Transcutaneous Pco2 Monitoring in Newborn Infants During General Anesthesia Is Technically Feasible

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BACKGROUND: Transcutaneous (TC) measurement of Pco2 (TC Pco2) is a well-established method to monitor assisted ventilation in neonatal intensive care, but its use in the operating room is limited, and the data regarding its performance during general anesthesia of the newborn are lacking. The aim of this study is to evaluate the performance of continuous TC Pco2 monitoring during general anesthesia in newborn infants.

METHODS: Infants (n = 25) with a gestational age of 23 to 41 weeks and a birth weight of 548 to 4114 g were prospectively enrolled. During general anesthesia and surgery, TC Pco2 was measured continuously and recorded at 1-minute intervals. Five-minute mean values were compared with simultaneously obtained blood gas (BG) analyses of Pco2. Only the first paired TC and BG samples were used in this analysis. We defined precision as 2.1 times the standard deviation of the difference of the 2 samples. P < .01 was considered statistically significant.

RESULTS: We obtained samples from 25 infants. The difference between TC and BG was 0.3 ± 0.7 kPa (mean ± standard deviation) giving a precision of 1.47 kPa. Nineteen of twenty-five (76%) sample pairs displayed a difference of <1 kPa (99% confidence interval, 48%–92%, P = .016). The difference in paired samples was similar for different gestational and postnatal ages and did not appear to be affected by electrocautery.

CONCLUSIONS: In this small study, we did not demonstrate that TC CO2 monitoring was accurate at P < .01. This partly reflects the small size of the study, resulting in wide 99% confidence bounds. (Anesth Analg 2016;123:1004–7)
Transcutaneous Pco₂ Monitoring

TC partial pressure of carbon dioxide (TC Pco₂; kilopascal) was measured continuously by use of the TC technique using the E5280 probe (TCM 4/40, Radiometer, Denmark) with a probe temperature of 43°C according to manufacturer recommendations. Heating of the probe increases capillary blood flow as well as the diffusion of CO₂ and O₂ through the skin. Before probe placement and at 4-hour intervals, the electrode was calibrated against air and test gas. If calibration failed, the electrode membrane was replaced, and the electrode was recalibrated. The probe was placed on the upper chest, and the measurement site was changed at least every hour to minimize skin redness/thermal injury. After each probe placement, the electrode was allowed to stabilize for 15 minutes before recording TC Pco₂ values at 1-minute intervals.

Blood Gas CO₂ Analysis

BG analysis was performed using capillary blood samples (100 μL/sample) obtained from each infant’s warmed foot and was immediately analyzed for Pco₂ (BG Pco₂; kilopascal) using an automated BG analyzer (ABL800, Radiometer). By warming the foot, the capillary blood is considered arterialized and has been shown to correlate very well with arterial blood CO₂ in newborn infants.11

Measurement Procedure

In preparation for anesthesia, the TC probe was placed simultaneously with the application of electrocardiogram leads and pulse oximetry. Anesthesia was induced with thiopental (3 mg/kg), atropine (0.02 mg/kg), fentanyl (1–10 μg/kg), and neuromuscular block obtained with atracurium (0.5 mg/kg). Anesthesia was maintained with sevoflurane supplemented with intermittent dosing of fentanyl. All patients were intubated using uncuffed endotracheal tubes (2.5–3.0 mm) with pharyngeal pack and were managed using an anesthesia delivery system and ventilator (FLOW-i, Maquet, Sweden) in pressure control (infants weighing <2.8 kg) or pressure-regulated volume control mode (infants weighing ≥2.8 kg). Tidal volumes were set at 7 mL/kg body weight with a respiratory rate of 40–60/min and adjusted according to standard monitoring (ET Pco₂).

The first blood sampling was performed after the anesthesia had been induced, the infant was intubated (including placement of a pharyngeal pack), maintained on the ventilator, and before the start of surgery. Additional blood sampling (1–2 per infant) was undertaken during the surgery and recovery, but it was not included further in this analysis. All study data monitoring and collection were performed by the same person who had no role in taking care of the patient. The OR team was blinded to the TC Pco₂ data but it had access to the BG data.

Treatment of Data

Statistical analysis was performed using Statistical Package for Social Science, SPSS version 20 (IBM Corp, Armonk, NY). The TC Pco₂ value was calculated as the mean of the 5 TC Pco₂ values immediately before BG sampling. Limits of agreement were evaluated by the use of Bland–Altman analysis.12 The analysis was based on the difference between paired measurements of TC and BG Pco₂ (ie, TC Pco₂ − BG Pco₂). Bias was calculated as the average difference. Precision was calculated as the standard deviation of the difference × 2.1 (calculated as the 2-sided t-inverse statistical for P = .05 and 24 degrees of freedom × square root (1 + 1/25). Differences were assessed by Student paired t test. Data are expressed as mean ± standard deviation or median (range). A P value of <.01 was considered statistically significant. A priori, we considered an accuracy ±1 kPa to be clinically acceptable based on previously reported results from older infants during anesthesia13,14 and from the NICU environment.8 The number of subjects was based on convenience. There was no power analysis before the study.

RESULTS

The analyzed data include BG and TC Pco₂ pairs from 25 infants (Figure 1). Bland–Altman analysis revealed a bias of 0.3 ± 0.7 kPa and a precision of ±1.47 kPa (Figure 2). The TC Pco₂ to BG Pco₂ difference was ≤1 kPa in 19 of 25 (76%) data pairs (99% confidence interval, 48%–92%, P = .016 versus random chance (ie, 50%).

The TC to BG Pco₂ bias (Table 2) and data pairs are displayed further in subgroups depending on postnatal age (<1 week or ≥1 week; Figure 3) and gestational age (preterm or term; Figure 4).

DISCUSSION

The present relatively small investigation does not demonstrate that TC measurements accurately reflect Pco₂ in newborn infants during general anesthesia. The precision was 1.47 kPa, less than our accepted accuracy of 1 kPa. Although the TC Pco₂ determination in 76% of the subjects was within our acceptable range of ±1 kPa of the concurrent BG Pco₂, this did not reach statistical significance at P < .01, as demonstrated by the lower confidence bound of 48% (less than random sample).

The recognition that extremes of Pco₂, even for brief periods of time, are associated with long-term neonatal morbidity emphasizes the need for reliable and continuous monitoring of Pco₂ during general anesthesia. Arterial BG analysis from intermittent sampling from an indwelling
catheter is considered the gold standard in measuring \( P_{\text{CO}_2} \). However, the dynamics of neonatal anesthetic management mandate the use of continuous measurements. Also, placing arterial lines in the tiniest infants is often painful, cumbersome, resource consuming, and it carries a risk of vascular thrombosis.\(^{15}\) The most commonly applied method in anesthesia, ET \( \text{CO}_2 \) monitoring, is known to be less accurate in infants with lung disease, high respiratory rate, and small tidal volumes,\(^{16}\) and it is therefore of variable value at times.

TC monitoring of \( P_{\text{CO}_2} \) is well established in the NICU, and several studies have demonstrated a good correlation between TC and BG \( P_{\text{CO}_2} \) in this setting.\(^8\) The method is independent of pulmonary disease, tidal volume, high respiratory rates, and ventilator mode (eg, small tidal volumes or high-frequency oscillatory ventilation), but it may be influenced by skin edema and hypoperfusion.\(^{17}\)

### Table 2. Transcutaneous to Blood Gas \( P_{\text{CO}_2} \)

| Infant Group | n | TC-BG  |
|---------------|---|--------|
| All           | 25| 0.3 ± 0.7 |
| PNA           |   |        |
| <1 wk         | 12| 0.1 ± 0.7 |
| >1 wk         | 13| 0.5 ± 0.7 |
| GA            |   |        |
| <37 wk        | 18| 0.4 ± 0.7 |
| >37 wk        | 7 | 0.1 ± 0.7 |

Values are bias ± standard deviation (kilopascal).

Abbreviations: BG, blood gas; GA, gestational age; PNA, postnatal age; TC, transcutaneous.
Two previous studies have evaluated TC for intraoperative use in pediatric patients.\textsuperscript{13,18} Both studies report a good agreement between TC and BG Pco\textsubscript{2}, but those studies did not include any newborn infants. The authors of these studies recommend using TC as a complement to ET monitoring of Pco\textsubscript{2}. In a review of the study by Molloy and Deakins\textsuperscript{19} in 2006 conclude that TC is superior to ET and promote the use of TC for noninvasive trend monitoring of Pco\textsubscript{2}, particularly in infants with pulmonary disease.

Arguably, management of a newborn in the NICU is distinct from that in the OR, where access to the small patient is limited by sterile draping and for the purpose of maintaining thermal stability. To measure TC Pco\textsubscript{2}, the electrode needs to be calibrated, heated, and repositioned at regular intervals. These procedures did not create a barrier to the performance of the measurements in our study, suggesting that TC Pco\textsubscript{2} monitoring requires minimal staff training.

To conclude, because of the small size of our study, we were unable to demonstrate that TC monitoring of Pco\textsubscript{2} in the OR was sufficiently accurate for clinical use. A larger study is required to address this question.

**DISCLOSURES**

Name: Victoria Karlsson, RN, MMSc.

Contribution: This author helped design the study, collect the data, analyze the data, and prepare the manuscript.

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Contribution: This author helped design the study, collect the data, and prepare the manuscript.

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Contribution: This author helped design the study, review the data, analyze the data, and prepare the manuscript.

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