Objective  To describe the changes in oxygen saturation (SpO₂) in healthy infants during the first 10 minutes of life.

Study design  In this observational study, infants \( \geq 35 \) weeks gestation at birth who did not require supplemental oxygen had continuous recordings taken of the preductal SpO₂ over the first 10 minutes of life.

Results  A total of 115 infants were analyzed. On average, infants delivered by cesarean delivery had a 3% lower SpO₂ than infants delivered by vaginal delivery (95% confidence interval [CI] = -5.8 to -0.7; \( P = .01 \)). Infants born by cesarean delivery also took longer (risk ratio, 1.79) to reach a stable SpO₂ \( \geq 85\% \) (95% CI = 1.02 to 3.14; \( P = .04 \)). At 5 minutes of age, median SpO₂ values (interquartile range) were 87% (80% to 95%) for infants delivered vaginally and 81% (75% to 83%) for those delivered through cesarean section. The median SpO₂ did not reach 90% until 8 minutes of age in either group.

Conclusions  The process of transitioning to a normal postnatal oxygen saturation requires more than 5 minutes in healthy newborns breathing room air. (J Pediatr 2006;148:590-4)

The indications for active resuscitation of newborns in Canada are based on clinical assessment according to guidelines specified in the Neonatal Resuscitation Program (NRP) of the American Heart Association and the American Academy of Pediatrics.1 The NRP guidelines direct health care providers to administer 100% free flow oxygen to the infant who exhibits central cyanosis even after establishing regular respirations.2

All newborns are “cyanotic” at birth; the arterial oxygen tension in the normal fetus is approximately 20 mm Hg, equivalent to an oxygen saturation of 60%.2 Several small studies using pulse oximetry in the delivery room have documented that it takes more than 5 minutes for a newborn undergoing normal postnatal transition to attain an oxygen saturation \( > 80\% \)3-6 and almost 10 minutes to reach 90%.6,7 Other studies have documented a difference in oxygen saturation between upper extremity (preductal) and lower extremity (postductal) sites,4,8 with lower oxygen saturation seen in postductal sites. These studies suggest that in the process of postnatal adaptation, a normal newborn undergoes a period of transitional physiological cyanosis. Administering 100% oxygen to a spontaneously breathing neonate based only on visual assessment of cyanosis may be unnecessarily invasive and lead to potentially harmful hyperoxia.9-12

The objectives of our study were to document the arterial oxygen saturation in healthy newborns \( \geq 35 \) weeks gestation during unassisted transition in the delivery room and to examine the association between the delivery method (vaginal or cesarean) and oxygen saturation at birth.

METHODS

Subjects  This study design was approved by the research ethics board at our institution. Informed consent was not obtained from the parents because no changes were made to the normal resuscitation protocol apart from applying a sensor probe. The pulse oximetry display was covered so as not to influence the actions of the resuscitation team, and no personally identifying information was collected. The study was conducted in a regional level III neonatal intensive care unit that performs approximately 5000 deliveries per year.

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CI  Confidence interval  
IQR  Interquartile range  
NRP  Neonatal Resuscitation Program  
SpO₂  Arterial oxygen saturation measured transcutaneously
The study center is approximately 1 km above sea level; the average atmospheric pressure at this altitude is 660 mm Hg (compared with 760 mm Hg at sea level).

Inclusion criteria were obstetric gestational age ≥ 35 weeks at birth and an uncomplicated pregnancy. Infants requiring intubation for meconium and those receiving supplemental oxygen at birth were not eligible for the study.

Study Design

This was a prospective, observational study.

Pulse Oximetry Measurements

Pulse oximetry measurements were carried out using an LNOP NeoPt-L pulse oximetry probe and a Radical SET pulse oximeter (Masimo, Irvine, Calif). This pulse oximeter and probe provide reliable continuous oxygen saturation values in newborns, overcoming previous limitations related to low perfusion states and motion artifact.

Our resuscitation team attended all “code pink” deliveries. Our institution designates a “code pink” status to any delivery characterized by 1 or more of the following: cesarean delivery, midforceps delivery with reassuring fetal heart rate, estimated gestational age of 34 to 36 weeks, estimated birth weight of 2000 to 2250 g, multiple births of ≤ 37 weeks gestation, diabetes in pregnancy, abnormal fetal presentation, suspected small for gestational age fetus, suspected oligohydramnios, prolonged or difficult labor, scalp pH of 7.15 to 7.20, active third-trimester bleeding, placenta previa, suspected sepsis, or when the presence of the resuscitation team is requested by the delivering physician or midwife.

The team reviewed the relevant antenatal history and obtained information on mode of delivery, maternal age, duration of rupture of membranes, and obstetric gestational age. All infants were assessed at birth. The time of birth was taken as the time of cord clamping. At our institution, the cord is routinely clamped immediately after birth.

Resuscitation protocols followed the NRP guidelines. All infants underwent nasal and oropharyngeal suctioning, but gastric suctioning was not routine. Physical stimulation (ie, back rubs) was initially provided to infants who had difficulty establishing regular respirations or who had a heart rate < 100 bpm.

A member of the resuscitation team placed a pulse oximetry probe over the newborn’s right hand or wrist as soon as possible after birth. The probe was connected to the oximeter cable before being applied to the newborn. The pulse oximeter display was covered, and alarms and audible beat-to-beat indicators were silenced, so as not to influence the resuscitation team’s decision making.

The pulse oximeter continuously recorded arterial oxygen saturation (SpO2) using 2-second averaging times. The “maximum sensitivity” setting was used because of its increased sensitivity in low-perfusion states. The pulse oximeter also recorded a corresponding hexadecimal code every 2 seconds; this code provided information regarding the functioning of the pulse oximeter and oximetry probe (ie, probe on/off, low pulsatility index, unit functioning properly). Pulse oximetry measurements continued until the infant appeared to have stabilized after transition, typically within 10 minutes after birth.

Data Management

We performed direct serial transfers of data from the pulse oximeter into a spreadsheet program (Excel; Microsoft, Redmond, Wash). Each line of data was individually reviewed. We used prespecified criteria and the pulse oximeter’s hexadecimal code at each time point to identify and remove questionable data. Specifically, we removed data that met any of the following criteria: (1) areas of data dropout (no saturation detected), (2) areas of rapid changes in saturation (≥ 10% change in oxygen saturation in a ≤ 10-second period), and (3) data collected during times of sensor malfunction or malplacement (identified by the oximeter as “sensor off,” “no sensor,” or “defective sensor”).

Statistical Analysis

We used STATA version 8 (Stata Corp, College Station, Tex) for all statistical analyses. One minute of SpO2 data (30 seconds of data before and after each minute of age) was averaged for each subject at 1-minute intervals. Median SpO2 measurements obtained at 1-minute intervals stratified by mode of delivery (cesarean vs vaginal) were summarized in boxplots.

The generalized estimating equation model accounting for intrasubject correlation among repeated measurements was used to examine the association of delivery route, maternal age, duration of rupture of membranes, and gestational age with the SpO2 measurements. The times to reach a stable target SpO2 of ≥ 85% based on delivery route were described using the Kaplan-Meier method and compared using the Cox proportional hazards model. The stable target SpO2 was defined as the first of 10 consecutive SpO2 readings of ≥ 85%.

RESULTS

We collected data from 164 newborns between September 2004 and April 2005. Data from 49 newborns were excluded because these newborns received oxygen supplementation at the time of birth. A summary of patient characteristics is presented in the Table. All of the newborns were ≥ 35 weeks gestation at birth. Subsequent results refer only to the 115 newborns included in the analyses.

Deletion of data not meeting the prespecified criteria as described in the Methods section resulted in the inclusion of 86% of collected data points in the statistical analyses. The median time to stable SpO2 readings after probe placement was 82 seconds (interquartile range [IQR], 30 to 140 seconds). Therefore, 1-minute SpO2 data were available for only 7 infants.

Figure 1 shows a boxplot graph of median SpO2 values over the first 10 minutes of age for infants born by cesarean...
and vaginal delivery. Median \( \text{SpO}_2 \) values (IQR) at 5 minutes were 87% (80% to 95%) for newborns delivered vaginally and 81% (75% to 83%) for those delivered by cesarean section. By 8 minutes of age, the median \( \text{SpO}_2 \) (IQR) rose to 91% (82% to 95%) in the vaginal delivery group and 90% (82% to 92%) in the cesarean delivery group.

The generalized estimating equation model,

\[
Y_i = 74.8 + 1.7 \text{ (age in minutes)} + 0.2 \text{ (gestational age)} - 0.1 \text{ (maternal age)} - 0.5 \text{ (gravidity)} - 3.3 \text{ (cesarean delivery)} + \epsilon_i,
\]

showed that on average, over the first 10 minutes of life the \( \text{SpO}_2 \) of an infant born by cesarean delivery was 3% lower than the \( \text{SpO}_2 \) of an infant born by vaginal delivery, after adjustment for age in minutes, gestational age, maternal age, and gravidity (95% CI = -5.8 to -0.7; \( P = .01 \)). No significant associations between \( \text{SpO}_2 \) and maternal age, duration of rupture of membranes, or gestational age were noted.

A Cox proportional hazards analysis of the Kaplan-Meier curves (Figure 2) demonstrated that infants born by cesarean delivery took significantly longer (risk ratio, 1.79) to reach a stable \( \text{SpO}_2 \geq 85\% \) than infants born by vaginal delivery (95% CI = 1.02 to 3.14; \( P = .04 \)).

### DISCUSSION

The transition from a parallel circulation in utero to an in-series circulation after birth results in a higher arterial oxygen content. The time required for this increase in oxygenation is partly dependent on the presence of residual cardiopulmonary shunts. We found that it took up to 8 minutes to reach a median \( \text{SpO}_2 \) of 90%; other studies have reported times of between 8 and 15 minutes.4,7,8 Our results support the assertion that during normal neonatal transition, it often takes 8 minutes or longer to achieve an oxygen saturation \( \geq 90\% \).

Our resuscitation team follows the NRP guidelines.1 None of the infants in our study was identified as having central cyanosis despite the fact that median oxygen saturation levels at 1 minute and 5 minutes were < 85%. Perhaps more importantly, the absence of visually detectable central cyanosis was not a reliable indicator that an infant’s oxygen saturation was \( \geq 85\% \). The NRP recommends providing supplemental oxygen to infants still exhibiting cyanosis after 30 seconds of stimulation. Our results suggest that possibly many newborns with “low” oxygen saturation are not being recognized.

### Table. Patient characteristics

<table>
<thead>
<tr>
<th></th>
<th>Included infants (n = 115)</th>
<th>Excluded infants (n = 49)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gestational age, median (range)</td>
<td>39 weeks (35 to 41)</td>
<td>39 weeks (35 to 42)</td>
</tr>
<tr>
<td>Apgars:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 minute, median (IQR)</td>
<td>9 (8 to 9)</td>
<td>8 (6 to 9)</td>
</tr>
<tr>
<td>5 minute, median (IQR)</td>
<td>9 (9 to 9)</td>
<td>9 (8 to 9)</td>
</tr>
<tr>
<td>Maternal age, median (range)</td>
<td>31 years (19 to 45)</td>
<td>32 years (19 to 42)</td>
</tr>
<tr>
<td>Gravidity, median (IQR)</td>
<td>2 (1 to 2)</td>
<td>2 (1 to 3)</td>
</tr>
<tr>
<td>Parity, median (IQR)</td>
<td>0 (0 to 1)</td>
<td>0 (0 to 1)</td>
</tr>
<tr>
<td>Antenatal steroids</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Intrapartum antibiotics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>87</td>
<td>40</td>
</tr>
<tr>
<td>1 dose</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>≥2 doses</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Maternal fever (≥38.5°C)</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Duration of ruptured membranes, mean (SD)</td>
<td>7.5 hours (8.8)</td>
<td>5.8 hours (8.4)</td>
</tr>
<tr>
<td>Delivery route</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vaginal</td>
<td>45 (42%)</td>
<td>30 (61%)</td>
</tr>
<tr>
<td>Cesarean</td>
<td>62 (58%)</td>
<td>16 (33%)</td>
</tr>
</tbody>
</table>

Figure 1. Median \( \text{SpO}_2 \) values in the first 10 minutes after birth. Boxes represent the IQR, which contains data between the 25th and 75th percentiles. Whiskers extend to the 1.5 IQR beyond each box. Circles represent outliers. The median is represented by a horizontal line within each box.
The infants in this study theoretically represent a high-risk group, because the resuscitation team was called to be in attendance at each delivery. It should be noted, however, that all infants included in this study had Apgar scores of ≥ 8. Nonetheless, these infants may not be completely representative of a normal newborn population. We excluded newborns requiring supplemental oxygen from the analyses, because our stated purpose was to observe changes in oxygen saturation at birth in healthy newborns.

The results of our study, obtained at an altitude of approximately 1 km, were similar to those reported by others at or close to sea level. Studies conducted at higher altitudes have not examined the period immediately after birth. Niermeyer reported that at very high altitudes (3000 to 4500 m), infants exhibited oxygen saturation levels of 91% to 92% between 6 and 24 hours of age, but these levels steadily declined to 87% to 89% by the end of the first week of life. We suspect that altitude had a modest effect on lowering the oxygen saturations that we measured. The average barometric pressure at our institution during the study period was 89.0 kparascal (667 mm Hg), which translates to a PAO2 of 18.7 kparascal (140 mm Hg) versus a PAO2 of 21.3 kparascal (160 mm Hg) at sea level.

The time to achieve a steady, reliable pulse oximetry reading was appreciably longer in our study than in previous reports. We attribute this to the strict criteria used in our study regarding the identification of a valid oximetry signal. Most of the excluded data came from the period immediately after placement of the saturation probe. The probe was placed on the infant after the oximetry monitor was turned on and the oximetry cable was connected. We chose this method because it reduced the number of steps required to apply the oximetry probe immediately after birth; however, this method has been shown to result in a longer time to the onset of data acquisition compared with applying the probe to the infant before connecting the cable.

REFERENCES
The use of magnets for removal of foreign objects from the esophagus, stomach, and tracheo-bronchial tree was first described over 100 years ago. The use of permanent magnets in medical devices has become increasingly widespread over the past 5 decades. Alnico magnets (alloys of Al, Fe, Ni, Co, Ti) were the first types of permanent magnets that were used for biomedical applications. The authors describe their successful experience with removal of ingested radio-opaque foreign objects using various sizes of Alnico magnets over a 5 year period (1949-1955). They also discuss their management protocol depending upon patient cooperation, object shape and size, and site of lodgment. The appropriate magnet was either attached to a catheter (passed nasally) or string (passed orally) and introduced without sedation or anesthesia if the child was cooperative. Fluoroscopic guidance was used to determine successful contact of the object to the magnet and its subsequent removal, occasionally under sedation or anesthesia. An endoscopist was always available in case of aspiration during removal.

Radiographic evaluation is still the first step to identify the object and its location, and coins continue to be the most common culprit. Although most swallowed foreign objects pass through the gastrointestinal tract uneventfully, those lodged in the esophagus for extended periods and those causing symptoms or have the potential to cause damage, should be removed. Ingested button (disc) battery lodged in the esophagus has emerged as a common indication for emergent removal due to its potential for causing chemical burns in a short period of time. Esophageal food impaction due to eosinophilic esophagitis is also becoming increasingly common.

Advances in the use of anesthetic agents and endoscopic techniques have promoted endoscopic removal under general anesthesia as the most popular method for retrieval of a foreign object from the gastrointestinal tract. Those lodged at or above the thoracic inlet continue to be removed using a rigid scope while a flexible video endoscope is used for more distal objects. The availability of several extraction devices including a variety of grasping forceps, nets, baskets, and overtubes, has provided the endoscopist with a wider choice to pick the most appropriate retrieval device depending upon the size and shape of the object as well as the location.