

Capnography: It's a Gas!

Capnography is the measurement of exhaled CO_2 ; the number is displayed in millimeters of Mercury (mm Hg) or percent (%) CO_2 . Capnography provides the clinician with a waveform which tracks exhaled CO_2 over time. The measuring device used is called a capnograph. The waveform displayed by the capnograph is called a capnogram. End-tidal CO_2 (EtCO_2) is the partial pressure of CO_2 at the end of an exhaled breath—normally 38mm Hg or 5%.¹

Capnography, the measurement of exhaled carbon dioxide (CO_2), has been gaining popularity in hospital critical care environments and more recently in the prehospital setting as well. Capnography was first used in the OR to continuously and noninvasively estimate arterial carbon dioxide (PaCO_2) levels on a breath-to-breath basis.¹ Measuring carbon dioxide in the patient's exhaled breath allowed

anesthesiologists to determine the adequacy and effectiveness of ventilation. The amount of carbon dioxide exhaled at the end of each breath (EtCO_2) is measured through a sensor located between the patient's airway and ventilator and is then numerically and graphically displayed as a waveform.

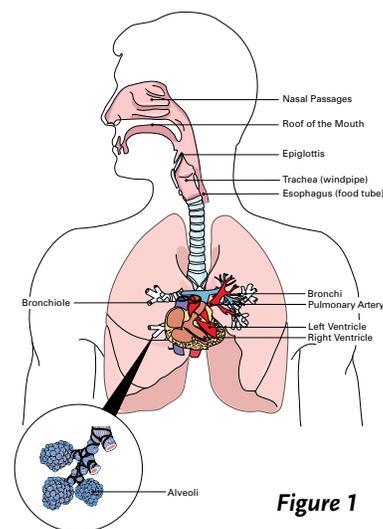


Figure 1

Today, capnography is being used to verify endotracheal tube placement and monitor its position, assess ventilation and treatment, and evaluate resuscitative efforts during cardiopulmonary resuscitation (CPR). Capnography is noninvasive, easy-to-use, and offers great promise in the assessment of acute and critically ill patients.²

Review of pulmonary anatomy & physiology

The primary function of the respiratory system is to exchange carbon dioxide for oxygen. During inspiration, air—which contains 21% oxygen—enters the upper airway via the nose where it is warmed, filtered, and humidified. The inspired air flows through the trachea and bronchial tree to enter the pulmonary alveoli—small air sacs in the lung—where the oxygen diffuses across the alveolar capillary membrane into the blood. The heart pumps the freshly oxygenated blood throughout the body to the cells where oxygen is metabolically consumed and the carbon dioxide produced as a byproduct diffuses out of the cells into the vascular system. Carbon dioxide rich blood is then pumped through the pulmonary capillary bed where the carbon dioxide diffuses across the alveolar capillary membrane and is exhaled via the nose or mouth. See figure 1.

Measurement methods

Single, one-point-in-time EtCO_2 measurements may be done using the visual colorimetric method where a litmus paper device attached to a patient's endotracheal tube undergoes a chemical reaction and color change in the presence of CO_2 . Electronic devices can furnish continuous information; they utilize infrared (IR) spectroscopy to measure the CO_2 molecules' absorption of IR light as the light passes through a gas sample.

Device CO_2 sensors may be mainstream, located directly on the patient's endotracheal tube (ETT), or sidestream, remote from the patient.³ Mainstream sampling occurs at the airway of an intubated patient and is not intended for use on non-intubated patients. Heavy and bulky adapter and sensor assemblies may make this method uncomfortable for non-intubated patients.

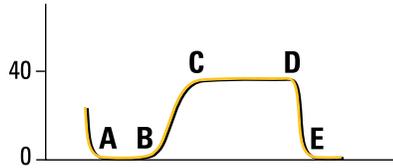
In sidestream capnographs the exhaled CO_2 is aspirated via ETT, cannula, or mask through a 5–10 foot long sampling tube connected to the instrument for analysis; this method is intended for the non-intubated patient. Both mainstream and sidestream technologies calculate the CO_2 value and waveform.

A new technology, Microstream, utilizes a modified sidestream sampling method, and employs a microbeam IR sensor that specifically isolates the CO_2 waveform. Microstream can be used on both intubated and non-intubated patients.

Components of the capnogram

A capnogram consists of 4 phases and plots CO₂ concentration over time. See figure 2. Phase I, respiratory baseline, is shown as A-B. It measures the CO₂-free gas in the deadspace of the conducting airways (so named because they conduct gas to the alveoli where gas exchange can occur). The A-B value is normally zero. Phase II—also known as the expiratory upstroke—is shown as B-C. The rapid rise seen in the capnogram represents mixing of deadspace (CO₂-free) and alveolar air (contains CO₂). The expiratory upstroke should be steep. Phase III, the expiratory plateau, represents exhalation of mostly alveolar gas; this is shown as C-D. Point D is the EtCO₂ level at the end of a normal exhaled breath; normally 38 mm Hg or 5%. Finally, the inspiratory downstroke or Phase IV, shown as D-E, reflects the inhalation of CO₂-free gas. The capnogram quickly returns to its baseline.^{3,4} Changes in the capnogram or EtCO₂ values reflect changes in metabolism, circulation, ventilation or equipment function.

Figure 2



Clinical applications of the technology

- Verification of endotracheal tube placement is one of the most common uses for EtCO₂.^{5,6} Other means to confirm proper ETT position are auscultation of the patient's chest to check for bilateral breath sounds, visual checks for chest movement and ETT clouding from the patient's exhaled breath, and auscultation of the patient's stomach. None of these methods are completely reliable since undetected esophageal intubation or movement of the ETT into the esophagus may still occur resulting in severe hypoxia and possible death. Next to direct visualization of the ETT through the vocal cords, EtCO₂ measurement is the most reliable way of confirming ETT position^{5,6} since CO₂ is normally exhaled through the trachea and not the esophagus. Also, since endotracheal tubes are easily displaced during transport and with patient movement, capnography has the added advantage of being able to alert the care giver to a change in ETT position.

- Adequacy of CPR is also easily assessed through capnography. Measuring EtCO₂ during a cardiopulmonary arrest is beneficial for two reasons: the measurement helps in assessing the effectiveness of CPR and can also help predict survival. EtCO₂ levels have a strong correlation with cardiac output. As cardiac output decreases during cardiopulmonary arrest, pulmonary blood flow diminishes, CO₂ available for exhalation is decreased, and EtCO₂ levels drop.⁵ Levine and colleagues reported 100% mortality in out of hospital cardiac arrests where EtCO₂ did not return to 10 mm Hg after 20 minutes of CPR.⁷
- Adequacy of ventilation is also monitored via EtCO₂. Arterial blood gas (ABG) analysis, routinely performed in the hospital, is the hallmark for assessing a patient's acid-base, oxygenation and ventilation levels. Arterial carbon dioxide pressure (PaCO₂) is normally 35–45 mm Hg and is the main ABG component used to determine a patient's level of ventilation.

Field clinicians do not normally draw ABGs so they may have to rely on EtCO₂ measurement to determine a patient's level of ventilation. EtCO₂ is often used to predict PaCO₂ in patients who have a normal matching of ventilation and perfusion; EtCO₂ is normally 1–5 mm Hg less than the PaCO₂. A patient underventilated as a result of a physiological abnormality or improper settings on the ventilator will present with an elevated EtCO₂. The converse is true as well: overventilated patients will present with a decreased EtCO₂. This knowledge will help the care giver make proper ventilator setting adjustments.

- Evaluation in asthma treatment is another use for EtCO₂. Analyzing the EtCO₂ waveform after aerosolized bronchodilator therapy has been administered helps to evaluate treatment effectiveness.

REFERENCES

- 1 Carroll, P. Evolutions of Capnography. *RN* Vol 62, No. 5, May 1999
- 2 Ahrens, T. Capnography: A Key Underutilized Technology. *Critical Care Nursing Clinics of North America*. Vol 11, No. 1, March 1999
- 3 Bhende, M. Capnography in the Pediatric Emergency Dept. *Pediatric Emergency Care*. Vol. 15, No. 1, 1999
- 4 Ward, K. End-tidal Carbon Dioxide Monitoring in Emergency Medicine, Part 1: Basic Principles. *Academic Emergency Medicine*. June 1998, Vol. 5, No. 6
- 5 Ornato, J. Prehospital End-Tidal Carbon Dioxide Monitoring—It's Not All Hot Air. *JEMS*. March 1993
- 6 Falk, J. Confirmation of Airway Placement. *Prehospital Emergency Care*. October/December 1999, Vol. 3, No. 4
- 7 Levine, R. End-Tidal Carbon Dioxide and Outcome of Out-Of-Hospital Cardiac Arrest. *The New England Journal of Medicine*. Vol. 337, No. 5, 1997

For further information, please contact your local Physio-Control representative at 800.442.1142 or visit our website at www.physio-control.com



Physio-Control Headquarters
11811 Willows Road NE
Redmond, WA 98052
www.physio-control.com

Customer Support
P. O. Box 97006
Redmond, WA 98073
Toll Free 800 442 1142
Fax 800 426 8049

Physio-Control Canada
Medtronic of Canada Ltd
99 Hereford Street
Brampton, ON
L6Y 0R3
Tel 888 879 0977
Fax 866 430 6115



Physio-Control, Inc., 11811 Willows Road NE, Redmond, WA 98052 USA