Continuous noninvasive monitoring of oxygenation in premature neonates with respiratory distress is essential to avoid the potential complications of hypoxemia and hyperoxia.

The accuracy and reliability of pulse oximetry (using an Ohmeda Biox) was evaluated in 15 premature neonates. Pulse oximetry oxygen saturation readings closely approximated arterial oxygen saturation values analyzed by an IL 282 CO-Oximeter (Instrumentation Laboratory, Lexington, MA). Forty-five pooled data points were obtained, and analysis was performed by linear regression $y = +1.19x -18.16$, $r = +0.87$. There was no correlation between carboxyhemoglobin levels (range 3.2% to 9.9%) and the difference between pulse oximetry and arterial oxygen saturations.

Ninety-five percent of the data points collected fell within the 85% to 95% saturation range. The correlation between pulse oximetry and arterial saturation found in the present study may not be generalizable to extremes in oxygen saturation in the premature neonate.

This study demonstrates the accuracy and reliability of pulse oximetry within the 85% to 95% saturation range in premature infants with respiratory distress over a wide range of carboxyhemoglobin concentrations.

Medical management of the premature neonate with respiratory disease has been improved by technology that allows continuous monitoring of arterial oxygenation. Administration of oxygen as a method of combating respiratory problems of the newborn has been documented in the literature as early as the 19th century. The unreliability of intermittent blood gas sampling, and the many complications from more invasive techniques of blood gas determinations, have resulted in the current emphasis on continuous noninvasive methods of blood gas monitoring.1-4

Critically ill neonates will develop periods of life-threatening desaturation. The potential sequelae of hypoxemia in the neonate include increased pulmonary vascular resistance, persistent pulmonary hypertension, neurological impairment, intellectual deficits, respiratory compromise and, finally, circulatory collapse.

However, the administration of oxygen to prematurely born neonates is not without hazard. The use of supplemental oxygen with these infants has been associated with an increased incidence of retinopathy of prematurity and bronchopulmonary dysplagia. Since the retinal vasculature does not mature until after birth at full term, the premature neonate is at risk for developing retinopathy of prematurity before the conceptual age of 44 weeks. The literature has documented cases of retinopathy of prematurity in preterm infants where the only supplemental oxygen received was during the course of a general anesthetic.5,6

Oximetry is a continuous noninvasive method of evaluating the oxygenation of arterial blood by measuring spectrophotometrically the percentage
of total hemoglobin saturated with oxygen. The technique is based on the known differences between the absorption spectra of reduced and oxygenated forms of hemoglobin according to Beer’s Law: the concentration of an absorbing substance is proportional to the logarithm of light transmittance. As extinction coefficients for oxyhemoglobin and reduced hemoglobin are known constants at specific wavelengths, using two frequencies of light permits the determination of their respective concentrations. From these data, the arterial oxygenation saturation, defined as the ratio of oxyhemoglobin to total hemoglobin, can be calculated.

In 1980, Yoshiya and his colleagues first published the idea of combining the techniques of photoplethysmography, which identifies arterial blood by waveform, with the concept of oximetry. This combination of the two techniques allowed the determination of the oxygen saturation of arterial blood based on the principle that arterial blood pulsates while other components, such as venous blood and tissue, normally do not. The pulsating arterial bed, by expanding and relaxing, modulates the amount of light passing through the tissue. A measurement taken in the absence of a pulse is compared with a measurement taken in the presence of a pulse, thus correcting for factors such as venous blood and other tissue. This technology has come to be known as pulse oximetry. The recent availability of a soft, pliant neonatal probe has expanded the application of this continuous noninvasive monitoring technique to the pediatric population.

Methodology

This clinical study was conducted at the neonatal intensive care unit of the Medical College of Pennsylvania. Forty-five data points were collected from 15 premature infants after informed parental consent was obtained. To be included in the study, subjects had to have a previously inserted umbilical arterial line. Excluded were infants with a hematocrit below 30 to minimize the necessity of a blood transfusion. All subjects were preterm with a mean gestational age of 30 weeks (range 27 to 34 weeks by the Dubowitz scale) and mean birth weight of 1378 g (range 730 to 2050 g). All were studied during the first week of life. Thirteen infants survived.

Thirteen infants had respiratory distress syndrome. In addition, four were diagnosed as having persistent pulmonary hypertension. One infant had a primary diagnosis of sepsis. One had pneumonia. Three of the infants required an oxyhood. The remaining 12 were treated by continuous positive airway pressure (CPAP), or intubated and mechanically ventilated (Table I).

When dictated by the patient’s condition, arterial blood gases were drawn from the indwelling arterial umbilical catheter into an airtight heparinized syringe. Samples were obtained when the infants were quiet or sleeping. Simultaneous pulse

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Birth weight (g)</th>
<th>Gestational age (wk)</th>
<th>Primary diagnosis</th>
<th>Respiratory support</th>
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<td>1</td>
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<td>730</td>
<td>29</td>
<td>RDS</td>
<td>Assisted ventilation</td>
</tr>
<tr>
<td>2</td>
<td>M</td>
<td>1750</td>
<td>33</td>
<td>RDS</td>
<td>Assisted ventilation, Oxyhood</td>
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<td>3</td>
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<td>1870</td>
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<td>RDS</td>
<td>Assisted ventilation</td>
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<tr>
<td>4</td>
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<td>800</td>
<td>27</td>
<td>RDS</td>
<td>Assisted ventilation, CPAP</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>850</td>
<td>27</td>
<td>RDS, PPH</td>
<td>Assisted ventilation</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
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<td>28</td>
<td>RDS, PPH</td>
<td>Assisted ventilation</td>
</tr>
<tr>
<td>7</td>
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<td>32</td>
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<td>Assisted ventilation</td>
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<tr>
<td>8</td>
<td>M</td>
<td>1900</td>
<td>30</td>
<td>Sepsis</td>
<td>Oxyhood, room air</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>1360</td>
<td>31</td>
<td>RDS, PPH</td>
<td>Assisted ventilation, CPAP</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>870</td>
<td>29</td>
<td>RDS</td>
<td>Room air</td>
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<tr>
<td>11</td>
<td>F</td>
<td>1200</td>
<td>30</td>
<td>RDS</td>
<td>CPAP</td>
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<tr>
<td>12</td>
<td>M</td>
<td>1530</td>
<td>28</td>
<td>RDS</td>
<td>Oxyhood</td>
</tr>
<tr>
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<td>Assisted ventilation, CPAP</td>
</tr>
<tr>
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<td>965</td>
<td>28</td>
<td>RDS</td>
<td>Assisted ventilation</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>1640</td>
<td>34</td>
<td>Pneumonia</td>
<td>Assisted ventilation</td>
</tr>
</tbody>
</table>

RDS = Respiratory distress syndrome
PPH = Persistent pulmonary hypertension
oximeter saturation readings and infant vital signs were recorded. Each blood sample was packed in ice and taken immediately to the pulmonary laboratory where actual arterial oxygen saturation was determined using an IL 282 CO-Oximeter which also measures the percentage of carboxyhemoglobin in the sample.

Results
A total of 45 paired pulse oximeter and arterial oxygen saturation measurements from 15 infants were collected. Each sample was treated as an independent observation. Arterial oxygen saturations ranged from 74.9% to 98.4% with a mean of 90.99% and a standard deviation of ± 4.40. Pulse oximeter oxygen saturation varied from 80% to 97% with a mean of 91.66% ±3.23% (Table II).

Linear regression demonstrated a strong positive correlation between arterial and pulse oximetry oxygen saturations, producing r = +0.87 (p< .0001) (Figure 1).

Carboxyhemoglobin levels ranged from 3.2% to 9.9% with a mean of 7.19% ±1.70%. There was no significant correlation between carboxyhemoglobin level and the difference between arterial and pulse oximeter oxygen saturation values, r = +0.12.

Discussion
Pulse oximetry and arterial blood gas oxygen saturation values as measured by an IL 282 CO-Oximeter were compared in preterm infants. The present study demonstrates a strong positive correlation between pulse oximetry and arterial oxygen saturation values (r = +0.87) over a 75% to 98% saturation range.

Time constraints limited data collection to 45 pooled data points from 15 premature neonates, 13 (86%) of whom had a primary diagnosis of respiratory distress syndrome (RDS). The correlation between pulse oximetry and arterial oxygen saturation (r = +0.87) in this study may not be generalizable to premature neonates with advanced cardiopulmonary involvement such as severe shunting, persistent pulmonary hypertension or low cardiac output with poor peripheral perfusion.

Critically ill neonates will develop periods of life-threatening hypoxia. Most of the data points collected were clustered between 85% and 95% saturation as is consistent with clinically safe target range. The accuracy of pulse oximetry saturation values at less than 85% saturation cannot be deduced from this study.

The difference between pulse oximetry and arterial oxygen saturation was analyzed as a function of blood carboxyhemoglobin concentration. No significant correlation was found (r = +0.12) between these variables despite carboxyhemoglobin levels of 3.2% to 9.9%.

Oxygen tension rather than oxygen saturation value has traditionally guided the management of ventilation in the premature neonate. The oxyhemoglobin dissociation curve represents the relationship between a given oxygen tension and the percentage of hemoglobin in chemical combination with oxygen. The oxygen saturation of whole blood at a given oxygen tension is a reflection of many factors, the percentage of fetal hemoglobin and 2, 3-DPG red blood cell content being of primary importance. Changes in temperature, pH, metabolic status and increased concentrations of dyshemoglobin also impact on the position of the oxyhemoglobin curve.

In the present study, oxygen tension ranged from 35 mmHg to 109 mmHg with a mean of 67 mmHg. It is generally considered that a PO2 below 50 mmHg in the premature neonate suggests respiratory failure. The American Academy of Pediatrics suggests maintaining the premature neonate PaO2 within the range for PaO2 of normal newborns, which is 50 to 100 torr.

<table>
<thead>
<tr>
<th>Oxygen saturation mean</th>
<th>SD</th>
<th>Range</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial</td>
<td>90.99% ± 4.40</td>
<td>74.9 to 98.4%</td>
<td></td>
</tr>
<tr>
<td>Pulse oximeter</td>
<td>91.66% ± 3.23</td>
<td>80 to 97%</td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>.67%</td>
<td>0 to 6.8%</td>
<td>0.05</td>
</tr>
</tbody>
</table>

n = 45
Research by Orzalesi et al. shows arterial oxygen saturation values in premature neonates. Data collected during the first 40 days of life from 40 radiologically normal and clinically stable premature neonates breathing spontaneously on room air show arterial oxygen tensions between 51.6 mmHg and 94.2 mmHg corresponding to an oxygen saturation range of approximately 85% to 98%.

In the present study, when oxygen saturation was between 90% and 96%, only one of the data points collected had a corresponding $\text{PaO}_2$ above 100 torr, with all other corresponding oxygen tension values falling within the range recommended by the American Academy of Pediatrics.

**Conclusion**

This study demonstrates the accuracy and reliability of pulse oximetry in premature infants in respiratory distress with oxygen saturation readings between 85% and 95%. Carboxyhemoglobin levels below 9.9% did not appear to influence the accuracy of pulse oximetry readings. While this study demonstrated a close correlation between pulse oximetry and arterial oxygen saturation in the premature infant, great caution should be ex-

![Figure 1](image-url)

**Figure 1**

Comparison of oxygen saturation measured by pulse oximetry and oxygen saturation measured by IL 282 CO-Oximeter in simultaneously drawn arterial blood samples.

Linear regression: $y = +1.19x - 18.16$, $r = +0.87$ (p < .0001).
ercised in attempting to generalize these findings to infants with extremes in saturation or those with cardiopulmonary involvement.

The only reliable monitor of acceptable oxygenation in the premature neonate is the direct or indirect measurement of arterial oxygen tension or saturation. Invasive sampling of arterial blood is intermittent and not without sequelae. Continuous noninvasive monitoring of the premature neonate allows the clinician to detect and treat mild desaturation before clinical signs become apparent. Maintaining the premature neonate's oxygen saturation within the 90% to 95% saturation range corresponds to an oxygen tension range of 50 to 100 mmHg, and will limit the potential complications of hypoxemia and hyperoxia in the premature neonate.

REFERENCES


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