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CHAPTER 14

The perfusion index of healthy term infants during transition at birth

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Submitted
Abstract

**Background:** Pulse oximetry (PO) derived perfusion index (PI) can be used to determine peripheral perfusion, but values during transition at birth have not been described.

**Aim:** To describe PI values in healthy term infants over time after birth.

**Methods:** PI of healthy term infants was recorded in the first 10 minutes after birth using a PO sensor placed preductally at the right wrist. Variability of PI was calculated using the coefficient of variation (CV).

**Results:** Recordings of 89 term infants (71 born vaginally, 18 by cesarean section) were included. No significant trend could be observed in vaginally delivered infants, but a significant increase was observed in infants born by cesarean section. Median PI was significantly higher in vaginally born infants compared to infants born by cesarean section (2.0 (1.3–2.9) vs. 1.8 (1.2–2.6); p<0.001).

**Conclusions:** Healthy term infants during transition at birth have no significant change in perfusion when vaginally born, but a small increase was observed in infants born by a cesarean section.
Introduction

In recent years, pulse oximetry (PO) has been recognized as an easily applicable, non-invasive monitoring tool and is used in the delivery room (DR) to monitor transition at birth (1-3). It is recommended to use PO for objective evaluation of heart rate (HR) and oxygen saturation (SpO₂) at birth (4;5) and to decide if interventions are necessary (6-8). In addition to HR and SpO₂, the infrared signal of a PO can also be used to determine the perfusion index (PI). PI is the ratio of the pulsatile signal (arterial blood flow) indexed against the non-pulsatile signal (static blood flow, skin and other tissues) and is a non-invasive indicator for peripheral perfusion (9). PI values of infants in the first days after birth have been described (10) and a low PI (<1.24) has been reported as an indicator for severe illness in infants (10;11).

During transition, significant respiratory and hemodynamic changes occur, influencing cardiac output and both systemic and peripheral perfusion (12-15). So far only SpO₂ and HR are used for evaluation, but these parameters do not reflect the complete hemodynamic status of the infant at birth (16). PI as a continuous parameter given by the PO could be useful for evaluating hemodynamic changes at birth and identify transitional problems. However, PI values in term infants during transition have been reported (17), but PI was not given with respect to time after birth.

The objective of this study was to evaluate PI of healthy term infants during the first 10 minutes after birth.

Methods

Measurements of PO recordings of healthy term infants born via uncomplicated vaginal delivery or elective cesarean section needing no support were used. The study was approved by the institutional review board of the LUMC and parents were antenatally approached for consent. Recordings of term infants born between February 2012 and March 2013 were reviewed retrospectively. Recordings were included if PI measurements were obtained shortly after birth and time of birth was indicated.

PI, HR and SpO₂ were recorded by placing a PO sensor (M-LNCS NeoPt-500, Masimo SET, Masimo, Irvine, CA, USA) preductally (on the ulnar aspect of the right wrist) (18) and subsequent connection to a PO (Masimo Radical 7, Masimo, Irvine, CA, USA) (19). PI, HR and SpO₂ were recorded at maximum sensitivity every 10 seconds from 2 minutes after birth.
until either 10 minutes after birth or earlier when the infant was placed in the transport incubator. The recorded values were collected using Spectra Physiological Recording Program (Grove Medical, London, UK) and stored on a laptop. Twenty seconds of time points (10 seconds before and after each 60 seconds) were averaged for each infant at minute intervals. Data were considered valid for analysis if PI, HR and SpO₂ were simultaneous present at a time point and the pulse wave was confirmed to be artifact free.

Statistical Analysis
Data were analyzed using SPSS 20.0 for Windows (IBM, Chicago, IL, USA). All variables were tested for normality using the Kolmogorov-Smirnov test. Data were presented as mean (SD), median (IQR) or absolute frequencies (percentage) where appropriate. For non-normally distributed data, a Mann-Whitney U test was used to compare PI between term infants born vaginally and by cesarean section and a Wilcoxon signed rank test was used to compare PI between time points within groups. A (two-sided) p-value of < 0.05 was considered as statistically significant.

Results
In 89 infants PO values were recorded and analyzed, of which 71 were born vaginally and 18 by cesarean section (table 1). HR and SpO₂ were within normal ranges as stated in the reference ranges (table 2) (20;21).

According to the criteria, 85% (6,600 data points) of the PI measurements were included. The median PI of the total cohort in the first 10 minutes after birth was 1.9 (1.3–2.9). No trend could be observed in vaginally delivered infants, but a small increase was observed in infants born by cesarean section (table 3). Overall PI was higher after a vaginal delivery when compared to after a cesarean section (2.0 (1.3–2.9) versus 1.8 (1.2–2.6); p < 0.001).

Table 1. Demographic and clinical characteristics.

|                      | Vaginal delivery (n = 71) | Cesarean section (n = 18) |
|----------------------|---------------------------|---------------------------|
| Gestation, mean (SD), wk | 40 (1)                   | 38 (1)                   |
| Birth weight, mean (SD), g | 3575 (482)               | 3355 (454)               |
| Male gender, n (%)     | 29 (41)                   | 10 (56)                  |
| Apgar, median (IQR)    |                           |                           |
| 1 minute              | 9 (9–9)                   | 9 (8–9)                  |
| 5 minutes             | 10 (10–10)                | 9 (8–10)                 |
The perfusion index of term infants at birth

When the data are plotted with respect to time after birth, PI after vaginal delivery was higher compared to cesarean section in the first 5 minutes, after which values were similar (figure 1).

Table 2. Heart rate (bpm) and oxygen saturation (%) measurements of healthy term infants in the first 10 minutes after birth.

| Time (m) | Vaginal delivery (n = 71) | Cesarean section (n = 18) |
|----------|---------------------------|---------------------------|
|          | HR (bpm)                  | SpO₂ (%)                  | HR (bpm)                  | SpO₂ (%)                  |
| 2        | 142 (77–169)              | 82 (73–90)                | 80 (69–159)              | 74 (70–81)                |
| 3        | 150 (120–165)             | 85 (76–91)                | 152 (115–166)            | 78 (69–87)                |
| 4        | 146 (134–158)             | 85 (80–91)                | 159 (149–166)            | 79 (71–87)                |
| 5        | 141 (133–152)             | 88 (79–93)                | 150 (135–162)            | 82 (75–89)                |
| 6        | 144 (123–156)             | 89 (83–94)                | 156 (146–163)            | 89 (83–92)                |
| 7        | 144 (132–157)             | 91 (86–95)                | 153 (144–163)            | 89 (84–94)                |
| 8        | 143 (130–156)             | 92 (87–95)                | 154 (146–162)            | 89 (84–94)                |
| 9        | 143 (133–154)             | 93 (88–96)                | 148 (143–159)            | 90 (87–95)                |
| 10       | 144 (134–153)             | 93 (90–97)                | 158 (145–165)            | 90 (83–96)                |

Table 3. Wilcoxon signed-rank test comparing perfusion index of healthy term infants in the first 10 minutes after birth.

| Time (m) | Vaginal delivery (n = 71) | Cesarean section (n = 18) |
|----------|---------------------------|---------------------------|
|          | n | PI (%) | p value | n | PI (%) | p value |
| 2        | 60 | 2.01 (1.39–3.28) | < 0.01 | 11 | 1.50 (0.83–2.80) | 0.75 |
| 3        | 64 | 2.08 (1.53–2.77) | < 0.05 | 15 | 1.40 (1.20–2.00) | 0.27 |
| 4        | 66 | 1.98 (1.35–2.80) | < 0.01 | 16 | 1.60 (1.15–2.70) | < 0.001 |
| 5        | 67 | 1.89 (1.30–3.05) | 0.65 | 15 | 1.40 (0.91–2.80) | 0.26 |
| 6        | 69 | 2.10 (1.36–3.31) | 0.34 | 18 | 1.93 (1.39–3.10) | < 0.05 |
| 7        | 69 | 1.80 (1.23–3.16) | 0.10 | 18 | 1.70 (1.30–2.30) | < 0.01 |
| 8        | 70 | 1.97 (1.34–2.79) | 0.31 | 18 | 2.00 (1.20–2.60) | < 0.05 |
| 9        | 70 | 1.90 (1.22–2.83) | 0.36 | 18 | 2.10 (1.20–2.60) | 0.97 |
Discussion

In this study we observed very little changes in PI of healthy term infants during transition after birth. The PI of infants born by cesarean section when compared to vaginally born infants was lower in the first minutes, after which they increased to similar levels as vaginally born infants.

Our finding that PI is quite consistent during transition at birth confirms previous findings where de Felice et al. reported no difference between a PI value measured at 0–1 minute and 1–5 minutes after birth (17). This indicates that pulsed wave forms measured preductally remain consistent despite the large hemodynamic changes that occur during transition. All infants cried and most likely aerated their lungs in the first breaths after birth before the cord was clamped. It has been shown that breathing before cord clamping leads to a more stable cardiovascular function and systemic circulation, which could have led to consistent PI (22;23). Also after cord clamping, the systemic vascular resistance increases while the lungs are aerated PVR decreased, which causes a left-to-right ductal shunt (24). This could have mitigated changes in peripheral circulation, which is in line with our previous observation that peripheral blood pressure remained

Figure 1. Perfusion index of healthy term infants in the first 10 minutes after birth. The box plots show median values (solid black bar), interquartile range (margins of box), and range of data.
stable during transition (16). More studies on circulation in the extremities would be needed to confirm or refute this.

We measured, preductally, a lower PI than Felice et al. measured postductally in healthy term infants (2.1 (1.5) vs 4.4 (2.1)) (17). This difference is difficult to explain, as a decreased perfusion would have been expected postductally when an increase in left-to-right shunt would occur in the ductus arteriosus (25). However, as PI is a scaled numerical value derived from the magnitude of the pulsations it is possible that the ductal steal (increase in left-to-right shunt in ductus arteriosus) would lead to larger pulse waves forms postductally. This is similar to the presence of bounding pulses as a clinical sign for a patent ductus arteriosus.

De Felice et al. also reported PI values <1.24 to be an accurate predictor for a high severity illness (17). Although we have not compared the values of the healthy term cohort with sick infants at birth, we cannot confirm this cut-off value <1.24 as approximately 25% of our healthy term infants have a PI <1.24. None of these infants needed support or were admitted later on.

The lower PI of infants born by cesarean section in the first minutes could reflect a delay in hemodynamic adaptation during transition. All were elective cesarean and these infants were born with lung liquid to clear as they were not exposed to uterine contractions and the surge of catecholamines (26). This could have led to a delay in lung aeration, which has then consequences for the hemodynamic adaptation. Indeed, a similar difference in postpartum adaptation between both methods of delivery is seen in terms of HR (20) and SpO₂ changes (21;27).

PI has been reported to vary between individuals due to changes associated with local vasodilatation and vasoconstriction, reflecting changes in the physiologic state at the measurement site (9). Comparable to HR and SpO₂, a trend in PI would give the caregiver more information than a single value. Although we reported values of healthy term infants, comparison with term infants with transitional problems is needed to determine whether PI can be a useful parameter for hemodynamic evaluation of transition and decision making.

In conclusion, we reported PI measurements in healthy term infants with respect to the course of time. during the first 10 minutes after birth. There was no significant change in PI in this period in vaginally born infants, but a small increase was observed in infants born by a cesarean section. Comparative data of infants with transitional problems are needed before PI can be used as an additional parameter for decision making at birth.
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