Capnometry and Capnography in the Emergency Department

Reuben Strayer
McGill Emergency Medicine
Policy Statements

Expired Carbon Dioxide Monitoring


The American College of Emergency Physicians believes that quality emergency care should be available to all who seek it. ACEP endorses the following principles regarding expired carbon dioxide monitoring:

• The established method for verifying proper endotracheal tube placement is by direct visualization of the endotracheal tube through the vocal cords into the trachea.
• Carbon dioxide monitoring of tracheal intubation placement is desirable, but should not be mandated at this time for all emergency patients.
• It is desirable to have carbon dioxide monitoring devices available to emergency physicians and prehospital providers to assist in confirming tracheal intubation. Absence of these monitoring devices to confirm tracheal intubation should not delay or preclude intubation in life-threatening emergencies.
• Endotracheal tube placement should be confirmed whenever carbon dioxide monitoring indicates possible esophageal intubation, and reconfirmed if there is a change in the patient’s clinical status, movement or transportation of patient, or suspected extubation.
• Carbon dioxide monitoring of expired gas in intubated patients can be performed qualitatively or quantitatively on a single, intermittent, or continuous basis with different monitoring systems.
• Carbon dioxide levels may be falsely low despite correct tracheal placement of the endotracheal tube in cardiac arrests, severe shock, and other clinical conditions with low cardiac outputs and inadequate tissue perfusion.
• Other uses of carbon dioxide monitoring are under investigation. Research is continuing to define the benefits and most appropriate uses of this technology.

The policy was prepared by the Clinical Policies Committee/EMS Committee and replaces one with the same title.
End-Tidal CO₂ Detectors Stir Controversy


One of the most important goals for Annals is to provide a forum for responsible and provocative debate. To that end, Annals recently published an article by William H Ginsburg, JD, titled, “When Does a Guideline Become a Standard? The American Society of Anesthesiologists Guidelines Give Us a Clue” [Ann Emerg Med December 1993;22:1891-1896]. This article provides us with an opportunity to discuss the development of practice standards, an issue of critical importance to emergency physicians. The article also provides a platform for thoughtful debate about the use, particularly in prehospital care, of end-tidal CO₂ detectors, a device that is being utilized but has not been completely studied.

Prehospital care is one of emergency medicine’s foremost responsibilities. As devices are introduced for use in prehospital care, we must ensure that they undergo vigorous scientific scrutiny to validate their use. Devices already in use must also continually be reassessed by experts in the field to ensure that they benefit patients. End-tidal CO₂ detectors have not been rigorously studied nor have they been in use long enough for those of us in the prehospital arena to be certain they are beneficial and cost-effective.

When considering this article for publication, I was reminded of a similar scenario with the pneumatic anti-shock garment. In the early 1970s, the pneumatic anti-shock garment was promoted extensively; however, the device had not undergone strict scientific evaluation before marketing. Once available, this device received acceptance and was used extensively in the field even though the precise mechanism of action, indications, and contraindications were not clearly identified for some time. In an attempt to ensure that history not repeat itself, Annals published the article by Ginsburg to stimulate our readers to consider not only the use of end-tidal CO₂ detectors but also the pro-
Basic Physiology of CO2

.03%

Three forms

Classical use of [CO2]

Alveolus Continuum

Ward 1998
Measuring CO2

Capnometry & Capnography
Measuring CO2

Ward 1998
Measuring CO2
PetCO2 vs. ScvO2
Measuring CO2

.03%

Three forms

Classical use of [CO2]

Alveolus Continuum

Infrared
Measuring CO2

Mainstream vs. Sidestream

Santos 1994
Time lag

Sullivan 2005
Capnograph
The PetCO2 Value

- CO2 production
- Delivery of blood to lungs
- Alveolar ventilation

Sanders 1989
The PetCO2 Value

Increased PetCO2

Decreased central drive
Muscle weakness
Diffusion problems

Fever
Burns
Hyperthyroidism
Seizure
Bicarbonate Rx
ROSC
Tourniquet
The PetCO2 Value

Decreased PetCO2

- Overventilation
- Hypothermia
- Sedation
- Paralysis

Decreased CO

Ventilating nonperfused lung (dead space)
The PetCO2 Value

Dead space ventilation

Ward 1998
The PetCO2 Value

Shunt perfusion

Ward 1998  Santos 1994
a-ADCO2

3-5 mmHg
Interpretation of the capnogram

No CO2

Low PetCO2

Failure to ventilate
Interpretation of the capnogram

No CO2

Low PetCO2

Failure to ventilate

Failure to circulate
Interpretation of the capnogram

Ward 1998
Interpretation of the capnogram

No CO2

Low PetCO2

Failure to ventilate

Failure to circulate

Changes in the slope of phase II and III
Interpretation of the capnogram

Kinked ETT

Ward 1998
Interpretation of the capnogram

Obstructive lung disease

Ward 1998
Interpretation of the capnogram

Curare cleft

Ward 1998
28

Interpretation of the capnogram

Cardiogenic oscillations

Cuff leak

Ward 1998
Use in the confirmation of tracheal intubation

Prehospital BVM
Use in the confirmation of tracheal intubation

Table 2. Foods in Which Vinegar is Added or Used in Processing

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<tr>
<td>Sushi rice</td>
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<tr>
<td>Sunomono (Japanese style salad)</td>
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<td>Naeng Myun (Korean soup)</td>
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<tr>
<td>Singgang (Philipino soup)</td>
</tr>
<tr>
<td>Inon-on (Vinegar marinated Philipino cooked fish)</td>
</tr>
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<td>Collard Greens</td>
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<td>Fish and Chips</td>
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</table>

Leong 2005
Use in the confirmation of tracheal intubation

Supraglottic ETT

Cardiac arrest

Do not rely on capnometry exclusively

- auscultation of breath sounds
- absence of gastric sounds
- observation of chest motion
- appropriate compliance of the bag-valve assembly
- tube condensation
- absence of gastric contents in the tube
- palpation of the tube cuff in the suprasternal notch
- use of a lighted stylet
- use of an esophageal detector device
- chest radiography
- bronchoscopy
- pulse oximetry

6 breaths

Li 2000  Montauk 1996  Li 2006
Use in displaying the respiratory rate
Use in displaying the respiratory rate

Respiratory Rate as an Indicator of Acute Respiratory Dysfunction

Thomas R. Gravelyn, John G. Weg, MD

- To assess respiratory rate as an indicator of acute respiratory dysfunction, we studied 58 consecutive patients four times daily during the postoperative period. Of 825 measurements of respiratory rate, 726 (89%) were normal (24/min or less). Elevations in respiratory rate without respiratory dysfunction were found in only 4% of all measurements. Patients without lung disease had a mean respiratory rate of 18±4/min, while patients with an abnormal respiratory rate and respiratory dysfunction had a mean of 27±5/min. Our study demonstrates that respiratory rate, if carefully measured, is a sensitive and reasonably specific marker of acute respiratory dysfunction.

*(JAMA 244:1123-1125, 1980)*
The Reliability of Vital Sign Measurements

Study objective: Vital sign measurements, specifically heart rate, respiratory rate, and blood pressure, play a fundamental role in many medical evaluations, yet little is known about the reliability of noninvasive vital sign measurements. We sought
Use in displaying the respiratory rate

GENERAL MEDICINE/ORIGINAL RESEARCH

The Vexatious Vital: Neither Clinical Measurements by Nurses Nor an Electronic Monitor Provides Accurate Measurements of Respiratory Rate in Triage

Paris B. Lovett, MD
Jason M. Buchwald, MD
Kai Stürmann, MD
Polly Bijur, PhD

From the Columbia University Medical Center, New York, NY (Lovett); Memorial West Hospital, Pembroke Pines, FL (Buchwald); Beth Israel Medical Center, New York, NY (Stürmann); and the Albert Einstein College of Medicine, New York, NY (Bijur).
Use in displaying the respiratory rate

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<th>Gender</th>
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<th>Age</th>
<th>BP</th>
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<td>29</td>
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<td>Male</td>
<td>Pain, Back</td>
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<td>58</td>
<td>147/87</td>
<td>97.9</td>
<td>85</td>
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</tbody>
</table>
Use in displaying the respiratory rate

In search of a reliable RR  Transthoracic impedance
The PEP respiratory monitor: a validation study

C N Brookes, J D Whittaker, C Moulton, D Dodds

The search for a reliable and accurate respiratory rate monitor for use in non-intubated patients has proved to be a long and fruitless one. A new device fulfilling the criteria for such a monitor has recently been described. The pyroelectric polymer (PEP) device is safe, non-invasive, and cheap. In this study the PEP device, transthoracic impedance, and standard observer counting were all compared with the existing gold standard of capnography in 12 healthy adult volunteers. Using a standard statistical technique it was shown that the PEP device performed as well as a capnograph and was more accurate than the other currently available methods of monitoring respiratory rate.

Figure 1  The pyroelectric polymer that can be easily incorporated into an oxygen mask.
Use in displaying the respiratory rate

Figure 1

Figure 2

Biro 1994  Greenberg 2006
Evaluation of a transcutaneous carbon dioxide monitor ("TOSCA") in adult patients in routine respiratory practice

S.M. Parker, G.J. Gibson*

Department of Respiratory Medicine, Freeman Hospital, Newcastle upon Tyne, NE7 7DN, UK

Received 9 March 2006; accepted 11 May 2006

Use in displaying the respiratory rate
Use in CPR

CO2 production, alveolar ventilation, and pulmonary perfusion
Study objective: To further define the relationship between cardiac output (CO) and end-tidal carbon dioxide tension (ETCO₂) at various levels of systemic flow.

Design: Prospective, controlled laboratory investigation.

End-Tidal Carbon Dioxide During Extremely Low Cardiac Output

Study objective: A number of studies have shown that expired CO₂ concentration is closely related to cardiac output, but that cardiac output was not controlled as an independent variable. In addition, the partial pressure of end-tidal CO₂ (P_{etCO₂}) during extremely low cardiac output has not been reported. The objective of the present study was to measure P_{etCO₂} during well-controlled, very low blood flow rates under condi-
Use in CPR
Use in CPR

CO\textsubscript{2} production, alveolar ventilation, and pulmonary perfusion

PetCO\textsubscript{2} reflects the adequacy of CPR

Long downtimes

Obstructive causes of cardiac arrest
Use in CPR
Use in CPR

Pseudo-PEA
Use in CPR

CO2 production, alveolar ventilation, and pulmonary perfusion

PetCO2 reflects the adequacy of CPR

Long downtimes

Obstructive causes of cardiac arrest

Bicarb & epi
Use in CPR
Use in CPR

CO2 production, alveolar ventilation, and pulmonary perfusion

PetCO2 reflects the adequacy of CPR

Long downtimes

Obstructive causes of cardiac arrest

Bicarb & epi

Guiding the termination of resuscitative efforts
Validation of a Rule for Termination of Resuscitation in Out-of-Hospital Cardiac Arrest

Laurie J. Morrison, M.D., Laura M. Visentin, B.Sc., Alex Kiss, Ph.D., Rob Theriault, Don Eby, M.D., Marian Vermeulen, B.Sc.N., M.H.Sc., Jonathan Sherbino, M.D., and P. Richard Verbeek, M.D., for the TOR Investigators*
Use of End-Tidal Carbon Dioxide to Predict Outcome in Prehospital Cardiac Arrest

Study objective: End-tidal CO$_2$ (ETCO$_2$) measurement can be used to predict death in prehospital cardiac arrest patients with pulseless electrical activity (PEA).
Use in CPR

CO2 production, alveolar ventilation, and pulmonary perfusion

PetCO2 reflects the adequacy of CPR

Long downtimes

Obstructive causes of cardiac arrest

Bicarb & epi

Guiding the termination of resuscitative efforts

Summary
Correlation of End-Tidal CO₂ Measurements to Arterial Paco₂ in Nonintubated Patients

Christopher W Barton, MD
Edward SJ Wang, MD

Study objective: To determine the accuracy of end-tidal carbon dioxide levels as a measure of arterial carbon dioxide levels in non-intubated patients presenting to an emergency department for care.

ORIGINAL ARTICLE

End tidal carbon dioxide as a predictor of the arterial PCO₂ in the emergency department setting

C Yosefy, E Hay, Y Nasri, E Magen, L Reisin

Concordance Between Capnography and Arterial Blood Gas Measurements of Carbon Dioxide in Acute Asthma

Jill Corbo, MD
Polly Bijur, PhD
Michael Lahn, MD
E. John Gallagher, MD

From the Department of Emergency Medicine, Albert Einstein College of Medicine, Bronx, NY.
Use as a PaCO2 surrogate
Use in procedural sedation

Chest rise

Hasel 2003    Cote 1991
The sensitivity of room-air pulse oximetry in the detection of hypercapnia

Michael D. Witting MD, MS*, Sam Hsu MD, Carlos Andres Granja MD¹

Division of Emergency Medicine, University of Maryland School of Medicine, Baltimore, MD 21201, USA
Conscious Sedation in the Emergency Department: The Value of Capnography and Pulse Oximetry

Seth W Wright, MD

Study objective: The purpose of this observational study was to describe the use of nasal capnography and pulse oximetry in monitoring heavily sedated emergency department patients.
Use in procedural sedation

Chest rise

Not good enough
Use in the management of asthma

**Figure 1.**
Capnogram of data from a normal subject and a subject with asthma.

- **P**, onset of expiration; **segment PQ**, mixing of dead space and alveolar gases; **segment QR**, plateau phase representing alveolar gas delivery; **R**, end of expiration; **segment RS**, beginning of inspiration; **ST**, low CO₂ concentration in the airway during the remainder of inspiration.

**Figure 2.**
Slope versus log of percent predicted PEFR.

Slope (dCO₂/dt) vs. Log of % Predicted PEFR

- Asthma
- Normal

r = 0.84, P < 0.001.
Use in the diagnosis of pulmonary embolism

PE makes dead space

vs. the A-a gradient
Use in the diagnosis of pulmonary embolism

Ward 1998
Use in the diagnosis of pulmonary embolism

Kline 1998
Measurement of expired carbon dioxide, oxygen and volume in conjunction with pretest probability estimation as a method to diagnose and exclude pulmonary venous thromboembolism

Jeffrey A. Kline¹-² and Melanie Hogg¹

¹Department of Emergency Medicine, Carolinas Medical Centre, and ²BreathQuant Medical Systems Inc., Charlotte, NC, USA
Use in the measurement of cardiac output

\[ \text{VO2} = (\text{CO} \times \text{CA}) - (\text{CO} \times \text{CV}) \]

\[ \text{CO} = \frac{\text{VO2}}{(\text{CA} - \text{CV})} \]

Cardiac Output = Oxygen Consumption / Arteriovenous Oxygen Difference
Conclusion

CO Physiology

The Capnograph

Confirming ETT placement
Displaying respiratory rate
Guiding CPR
PaCO2 surrogate
Procedural sedation
Asthma
PE
Cardiac output
References

10. Li, J. Capnography alone is imperfect for endotracheal tube placement confirmation during emergency intubation. JEM 2001; 20(3) 223.
25. Rosen’s Emergency Medicine, 4th Ed.