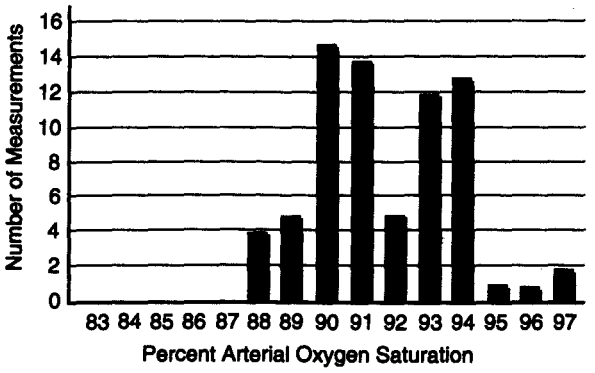

Figure 1. SaO_2 in 72 healthy, quiet, awake infants.

Summit County, Colorado, at Keystone (2818 m, 9250 ft) and Dillon (2774 m, 9099 ft). The Colorado Altitude Research Institute has measured the annual mean barometric pressure to be approximately 540 mmHg. Arterial oxygen saturation was measured in every child aged 2 years or less visiting either facility for any reason and who was also a resident of Summit County. Premature newborns less than 37 weeks' gestation were excluded from the study. We attempted to make measurements while the child was awake and while quiet. We noted, however, other activity states, such as crying, nursing, or sleeping, during the measurement.

All oxygen saturation measurements were made by one of the authors (RN) with an Ohmeda 3740 (Louisville, CO) pulse oximeter using the Neonatal Flex II probe. Measurements were usually obtained by placing the probe across the central portion of the child's right palm. Occasionally measurements were obtained using the lateral border of the foot. Saturation measurements were considered adequate when an arterial pulse wave form was displayed for at least 2 minutes and the displayed pulse rate was consistent with that palpated by the examiner.

Data Analysis

Data analysis included SaO_2 measurements from healthy infants taken during routine well-child visits and SaO_2 measurements on subsequent clinic visits. The initial measurement is reported for 72 different awake infants who ranged in age from 3 days to 670 days. In these 72 infants, SaO_2 levels measured on a subsequent routine visit an average of 61 days later, with the child continuing to be healthy, were compared with the initial values by a paired t-test. Saturation measurements for infants with upper or lower respiratory tract infections were recorded on the first visit to the clinic; subsequent SaO_2 measurements in these infants or measurements made on recovery from illness were not recorded. SaO_2 measurements in infants with minor nonrespiratory illness were reported as a separate group. Measurements in each cohort were reported by histogram, and mean and standard deviation were given. Differences between the groups were analyzed by a two-population t-test. Differences were considered significant when $P < 0.05$.

Results

At the Dillon Clinic (2774 m, 9099 ft) 43 healthy, awake, and quiet infants and newborns aged 3 days to 582 days had initial SaO_2 measurements of 91.8 ± 1.8 percent. The SaO_2 measurements of 91.6 ± 2.5 percent ($P = 0.35$) for the 29 healthy, awake, and quiet infants and newborns aged 2 to 670 days at the Keystone Clinic (2818 m, 9250 ft) did not differ significantly, and the measurements from the two clinics have been combined. Examination of the histogram (Figure 1) for all 72 infants shows that the lowest value observed was 88 percent. The average for the two clinics was 91.7 ± 2.1 percent.

Because saturation is strongly influenced by voluntary ventilation, and because hyperventilation could have caused the relatively high saturations of 95 percent and higher in a few (5 percent) infants, we attempted to determine the variation by repeat SaO_2 measurements in some of the awake and quiet, healthy infants. In 20 children a second measurement (mean 61 days later) showed that, while the second measurement could be randomly higher or lower than the first, on average, the difference was not significant (−0.1 ± 2.3

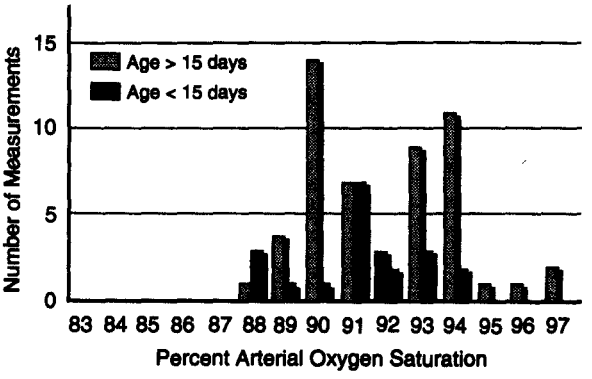

Figure 2. SaO_2 in 19 newborns less than 15 days of age compared with infants more than 15 days of age.

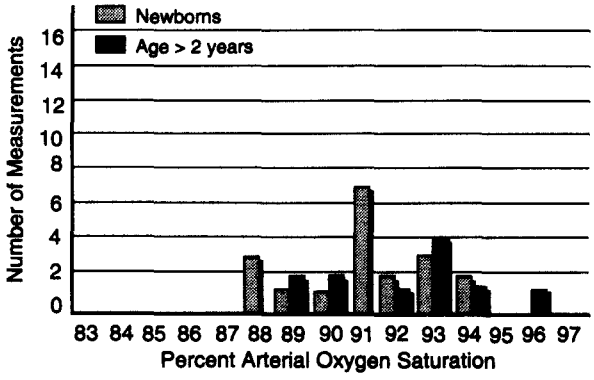

Figure 3. SaO_2 in 19 newborns less than 15 days of age compared with the 11 oldest children more than 2 years of age.

percent, P = NS). Without regard to the algebraic sign, however, the second measurement differed from the first by 1.9 ± 1.3 percent. Thus the average difference between the two measurements in awake, healthy children was similar to the standard deviation for the group, suggesting that much of the variation in the group data reflected variation within, rather than between, individuals.

We questioned whether variation of SaO_2 levels was a result of increasing age. Oxygen saturations in 19 awake, quiet healthy newborns aged 15 days or less ranged between 88 to 94 percent, i.e., within the normal range for the group as a whole (Figure 2). Newborns did not have lower mean oxygen saturation levels. In particular, the average saturation level for the 19 newborns (91.1 ± 1.9 percent) in the cohort was not different (P = 0.3) from that of the 11 oldest children, those older than 2 years (92 ± 2.2 percent) (Figure 3).

Activity state of an infant has been considered to alter arterial oxygen saturation.[2] In one of the newborns, crying was associated with a saturation of 88 percent. In 7 other healthy newborns, sleeping, crying, or nursing was not associated with saturations outside the normal range (91.38 ± 2 percent). In 5 older infants (64 to 250 days) who were sleeping, crying, or nursing, saturations averaged 91.2 ± 2.3 percent, also within the normal range.

In the course of the clinic practice, these healthy and other infants were seen for minor nonrespiratory tract ailments (viral exanthems 12, gastroenteritis 6, conjunctivitis 3, teething 4, and miscellaneous 9). SaO_2 measurements for these 34 children, aged 19 to 719 days, had a distribution and an average saturation level (91.8 ± 1.7 percent) that were not different from those of the well children (Figure 4).

SaO_2 measurements for 41 infants seen with upper respiratory tract illness (otitis media 23, viral upper respiratory tract infections 17, pharyngitis 1) had a distribution as shown in Figure 5. Although the mean saturation level (91.1 ± 2.1 percent) was not different from that of the healthy children, there were 3 children with SaO_2 levels below 88 percent. Measurements in 2 children who were crying or sleeping averaged 87.5 ± 2.1 percent, which was less than that in healthy sleeping or crying children.

In 9 awake infants with lower respiratory tract illness (bronchiolitis 3, pneumonia 3, respiratory syncytial virus 3), arterial saturation ranged from 83 to 92 percent (Figure 6). The mean of 87.8 percent (± 2.8 percent) was lower than the normal range for healthy awake children. In 13 infants with lower respiratory tract infections who were sleeping, nursing, or crying, the mean saturation of 87.6 ± 5.4 percent was below the normal range.

Discussion

In the present study we report SaO_2 levels observed for healthy infants and newborns and those with common illnesses who reside at an altitude of approximately 2800 m (9000 ft). While normal values of 96 ± 2 percent and 94 ± 2 percent have been reported for infants at sea level and Denver (1600 m), respectively, the present study is the first report of values at 2800 m.[2,3] Infants have a variable state of activity while being examined by a physician, and hyper- or hypoventilation has a

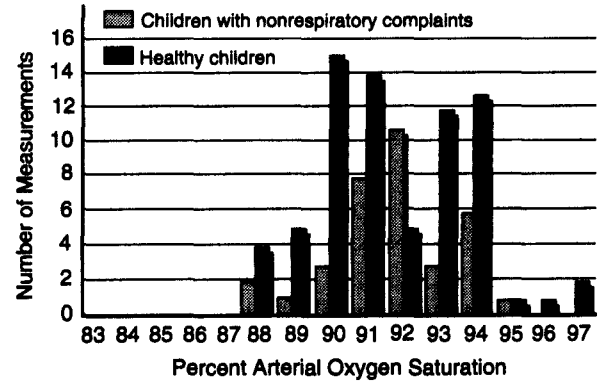

Figure 4. SaO_2 in 34 infants seen for nonrespiratory complaints compared with healthy children.

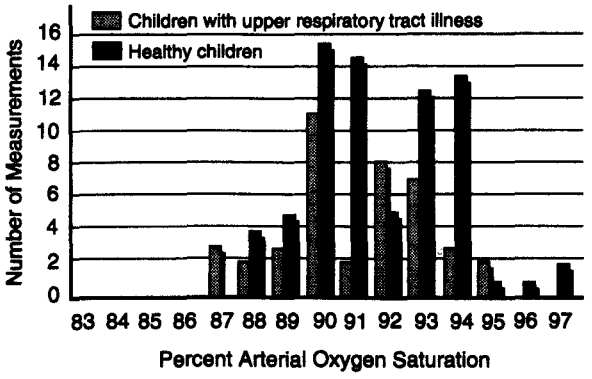

Figure 5. SaO_2 in 41 infants with upper respiratory tract illness compared with healthy children.

greater effect on oxygen saturation in an hypoxic environment than at sea level. It was important therefore that we made measurements in the usual clinical setting and assessed the reliability of the measurements. The measurements appeared to be reliable in that repeat SaO_2 measurements on a different day were randomly scattered about the initial measurement. The finding that the magnitude of the scatter associated with an individual accounted for much of the variation within the group would be expected if there were random variation in the magnitude of the voluntary ventilation. Our finding that children with minor nonrespiratory tract disorders had SaO_2 levels nearly identical to those in normal children was in contrast to the reduced saturation levels in some children with respiratory tract illness and provided independent support for the reported range of normal. From the above, our measurements appeared to be reliable, and the variation observed largely reflected variations in voluntary ventilation.

The oxygen saturations were independent of age for the range of ages examined. In particular, our finding of similar SaO_2 levels in the youngest (younger than 15 days) and the oldest (older than 2 years) children was consistent not only with a single standard of normal values for this age range but also with the report that fetal hemoglobin or bilirubin does not materially affect the oximeter reading.[4,5] Thilo, et al.[3] found no effect of age on SaO_2 levels the first 48 hours of life at sea level regardless of the activity level of the newborn. Mok, et al.[2] found that sleep and feeding decreased saturation level slightly. Although we did not specifically examine the effect of sleeping, nursing, or crying in our healthy infants, these activity states did not depress oxygen saturations below 88 percent, indicating relatively good ventilatory control in the newborns at this altitude.

In contrast to the healthy infants and those with minor nonrespiratory tract illness, those with common respiratory tract illness were at greater risk than normal for reduced oxygen saturation. Some infants with upper respiratory tract illness had mild reductions in saturation levels, which probably reflected either upper airway obstruction or unsuspected lower respiratory tract involvement. Also infants with upper respiratory tract illness were at greater risk of reduced oxygen saturation during sleep or while crying.

The present study found that infants who had a lower respiratory tract illness, in particular, had reductions in SaO_2 that were exacerbated by sleep or crying. Bronchitis, whether caused by bacteria or the respiratory syncytial virus, and pneumonia not only impede ventilation to the smallest lung units but also interfere with the matching of ventilation to perfusion. Further, the hypoventilation that accompanies sleep or the breath-hold phase of crying further compounds the hypoxemia. The environmental hypoxia of moderate altitude adversely impacts on all of these mechanisms. Finally, the more such mechanisms reduce the oxygen saturation, the nearer the saturation readings are to the steep portion of the oxygen-hemoglobin dissociation curve and the greater the risk of further desaturation with additional perturbations of respiratory function.

Findings from the present study have implications for both the physiologist and the clinical physician. The physiologist might see that the healthy infant at moderate altitude, as at sea level,

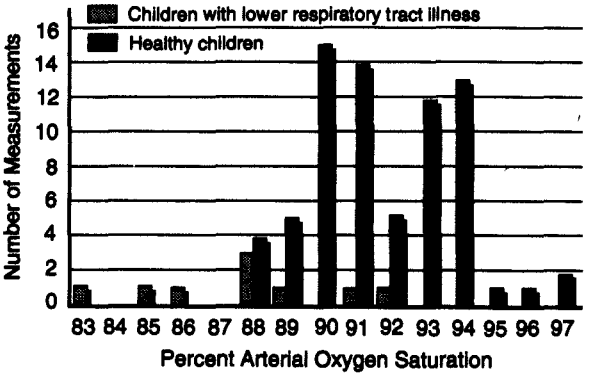

Figure 6. SaO_2 in 9 infants with lower respiratory tract illness compared with healthy children.

has respiratory control adequate to maintain SaO_2 levels in the normal range. The physician might better judge how to regulate oxygen therapy. For example, saturation levels of 90 percent are within one standard deviation of the normal mean, indicating that 84 percent of healthy children will have values of 90 percent or higher. In our practice a healthy child with SaO_2 levels greater than 88 percent at 2800 m (9000 ft) is not considered to need supplementary oxygen. In the event of respiratory tract illness, 90 percent or more SaO_2 is not likely to require treatment with increased inspired oxygen. Because of the cost associated with supplemental oxygen and possible toxic effects of high-flow oxygen, physicians do not want to administer oxygen unnecessarily.

For saturations less than 90 percent, as can occur with respiratory tract illnesses, the physician must use clinical judgment when ordering supplemental oxygen, recalling that SaO_2 levels can fall during sleep and that in infants desaturation is difficult to detect by inspection. Further research is needed to establish for pediatric illness the most effective use of the oximeter and more precise guidelines for oxygen administration at moderate altitude.

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