



## January 2008: VOLUME 5, NUMBER 5

*Editor's Note:*

### **Over 800 Responses to our Survey**

Thank you for answering the call...we received 818 responses! We appreciate your enthusiasm about *eNeonatal Review* and pledge to always maintain our high standards. We have chosen 3 remarkable comments and will announce the winners with next month's issue.

### ***The State of Non-Invasive CO<sub>2</sub> Monitoring Techniques***

### **In this Issue...**

Blood gas status is used to determine the need for initiation, adjustment, and discontinuation of mechanical ventilatory support in the neonate. Carbon dioxide monitoring by transcutaneous (TcPCO<sub>2</sub>) and end tidal (PetCO<sub>2</sub>) measurements have been proposed as noninvasive surrogates to analysis of CO<sub>2</sub> from arterial blood sampling. These monitoring techniques have not substituted for, but instead have been used as an adjunct to, standard monitoring of arterial (PaCO<sub>2</sub>) and capillary (PcapCO<sub>2</sub>) blood gases.

In this issue, we review recent reports of how these CO<sub>2</sub> monitoring techniques have been used in preterm and term infants for a variety of conditions and applications.

## THIS ISSUE

### ■ **IN THIS ISSUE**

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BY EAR SENSOR IN NEONATES**

■ **END TIDAL CO<sub>2</sub> MONITORING IN THE  
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### **Program Information**

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1.0 hours Physicians  
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### **Next Issue**

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■ [CHANGES IN TRANSCUTANEOUS, END TIDAL AND END INSPIRATORY CO<sub>2</sub> IN MECHANICALLY VENTILATED NEONATES](#)

■ [CAPNOGRAPHY FOR ASSESSMENT OF INTUBATION](#)

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**Guest Faculty Disclosure**

**Nelson Claire, MSc, PhD** has disclosed no relevant financial relationships.

**Unlabeled/Unapproved Uses**

The author has indicated that there will be no reference to unlabeled/unapproved uses of drugs or products in the presentation.

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## LEARNING OBJECTIVES

**At the conclusion of this activity, participants should be able to:**

- Discuss the current research assessing non-invasive CO<sub>2</sub> monitoring techniques in preterm and term infants, under different conditions and for different purposes
- Describe the reported advantages and limitations of non-invasive CO<sub>2</sub> monitoring
- Identify how the information presented can be used to optimize monitoring of preterm and term infants with respiratory failure

## JANUARY PODCAST



eNeonatal Review is proud to continue our accredited **PODCASTS for 2008**. [Listen here.](#)

In this audio interview, Nelson Claire, MSc, PhD, and Robert J. Kopotic, MSN, RRT, FAARC, discuss additional topics related to The State of Non-Invasive CO<sub>2</sub> Monitoring Techniques.

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Careful management is required to avoid the extremes of PaCO<sub>2</sub> associated with mechanical ventilatory support. Noninvasive TcPCO<sub>2</sub> and PetCO<sub>2</sub> monitors have been proposed as means to reduce blood sampling while providing near continuous assessment. Currently, TcPCO<sub>2</sub> is commonly used as an adjunct PaCO<sub>2</sub> or PcapCO<sub>2</sub>, while PetCO<sub>2</sub> monitoring is used less frequently.

Performing a TcPCO<sub>2</sub> measurement consists of creating a skin-electrode unit of increased local perfusion by controlled hyperemia. The neonate's thin epidermal layer has a small metabolic CO<sub>2</sub> production, and diffusing CO<sub>2</sub> molecules change the pH of an electrolyte solution. However, poor perfusion can result in overestimation due to reduced removal of the CO<sub>2</sub> produced locally. Many TcPCO<sub>2</sub> devices include a metabolism correction factor, and TcPCO<sub>2</sub> is often post-calibrated to PaCO<sub>2</sub> or PcapCO<sub>2</sub>. Further, in preterm infants, heating can produce injury, which limits application time at a single site.

Among the studies reviewed herein, Aliwalas et al reported acceptable TcPCO<sub>2</sub> bias in infants of ≤ 28 weeks (w) of gestational age (GA), but warned of between-patient variability; Tingay et al reported a small overestimation bias in TcPCO<sub>2</sub> that did not change at higher PaCO<sub>2</sub> during transport; and Bernet-Buettiker et al reported that bias in estimation of PaCO<sub>2</sub> with an ear TcPCO<sub>2</sub> electrode was small but was accompanied by variability between patients, and that TcPCO<sub>2</sub> was tightly related to PcapCO<sub>2</sub>. Although PcapCO<sub>2</sub> may not always reflect PaCO<sub>2</sub>, this correlation is important because in preterm infants, invasive arterial lines are not commonly in place beyond the critical period of respiratory failure.

PetCO<sub>2</sub> monitoring is performed by placing infrared sensors mainstream, or by sidestream gas sampling. Both the Aliwalas and Wu studies showed acceptable bias in PetCO<sub>2</sub> with respect to PaCO<sub>2</sub> in preterm infants after birth, and in older preterm and term infants using low-flow sidestream and mainstream measurements, respectively. Both studies showed important between-patient variability. However, they differed in their recommendations. Further, Tingay found PetCO<sub>2</sub> underestimated PaCO<sub>2</sub> during ground transport.

PetCO<sub>2</sub> is more responsive to changes in PaCO<sub>2</sub> than TcPCO<sub>2</sub>. However, preterm infants have a relatively large anatomical dead space and PetCO<sub>2</sub> depends on tidal volume (V<sub>T</sub>) size.<sup>1</sup> PetCO<sub>2</sub> is also influenced by the arterial-alveolar gradient in infants with lung disease. Use of this gradient as a longitudinal correlate to advancing lung disease should be further examined.

Capnography may be informative in the preterm infant but can present some shortcomings. Claire et al described capnographic patterns associated with rebreathing, while others suggested patterns associated with lung disease.<sup>2</sup> New mainstream PetCO<sub>2</sub> sensors have small dead space volumes (<1 ml), and — although this has not been documented in small preterm infants — have been shown to induce rebreathing in preterm infants in a manner similar to flow sensors of comparable size. In larger preterm infants, a mainstream PetCO<sub>2</sub> sensor of 2 ml dead space increased TcPCO<sub>2</sub> due to rebreathing.<sup>3</sup> High sidestream sampling flows can provide inaccurate data by diluting the end expiratory gas. Low-flow sidestream



PetCO<sub>2</sub> monitors have only recently become available.

In comparison to the older literature, these newer reports show improved bias with these monitoring techniques. However, there is poor precision, as indicated by wide between-patient variability. Under routine clinical conditions, the lack of certainty when a CO<sub>2</sub> reading is outside the desirable range is an important limitation. In most cases, this finding requires repeat preparation and application procedures, and often requires additional blood sampling.

The availability of monitoring data over time is important, but the ability to trend such data has not been fully exploited. Preterm infants undergo different phases of respiratory disease, and an association has been found between extremes and fluctuations in PaCO<sub>2</sub> with IVH.<sup>4</sup> Detection of ensuing changes that lead to extreme hypo- or hypercarbia may be important triggers for intervention. In many centers, TcPCO<sub>2</sub> monitoring is started ahead of a blood sample to assure stability, and monitoring often continues if the ventilatory support is changed. Although TcPCO<sub>2</sub> or PetCO<sub>2</sub> readings alone should not be used to adjust the support, they may give an early warning of impaired ventilation.

The usefulness of CO<sub>2</sub> monitoring may be enhanced when combined with ventilation data. As Claure et al reported (reviewed herein), in preterm infants, increases in PetCO<sub>2</sub> and TcPCO<sub>2</sub> correlated with rebreathing and occurred in parallel to a rise in total ventilation due to increased spontaneous breathing. In prior studies, during volume-targeted ventilation, a lower target VT led to an increase in TcPCO<sub>2</sub> and spontaneous ventilation while total ventilation remained unchanged.<sup>5</sup> Further, when preterm infants were switched from nasal CPAP to noninvasive pressure support, there was a greater increase in ventilation than among preterm infants that started with a higher baseline TcPCO<sub>2</sub>.<sup>6</sup>

Detection of exhaled CO<sub>2</sub> has been used as an adjunct to standard methods to assess proper intubation. The report by Repetto et al suggests a means to more quickly detect improper intubation. However, PetCO<sub>2</sub> alone may not be recommended, since conditions of reduced pulmonary circulation could lead to poor CO<sub>2</sub> detection in spite of a correct intubation. A recent (2007) report recommends caution due to the risk of false-positive color change in colorimetric CO<sub>2</sub> detectors in the presence of epinephrine, atropine, calfactant, and naloxone administered through the endotracheal tube.<sup>7</sup>

The recent peer-reviewed reports summarized herein, evaluating TcPCO<sub>2</sub> and PetCO<sub>2</sub> usefulness in estimating PaCO<sub>2</sub>, indicate that TcPCO<sub>2</sub>, in spite of its limitations, can be used as an acceptable estimate of CO<sub>2</sub> measured with arterial and capillary blood gases. These newer data also suggest improved accuracy of PetCO<sub>2</sub>. However, most of these reports, similar to prior ones, do not justify substitution of PaCO<sub>2</sub> analysis with these non-invasive methods. Nonetheless, the use of continuous CO<sub>2</sub> monitoring as an adjunct to standard care has been shown beneficial in newborns in respiratory failure and, perhaps more particularly, in labile preterm infants by providing CO<sub>2</sub> trending and variability data.

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## TRANSCUTANEOUS AND END TIDAL MONITORING IN PRETERM INFANTS ( $\leq 28$ WEEKS GESTATION) WITH RDS

Aliwalas LL, Noble L, Nesbitt K, Fallah S, Shah V, Shah PS. **Agreement of carbon dioxide levels measured by arterial transcutaneous and end tidal methods in preterm infants  $\leq 28$  weeks gestation**. *J Perinatol*. 2005; 25(1):26-29.

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Aliwalas et al sought to assess the agreement between measurements of TcPCO<sub>2</sub> and sidestream PetCO<sub>2</sub> with PaCO<sub>2</sub> at 3 time points during the first 24 hours after birth (at 4, 12 and 24 h) in infants born at  $\leq 28$  w GA. Data were obtained from 27 ventilated infants with RDS who had a mean GA of  $26.3 \pm 1$  w and a birth weight (BW) of  $875 \pm 14$  grams (g). TcPCO<sub>2</sub> was measured at 44°C and a metabolic correction factor of 5 mmHg was applied.

The intraclass correlation coefficient indicated moderate agreement between TcPCO<sub>2</sub> and PaCO<sub>2</sub> and between PetCO<sub>2</sub> and PaCO<sub>2</sub> at the 3 time points during the first 24 hours. The bias observed in these two methods was relatively small (2.2, 4.4, and 2.6 mmHg for TcPCO<sub>2</sub>, and -0.3, 2.4, and 1.9 mmHg for PetCO<sub>2</sub> at 4, 12 and 24h, respectively). However, the precision reflected a wide between-patient variation. Interestingly, both bias and precision did not change with time. The comparisons (TcPCO<sub>2</sub> – PaCO<sub>2</sub> and PetCO<sub>2</sub> – PaCO<sub>2</sub>) were not influenced by BW, mean airway pressure, mean blood pressure, or application site of the transcutaneous probe. The investigators acknowledge that the lack of observed effect of these factors may be related to the sample size.

This well-conducted study presents valuable data obtained during the initial phase of respiratory failure. The investigators cautiously conclude that agreement is moderate but not sufficient to recommend substitution of the standard practice of PaCO<sub>2</sub> sampling. Nonetheless, these results show smaller measurement bias compared to older reports. Further, although these data included 3 time points during the first 24 hours, within-patient trending data were not given. Such

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information could provide additional insights on the ability of these monitoring methods to follow trends. Moreover, longitudinal data beyond day 1 would have provided additional valuable information.

## TRANSCUTANEOUS AND END TIDAL CO<sub>2</sub> MONITORING DURING NEONATAL TRANSPORT

Tingay DG, Stewart MJ, Morley CJ. **Monitoring of end tidal carbon dioxide and transcutaneous carbon dioxide during neonatal transport.** *Arch Dis Child Fetal Neonatal Ed.* 2005; 90(6):F523-526.

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The aim of this study was to assess the accuracy and reliability of end tidal CO<sub>2</sub> during neonatal transport. Sidestream PetCO<sub>2</sub> measurements were compared to arterial and transcutaneous measurements in mechanically ventilated infants during neonatal transport. PetCO<sub>2</sub>, TcPCO<sub>2</sub>, and PaCO<sub>2</sub> data were obtained from 21 infants with GA between 26 to 40 w, age at study 1.8 to 61.2 hours, who underwent ground transport. Recordings of TcPCO<sub>2</sub> and PetCO<sub>2</sub> were calibrated to simultaneous PaCO<sub>2</sub> values.

Although PetCO<sub>2</sub>, TcPCO<sub>2</sub> and PaCO<sub>2</sub> were linearly related, the investigators found that PetCO<sub>2</sub> underestimated PaCO<sub>2</sub> by a consistent bias of 7.8 mmHg, while TcPCO<sub>2</sub> overestimated PaCO<sub>2</sub> by 0.97 mmHg. This finding was more evident among infants with severe lung disease. Further, the bias observed with TcPCO<sub>2</sub> and PetCO<sub>2</sub> did not change with PaCO<sub>2</sub>. Two-thirds of the TcPCO<sub>2</sub> values were within 5.3 mmHg of the paired PaCO<sub>2</sub> value, while 81% of TcPCO<sub>2</sub> values were within 7.5 mmHg of PaCO<sub>2</sub>. In contrast, only 48% of PetCO<sub>2</sub> values were within 7.5 mmHg of PaCO<sub>2</sub>.

This study indicates that TcPCO<sub>2</sub> is sufficiently accurate for PaCO<sub>2</sub> estimation during neonatal transport, while sidestream PetCO<sub>2</sub> readings should be used with caution as they (on average) underestimated PaCO<sub>2</sub>. The investigators suggest TcPCO<sub>2</sub> as the preferred method for CO<sub>2</sub> monitoring. These data could be extrapolated to the NICU, where conditions may facilitate the use of these devices in situations comparable to neonatal transport. Finally, although not provided, additional information may have been gained by stratified analysis, since the study included such a wide range of GA.

## TRANSCUTANEOUS CO<sub>2</sub> MONITORING BY EAR SENSOR IN NEONATES

Bernet-Buettiker V, Ugarte MJ, Frey B, Hug MI, Baenziger O, Weiss M. **Evaluation of a new combined transcutaneous measurement of PCO<sub>2</sub>/pulse oximetry oxygen saturation ear sensor in newborn patients.** *Pediatrics.* 2005; 115(1):e64-68.

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The aim of this study was to evaluate a newly developed combination TcPCO<sub>2</sub>/pulse oximetry (SpO<sub>2</sub>) sensor that obtains measurements from the neonate's ear. This sensor works at a temperature of 42° C at the point of contact to the skin. The investigators compared TcPCO<sub>2</sub> data to PaCO<sub>2</sub> readings from 30 infants of a median age of 3.5 (1-28) d and at 38.3 (28.7-40.7) w post-conception.

TcPCO<sub>2</sub> data were also compared to PcapCO<sub>2</sub> readings in a second group of 30 infants of a median age of 9.1 (1-28) d and at 37.9 (29.9-41.0) w post conception. In the TcPCO<sub>2</sub> - PaCO<sub>2</sub> comparison group, the ear TcPCO<sub>2</sub> sensor overestimated PaCO<sub>2</sub> with a bias of 3.21 mmHg and a precision of 6.02 mmHg (2 SD of the mean difference). In this group 23/30 infants were receiving conventional or high frequency ventilation and only 3 infants had a BW <1500g. In the second group, the TcPCO<sub>2</sub> - PcapCO<sub>2</sub> comparisons revealed that the ear TcPCO<sub>2</sub> sensor overestimated PcapCO<sub>2</sub> with a bias of only 0.67 mmHg and 8.07 mmHg precision. In this group, only 2/30 infants were receiving conventional ventilation.

These results indicate that this new TcPCO<sub>2</sub> device can be used to detect PaCO<sub>2</sub> with an acceptable bias, an improvement in the measurement as compared to older data. However, precision data indicating limits of agreement suggest caution in using TcPCO<sub>2</sub> alone or as a primary factor to guide an intervention. Interestingly, TcPCO<sub>2</sub> measurements were close to those obtained by PcapCO<sub>2</sub>. This is likely due to the fact that both estimate capillary bed CO<sub>2</sub> tension. Although capillary blood sampling may not always reflect arterial blood gases, it is the only method available for infants without invasive arterial catheters. The sensor temperature of 42° C is sufficient for TcPCO<sub>2</sub>, and is more appealing in small infants with immature skin than the 44° C, typically needed for monitoring TcPO<sub>2</sub>. However, this study did not include infants under 28 w GA; therefore, these results cannot be extrapolated to this population. Further, the application of this sensor in small preterm infants remains to be evaluated.

## END TIDAL CO<sub>2</sub> MONITORING IN THE NICU

Wu CH, Chou HC, Hsieh WS, Chen WK, Huang PY, Tsao PN. **Good estimation of arterial carbon dioxide by end-tidal carbon dioxide monitoring in the neonatal intensive care unit.** *Pediatr Pulmonol.* 2003; 35(4):292-295.

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The objective of this investigation was to evaluate mainstream PetCO<sub>2</sub> measurements for estimation of PaCO<sub>2</sub> in term and preterm neonates. The study population included 20 term and 41 preterm ventilated infants of a median GA of 31.4 (22.8 - 42.2) w, who were studied at a median age of 13 days. Paired values of PetCO<sub>2</sub> and PaCO<sub>2</sub> were compared in both groups of infants.

In the term infants, PetCO<sub>2</sub> underestimated PaCO<sub>2</sub> with a bias of 3.5 ± 9.0 mmHg. Measurements in the preterm infant group also showed that PetCO<sub>2</sub> underestimated PaCO<sub>2</sub> with a bias of 3.4 ± 6.0 mmHg. Precision (2 SD of the mean difference) was 18 mmHg and 12 mmHg for term and preterm infants, respectively. The assessment of correlation between PetCO<sub>2</sub> and PaCO<sub>2</sub> showed an r-value of 0.78 and 0.85 for term and preterm infants respectively.

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These data indicate good correlation and an acceptable bias in the estimation of PaCO<sub>2</sub> with mainstream PetCO<sub>2</sub> monitoring in term and preterm ventilated infants. This report describes one of the better correlations reported in the literature, and based on the findings, the investigators recommend use of PetCO<sub>2</sub> instead of PaCO<sub>2</sub> to reduce blood loss. The reported precision, however, indicates significant between-patient variability — which was surprisingly better in the preterm than in the term group of infants.

## CHANGES IN TRANSCUTANEOUS, END TIDAL AND END INSPIRATORY CO<sub>2</sub> IN MECHANICALLY VENTILATED NEONATES

Claire N, D'Ugard C, Bancalari E. **Elimination of ventilator dead space during synchronized ventilation in premature infants.** *J Pediatr.* 2003; 143(3):315-320.

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In this study, the investigators sought to document the effects of increased instrumental dead space caused by mainstream flow sensors, and to develop a method to reduce these effects during synchronized ventilation in preterm infants.

The effects were assessed by measurements of ventilation, TcPCO<sub>2</sub>, and measurements of end-inspiratory and end tidal CO<sub>2</sub> from sidestream capnography. Ten ventilated preterm infants with a mean BW of 835 ± 244 g, GA 26 ± 2 w, age 19 ± 9 days underwent 4 30-minute periods of IMV (w/o flow sensor), IMV (with flow sensor), SIMV (with flow sensor), and SIMV with a continuous washout of the flow sensor.

The authors report that the presence of the flow sensor induced rebreathing. End-inspiratory CO<sub>2</sub> increased consistently in all patients from a mean of 1 to 5.2 mmHg, while the end-tidal CO<sub>2</sub> increased from 42 to 48 mmHg. This increase was also consistently detected by TcPCO<sub>2</sub>, with changes from a mean of 60 to 64.5 mmHg.

This increase in CO<sub>2</sub> occurred in spite of an increase in minute ventilation. On average, the presence of the flow sensor led to a 40% increase in minute ventilation. Since ventilator settings were not changed, this increase in ventilation was mostly due to an increase in spontaneous breathing effort.

The presence of the flow sensor altered end-inspiratory, end tidal CO<sub>2</sub> values and altered the capnogram waveform in early inspiration, indicating a higher concentration of CO<sub>2</sub> present in the inhaled gas at the beginning of the breath. Although the sensor added < 1 ml of dead space, it increased rebreathing as indicated by an increased end-inspiratory and end tidal CO<sub>2</sub>. The observed changes in PetCO<sub>2</sub> and TcPCO<sub>2</sub> were consistently correlated. In response, spontaneous ventilation increased.

Although the objective of this study was to show the effects of instrumental dead space, the findings clearly document the ability of TcPCO<sub>2</sub> and PetCO<sub>2</sub> to detect trends in CO<sub>2</sub>. Under most conditions a rise in CO<sub>2</sub> would indicate reduced ventilation; in this study, CO<sub>2</sub> changed in the same direction as ventilation. Thus, both pieces of information are complementary. Capnography tracked the mechanism by which rebreathing affects ventilation efficacy.



## CAPNOGRAPHY FOR ASSESSMENT OF INTUBATION

Repetto JE, Donohue PA-C PK, Baker SF, Kelly L, Noguee LM. **Use of capnography in the delivery room for assessment of endotracheal tube placement.** *J Perinatol.* 2001; 21(5):284-287.

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The objective of this study was to determine the effectiveness of end-tidal CO<sub>2</sub> detection as an adjunct to neonatal intubation procedures in the delivery room. Although an investigator accompanied the clinical team and obtained mainstream capnography, the clinical team was unaware of the readings and did not use these data to determine proper endotracheal intubation.

Data from 27 intubations for resuscitation or stabilization on 16 infants were obtained. These infants had a mean BW of 1209 ± 461 g and GA 29 ± 4 w. Sixteen intubations were tracheal and 11 were esophageal. They were all correctly identified as such by capnography. A correct endotracheal intubation was judged by the presence of a normal capnographic wave, rather than the end tidal reading.

The time required to identify tracheal or esophageal intubations by capnography was consistently faster than clinical methods in all intubations. The mean time to recognize endotracheal intubation was 11 ± 6 seconds (s) with capnography, compared to 33 ± 14 s by clinical methods; the time of recognition of esophageal intubation with capnography was 9 ± 3 s, compared to 46 ± 25 s by clinical methods. The mean end tidal CO<sub>2</sub> detected during esophageal intubations was 9 ± 3 mmHg, compared to 39 ± 2 mmHg during endotracheal intubations.

These data are suggestive of a potential benefit of CO<sub>2</sub> detection as an adjunct to standard procedures to assess appropriate intubation in a timely manner. Although the end tidal readings between endotracheal and esophageal intubations did not overlap, it is apparent that CO<sub>2</sub> was detected in some of the esophageal intubations. This may be due to exhaled gases being forced into the stomach during preceding mask bag ventilation. This finding indicates added specificity when using the cycling capnographic waveform in the detection of endotracheal intubation rather than CO<sub>2</sub> detection alone. However, this study did not include infants who had poor pulmonary blood flow (such as in cardiopulmonary arrest), a condition that would prevent accurate CO<sub>2</sub> detection in spite of correct endotracheal intubation.

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## Credit Designations — [back to top](#)

### Physicians

**eNewsletter:** The Johns Hopkins University School of Medicine designates this educational activity for a maximum of 1.0 *AMA PRA Category 1 Credit(s)*<sup>TM</sup>. Physicians should only claim credit commensurate with the extent of their participation in the activity.

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### Nurses

**eNewsletter:** This 1.0 contact hour Educational Activity (Provider Directed/Learner Paced) is provided by The Institute for Johns Hopkins Nursing. Each newsletter carries a maximum of 1.0 contact hours.

**Podcast:** This 0.5 contact hour Educational Activity (Provider Directed/Learner Paced) is provided by The Institute for Johns Hopkins Nursing. Each podcast carries a maximum of 0.5 contact hours.

### Respiratory Therapists

**For United States:** [Visit this page](#) to confirm that your state will accept the CE Credits gained through this program.

**For Canada:** [Visit this page](#) to confirm that your province will accept the CE Credits gained through this program.

## Post-Test — [back to top](#)

To take the post-test for eNeonatal Review you will need to visit [The Johns Hopkins University School of Medicine's CME website](#) or [The Institute for Johns Hopkins Nursing](#). If you have already registered for another Hopkins CME program at these sites, simply enter the requested information when prompted. Otherwise, complete the registration form to begin the testing process. A passing grade of 70% or higher on the post-test/evaluation is required to receive CME/CNE credit.

## Statement of Responsibility — [back to top](#)

The Johns Hopkins University School of Medicine and The Institute for Johns Hopkins Nursing take responsibility for the content, quality, and scientific integrity of this CME/CNE activity.

## Target Audience — [back to top](#)

This activity has been developed for neonatologists, NICU nurses and respiratory therapists working with neonatal patients. There are no fees or prerequisites for this activity.

## Learning Objectives — [back to top](#)

At the conclusion of this activity, participants should be able to:

- Discuss the current research assessing non-invasive CO<sub>2</sub> monitoring techniques in preterm and term infants, under different conditions and for different purposes
- Describe the reported advantages and limitations of non-invasive CO<sub>2</sub> monitoring
- Identify how the information presented can be used to optimize monitoring of preterm and term infants with respiratory failure

## Internet CME/CNE Policy — [back to top](#)

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PHYSICIAN  
POST-TEST

NURSE  
POST-TEST

### Respiratory Therapists

Visit this page to confirm that your state will accept the CE Credits gained through this program or click on the link below to go directly to the post-test.

RESPIRATORY  
THERAPIST  
POST-TEST

## Faculty Disclosure — [back to top](#)

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- **Edward E. Lawson, MD** has indicated a financial relationship of grant/research support from the National Institute of Health (NIH). He also receives financial/material support from Nature Publishing Group as the Editor of the *Journal of Perinatology*.
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- **Mary Terhaar, DNSc, RN** has indicated no financial relationship with commercial supporters.
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