

WORKSHEET for PROPOSED Evidence-Based GUIDELINE RECOMMENDATIONS

Worksheet Author:	Home Subcommittee: BLS
Author's Home Resuscitation Council: NRP	Date Submitted to Subcommittee: <u>9/30/03</u> ; revised 30Sep04; 03Nov04

STEP 1: STATE THE PROPOSAL. State if this is a proposed new guideline; revision to current guideline; or deletion of current guideline.

Revision of current guideline. Should CO₂ detectors be recommended for secondary confirmation intubation for resuscitation of neonates?

Existing guideline, practice or training activity:

An exhaled-CO₂ monitor is one of several secondary confirmation devices that should be used to verify tracheal tube placement. These devices are associated with some false-negative results (may lead to removal of a properly placed tube), but rarely false-positive results so it does not lead to thinking an incorrectly placed tube is in the trachea. Monitoring of exhaled CO₂ can be useful in the secondary confirmation of tracheal intubation in the newly born, particularly when clinical assessment is equivocal (Class Indeterminate).

Step 1A: Refine the question; state the question as a positive (or negative) hypothesis. State proposed guideline recommendation as a specific, positive hypothesis. Use single sentence if possible. Include type of patients; setting (in-/out-of-hospital); specific interventions (dose, route); specific outcomes (ROSC vs. hospital discharge).

CO₂ detectors should be recommended as standard of care for secondary confirmation of endotracheal intubation in resuscitation of neonates in the delivery room.

Step 1B: Gather the Evidence; define your search strategy. Describe search results; describe best sources for evidence.

List electronic databases searched (at least MEDLINE (<http://igm.nlm.nih.gov/>) and hand searches of journals, review articles, and books.

Medline, National Library of Medicine, Cochrane Database, hand searches of journals, review articles and books

- State major criteria you used to limit your search; state inclusion or exclusion criteria (e.g., only human studies with control group? no animal studies? N subjects > minimal number? type of methodology? peer-reviewed manuscripts only? no abstract-only studies?)

MeSH term search: capnography, limited to all infants birth-23 months, human no abstracts

- Number of articles/sources meeting criteria for further review: Create a citation marker for each study (use the author initials and date or Arabic numeral, e.g., "Cummins-1"). If possible, please supply file of best references; End Note 4+ preferred as reference manager, though other reference databases acceptable.

19

STEP 2: ASSESS THE QUALITY OF EACH STUDY

Step 2A: Determine the Level of Evidence. For each article/source from step 1, assign a level of evidence—based on study design and methodology.

Level of Evidence	Definitions (See manuscript for full details)
Level 1	Randomized clinical trials or meta-analyses of multiple clinical trials with substantial treatment effects
Level 2	Randomized clinical trials with smaller or less significant treatment effects
Level 3	<u>Prospective</u> , controlled, non-randomized, cohort studies
Level 4	<u>Historic</u> , non-randomized, cohort or case-control studies

Level 5	<u>Case series</u> : patients compiled in serial fashion, lacking a control group
Level 6	Animal studies or mechanical model studies
Level 7	Extrapolations from existing data collected for other purposes, theoretical analyses
Level 8	Rational conjecture (common sense); common practices accepted before evidence-based guidelines

Step 2B: Critically assess each article/source in terms of research design and methods.

Was the study well executed? Suggested criteria appear in the table below. Assess design and methods and provide an overall rating. Ratings apply within each Level; a Level 1 study can be excellent or poor as a clinical trial, just as a Level 6 study could be excellent or poor as an animal study. Where applicable, please use a superscripted code (shown below) to categorize the primary endpoint of each study. For more detailed explanations please see attached assessment form.

Component of Study and Rating	Excellent	Good	Fair	Poor	Unsatisfactory
Design & Methods	Highly appropriate sample or model, randomized, proper controls AND Outstanding accuracy, precision, and data collection in its class	Highly appropriate sample or model, randomized, proper controls OR Outstanding accuracy, precision, and data collection in its class	Adequate, design, but possibly biased OR Adequate under the circumstances	Small or clearly biased population or model Weakly defensible in its class, limited data or measures	Anecdotal, no controls, off target end-points Not defensible in its class, insufficient data or measures

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint

B = Survival of event D = Intact neurological survival

Step 2C: Determine the direction of the results and the statistics: supportive? neutral? opposed?

DIRECTION of study by results & statistics:	SUPPORT the proposal	NEUTRAL	OPPOSE the proposal
Results	Outcome of proposed guideline superior, to a clinically important degree, to current approaches	Outcome of proposed guideline no different from current approach	Outcome of proposed guideline inferior to current approach

Step 2D: Cross-tabulate assessed studies by a) level, b) quality and c) direction (ie, supporting or neutral/ opposing); **combine and summarize.** Exclude the *Poor* and *Unsatisfactory* studies. Sort the *Excellent*, *Good*, and *Fair* quality studies by both *Level and Quality of evidence*, and *Direction of support* in the summary grids below. Use citation marker (e.g. author/ date/source). In the

Neutral or Opposing grid use bold font for Opposing studies to distinguish them from merely neutral studies. Where applicable, please use a superscripted code (shown below) to categorize the primary endpoint of each study.

Supporting Evidence

CO₂ detectors should be recommended as standard of care for secondary confirmation of endotracheal intubation in resuscitation of neonates in the delivery room.

Quality of Evidence	Excellent								
	Good					Aziz 1999 ^E Arsowa 1997 ^E Bhende 2002 ^E Bhende 1995 ^{A,B,E} Bhende 1992a ^E Bhende 1992b ^E Campbell 1994 ^E Repetto JE, 2001 Roberts 1995 ^E	Garcia Canto 1997 ^E Hagerty 2002 ^E Meredith 1990 ^E Nangia 1997 ^E Rozycki 1998 ^E Rich 1991 ^E Sivan 1992 ^E Tobias 1997 ^E Wu, 2003		
	Fair								
		1	2	3	4	5	6	7	8
Level of Evidence									

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
 B = Survival of event D = Intact neurological survival

Neutral or Opposing Evidence

CO₂ detectors should be recommended as standard of care for secondary confirmation of endotracheal intubation in

resuscitation of neonates in the delivery room.

Quality of Evidence	Excellent								
	Good								
	Fair								
		1	2	3	4	5	6	7	8
		Level of Evidence							

A = Return of spontaneous circulation C = Survival to hospital discharge E = Other endpoint
 B = Survival of event D = Intact neurological survival

REVIEWER’S PERSPECTIVE AND POTENTIAL CONFLICTS OF INTEREST: Briefly summarize your professional background, clinical specialty, research training, AHA experience, or other relevant personal background that define your perspective on the guideline proposal. List any potential conflicts of interest involving consulting, compensation, or equity positions related to drugs, devices, or entities impacted by the guideline proposal. Disclose any research funding from involved companies or interest groups. State any relevant philosophical, religious, or cultural beliefs or longstanding disagreements with an individual.

Academic neonatologist with research interest in respiratory disorders; past member of the NRP Steering Committee. No conflict of interest. Funded by NIH. No disagreements.

REVIEWER’S FINAL COMMENTS AND ASSESSMENT OF BENEFIT / RISK: Summarize your final evidence integration and the rationale for the class of recommendation. Describe any mismatches between the evidence and your final Class of Recommendation. “Mismatches” refer to selection of a class of recommendation that is heavily influenced by other factors than just the evidence. For example, the evidence is strong, but implementation is difficult or expensive; evidence weak, but future definitive evidence is unlikely to be obtained. Comment on contribution of animal or mechanical model studies to your final recommendation. Are results within animal studies homogeneous? Are animal results consistent with results from human studies? What is the frequency of adverse events? What is the possibility of harm? Describe any value or utility judgments you may have made, separate from the evidence. For example, you believe evidence-supported interventions should be limited to in-hospital use because you think proper use is too difficult for pre-hospital providers.

Worksheet Author Recommendations for Secondary Confirmation of Proper Endotracheal Tube Placement:

Appropriate endotracheal tube placement must be assessed following intubation using physical examination techniques (primary confirmation). A secondary confirmation technique should be used in addition to the physical examination following endotracheal intubation (Class IIA). The techniques for secondary confirmation include qualitative exhaled CO₂ detectors and quantitative CO₂ measuring devices. Other techniques for secondary confirmation (e.g. evaluation of condensed humidified gas during exhalation) can be used but these have not been evaluated in rigorously designed studies in neonates (Aziz 1999, Bhende 1995, Repetto 2001, Roberts 1995).

A positive test (detection of exhaled CO₂) confirms placement of the endotracheal tube within the trachea, whereas a negative test strongly suggests esophageal intubation. Poor or absent pulmonary blood flow may give false negative results, but tracheal tube placement is correctly identified in nearly all patients who are not in cardiac arrest. End-tidal CO₂ detection or measurement identifies esophageal intubations faster than using clinical assessments only.

Because of the lack of randomized controlled trials in neonates undergoing resuscitation to document important benefits, recommendation is only a Class IIA. There is low likelihood for harm except in critically ill infants with cardiac arrest, in whom a false negative result may lead to an unnecessary extubation. Low cardiac output can lead to low CO₂ delivery to the alveoli and thus a false negative test.

Absolute end-tidal CO₂ values correlate well with PaCO₂ values, but frequently underestimate PaCO₂ values especially with increasing pulmonary disease. Qualitative data from the various studies are homogeneous. The heterogeneity in the quantitative CO₂ measurement should not affect the use of exhaled CO₂ devices to confirm intubation.

Animal and adult data consistently document the usefulness of CO₂ detection in the secondary confirmation of endotracheal intubation.

Preliminary draft/outline/bullet points of Guidelines revision: Include points you think are important for inclusion by the person assigned to write this section. Use extra pages if necessary.

Attachments:

- Printed (paper) bibliography; and on diskette using a reference manager. It is recommended that the bibliography be printed in annotated format. This will include the article abstract and any notes you would like to make providing specific comments on the quality, methodology and/or conclusions of the study.
- Key figures or tables from evidence-based analysis
- Full hard copies of most critical cited papers

Citation List

Citation Marker	Full Citation*
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{Arsowa, 1997 #1}	Arsowa S, Schmalisch G, Wauer RR. Simultaneous measurements of end-expiratory and transcutaneous carbon dioxide partial pressure in ventilated premature and newborn infants. <i>Klin Padiatr.</i> 1997. 209:47-53.
{Aziz, 1999 #2}	Aziz HF, Martin JB, Moore JJ. The pediatric disposable end-tidal carbon dioxide detector role in endotracheal intubation in newborns. <i>J Perinatol.</i> 1999. 19:110-113. Bhende MS, Allen WD Jr. Evaluation of a Capno-Flo resuscitator during transport of critically ill children. <i>Pediatr Emerg Care.</i> 2002.18:414-416.
{Bhende, 1992 #5}	Bhende MS, Thompson AE. Evaluation of an end-tidal CO ₂ detector during pediatric cardiopulmonary resuscitation. <i>Pediatrics.</i> 1995. 95:395-399.
{Bhende, 1992 #6}	Bhende MS, Thompson AE, Cook DR, Saville AL. Validity of a disposable end-tidal CO ₂ detector in verifying endotracheal tube placement in infants and children. <i>Annals of Emergency Medicine.</i> 1992b. 21:142-145.
{Bhende, 1995 #4}	Bhende MS, Thompson AE, Orr RA. Utility of an end-tidal carbon dioxide detector during stabilization and transport of critically ill children. <i>Pediatrics.</i> 1992a. 89:1042-1044.
{Bhende, 2002 #3}	Campbell FA, McLeod ME, Bissonnette B, Swartz JS. End-tidal carbon dioxide measurement in infants and children during and after general anaesthesia. <i>Can J Anaesth.</i> 1994. 41:107-110. Garcia CE, Gutierrez LA, Izquierdo MI, Alberola PA, Moricillo SF. The value of capnography and exhaled CO ₂ in neonatal intensive care units. <i>An Esp Padiatr.</i> 1997. 47:177-80.
{Campbell, 1994 #7}	
{Garcia Canto, 1997 #8}	Hagerty JJ, Kleinman ME, Zurakowski D, Lyons AC, Krauss B. Accuracy of a new low-flow sidestream capnography technology in newborns: a pilot study. <i>J Perinatol.</i> 2002. 22:219-225.
{Hagerty, 2002 #19}	Hsieh KS, Lee CL, Lin CC, Wu SN, KO FY, Huang YF, Huang TC. Quantitative analysis of end-tidal carbon dioxide during mechanical and spontaneous ventilation in infants and young children. <i>Pediatr Pulmonol.</i> 2001. 32:453-458.
{Hsieh, 2001 #10}	Meredith KS, Monaco FJ. Evaluation of a mainstream capnometer and end-tidal carbon dioxide monitoring in mechanically ventilated infants. <i>Pediatr Pulmonol.</i> 1990. 9:254-459.
	Nangia S, Saili A, Dutta AK. End tidal carbon dioxide monitoring--its reliability in neonates. <i>Indian J Padiatr.</i> 1997. 64:389-394.
{Meredith, 1990 #11}	Repetto JE, Donohue PA-C PK, Baker SF, Kelly L, Nogee LM. Use of Capnography in the Delivery Room for Assessment of Endotracheal Tube Placement. <i>JPerinatol.</i> 2001. 2221:284-287.
{Nangia, 1997 #12}	Rich GF, Sconzo JM. Continuous end-tidal CO ₂ sampling within the proximal endotracheal tube estimates arterial CO ₂ tension in infants. <i>Can J Anaesth.</i> 1991. 38:201-203.
{Repetto, 2001 #13}	Roberts WA, Maniscalco WM, Cohen AR, Litman RS, Chhibber A. The use of capnography for recognition of esophageal intubation in the neonatal intensive care unit. <i>Pediatr Pulmonol.</i> 1995. 19:262-268.
{Rich, 1991 #14}	Rozycki HJ, Sysyn GD, Marshall MK, Malloy R, Wiswell TE. Mainstream end-tidal carbon dioxide monitoring in the neonatal intensive care unit. <i>Pediatrics.</i> 1998. 101:648-653.
{Roberts, 1995	Sivan Y, Eldadah MK, Cheah TE, Newth CJ. Estimation of arterial carbon dioxide by

#15}	end-tidal and transcutaneous PCO ₂ measurements in ventilated children. <i>Pediatr Pulmonol.</i> 1992. 12:153-157.
{Rozycki, 1998 #16}	Tobias JD, Meyer DJ. Noninvasive monitoring of carbon dioxide during respiratory failure in toddlers and infants: end-tidal versus transcutaneous carbon dioxide. <i>Anesth Analg.</i> 1997. 85:55-58.
{Sivan, 1992 #17}	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. <i>Pediatr Pulmonol.</i> 2003. 35:292-295.
{Tobias, 1997 #18}	
{Wu, 2003 #19}	

*Type the citation marker in the first field and then paste the full citation into the second field. You can copy the full citation from EndNote by selecting the citation, then copying the FORMATTED citation using the short cut, Ctrl-K. After you copy the citation, go back to this document and position the cursor in the field, then paste the citation into the document (use Ctrl-V). For each new citation press Enter to move down to start a new paragraph.

Arsova S, Schmalisch G, Wauer RR. Simultaneous measurements of end-expiratory and transcutaneous carbon dioxide partial pressure in ventilated premature and newborn infants. *Klin Padiatr.* 1997. 209:47-53.

Abstract

BACKGROUND: The aim of the present trial was to study the relationship between end-tidal pCO₂ (p(et)CO₂) and transcutaneous pCO₂ (ptcCO₂) after in-vivo calibration in ventilated newborns. **PATIENTS:** 61 end-tidal and transcutaneous pCO₂ measurements were simultaneously performed in 30 ventilated preterm and term newborn infants (weight at birth 1862.6 +/- 981.9 g). **METHOD:** End-tidal pCO₂ was measured in mainstream mode at the end of the endotracheal tubus (Novamatrix 7000 Medical Systems Inc., USA, dead volume of the chamber 0.6 ml). Transcutaneous pCO₂ was measured by means of a Servomed (SMK 365 Hellige, FRG) analyser. **RESULTS:** The statistical analysis demonstrated a good correlation ($r = 0.72$, $p < 0.001$) between ptcCO₂ (mean +/- SD, 44.3 +/- 11.2 mmHg) and p(et)CO₂ (32.4 +/- 10.4 mmHg). A considerable difference between transcutaneous and end-tidal pCO₂ values was observed (p(tc-et)CO₂ = +11.9 +/- 8.7 mmHg). This phenomenon was probably caused by ventilation-perfusion disturbances in the studied critically ill neonates. The statistical analysis revealed that the absolute magnitude of the P(tc-et)CO₂ difference was independent from disease, episodes of spontaneous respiration or of respiratory frequency. **CONCLUSIONS:** Capnographic determination of P(et)CO₂ provides informations about alveolar ventilation-perfusion-disturbances. Capnography enables the on-line control of end-tidal pCO₂ in neonates with respiratory failure. It cannot replace transcutaneous pCO₂ measurements or blood gas analysis but it can reduce its frequency in clinically stable patients. The analysis of the capnogram can be used to optimise artificial ventilation. A quantitative evaluation of the capnogram by calculation of Muranyi's-CO₂-Index was possible only in 28% of the ventilated newborns which limits its value in such patients.

(LOE 5 Supportive)

Aziz HF, Martin JB, Moore JJ. The pediatric disposable end-tidal carbon dioxide detector role in endotracheal intubation in newborns. *J Perinatol.* 1999. 19:110-113.

Abstract

OBJECTIVE: To determine the practical value of the new pediatric disposable ETCO₂ detector Pedi-CAP in verifying endotracheal tube placement in neonatal resuscitation. **METHODS:** Infants who required endotracheal intubation in the delivery room or the neonatal intensive care unit (NICU) were included in a prospective study in which the endotracheal tube placement was determined clinically and simultaneously by the Pedi-CAP and confirmed by chest radiograph. The Pedi-CAP and clinical evaluation determination times of the endotracheal tube placement were measured and compared. The accuracy and ease of the Pedi-CAP use were tested. **RESULTS:** Forty-five newborns (450 to 4620 gm) who needed endotracheal intubation were included in the study. Twenty-four (53.3%) were intubated in the delivery room and 21 (46.7%) in the NICU. The Pedi-CAP color indicator correlated with the clinical evaluation and radiograph findings of proper intubation in 30 of 33 patients (sensitivity 91%, specificity 100%, positive predictive value 100%, and negative predictive value 80%). There were three false-negative results in patients with severe cardiorespiratory depression. The Pedi-CAP color indicator correlated with the clinical evaluation for the ET-tube being in the esophagus in 12 of 12 patients (sensitivity, specificity, and positive and negative predictive value were all 100%). The time required to determine the tube position by clinical evaluation was 0 to 90 seconds (mean = 39.7 seconds; SD +/- 15.3 seconds). The time required with the disposable ETCO₂ detector was 4 to 12 seconds (mean = 8.1 seconds; SD +/- 2.9 seconds; $p < 0.001$). **CONCLUSION:** The use of a disposable pediatric endotracheal CO₂ detector significantly reduces the time spent in verifying the endotracheal tube position (trachea versus esophagus) in newborns, including premature babies with body weight < 1000 gm. This is of particular benefit to babies who are erroneously intubated in the esophagus, because using the device allows much faster detection of this problem and much earlier reintubation

(LOE 5 Supportive)

Bhende MS, Allen WD Jr. Evaluation of a Capno-Flo resuscitator during transport of critically ill children. *Pediatr Emerg Care.* 2002.18:414-416.

Abstract

STUDY OBJECTIVE: To examine the validity of a disposable, colorimetric end-tidal CO₂ detector in verifying endotracheal tube (ETT) placement in infants and children. DESIGN: The detector was studied prospectively in 151 intubations. SETTING: Operating room, ICU, and emergency department of a children's hospital. PARTICIPANTS: One hundred thirty-seven children undergoing endotracheal intubation for anesthesia (52), respiratory support (76), or CPR (23). INTERVENTIONS: After endotracheal intubation, tube position was verified, the detector was attached, and readings were obtained. MEASUREMENTS AND RESULTS: The detector correctly identified tube position (trachea, 124; esophagus, four) in all 120 patients who were not in cardiac arrest (P less than .01). In the cardiac arrest setting, all six esophageal intubations were correctly identified, but two of the 17 tracheal intubations were incorrectly interpreted as esophageal intubations (P less than .01). CONCLUSION: The detector accurately identifies ETT position in children with spontaneous circulation who weigh more than 2 kg. During CPR, a positive test correctly indicates that the ETT is in the airway, but a negative result (suggesting esophageal placement) requires an alternate means of confirming ETT position.

(LOE 5 Supportive)

Bhende MS, Thompson AE. Evaluation of an end-tidal CO₂ detector during pediatric cardiopulmonary resuscitation. Pediatrics. 1995. 95:395-399.

Abstract

Critically ill children often require endotracheal intubation prior to transport to a medical center. Correct endotracheal tube placement and maintenance during transport are essential. The utility of a portable colorimetric end-tidal CO₂ detector during transport of critically ill children was evaluated. Fifty-eight children with spontaneous circulation (aged 1 day to 12 years, weight 0.9 to 26 kg) who underwent 59 intubations during transport by ground (n = 31) or air (n = 27) were studied. Tube position was confirmed by physical examination, arterial blood gas values, or arterial oxygen saturation, and sometimes by chest radiography. The detector was attached and readings were obtained after intubation; readings were repeated if endotracheal tube position was rechecked during transport. Fifty-seven of 58 tracheal positions and the 1 esophageal tube position were correctly identified. One false-negative result occurred in a severely hypocarbic 900-g premature newborn. On each occasion that the detector was used en route, the endotracheal tube position was correctly identified. It is concluded that the end-tidal CO₂ detector is a useful tool for confirming endotracheal tube position during transport of critically ill children weighing more than 2 kg who are not in cardiopulmonary arrest.

Bhende MS, Thompson AE, Cook DR, Saville AL. Validity of a disposable end-tidal CO₂ detector in verifying endotracheal tube placement in infants and children. Annals of Emergency Medicine. 1992b. 21:142-145.

Abstract

OBJECTIVE. To determine the utility of a disposable colorimetric end-tidal CO₂ detector during pediatric cardiopulmonary resuscitation (CPR) for (1) confirming endotracheal tube (ETT) position, and (2) assessing the relationship between end-tidal CO₂ recorded by this method and outcome of pediatric CPR. DESIGN/SETTING. Prospective observations during CPR in a university children's hospital. PARTICIPANTS. Forty children (28 male, 12 female) aged 1 week to 10 years (25 children aged < or = 1 year, mean age 27.2 months, median 7 months), weighing 2.5 to 40 kg (31 children weighing < or = 15 kg, mean 10.94 kg, median 7 kg) who underwent a total of 48 endotracheal intubations during CPR. METHODS. After intubation, ETT position was verified by usual clinical methods including direct visualization. The device was attached between the ETT and ventilation bag, the patient was manually ventilated, and a first reading was obtained. Any color change from purple (Area A, end-tidal CO₂ < 0.5%) to tan or yellow (Area B or C, end-tidal CO₂ > or = 0.5%) was considered to be positive for airway intubation. CPR was conducted as per Pediatric Advanced Life Support guidelines. A second reading was obtained when the decision to discontinue CPR was made. RESULTS. All nine esophageal tube positions were correctly identified by the detector. Thirty-three of 39 tracheal tube positions were correctly identified (P < .001). For verifying ETT position, the device had a sensitivity of 84.6%, specificity of 100%, positive predictive value of 100%, and negative predictive value of 60%. Readings were obtained at the end of CPR in 25 patients. All 13 patients who regained spontaneous circulation and survived to ICU admission had a second reading in the C range, while none of the 12 patients with a second reading in the A or B range survived. Both the first and second end-tidal CO₂ readings in the C range correlated significantly with short-term survival (P = .01 and P < .001, respectively). Two patients were eventually discharged from the hospital. CONCLUSIONS. During CPR a positive test confirms placement of the ETT within the airway, whereas a negative test indicates either esophageal intubation or airway intubation with poor or absent pulmonary blood flow and requires an alternate means of confirmation of tube position. The detector may be of prognostic value for return of spontaneous circulation and short-term survival.

(LOE 5 Supportive)

Bhende MS, Thompson AE, Orr RA. Utility of an end-tidal carbon dioxide detector during stabilization and transport of critically ill children. Pediatrics. 1992a. 89:1042-1044.

Abstract

OBJECTIVES: Critically ill children often require endotracheal intubation prior to transport to a tertiary care center. Correct endotracheal tube (ETT) placement (trachea vs esophagus) and maintenance of ETT position during transport are of utmost importance. We evaluated the use of a Capno-Flo resuscitator (ventilation bag with a pH-sensitive colorimetric strip in the patient connector; Kirk Specialty Systems, Carrollton, TX) during transport of critically ill children. **METHODS:** Thirty-nine intubations were evaluated in 38 patients (one patient was intubated twice) aged 1 day to 19 years (median age, 13 mo) and weighing 0.9 to 80 kg (median weight, 11 kg) who were intubated and transported by air (= 26, 68%) and ground ambulance (= 12, 32%). ETT position was confirmed by physical examination, pulse oximetry, and in some patients, arterial blood gases and chest roentgenograms. ETT position was also assessed using the Capno-Flo after six breaths after intubation and was read as positive if the color changed from purple to yellow (tracheal tube position) and negative if the strip remained purple (esophageal tube position). The Capno-Flo ambu-bag was used continuously during transport and evaluated by the nurses or respiratory therapists, who also completed a brief questionnaire. **RESULTS:** Two esophageal and 37 tracheal tube positions were correctly identified by the device. There were no false-positive or false-negative results; the device was 100% sensitive and specific for the initial reading. It sometimes took longer to obtain this initial reading (> six breaths) in three patients. During transport, most personnel (36/38) noted minimal or no color change during inspiration and expiration, and therefore, it was not helpful in the continued verification of ETT position. **CONCLUSIONS:** The Capno-Flo resuscitator is useful in the initial confirmation of ETT position but not for continuous evaluation of ETT position during transport.

(LOE 5 Supportive)

Campbell FA, McLeod ME, Bissonnette B, Swartz JS. End-tidal carbon dioxide measurement in infants and children during and after general anaesthesia. Can J Anaesth. 1994. 41:107-110.

Abstract

OBJECTIVES: Critically ill children often require endotracheal intubation prior to transport to a tertiary care center. Correct endotracheal tube (ETT) placement (trachea vs esophagus) and maintenance of ETT position during transport are of utmost importance. We evaluated the use of a Capno-Flo resuscitator (ventilation bag with a pH-sensitive colorimetric strip in the patient connector; Kirk Specialty Systems, Carrollton, TX) during transport of critically ill children. **METHODS:** Thirty-nine intubations were evaluated in 38 patients (one patient was intubated twice) aged 1 day to 19 years (median age, 13 mo) and weighing 0.9 to 80 kg (median weight, 11 kg) who were intubated and transported by air (= 26, 68%) and ground ambulance (= 12, 32%). ETT position was confirmed by physical examination, pulse oximetry, and in some patients, arterial blood gases and chest roentgenograms. ETT position was also assessed using the Capno-Flo after six breaths after intubation and was read as positive if the color changed from purple to yellow (tracheal tube position) and negative if the strip remained purple (esophageal tube position). The Capno-Flo ambu-bag was used continuously during transport and evaluated by the nurses or respiratory therapists, who also completed a brief questionnaire. **RESULTS:** Two esophageal and 37 tracheal tube positions were correctly identified by the device. There were no false-positive or false-negative results; the device was 100% sensitive and specific for the initial reading. It sometimes took longer to obtain this initial reading (> six breaths) in three patients. During transport, most personnel (36/38) noted minimal or no color change during inspiration and expiration, and therefore, it was not helpful in the continued verification of ETT position. **CONCLUSIONS:** The Capno-Flo resuscitator is useful in the initial confirmation of ETT position but not for continuous evaluation of ETT position during transport.

(LOE 5 Supportive)

Garcia CE, Gutierrez LA, Izquierdo MI, Alberola PA, Moricillo SF. The value of capnography and exhaled CO₂ in neonatal intensive care units. An Esp Pediatr. 1997. 47:177-80.

Abstract

OBJECTIVE: The objective of this study was to investigate the reliability of end-tidal CO₂ (PetCO₂) as a non-invasive guide of PaCO₂ in the newborn and to analyze the influence of the relationship between ventilation-perfusion in the correlation between both determinations. **PATIENTS AND METHODS:** End-tidal CO₂ (PetCO₂) was monitored by capnography in 9 ventilated newborns: 146 arterial blood gas samples were drawn and the results were compared with the PetCO₂ values obtained. The gradient or difference between PaCO₂ and PetCO₂ was calculated to determine the correlation. The ratio a/AO₂ was used as an indirect indicator of the ventilation/perfusion relationship (V/Q ratio). **RESULTS:** The mean gestational age was 30.9 +/- 2.8 weeks and birth weight 1,648 +/- 596 g. The age at the beginning of the study was 2 +/- 1.5 days. The diagnoses corresponded to 5 cases of RDS (56%), 2 cases of wet lung syndrome (22%), 1 case of pneumonia (11%) and 1 pneumothorax (11%). The results of this monitoring were classified in function of the a/AO₂ ratio obtained: Group A, a/AO₂ < 0.2 and PaCO₂-PetCO₂ gradient = 13.3 +/- 5; Group B, a/AO₂ = 0.2-0.29 and PaCO₂-PetCO₂ gradient = 8 +/- 2.7; and Group C, a/AO₂ > 0.29 and PaCO₂-PetCO₂ gradient = 2 +/- 1.7. The results show a very good correlation from a a/AO₂ ratio > or = 0.3 onwards. The a/AO₂ ratio is the major determinant of PaCO₂-PetCO₂ differences and respiratory frequency has less influence. **CONCLUSIONS:** 1) Monitoring of end-tidal CO₂ does not maintain a good correlation with PaCO₂ in serious lung illness. 2) End-tidal CO₂ measurement is an effective and accurate technique for the monitoring of newborns when the a/AO₂ ratio > or =

0.3 and it can be useful for weaning of mechanical ventilation. 3) PaCO₂-PetCO₂ differences accurately show the changes in the ventilation-perfusion relationship.

(LOE 6 Supportive)

Hagerty JJ, Kleinman ME, Zurakowski D, Lyons AC, Krauss B. Accuracy of a new low-flow sidestream capnography technology in newborns: a pilot study. J Perinatol. 2002. 22:219-225.

Abstract

OBJECTIVE: To evaluate the accuracy of a new low-flow sidestream capnography technology and analyze components of the capnogram in mechanically ventilated newborns with and without pulmonary disease. **METHODS:** Twenty patients were prospectively identified. Eligible infants were mechanically ventilated and had an indwelling arterial catheter. Two groups were identified: newborns who were receiving mechanical ventilation for pulmonary diseases, and newborns who were receiving postoperative mechanical ventilation for nonpulmonary conditions. End-tidal CO₂ (PetCO₂) was measured for 1-minute pre- and post-arterial blood sampling, and PetCO₂ and PaCO₂ were compared for each patient. Eight quantitative waveform parameters were also measured on all patients. **RESULTS:** Newborns in the pulmonary group (n=13) (persistent pulmonary hypertension of the newborn/meconium aspiration syndrome, respiratory distress syndrome, pneumonia) and newborns in the control group (n=7) were matched for birth weight, gestational age, and postnatal age. PetCO₂-PaCO₂ Gradient values were higher in the pulmonary group (7.4±3.3 mm Hg) than controls (3.4±2.4 mm Hg). Four waveform parameters (ascending slope, alveolar angle, alpha angle, descending angle) were identified, which independently differentiated patients with pulmonary disease from controls. **CONCLUSIONS:** Low-flow capnography with Microstream technology accurately measured alveolar CO₂ in newborns without pulmonary disease, as demonstrated by normal PetCO₂-PaCO₂ gradients. The measured PetCO₂-PaCO₂ gradient, as expected, was significantly higher in newborns with pulmonary disease. We also identified four quantitative waveform parameters that may be useful in differentiating between mechanically ventilated newborn patients with and without lung disease.

(LOE 6 Supportive)

Hsieh KS, Lee CL, Lin CC, Wu SN, KO FY, Huang YF, Huang TC. Quantitative analysis of end-tidal carbon dioxide during mechanical and spontaneous ventilation in infants and young children. Pediatr Pulmonol. 2001. 32:453-458.

Abstract

Capnography provides a substitute for monitoring of arterial carbon dioxide tension (PCO₂). We performed a prospective study to evaluate a new application of capnography, using quantitative curve analysis in the pediatric ICU. Twenty-five infants and children admitted to the pediatric ICU after cardiovascular surgery for congenital heart diseases were included in the study. Capnographic curves were recorded during 3 phases of mechanical and spontaneous ventilation: phase 1, immediate postoperative period; phase 3, preextubation period; and phase 2, period between phases 1 and 3. Each recording included 17 sec of capnographic tracings from consecutive spontaneous and/or ventilator-driven breaths. Quantitative curve analysis was made to define parameters including peak value of exhaled PCO₂ (P), mean rate of rise of PCO₂ (R), and area under each capnographic curve (A). Qualitative inspection of the wave contour showed no obvious difference in phase 3 during spontaneous and mechanically assisted ventilator breaths. However, an obvious difference existed between spontaneous and mechanically assisted breaths in phase 2. For each parameter (P, R, and A), there was a significant difference in phases 2 and 3 from spontaneous breaths. However, there was no significant difference in phases 2 and 3 from ventilator-assisted breaths. We further calculated the ratio of parameters of spontaneous breaths (S) and ventilator-assisted breaths (V) in phase 2 and phase 3. The ratio of S/V for P, R, and A showed significant differences between phase 2 and phase 3. We conclude that quantitative analysis of exhaled end-tidal PCO₂ curves revealed significant changes of specific parameters during the transition from the ventilator-dependent state to the spontaneously breathing ventilator-independent state. This new approach provides a new way to estimate respiratory status in infants and children receiving ventilator therapy. Through quantitative capnographic curve analysis, if P, R, and A from spontaneous breaths approached those of ventilator-assisted breaths, patients have resumed reasonable pulmonary mechanics, and extubation may then be considered.

(LOE 6 Supportive)

Meredith KS, Monaco FJ. Evaluation of a mainstream capnometer and end-tidal carbon dioxide monitoring in mechanically ventilated infants. Pediatr Pulmonol. 1990. 9:254-459.

Abstract

We evaluated a new lightweight capnometer with a less than 1 mL deadspace neonatal airway adapter and endotracheal tube connector unit (NAC) for use in mechanically ventilated neonates. The evaluation consisted of: 1) a bench test comparison of air flow resistance between the standard endotracheal tube and connector with the new NAC (flow rates, 1.5 to 12.8 L/min); 2) a determination of the effect of NAC placement on Paco₂; 3) pre- and post-NAC pulmonary mechanics; and 4) analysis of paired PetCO₂ and PACO₂ in 16 infants requiring mechanical ventilation. Paired t test of the slopes of the resistance curves was significant (P = 0.002) while analysis of variance of differential pressures was not (P = 0.29). All post-NAC placement Paco₂ were smaller than pre-placement values; there were no differences in

pulmonary mechanics, and Petco₂ correlated closely with Paco₂ (n = 132, r = 0.79) defined as Petco₂ = 0.68.Paco₂ + 5.52; means +/- 1 SD, Paco₂ -Petco₂ was 4.7 +/- 4.7 torr and Petco₂/Paco₂ was 0.86 +/- 0.14.

(LOE6 Supportive)

Nangia S, Saili A, Dutta AK. End tidal carbon dioxide monitoring--its reliability in neonates. Indian J Pediatr. 1997. 64:389-394

Abstract

End tidal Carbon dioxide monitoring was undertaken prospectively in all Ventilated neonates in our NICU admitted from March 1995 to August 1995 irrespective of the birth weight, gestational age and indication of ventilation. The aim was to determine the correlation between ETCO₂ and PaCO₂ in various clinical situations. The arterial blood gases were obtained in all ventilated babies with simultaneous and continuous ETCO₂ monitoring and were analysed by AVL 995 Hb blood gas analyser. ETCO₂ was analysed by side stream technique by Datex Cardiocap II monitor. A total of 152 samples from in-dwelling radial artery catheters were analysed from babies with birth weight from 900 g to 3400 g, gestation age from 28 to 42 wks and were ventilated for various indications like Severe Birth Asphyxia (SBA), Meconium Aspiration Syndrome (MAS), Recurrent Apnoea and Hyaline Membrane Disease (HMD). Statistical analysis was done in 10 groups to see if the ETCO₂ correlated with its corresponding PaCO₂ value. The study groups comprised three groups based on birth weight being < 1.5-2.5 kg and > 2.5 kg three groups as per the gestational age being 28-31+6 wks, 32-36+6 wks and 37-41+6 wks and four groups as per the need for ventilation being Severe Birth Asphyxia, Meconium Aspiration Syndrome, Apnoea of Prematurity and Hyaline Membrane Disease. Results of the correlation analysis revealed that the correlation coefficient in the study group ranged from 0.55 to 0.96 and was statistically significant in babies > 2.5 kg and 1.5-2.5 kg, in term and preterms 32-36 wks, and in babies with MAS, SBA and Recurrent Apnoea. The correlation coefficient was lowest in babies with HMD, being 0.55. The study showed that ETCO₂ correlates closely with PaCO₂ in most clinical situations in neonates and we recommend its use in all level III NICUs in ventilated babies.

(LOE 6 Supportive)

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. JPerinatol. 2001. 2221:284-287. Abstract OBJECTIVE: Determine whether end-tidal CO₂ (ETCO₂) monitoring allows for more rapid discrimination of tracheal versus esophageal intubation than standard clinical assessment during neonatal resuscitation in the delivery room. STUDY DESIGN: Endotracheal tube (ETT) placement was assessed using either a hand-held monitor that displayed graphic and quantitative ETCO₂ by an investigator not involved in the resuscitation, or using clinical parameters by the resuscitation team unaware of the ETCO₂ data. The time differences between ETCO₂ and clinical determinations of ETT placement were compared. RESULTS: Capnography correctly identified all 16 tracheal and 11 esophageal intubations performed on 16 study infants. The median times (and range) in seconds required for capnographic and clinical determination of tracheal intubation were 9 (4 to 26) vs. 35 (18 to 70), p<.001, and for esophageal intubation were 9 (4 to 17) vs. 30 (25 to 111), p=.001. CONCLUSION: Capnography allowed more rapid determination of both tracheal and unintended esophageal intubation than clinical assessment.

Rich GF, Sconzo JM. Continuous end-tidal CO₂ sampling within the proximal endotracheal tube estimates arterial CO₂ tension in infants. Can J Anaesth. 1991. 38:201-203

Abstract

End-tidal CO₂ (ETCO₂) sampled using a 22-gauge needle inserted through the wall of the proximal endotracheal tube was compared with ETCO₂ obtained from the standard proximal connector to determine which was the more accurate sampling site for estimation of arterial CO₂ tension (PaCO₂). Fourteen infants were anaesthetized and their lungs ventilated using a Drager ventilator and a paediatric circle system. Blood gas determination of PaCO₂ was obtained from an arterial catheter and compared with continuous sampling of ETCO₂ analyzed by raman spectroscopy. The PaCO₂ (35.3 +/- 4.9 mmHg, x +/- SD) was not different from the ETCO₂ sampled within the proximal endotracheal tube (34.7 +/- 3.8 mmHg), but was greater (P less than 0.05) than the ETCO₂ at the proximal connector (31.6 +/- 4.0 mmHg). We conclude that in infants during ventilation with a circle system, the PaCO₂ can be accurately assessed by continuous sampling of ETCO₂ from the proximal endotracheal tube.

(LOE 6 Supportive)

Roberts WA, Maniscalco WM, Cohen AR, Litman RS, Chhibber A. The use of capnography for recognition of esophageal intubation in the neonatal intensive care unit. Pediatr Pulmonol. 1995. 19:262-268. Abstract

Failure to recognize esophageal intubation can result in severe hypoxia and permanent neurologic injury. Capnography is a standard monitoring modality in the operating room but has not been utilized fully in other environments. We used capnography at the time of endotracheal intubation in the neonatal intensive care unit (NICU) to determine whether capnography could more quickly and accurately identify endotracheal tube position than other clinical indicators of

endotracheal tube position. One hundred intubation episodes were studied in 55 neonates. Capnograms were obtained 15 and 120 sec following tube placement. Intubating personnel were blinded to the capnographic data and determined endotracheal tube location (trachea vs. esophagus) by clinical criteria only. The sensitivity and specificity of capnography and clinical examination for identification of tube position were analyzed, and the time required for establishing by clinical confirmation whether the tube was in the trachea or not was compared to that required for capnography. Forty of 100 intubation attempts resulted in esophageal intubation. Capnography correctly identified these errant tube placements in 39 of 40 instances and did so in 1.6 sec (SD +/- 2.4). Capnography failed to identify successful endotracheal intubation on only one occasion. Clinical indicators of tube position required 97.1 sec (SD +/- 92.6) to identify an esophageal intubation and failed to identify successful endotracheal intubation in 5 of 60 cases. We conclude that capnography is a valuable adjunct to clinical examination to demonstrate whether an endotracheal tube is placed correctly in the trachea of neonates in the NICU.

(LOE 5 Supportive)

Rozycki HJ, Sysyn GD, Marshall MK, Malloy R, Wiswell TE. Mainstream end-tidal carbon dioxide monitoring in the neonatal intensive care unit. Pediatrics. 1998. 101:648-653.

Abstract

BACKGROUND: Continuous noninvasive monitoring of arterial carbon dioxide (CO₂) in neonatal intensive care unit (NICU) patients would help clinicians avoid complications of hypocarbia and hypercarbia. End-tidal CO₂ monitoring has not been used in this population to date, but recent technical advances and the introduction of surfactant therapy, which improves ventilation-perfusion matching, might improve the clinical utility of end-tidal monitoring. **OBJECTIVE:** To determine the accuracy and precision of end-tidal CO₂ monitoring in NICU patients. **DESIGN:** Nonrandomized recording of simultaneous end-tidal and arterial CO₂ pairs. **SETTING:** Two university NICUs. **PATIENTS:** Forty-five newborn infants receiving mechanical ventilation who had indwelling arterial access, and a predefined subsample of infants who were <1000 g birth weight, <8 days of age, and who received surfactant therapy (extremely low birth weight -ELBW- <8). **OUTCOME MEASURES:** The correlation coefficient, degree of bias, and 95% confidence interval were determined for both the overall population and the ELBW <8 subgroup. Those factors which significantly influenced the bias were identified. The ability of the end-tidal monitor to alert the clinician to instances of hypocarbia or hypercarbia was determined. **RESULTS:** There were 411 end-tidal/arterial pairs analyzed from 45 patients. The correlation coefficient was 0.833 and the bias was -6.9 mm Hg (95% confidence interval, +/-11.5 mm Hg). The results did not differ markedly in the ELBW <8 infants. Measures of the degree of lung disease, the ventilation index and the oxygenation index, had small influences on the degree of bias. This type of capnometry identified 91% of the instances when the arterial CO₂ pressure was between 34 and 54 mm Hg using an end-tidal range of 29 to 45 mm Hg. End-tidal values outside this range had a 63% accuracy in predicting hypocarbia or hypercarbia. **CONCLUSION:** End-tidal CO₂ monitoring in NICU patients is as accurate as capillary or transcutaneous monitoring but less precise than the latter. It may be useful for trending or for screening patients for abnormal arterial CO₂ values.

(LOE 6 Supportive)

Sivan Y, Eldadah MK, Cheah TE, Newth CJ. Estimation of arterial carbon dioxide by end-tidal and transcutaneous PCO₂ measurements in ventilated children. Pediatr Pulmonol. 1992. 12:153-157.

Abstract

BACKGROUND: Continuous noninvasive monitoring of arterial carbon dioxide (CO₂) in neonatal intensive care unit (NICU) patients would help clinicians avoid complications of hypocarbia and hypercarbia. End-tidal CO₂ monitoring has not been used in this population to date, but recent technical advances and the introduction of surfactant therapy, which improves ventilation-perfusion matching, might improve the clinical utility of end-tidal monitoring. **OBJECTIVE:** To determine the accuracy and precision of end-tidal CO₂ monitoring in NICU patients. **DESIGN:** Nonrandomized recording of simultaneous end-tidal and arterial CO₂ pairs. **SETTING:** Two university NICUs. **PATIENTS:** Forty-five newborn infants receiving mechanical ventilation who had indwelling arterial access, and a predefined subsample of infants who were <1000 g birth weight, <8 days of age, and who received surfactant therapy (extremely low birth weight -ELBW- <8). **OUTCOME MEASURES:** The correlation coefficient, degree of bias, and 95% confidence interval were determined for both the overall population and the ELBW <8 subgroup. Those factors which significantly influenced the bias were identified. The ability of the end-tidal monitor to alert the clinician to instances of hypocarbia or hypercarbia was determined. **RESULTS:** There were 411 end-tidal/arterial pairs analyzed from 45 patients. The correlation coefficient was 0.833 and the bias was -6.9 mm Hg (95% confidence interval, +/-11.5 mm Hg). The results did not differ markedly in the ELBW <8 infants. Measures of the degree of lung disease, the ventilation index and the oxygenation index, had small influences on the degree of bias. This type of capnometry identified 91% of the instances when the arterial CO₂ pressure was between 34 and 54 mm Hg using an end-tidal range of 29 to 45 mm Hg. End-tidal values outside this range had a 63% accuracy in predicting hypocarbia or hypercarbia. **CONCLUSION:** End-tidal CO₂ monitoring in NICU patients is as accurate as capillary or transcutaneous monitoring but less precise than the latter. It may be useful for trending or for screening patients for abnormal arterial CO₂ values.

(LOE6 Supportive)

Tobias JD, Meyer DJ. Noninvasive monitoring of carbon dioxide during respiratory failure in toddlers and infants: end-tidal versus transcutaneous carbon dioxide. Anesth Analg. 1997. 85:55-58. Abstract

We prospectively compared the accuracy of two noninvasive monitors of arterial CO₂ (end-tidal and transcutaneous) in mechanically ventilated infants and toddlers with respiratory failure. The study included infants and toddlers less than 48 mo of age who required tracheal intubation and mechanical ventilation for respiratory failure. In each patient, both ET-CO₂ and transcutaneous CO₂ (TC-CO₂) were simultaneously monitored and compared with PaCO₂ when an arterial blood gas analysis was performed. The cohort for the study included 25 toddlers and infants ranging in age from 1 to 40 mo and in weight from 3.3 to 19.1 kg. A total of 100 sample sets (PaCO₂, ET-CO₂, TC-CO₂) was compared. The ET-CO₂ to PaCO₂ difference was 6.8 +/- 5.1 mm Hg, while the TC-CO₂ to PaCO₂ difference was 2.3 +/- 1.3 mm Hg (P < 0.0001). The absolute difference of the TC-CO₂ and PaCO₂ was 4 mm Hg or less in 96 of the 100 values, while the ET-CO₂ to PaCO₂ difference was 4 mm Hg or less in 38 of the 100 values (P < 0.0001). Bland-Altman analysis revealed a bias of -0.68 with a precision of +/-2.35 when comparing the TC-CO₂ and the PaCO₂ and a bias of -6.68 with a precision of +/-5.01 when comparing ET-CO₂ with PaCO₂. In neonates and infants with respiratory failure, TC-CO₂ monitoring provided a more accurate estimation of PaCO₂ than ET-CO₂ monitoring.

(LOE 6 Supportive)

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. 35:292-295.

Abstract

End-tidal carbon dioxide pressure (PetCO₂) was measured in the neonatal intensive care unit (NICU) to assess its reliability and accuracy in predicting arterial partial pressure of carbon dioxide (PaCO₂). Arterial blood was drawn for gas analysis and compared with exhaled CO₂ measured by mainstream capnography. In total, 130 PetCO₂/PaCO₂ comparisons were obtained from 61 patients (20 term and 41 preterm infants). PetCO₂ was significantly different from PaCO₂ (PetCO₂ = 42.3 +/- 10.5 mmHg vs. PaCO₂ = 45.8 +/- 12.3 mmHg, P < 0.001, mean +/- SD). The overall PetCO₂ bias (mean +/- SD) was 3.5 +/- 7.1 mmHg. There was a positive correlation between PetCO₂ and PaCO₂ (n = 130, r = 0.818, P < 0.001) in both term (n = 44, r = 0.779, P < 0.001) and preterm infants (n = 86, r = 0.849, P < 0.001). The PetCO₂ biases (95% CI) were 3.5 +/- 9.0 mmHg (0.8-6.2) in the term group and 3.4 +/- 6.0 mmHg (2.2-4.7) in the preterm group. Therefore, PetCO₂ was a valid and reliable method for monitoring PaCO₂ in neonates, especially preterm infants. This method decreases blood loss and prevents

complications associated with arterial catheters. In conclusion, we recommend using mainstream capnography to monitor PetCO(2) instead of measuring PaCO(2) in the NICU.
(LOE 5 Supportive)