Objective Because the optimal concentration of oxygen (FiO₂) required for stabilization of the newly born infant has not been established, the FiO₂ is commonly adjusted according to the infant's oxygen saturation (SpO₂). We aimed to determine the range of pre-ductal SpO₂ in the first minutes of life in healthy newborn infants.

Study design We applied an oximetry sensor to the infant’s right palm or wrist of term and preterm deliveries immediately after birth. Infants who received any resuscitation or supplemental oxygen were excluded. SpO₂ was recorded at 60 second intervals for at least 5 minutes and until the SpO₂ was >90%.

Results A total of 205 deliveries were monitored; 30 infants were excluded from the study. SpO₂ readings were obtained within 60 seconds of age from 92 of 175 infants (53%). The median (interquartile range) SpO₂ at 1 minute was 63% (53%-68%). There was a gradual rise in SpO₂ with time, with a median SpO₂ at 5 minutes of 90% (79%-91%).

Conclusion Many newborns have an SpO₂ <90% during the first 5 minutes of life. This should be considered when choosing SpO₂ targets for infants treated with supplemental oxygen in the delivery room. (J Pediatr 2006;148:585-9)

The transition from fetus to newborn is a complex physiological process. There is growing interest in the use of pulse oximetry to assess the condition of infants immediately after birth.1,2 The subcommittee of the International Liaison Committee on Resuscitation have noted the paucity of information on oxygen saturations (SpO₂) of healthy term and preterm infants during the first minutes of life. They have called for more data before making “evidence-based recommendations on the meaning of pulse oximetry measurements in sick babies at birth.”3 Previous reports describe term infants delivered vaginally,4 infants who were resuscitated or received supplemental oxygen (O₂),5,6 or who were monitored with technology that is now outdated.7-9 The aim of our study was to describe the SpO₂ of healthy newly born preterm and term infants using newer generation pulse oximetry.

METHODS

We conducted a prospective observational study of SpO₂ in newly born infants between May 2004 and April 2005. The study was endorsed by the Human Research and Ethics Committees of the Royal Women’s Hospital, Melbourne, Australia. Verbal parental consent for the study was obtained before delivery. The investigating team was not involved in the care of the infants in the delivery room.

Infants ≥31 weeks gestation who were not anticipated to need resuscitation were studied when an investigator was available to attend their delivery with a pulse oximeter. A stopwatch was started when the cord was clamped. All infants were dried and wrapped with warmed towels. Infants were excluded when they received supplemental O₂ or assisted ventilation, or when we were unable to obtain oximetry data. We used the Masimo Radical (Masimo Corporation, Irvine, Calif) set to detect a signal with maximal sensitivity and averaged it over 2 seconds. The sensor was applied either to the palm of the right hand or to the right wrist to obtain preductal SpO₂ and secured with Coban wrap (3M Health Care, St. Paul Minn). The sensor was then connected to the oximeter, because this leads to the fastest acquisition of data.3 The times taken to apply the sensor and to display data were noted. SpO₂ was continuously monitored, with values recorded at 60-second intervals from birth for at least 5 minutes and until the SpO₂ was >90%.

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Where necessary, the sensor remained attached after the infant was given to the parents. The time taken to achieve SpO₂ ≥ 75% and ≥ 90% was noted.

The presence and the quality of the oximetry data were verified by the investigator using the display; thus the caregivers were not masked to the oximetry data. Apgar scores were assigned by the pediatricians or midwives caring for the babies at delivery. The type of delivery, maternal analgesia and method of anesthesia were recorded.

**Statistical Analysis**

Data are presented as means (SD) and analyzed with 2-tailed t tests when normally distributed. Median and interquartile ranges (IQR) are provided and analyzed with non-parametric tests (2-tailed Mann–Whitney U test) when the distribution of the variable was skewed. Multivariate regression analysis was used to analyze potential confounding variables contributing to the primary end point (time taken for SpO₂ ≥ 90%). A P value of < .05 was considered to be statistically significant. Data were analysed with SPSS software for Windows (SPSS, Chicago, Ill), version 11.5.

**RESULTS**

A total of 205 deliveries were attended. Figure 1 shows the characteristics of infants who were excluded (n = 30) and infants who were included (n = 175). Technical difficulties obtaining data occurred in 12 term infants, none of whom was resuscitated or given supplemental oxygen. Patient characteristics and the time taken for sensor application and signal detection are shown in Table I.

The median SpO₂ values (IQR) at 1, 2, 3, 4, and 5 minutes were 63% (53%–68%; n = 92), 70% (58%–78%; n = 164), 76% (64%–87%; n = 172), 81% (71%–91%; n = 174), 90% (79%–91%; n = 175), respectively (Figure 2).

For the whole group, the mean (SD) time to achieve SpO₂ > 90% was 5.8 (3.2) minutes (range, 1.3–20.2 minutes). With multivariate regression, the most important determinants of the time to reach SpO₂ > 90% were gestational age and presence of labor (R² = 0.09 and 0.15; P < .001 [analysis of variance]).

Of the 175 infants studied, 63 were admitted to the nursery. Eleven infants (all ≤ 34 weeks) were given supplemental oxygen in the nursery; 8 of these infants were also treated with nasal continuous positive pressure (nCPAP). No infants were intubated or treated for persistent pulmonary hypertension of the newborn. The median (IQR) age at which supplemental oxygen and/or nCPAP was started and duration of therapy were 0.5 (0.3–0.6) hours and 55 (4–74) hours, respectively. The median (IQR) SpO₂ of these 11 infants at 5 minutes in the delivery room was 78% (69%–82%) compared with a median of 91% (81%–91%) in the 164 infants who were not given supplemental oxygen or nCPAP (P = .001).

**Effect of Mode of Delivery, Prematurity, Analgesia, and Anesthetic on SpO₂**

The effect of mode of delivery and gestational age on SpO₂ at 5 minutes are shown as medians (IQR) in Figure 3A and B. The median SpO₂ at 5 minutes was lower after elective cesarean section than after spontaneous vaginal delivery and vacuum extraction (Mann Whitney U test; P = .013 and .001, respectively). The median SpO₂ at 5 minutes was significantly lower in preterm infants than term infants (P < .001). The time for each group to reach a SpO₂ ≥ 75% and ≥ 90% are shown in Table II. We found no association between SpO₂ and maternal analgesia or anesthesia (Figure 3C and D).

**DISCUSSION**

The appropriate FiO₂ to use for neonatal resuscitation is subject to debate. It has been suggested that the FiO₂ could be determined by monitoring infants’ SpO₂ by using pulse oximetry. 11,12 Surveys suggest that many clinicians are already using this approach. 13,14 There is limited information about infants’ SpO₂ in the minutes after birth. Toth et al measured the pre- and post-ductal SpO₂ of 50 vaginally born healthy term infants with an older generation pulse oximeter. 15 They found SpO₂ at 2 minutes of age as low as 34%, and that these infants took 12 to 14 minutes to reach SpO₂ values ≥ 95%, and that pre-ductal SpO₂ rose more quickly than the post-ductal value. Rao et al used an older oximeter to study the
pre-ductal SpO2 of 95 infants who were asphyxiated and resuscitated and 30 control infants who were not resuscitated.16 The resuscitated infants were part of the Resair 2 study,17 a multicenter trial comparing air and 100% O2 for resuscitation of infants with birth weight >999 g who had bradycardia and poor respiratory effort at birth. The maturity and mode of delivery of the infants in Rao’s study were not clear.18 Data were not obtained from 12 (10%) infants, and it took longer to obtain data from infants who were asphyxiated. In the control group, SpO2 values as low as 43% were found at 1 minute of age and rose to a mean of 90% by 15 minutes. In infants who were asphyxiated, SpO2 rose more slowly; however, the results were not reported according to the FiO2 used, thus the effect of using 21% or 100% oxygen was not clear. Saugstad et al subsequently reported the SpO2 values from 229 of the 591 infants recruited to Resair 2.19 They reported that median SpO2 rose from about 65% at 1 minute to 90% at 5 minutes and rose equally quickly whether infants were resuscitated with air or 100% oxygen. The oximeter(s) used, site of sensor application, gestational age of the infants, and modes of delivery were not reported.

Using the Masimo SET technology, we measured the SpO2 of newly born infants who were not resuscitated or given supplemental oxygen. In addition, we examined the effect of preterm delivery, mode of delivery, presence of labor, and maternal analgesia and anesthesia. We did not obtain data from 12 (6%) infants. All were active term babies. We believe that, as has been described, poor alignment of the light emitting diode and detector was responsible.20 The SpO2 in our infants closely resemble those found by others in non-resuscitated term infants21,22 and mildly compromised infants resuscitated with either air or 100% oxygen.23,24

Our findings suggest that gestation and the presence of labor have an effect on SpO2 in the minutes after birth. Like other authors,5 we did not demonstrate an effect of either maternal analgesia or anesthesia on SpO2. Oximetry data can be obtained within 1 to 2 minutes after birth and gives a continuous, non-invasive measure of SpO2 and heart rate. Other authors have had difficulties obtaining data with older pulse oximeters26; this may be because of low peripheral perfusion or motion artifact. The Masimo Radical pulse oximeter, uses the same principles as conventional pulse oximetry, but also has signal processing algorithms to reduce “noise” (eg, poor signal in low perfusion states or patient motion).

With a 2–second averaging interval, the oximeter tracked the rapidly changing SpO2 during postnatal adaptation. We obtained data faster (median, 1.2 versus 2.3 minutes) than an earlier study assessing this oximeter in preterm infants during resuscitation.27 This difference may be caused by different methods of sensor application, because we have also obtained data quickly at high-risk deliveries (median, 68 seconds).28

In summary, we have demonstrated the feasibility of

### Table I. Demographic data and times taken to apply patient sensor, signal processing, and time from birth to display oximetry data by gestation

<table>
<thead>
<tr>
<th></th>
<th>All infants</th>
<th>Preterm (&lt;37 weeks; N = 54)</th>
<th>Term infants (≥37 weeks; N = 121)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestation (weeks)</td>
<td>37.5 (3.0)</td>
<td>33.5 (1.8)</td>
<td>39.3 (1.3)</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>2953 (867)</td>
<td>1965 (357)</td>
<td>3393 (560)</td>
</tr>
<tr>
<td>5 minute Apgar</td>
<td>9 (9–9)*</td>
<td>9 (9–9)*</td>
<td>9 (9–9)*</td>
</tr>
<tr>
<td>1 minute Apgar†</td>
<td>8 (7–9)* n = 92</td>
<td>8 (7–9)* n = 37</td>
<td>8 (8–9)* n = 55</td>
</tr>
<tr>
<td>Time to apply sensor</td>
<td>58 (21)</td>
<td>53 (16)</td>
<td>60 (23)</td>
</tr>
<tr>
<td>Time for signal processing</td>
<td>16 (4)</td>
<td>16 (3)</td>
<td>16 (5)</td>
</tr>
<tr>
<td>Total time from birth to first data (seconds)</td>
<td>74 (22)</td>
<td>71 (20)</td>
<td>75 (23)</td>
</tr>
</tbody>
</table>

Data are mean (SD) or * median (IQR).
Times are measured from the point of cord clamping.
No statistically significant differences seen between the groups.
† Of infants for whom O2 saturations available at 1 minute.

![Figure 2. Box plots showing the median, quartiles, range, (1.5 times the quartile on that side), outliers, and extreme values for SpO2 at each minute after birth for the first 5 minutes (N = number of patients in whom SpO2 was obtained). A number <175 indicates that SpO2 was not obtained in all cases.](image_url)
Figure 3. Box plots showing the median, quartiles, range, (1.5 times the quartile on that side) outliers, and extreme values, of SpO₂ at 5 minutes from birth by: A, mode of delivery; B, maturity; C, maternal analgesia; and D, maternal anaesthesia. SVD, Spontaneous vaginal delivery; Vacuum, a vaginal delivery assisted by vacuum extraction (Ventouse) delivery; Forceps, a vaginal delivery assisted by forceps; EM.CS, emergency cesarean section delivery; Elect.CS, elective cesarean section delivery; Preterm, delivery before 37 weeks gestation; Term, delivery from 37 weeks gestation; N₂O, nitrous oxide analgesia; Opioid, analgesia with narcotic; Spinal, delivery with spinal anesthetic; General, delivery with general anesthetic.

Table II. Comparison of times in minutes (median [IQR]) for infants to attain SpO₂ >75% and >90% by mode of delivery, presence of labor and by gestational age (<37 wk versus ≥37 wk)

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Time to reach an SpO₂ &gt;75% (min)</th>
<th>p*</th>
<th>Time to reach an SpO₂ &gt;90% (minutes)</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaginal birth</td>
<td>68</td>
<td>2.4 (1.6–3.7)</td>
<td>.006</td>
<td>4.0 (3.0–6.1)</td>
<td>.001</td>
</tr>
<tr>
<td>Abdominal birth</td>
<td>107</td>
<td>3.5 (2.0–4.8)</td>
<td></td>
<td>5.9 (3.9–7.9)</td>
<td></td>
</tr>
<tr>
<td>Labor</td>
<td>137</td>
<td>2.7 (1.7–4.2)</td>
<td>.004</td>
<td>4.7 (3.2–6.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Not in labor</td>
<td>38</td>
<td>4.1 (2.6–5.4)</td>
<td></td>
<td>7.0 (5.1–10.0)</td>
<td></td>
</tr>
<tr>
<td>GA ≥37 weeks</td>
<td>121</td>
<td>2.5 (1.6–4.0)</td>
<td>&lt;.001</td>
<td>4.7 (3.3–6.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>GA &lt;37 weeks</td>
<td>54</td>
<td>4.2 (2.7–6.1)</td>
<td></td>
<td>6.5 (4.9–9.8)</td>
<td></td>
</tr>
</tbody>
</table>

GA, Gestational age.

*Mann Whitney U test used to compare data.
pulse oximetry in the delivery room. We have shown that infants >31 weeks gestation who receive neither assisted ventilation nor supplemental oxygen have a gradual rise in SpO₂ during the first 5 minutes of life. This period is slower than expected in premature infants and those born by cesarean section without labor. We did not demonstrate an effect of maternal analgesia or anesthesia. The range of SpO₂ during this time extends well below those currently targeted in our neonatal intensive care units. Despite the similarities in the range of SpO₂ seen in our infants and those of term infants who were exercised before assuming that the range of SpO₂ seen in healthy infants applies to sick preterm and term infants.₁⁰,₂⁵,₂⁹

REFERENCES