Elective caesarean delivery adversely affects preductal oxygen saturation during birth transition

Vincenzo Zanardo, Valentina Dal Cengio, Matteo Parotto, Francesco Cavallin, Daniele Trevisanuto

ABSTRACT
Objective To compare preductal oxygen saturation (SpO₂), heart rate (HR) and cord blood pH after birth in healthy term neonates delivered by elective caesarean delivery (CD) and vaginal delivery (VD), managed according to 2010 Neonatal Resuscitation Guidelines.

Design In a prospective cohort study, sensors were placed on the right hand of the neonate.

Setting III level Maternity ward of the Department of Obstetrics and Gynaecology of Padua University, Padua, Italy.

Main outcomes measures SpO₂ and HR were recorded during the first 10 min after birth. Umbilical artery blood gas analysis was obtained immediately after delivery.

Patients We studied 60 newborn infants by elective CD and 60 by VD.

Results The SpO₂ gradually significantly improved during the first 10 min of life (p<0.0001), with a trend towards a slower increase in caesarean-delivered neonates (p=0.09) (Friedman’s two-way non-parametric analysis of variance (ANOVA)). Instead, HR varied during the first 10 min of life (p=0.001) without significant difference between the two delivery groups (p=0.41). Umbilical artery pH values were lower in VD (p=0.005). At 10th minute, elective CD had a significantly negative effect on SpO₂ (β=-2.44; 95% CI -4.52 to -0.36; p=0.02) with respect to VD. Conversely, at 10th minute, delivery mode had no statistically significant effect on HR (β=0.33; 95% CI -9.39 to 10.01; p=0.95).

Conclusions In healthy term neonates, the SpO₂ gradually improved during the first 10 min of life. At 10th minute, elective CD had a significantly negative effect on SpO₂, but these changes did not result in an impaired HR pattern.

INTRODUCTION
The transition from fetus to newborn infant is a complex process. All newborn infants are ‘cyanotic’ at birth; the arterial oxygen tension in the normal fetus is approximately 20 mm Hg, equivalent to an oxygen saturation (SpO₂) of 60%. Classical studies using pulse oximetry in the delivery room have documented that it takes more than 5 min for a newborn infant undergoing normal postnatal transition to attain an SpO₂ >80% and almost 10 min to reach 90%. The nomogram, recently published by Dawson et al., which results from the merging of three separate databases with a total of 468 newly born infants with gestational ages ranging from 25 to 42 weeks who did not receive oxygen at birth and using the same methodology, last generation monitors for registering SpO₂, represents a reference range for SpO₂ for normal babies in the first 10 min after birth, where the median time to reach SpO₂>90% was of 7.9 min (IQR: 5.0–10.0). Of note, preterm infants needed significantly more time to reach this saturation, and the time needed to reach SpO₂>90% inversely correlated with gestational age. At present, this is the only available SpO₂ nomogram and represents the best estimate of the most appropriate SpO₂ targets for term, but especially for preterm infants during the first minutes of life. However, other studies performed in term newborn infants have shown that some normal newborn infants need even more time especially if they are born by caesarean section. This assumption does not differentiate between neonates born by elective, prelabour and emergency caesarean delivery (CD), nor between term, early-term, late-preterm and preterm or intrauterine growth restriction CD neonates. This is relevant considering that CD has increased rapidly worldwide, and the rise in elective, pre-labour CD is particularly concerning. Pre-labour CD, deprived of hormonal and neuroendocrinal advantages of the experience of labour, is associated with increased risk of delayed lung fluid clearance, respiratory distress syndrome, air leak syndrome and increased risk of neonatal resuscitation, mainly if performed before 39 weeks. Moreover, in-labour, emergency CD is often complicated by the cumulative
impact of different intrapartum interventions and fetal distress, which may affect a neonate’s ability to initiate breathing.12

In recent years, interest has grown in the use of pulse oximetry to monitor preductal arterial SpO2 and heart rate (HR) during neonatal transition and resuscitation in delivery room, and there is an ongoing discussion about the use of supplemental oxygen.2 The 2010 American Academy of Pediatrics and Neonatal Resuscitation Program (AAP & NRP) recommend SpO2 for both term and preterm deliveries in case of anticipated need for resuscitation, need for positive pressure ventilation for more than few breaths, persistent cyanosis, supplementary oxygen.11 Importantly, it also has been shown that the use of lower oxygen load during resuscitation significantly decreases oxidative stress and improves clinical outcome.14 Moreover, AAP & NRP provided target SpO2 ranges as part of the resuscitation algorithm, indicating that the goal in neonates should be an SpO2 value in the IQR of SpO2 measured in healthy babies following vaginal birth at sea level as reflected in the above-mentioned nomogram recently published by Dawson et al.2

The main question remains as to whether SpO2 shows significant differences during transition in at-term neonates according to mode of delivery, vaginal or surgical without experience of labour. Therefore, the purpose of this study was to analyse SpO2 and HR values during the first 10 min after birth in term babies delivered vaginally or by elective caesarean section. Data on umbilical artery blood gas analysis at delivery were also obtained.

PATIENTS AND METHODS

This was a prospective, observational cohort study performed between 1 September 2013 and 15 January 2014 in the III level Maternity ward of the Department of Obstetrics and Gynaecology of Padua University, Padua, Italy. Pregnant women admitted between 38 and 41 weeks’ gestation without exclusion criteria were asked to sign informed consent before delivery as approved by the Ethical Committee of our hospital.

Eligibility criteria were: spontaneously breathing and active at term, appropriate-for-gestational-age neonates born by vaginal or CD, receiving identical treatment in the delivery room in adherence to the resuscitation algorithm provided by the 2010 AAP & NRP Guidelines.2

Exclusion criteria were: babies born to mothers under general anaesthesia, severe congenital malformations, Apgar scores at 5 min <5, fetal malnourishment, vacuum-assisted deliveries, supplemental oxygen requirement and ventilation and/or medications requirements at birth, neonatal intensive care unit admission, inability to adequately obtain required data in the first 10 min after birth by the member of the research team (VDC).

All infants were assessed at birth. After that, all infants were dried and wrapped with warmed towels and were immediately positioned supine under a radiant heater or prone on the mother’s chest, according to surgical or vaginal delivery (VD) mode, for the rest of the 10 min transition period. A nurse or a midwife observed the transition of the newborn infant and recorded Apgar scores at 1, 5 and 10 min.

Demographic findings (mode of delivery, relevant antenatal history, maternal age, obstetric gestational age and parity) and Apgar scores were recorded on data collection forms. Spinal anaesthesia was used for caesarean deliveries according to standard operating procedures.

Pulse oximetry and HR measurements were performed using new-generation pulse oximeters (Masimo Radical, Masimo, Irvine, California, USA). The sensors were placed on the right hand for the preductal SpO2 monitoring and HR measurements immediately after cord clamping by the investigator, who was not involved in newborn resuscitation. Next, the probe was connected to the pulse oximetry monitor. The maximum sensitivity setting was chosen. The chronometer was started at the time of cord clamping. Time in minutes to reach reliable SpO2 and HR readings was recorded. To detect and eliminate artefacts, the following quality criteria for SpO2 and HR measurements were verified by the investigator using the display, thus the caregivers were not masked to the oximetry data. For physiological reasons, the SpO2 was considered reliable when the pulse wave retrieved by the pulse oximeter was regular and adequately shaped. Furthermore, if HR exhibited in the monitor did not coincide with that audible and obtained by auscultation, the data were not imported into the database. The resuscitation team followed the 2010 Guidelines of American Heart Association (AHA) and AAP.2 The time to apply the sensor and the time elapsed from birth until the first reliable reading of SpO2 level were noted. Next, SpO2 levels (right hand) were recorded manually from the oximeter display every 1 min to a computer and entered into individual Excel spreadsheets, according to Kamlin et al.2 11 Pulse oximetry measurement was continued for 10 min. The SpO2 and HR levels after each minute of age were accepted as a 1 min result of that interval. Pulse oximetry readings, SpO2 and HR, and blood gas analysis values were registered and stored until analysis.

The time of birth was determined at the time of cord clamping, which routinely occurred immediately after birth, and blood was drawn from the umbilical artery into 1 mL plastic syringes flushed with a 1000 U/mL heparin solution. The arterial blood gas analysis was performed within 3/5 min in automatic blood gas analysers (Radiometer ABL800 FLEX analyser, Copenhagen, Denmark).

Statistical analysis

Continuous data were expressed as median and IQR because Shapiro test rejected the hypothesis of normal distribution for most of continuous variables. Categorical data were compared between two groups using Fisher test, whereas continuous data using Mann–Whitney test. Variables recorded at different time points (SpO2 levels and HR) were analysed using Friedman’s two-way non-parametric ANOVA. Linear regression model estimation was performed to identify the effect of delivery mode on SpO2 levels and HR at 10th minute after birth, adjusting for clinically relevant confounders. The variables statistically different between the delivery groups were chosen as confounders. A p value <0.05 was considered statistically significant. Statistical analysis was performed using the R 2.12 language. (http://www.R-project.org).

RESULTS

A total of 136 singleton full-term neonates were included in the study. However, during the study period, although initially fulfilling the study requirements 16 neonates were excluded: two infants VD were excluded because of the need of respiratory support after delivery; three infants delivered by elective CD were excluded because SpO2 and/or HR values could not be measured within 10 min; two infants VD were excluded because of the need for oxygen after delivery; three infants delivered by elective CD were not assessed because of organisational reasons (overlapping delivery time); and six infants were excluded because they failed VD (four infants, CD; two infants, vacuum-assisted delivery). The final sample included 120 neonates, 60 vaginally delivered and 60 delivered by elective caesarean section.
General characteristics of mothers and infants are shown in table 1. Mothers in the elective CD group were older than those in VD (median difference 4 years; p=0.0002) and newborn infants in elective CD had slightly lower gestational age than those in VD (median difference 1 week; p=0.0001). Umbilical artery cord blood sample at delivery revealed lower pH values in VD neonates versus elective CD neonates (median 7.28 vs 7.32, respectively; p=0.0005). HCO$_3^-$ and actual base excess (ABE) levels were lower in VD neonates versus elective CD neonates (HCO$_3^-$ median 24.0 vs 25.8; p=0.0002; ABE: median −3.4 and −0.8; p<0.0001). Noteworthy, haematocrit value was lower in elective CD versus VD (median 43 vs 45, respectively; p<0.0001). The other maternal and neonatal characteristics—including Apgar scores at 1, 5 and 10 min—were similar in the two groups (table 1).

By 1 and 2 min, saturation signals (SpO$_2$ and HR) could be measured in at least 66% and 74% of all infants, respectively. By 3 min, both saturation signals (SpO$_2$) and HR could be measured in at least 90% of infants.

SpO$_2$ median value increased from 87 (IQR 78–92) at 1st minute to 97 (IQR 95–99) at 10th minute in VD group and from 73 (IQR 65–79) to 96 (IQR 91–99) in elective CD group (table 2).

The increment was statistically significant over time (p<0.0001), with small difference between the two groups (p=0.09) (Friedman’s two-way non-parametric ANOVA) (figure 1).

HR median value varied from 152 (IQR 129–162) at 1st minute to 151 (IQR 139–168) at 10th minute in VD group and from 160 (IQR 130–172) to 160 (IQR 147–171) in elective CD group (table 2).

The variation was statistically significant over time (p=0.001), without significant difference between the groups (p=0.41) (Friedman’s two-way non-parametric ANOVA) (figure 2).

Multivariable analysis revealed that at the 10th minute, CD had a significantly negative effect on SpO$_2$ (β=−2.4; 95% CI −4.2 to −0.6; p=0.02) with respect to VD, adjusting for ABE, pH, mother’s age, haematocrit, HCO$_3^-$, gestational age, length, Apgar at 5 min and birth weight as clinically relevant confounders. Conversely, at 10th minute, delivery mode had no statistically significant effect on HR (β=0.33; 95% CI −9.39 to 10.01; p=0.95), adjusting for ABE, pH, mother’s age, haematocrit, HCO$_3^-$, gestational age, length, Apgar at 5 min) and birth weight as clinically relevant confounders.

DISCUSSION

Several previous observational studies have shown that there are significant differences in the time course of arterial SpO$_2$ according to the mode of delivery. In particular, newborn infants after CD presented lower saturation values during transition compared with infants after VD.3 7 11 This situation was described as secondary to delayed clearance of lung fluid during caesarean1 2 and/or absence of the neuroendocrine benefits of labour experience for correct transition to extrauterine life and lung function.4 6 However, this assumption did not differentiate at-term neonates delivered by elective, pre-labour and emergency, in-labour CD.

Our study shows that infants born by elective CD, managed according to 2010 Neonatal Resuscitation Guidelines2, have slightly lower SpO$_2$ after birth and require about 10 min to reach the SpO$_2$ of the infants delivered by VD, despite higher pH and in the absence of clinically significant HR pattern differences. While half of VD neonates obtain an SpO$_2$ >90% at 4 min and three-fourth at 6 min, CD took 6 and 9 min, respectively. In addition, multivariable analysis confirmed that at 10th minute, elective CD had a significantly negative effect on SpO$_2$ with respect to VD, adjusting for gestational age, pH, haematocrit and possible confounders.

Traditionally, oxygenation levels of newly born infants have been assessed clinically, and in most publications, authors included neonates after uncomplicated birth proved by non-compromised Apgar values without differentiating postnatal transition of term, early-term and premature or small for gestational age infants. However, O’Donnell et al17 showed that there is substantial interobserver and intraobserver variability in assessments of infant colour at delivery. Therefore, experts have recommended the use of pulse oximetry to measure oxygenation in this setting.2 7

Thus, the course of the SpO$_2$ recorded in the present study extends what was previously described in the literature. Rabi et al1 demonstrated in 2006 that infants born >35 weeks by CD and not requiring supplemental oxygen, had modestly lower SpO$_2$ and required longer to reach a stable SpO$_2$ >85%

### Table 1

Maternal and neonatal characteristics in at-term healthy, active neonates according to delivery mode.

<table>
<thead>
<tr>
<th>N</th>
<th>Vaginal delivery</th>
<th>Elective CD</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age (years)</td>
<td>32 (28–35)</td>
<td>36 (32–38)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Native</td>
<td>35 (60.3)</td>
<td>44 (73.3)</td>
<td>0.17</td>
</tr>
<tr>
<td>Nulliparous</td>
<td>32 (53.3)</td>
<td>24 (40.0)</td>
<td>0.20</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>39 (38–40)</td>
<td>38 (38–40)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Weight (g)</td>
<td>3365 (3155–3685)</td>
<td>3285 (2975–3458)</td>
<td>0.11</td>
</tr>
<tr>
<td>Head circumference (cm)</td>
<td>34 (33–35)</td>
<td>35 (34–35)</td>
<td>0.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Apgar</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1 min</td>
<td>9 (9–9)</td>
<td>9 (9–9)</td>
<td>0.67</td>
</tr>
<tr>
<td>5 min</td>
<td>10 (10–10)</td>
<td>10 (10–11)</td>
<td>0.11</td>
</tr>
<tr>
<td>10 min</td>
<td>10 (10–10)</td>
<td>10 (10–10)</td>
<td>0.09</td>
</tr>
<tr>
<td>pH</td>
<td>7.28 (7.22–7.32)</td>
<td>7.32 (7.28–7.35)</td>
<td>0.005</td>
</tr>
<tr>
<td>PCO$_2$</td>
<td>52.1 (44.2–60.3)</td>
<td>51.6 (47.8–55.7)</td>
<td>0.09</td>
</tr>
<tr>
<td>PO$_2$</td>
<td>17.0 (13.6–21.9)</td>
<td>16.7 (14.8–22.7)</td>
<td>0.43</td>
</tr>
<tr>
<td>HCO$_3^-$</td>
<td>24.0 (22.3–25.7)</td>
<td>25.8 (24.2–27.4)</td>
<td>0.0002</td>
</tr>
<tr>
<td>BE</td>
<td>−3.4 (−5.0–−2.0)</td>
<td>−0.8 (−2.5–0.5)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Haematocrit (%)</td>
<td>45 (43–47)</td>
<td>43 (40–44)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Data expressed as n (%) or median (IQR). CD, caesarean delivery.

### Table 2

SpO$_2$ and HR levels in the first 10 min after birth in at-term healthy, active neonates according to delivery mode.

<table>
<thead>
<tr>
<th>Minute</th>
<th>SpO$_2$</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaginal delivery</td>
<td>Elective CD</td>
<td>Vaginal delivery</td>
</tr>
<tr>
<td>1</td>
<td>87 (78–92)</td>
<td>73 (65–79)</td>
</tr>
<tr>
<td>2</td>
<td>85 (74–91)</td>
<td>77 (69–83)</td>
</tr>
<tr>
<td>3</td>
<td>87 (81–92)</td>
<td>81 (75–87)</td>
</tr>
<tr>
<td>4</td>
<td>91 (85–95)</td>
<td>85 (80–91)</td>
</tr>
<tr>
<td>5</td>
<td>92 (88–96)</td>
<td>90 (81–93)</td>
</tr>
<tr>
<td>6</td>
<td>95 (91–97)</td>
<td>90 (84–94)</td>
</tr>
<tr>
<td>7</td>
<td>96 (92–98)</td>
<td>91 (86–95)</td>
</tr>
<tr>
<td>8</td>
<td>96 (93–98)</td>
<td>93 (88–96)</td>
</tr>
<tr>
<td>9</td>
<td>97 (93–99)</td>
<td>93 (90–98)</td>
</tr>
<tr>
<td>10</td>
<td>97 (95–99)</td>
<td>96 (91–99)</td>
</tr>
</tbody>
</table>

Data expressed as median (IQR). CD, caesarean delivery; HR, hearth rate; SpO$_2$, oxygen saturation.
in the immediate newborn period compared with infants born vaginally. The mean difference at 5 min was 3%. Three very similar results were reported by Kamlin et al.\textsuperscript{15} in infants >31 weeks’ gestation born by elective caesarean section who took on average 2 min longer to reach an SpO\textsubscript{2} 90% than infants born by spontaneous VD. Harris et al.\textsuperscript{18} found, using an early generation oximeter, that SpO\textsubscript{2} was much lower in term caesarean-section deliveries. Mariani et al.\textsuperscript{18} found a similar difference in a cohort of late preterm and at term infants >35 weeks delivered by prelabour CD in comparison with babies born by VD. Recently, Dawson et al.\textsuperscript{2} defining the reference range for SpO\textsubscript{2} for infants who received no medical intervention in the delivery room showed in a large group of patients with a mean gestational age of 38±4 weeks and birth weight of 2970±918 g that there were significantly lower values in infants delivered by caesarean birth from 1 until 5 min after birth. Thereafter, the SpO\textsubscript{2} values did not differ. Furthermore, Gonzales and Salirrosas\textsuperscript{19} and Dawson et al.\textsuperscript{2} show that HR was significantly lower in newborn infants after CD (from 1 to 5 min, and from 2 to 10 min, respectively). In contrast, others found no significant difference in SpO\textsubscript{2} measurements in preterm and term infants delivered vaginally or by caesarean section, regardless of the presence or type of anaesthesia.\textsuperscript{15} The latter studies had smaller samples and used older generation pulse oximeters, which might explain their findings.

Finally, the recent Urlesberger et al.\textsuperscript{20} study presented SpO\textsubscript{2} values, HR and pH values in a very similar setting as the present manuscript, including only at-term newborn infants >37 weeks’ gestational age, either by VD or by elective CD. However, the study design consented the inclusion of early-term neonates delivered after an uncomplicated pregnancy and reported only the pH among cord blood gas analysis values, without defining the impact of blood gas changes in SpO\textsubscript{2} and/or HR pattern.

Therefore, the course of the SpO\textsubscript{2} but not of HR values of the present study are in accordance with the literature.\textsuperscript{2,7,8,20} However, to the best of our knowledge, there are no studies evaluating differences in vaginal or CD neonatal SpO\textsubscript{2}, HR and umbilical arterial blood pH values together. Despite the continuing discussions about HR threshold values, it is proposed that HR should be taken into account when evaluating steps in neonatal resuscitation. HR is considered to be an objective indicator of fetal acid–base balance and fetal response to birth stress.\textsuperscript{21,22} Several studies have addressed the correlations between SpO\textsubscript{2} measured by intrapartum pulse oximetry and pH in fetal blood.\textsuperscript{23,24} Low arterial SpO\textsubscript{2} at birth has been associated to low pH in umbilical blood. Readings below 60% or the development of an unstable baseline SaO\textsubscript{2} reading is related to hypoxia and acidosis.\textsuperscript{25,26} Kühnert et al.\textsuperscript{27} stated that when the arterial SpO\textsubscript{2} fell below 30%, it was highly predictive of a pH below 7.20 and evolving blood acidosis. Arik et al.\textsuperscript{26} found that low preductal fetal SpO\textsubscript{2} measured at birth seemed to be associated with low fetal pH and base excess. Umbilical artery cord blood pH values were lower in vaginally delivered neonates (perhaps as a result of the fact that they may be participating more directly in labour and delivery), suggesting that these SpO\textsubscript{2} values are not sufficient to produce hypoxia and acidemia, or that a more prolonged time of low SpO\textsubscript{2} is needed to produce an alteration in SpO\textsubscript{2} and HR.\textsuperscript{19}

Our study has obvious limitations. It is an observational study, which included well-adapted at-term patients not needing supplemental oxygen, advocating use of Dawson et al. targeted SpO\textsubscript{2} normographs in the delivery room, especially important when treating extremely preterm infants at risk of hyperoxia. For this reason, we did not compare them with ‘near-term’, ‘early-term’ or ‘preterm’ prelabour-delivered infants who did not receive supplemental oxygen or expanded resuscitation in delivery room. More aggressive use of the newer generation pulse oximeter in the delivery setting, possibly equipped to store high-quality information, may facilitate achieving the best definition of ‘normoxia’ that leads to the best short-term and long-term outcomes after resuscitation. Inevitably, the sample was also biased because severely affected babies were not enrolled. Studies to compare...
different ranges of normoxia (ie, in this study, SpO₂ values are so much higher than the Dawson curves) will take many years. Until then, Dawson et al percentile charts provide our best estimates of the appropriate SpO₂ targets during resuscitation.

In conclusion, SpO₂ in babies in the first minutes of life is influenced by a series of different factors such as adherence to standard practice, gestational age, CD, and also, as shown in this study, by the experience of labour in at-term caesarean deliveries in adherence to the SpO₂ targets algorithm of Dawson et al provided by the 2010 AAP & NRP Guidelines during resuscitation. Accordingly, further evidence is needed as regards SpO₂, HR and umbilical artery blood gas changes at birth to achieve the best definition of ‘normoxia’ that leads to the best short-term and long-term outcomes after resuscitation in preterm, late preterm and early-term neonates delivered to support the advantages of labour experience for correct transition to extraterine life and lung function.

Competing interests None declared.

Ethics approval This study was conducted with the approval of the ethics committee of Padua Hospital.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

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