



# Capnography: It's a Gas!

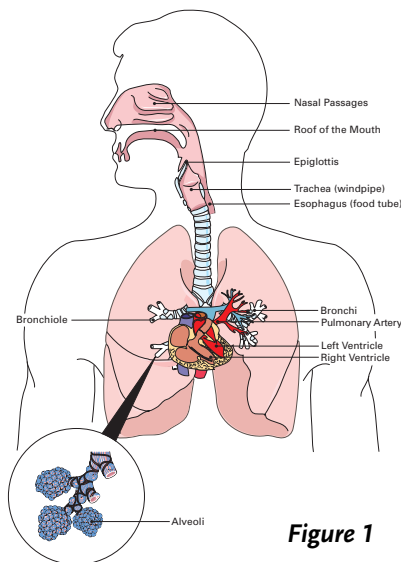
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Capnography is the measurement of exhaled CO<sub>2</sub>; the number is displayed in millimeters of Mercury (mm Hg) or percent (%) CO<sub>2</sub>. Capnography provides the clinician with a waveform which tracks exhaled CO<sub>2</sub> over time. The measuring device used is called a capnograph. The waveform displayed by the capnograph is called a capnogram. End-tidal CO<sub>2</sub> (EtCO<sub>2</sub>) is the partial pressure of CO<sub>2</sub> at the end of an exhaled breath—normally 38mm Hg or 5%.<sup>1</sup>

Capnography, the measurement of exhaled carbon dioxide (CO<sub>2</sub>), 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<sub>2</sub>) levels on a breath-to-breath basis.<sup>1</sup> 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<sub>2</sub>) is measured through a sensor located between the patient's airway and ventilator and is then numerically and graphically displayed as a waveform.

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.<sup>2</sup>



**Figure 1**

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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.*

## 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

## Measurement methods

Single, one-point-in-time EtCO<sub>2</sub> 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<sub>2</sub>. Electronic devices can furnish continuous information; they utilize infrared (IR) spectroscopy to measure the CO<sub>2</sub> molecules' absorption of IR light as the light passes through a gas sample.

Device CO<sub>2</sub> sensors may be mainstream, located directly on the patient's endotracheal tube (ETT), or sidestream, remote from the patient.<sup>3</sup> 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.

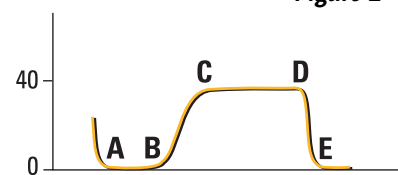
In sidestream capnographs the exhaled CO<sub>2</sub> is aspirated via ETT, cannula, or mask through a 5–10 foot long sampling tube connected to the instrument for analysis; this method is intended for the non-intubated patient. Both mainstream and sidestream technologies calculate the CO<sub>2</sub> value and waveform.

A new technology, Microstream, utilizes a modified sidestream sampling method, and employs a microbeam IR sensor that specifically isolates the CO<sub>2</sub> waveform. Microstream can be used on both intubated and non-intubated patients.

## Components of the capnogram

A capnogram consists of 4 phases and plots CO<sub>2</sub> concentration over time. See figure 2. Phase I, respiratory baseline, is shown as A-B. It measures the CO<sub>2</sub>-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 (CO<sub>2</sub>-free) and alveolar air (contains CO<sub>2</sub>). 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 EtCO<sub>2</sub> 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 CO<sub>2</sub>-free gas. The capnogram quickly returns to its baseline.<sup>3,4</sup> Changes in the capnogram or EtCO<sub>2</sub> 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 EtCO<sub>2</sub>.<sup>5,6</sup> 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, EtCO<sub>2</sub> measurement is the most reliable way of confirming ETT position<sup>5,6</sup> since CO<sub>2</sub> 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 EtCO<sub>2</sub> during a cardiopulmonary arrest is beneficial for two reasons: the measurement helps in assessing the effectiveness of CPR and can also help predict survival.

EtCO<sub>2</sub> levels have a strong correlation with cardiac output. As cardiac output decreases during cardiopulmonary arrest, pulmonary blood flow diminishes, CO<sub>2</sub> available for exhalation is decreased, and EtCO<sub>2</sub> levels drop.<sup>5</sup> Levine and colleagues reported 100% mortality in out of hospital cardiac arrests where EtCO<sub>2</sub> did not return to 10 mm Hg after 20 minutes of CPR.<sup>7</sup>

- Adequacy of ventilation is also monitored via EtCO<sub>2</sub>. 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 (PaCO<sub>2</sub>) 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 EtCO<sub>2</sub> measurement to determine a patient's level of ventilation. EtCO<sub>2</sub> is often used to predict PaCO<sub>2</sub> in patients who have a normal matching of ventilation and perfusion; EtCO<sub>2</sub> is normally 1–5 mm Hg less than the PaCO<sub>2</sub>. A patient underventilated as a result of a physiological abnormality or improper settings on the ventilator will present with an elevated EtCO<sub>2</sub>. The converse is true as well: overventilated patients will present with a decreased EtCO<sub>2</sub>. This knowledge will help the care giver make proper ventilator setting adjustments.

- Evaluation in asthma treatment is another use for EtCO<sub>2</sub>. Analyzing the EtCO<sub>2</sub> waveform after aerosolized bronchodilator therapy has been administered helps to evaluate treatment effectiveness.

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