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# Arterial oxygen saturation in healthy young infants in the highlands of Papua New Guinea

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## SUMMARY

**To determine the effect of moderate altitude on arterial oxygen saturation ($SaO_2$), pulse oximetry was performed on 302 children aged <3 months attending a clinic in Goroka, Eastern Highlands Province (1584 metres above sea level) for minor ailments or immunization. Respiratory and heart rates were also measured. The overall mean $SaO_2$ was 96%. Comparison between log-transformed means showed that $SaO_2$ was significantly lower in the first month of life than later (p=0.04). 6% of $SaO_2$ values were <92%, which is a practical cut-off for normal $SaO_2$ in this population of highland children aged <3 months. Mean respiratory and heart rates were 50/minute and 145/minute, respectively. After adjusting for age, respiratory rate increased significantly as $SaO_2$ declined (p=0.002). We have thus defined reference values for $SaO_2$, respiratory rate and heart rate in healthy young infants residing in the highlands of Papua New Guinea. Further investigation is needed to determine whether $SaO_2$ is lower in babies when they are asleep and to define reference values for older children in the highlands.**

## Introduction

Although arterial oxygen saturation ($SaO_2$) measured by pulse oximetry is commonly used in developed countries both in outpatient and inpatient settings, little has been reported in Papua New Guinea (PNG) on the impact of altitude on oxygen saturation in normal as well as sick children.

We report here on $SaO_2$ measured by pulse oximetry in healthy young infants attending an outpatient clinic in Goroka, Eastern Highlands Province (EHP).

## Methods

Subjects were drawn from attenders at a clinic run by nurses of the Papua New Guinea Institute of Medical Research. Children aged <3 months presenting between September 1992 and October 1994 with minor ailments such as upper respiratory tract infection (URTI) and skin rashes or who came for immunizations were eligible for inclusion in the study. Arterial oxygen saturation was measured using an oxisensor Nellcor model N-25 (Hayward, USA). Mothers were reassured of the safety of the instruments by briefly attaching the oxisensor to the mother's index finger before actually performing oximetry on her child. The oxisensor was then attached to the large toe of either foot and the maximum saturation reading over a 60-second period was recorded. The heart rate recorded by the oximeter was also noted. The status of the child during oximetry was noted (eg awake and quiet, asleep, agitated) and respiratory rate was measured over 1 minute.

Data were analyzed using linear regression. Empirical logistic transformation was used to adjust for the negatively skewed distribution of $SaO_2$ (1), when statistical comparisons were made.

## Results

A total of 302 children were enrolled, 130 aged <1 month (43%), 104 (34%) aged 1

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**TABLE 1**

NUMBER OF CHILDREN ON WHOM PULSE OXIMETRY WAS PERFORMED, THE NUMBER (%) WHO HAD $SaO_2$ <92% AND <95% AND MEAN (95% CI) AND MEDIAN $SaO_2$ BY AGE

| Age (months) | No | $SaO_2$ <92% | $SaO_2$ <95% | Mean $SaO_2$ %* | (95% CI) | Median $SaO_2$ % |
|---|---|---|---|---|---|---|
| 0 | 130 | 9 (7%) | 39 (30%) | 96.6 | (96.1-97.1) | 96.0 |
| 1 | 104 | 5 (5%) | 14 (13%) | 97.3 | (96.8-97.8) | 97.0 |
| 2 | 68 | 3 (4%) | 17 (25%) | 97.5 | (96.7-98.1) | 97.0 |
| **Total** | 302 | 17 (6%) | 70 (23%) | 97.1 | (96.7-97.4) | 97.0 |

* empirical logistic transformation of the mean and derived confidence interval (1) – since the values of $SaO_2$ are not normally distributed the transformed means must be used for all statistical comparisons

**TABLE 2**

MEAN AND MEDIAN $SaO_2$ BY ACTIVITY RECORDED DURING OXIMETRY IN 297 CHILDREN AGED <3 MONTHS

| Activity | No | % | Mean $SaO_2$ % | Median $SaO_2$ % |
|---|---|---|---|---|
| Asleep | 7 | (2.4%) | 92.3 | 95.0 |
| Awake and quiet | 234 | (78.8%) | 96.2 | 97.0 |
| Awake and feeding | 51 | (17.2%) | 95.6 | 96.0 |
| Agitated | 5 | (1.7%) | 97.2 | 98.0 |
| **Total** | 297 | (100%) | 96.0 | 97.0 |

month and 68 (23%) aged 2 months (Table 1). 160 were male and 142 were female. The majority of subjects (96%) were awake and either breastfeeding or quiet during oximetry measurement (Table 2).

The mean $SaO_2$ was 96% and the median 97%. The log-transformed mean $SaO_2$ was 97%; 70 readings (23%) were <95% and 6% <92% (Table 1). Figure 1 shows the distribution of $SaO_2$ values in all 302 children: 4% of babies had $SaO_2$ values ≤90%. $SaO_2$ was significantly lower in children aged <1 month than in older babies (p=0.04). $SaO_2$ tended to be lower in children who were asleep (Table 2). However, after adjusting for age, no significant difference in $SaO_2$ levels was detected between babies who were asleep and those who were awake.

The overall mean respiratory rate was

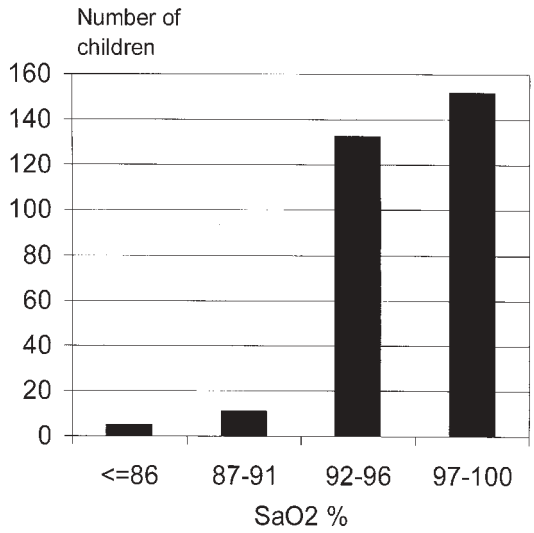


Figure 1. Distribution of $SaO_2$ of healthy children aged <3 months in Goroka.

**TABLE 3**

MEAN RESPIRATORY RATE AND HEART RATE BY AGE

| Age (months) | Respiratory rate/minute | | | Heart rate/minute | | |
|---|---|---|---|---|---|---|
| | No | Mean | (95% CI) | No | Mean | (95% CI) |
| 0 | 130 | 51.0 | (49.0-53.0) | 127 | 143.9 | (140.4-147.4) |
| 1 | 104 | 49.8 | (48.0-51.5) | 104 | 147.3 | (143.7-150.8) |
| 2 | 68 | 48.6 | (46.5-50.7) | 67 | 144.3 | (139.7-149.0) |
| **Total** | 302 | 50.0 | (48.9-51.2) | 298 | 145.1 | (142.9-147.4) |

**TABLE 4**

MEAN RESPIRATORY RATE/MINUTE BY AGE AND $SaO_2$

| Age (months) | $SaO_2$ % | No | Mean respiratory rate/minute |
|---|---|---|---|
| 0 | ≤90 | 5 | 56.4 |
| | 91-95 | 50 | 52.8 |
| | 96-100 | 75 | 49.4 |
| 1 | ≤90 | 4 | 60.0 |
| | 91-95 | 23 | 48.8 |
| | 96-100 | 73 | 49.2 |
| 2 | ≤90 | 3 | 51.3 |
| | 91-95 | 23 | 46.5 |
| | 96-100 | 41 | 49.7 |
| **Total** | ≤90 | 12 | 56.3 |
| | 91-95 | 96 | 50.4 |
| | 96-100 | 189 | 49.4 |
| | **Total** | 297 | 50.0 |

50/minute and mean heart rate 145/minute (Table 3) with no significant difference in rates by month of age. Mean respiratory rate declined with increasing $SaO_2$. Using log-transformed $SaO_2$ and adjusting for age and level of activity, respiratory rate rose significantly with declining $SaO_2$ (p=0.002) (Table 4).

## Discussion

This study has defined reference values for arterial oxygen saturation in young infants resident at approximately 1600 metres above sea level (asl). The youngest babies have lower mean arterial oxygen saturation than older babies.

During the present study we did not record whether children had nasal congestion, partly because nasal congestion is almost universal in this population. Nasal congestion may reduce arterial oxygen levels. In a study in Utah, USA, the mean oxygen saturation of well children aged 2-23 months was 99% compared to 97.5% in those with an upper respiratory infection (2).

The results of our study are consistent with reports from other parts of the world with the

trend of lower mean $SaO_2$ with increasing altitude above sea level (2-5). Awake children aged 1 and 3 months of age in Denver, Colorado, USA (altitude 1610 m asl) had mean $SaO_2$ of 93-94% (5). Mean $SaO_2$ in healthy awake children aged <2 years living at 2800 m asl has been reported as 93% (4), while awake infants aged 0-5 months residing at 4018 m asl in Bolivia had a mean $SaO_2$ of 88% (3). In both the Bolivian and the Denver studies, babies who were asleep tended to have lower $SaO_2$ levels. This was also noted in the present study carried out in PNG, but the differences did not reach statistical significance in any of the studies. A larger sample size would be required to ensure adequate power of detecting any difference in $SaO_2$ between sleeping and awake babies.

It is important to note the reference values reported here when considering which inpatients should be given oxygen, the level at which $SaO_2$ should be maintained during treatment and when oxygen therapy may be stopped. We suggest that 92% would be the most appropriate cut-off for normal $SaO_2$ in children under 3 months of age in the Papua New Guinea highlands. From the respiratory rate data collected on these healthy young infants, we can also conclude that a respiratory rate of 50/minute would be an appropriate cut-off in standard management schedules for lower respiratory tract infections of young infants. Reference values of $SaO_2$ now need to be determined for children aged 3 months or more in the highlands region.

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