

Clinical Tips and Tricks: Capnography in the Emergency Department: A primer

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Abstract

Capnography is an underappreciated tool in the emergency department. Continuous monitoring of a patient's exhaled carbon dioxide (CO₂) provides insights into their ventilatory, perfusion, and metabolic status at the bedside. Since it is a continuous process, capnography can often warn of patient deterioration seconds to minutes before other modalities (e.g., pulse oximetry and blood pressure). This article briefly reviews the physiology behind CO₂ production, how capnography monitors work, and what they tell us. Common and important waveforms are reviewed, with emphasis on those that may impact immediate patient care decisions. The remainder of the article briefly discusses various clinical presentations and how the associated capnography measurements, along with patient history and other diagnostic tools, can provide early notice of life-threatening conditions or deterioration.

Keywords: capnography, emergency capnography, EMS, emergency department, ETCO₂

Background

Capnography is a system that continuously monitors exhaled carbon dioxide (CO₂). Typical capnography monitors used in emergency medical services (EMS) and emergency departments have three displays (Ward & Yealy, 1998):

- A waveform that displays the patient's ventilatory pattern over time. This is referred to as a capnogram.
- A numeric indication of the amount of exhaled CO₂ at the end of each breath. This is referred to as the End-Tidal CO₂ (ETCO₂) measurement.

- The number of ventilations per minute. These two numeric displays are collectively referred to as capnometry.

CO₂ is an acidic by-product of aerobic metabolism. Aerobic metabolism depends on cells being well perfused with oxygen and nutrients, with sufficient blood flow to remove the CO₂ (Kamel & Halperin, 2017). Since CO₂ is a gas, its excretion depends on the patient's ability to ventilate adequately. Capnography, therefore, is a tool that allows providers to non-invasively monitor the patient's metabolism, perfusion, and ventilations (Ward & Yealy, 1998). Capnography measurements must be interpreted in the context of the patient's history and other diagnostic signs. For example, ETCO₂ measurements above 45 mmHg (6 kPa) could indicate CO₂ trapping (e.g., bronchospasm) or a hypermetabolic state (e.g., fever, stimulant overdose). Similarly, ETCO₂ measurements below 35 mmHg (4.7 kPa) could indicate a hypometabolic state or an acidotic state (e.g., shock).

As acidosis progresses, the body's stores of bicarbonate (HCO₃) are consumed, buffering the abnormal acids. Unfortunately, HCO₃ is also necessary for removing CO₂ from the blood stream, so it may be exhaled via the lungs. This results in seemingly paradoxical low ETCO₂ measurements as acidosis increases. These low measurements, along with the patient's history and other diagnostic indicators, provide clues as to the depth and nature of the patient's illness (Ward, 2011).

The following sections illustrate how capnography can benefit emergency department patients.

Airway Management

The patency of an advanced airway (i.e., endotracheal tubes or supraglottic airways) can be quickly assessed by observing the patient's capnogram. A normal wave form is shown in Figure 1 (Ward & Yealy, 1998). Figure 2 shows the waveform of a patient with a kinked endotracheal tube or partially clogged advanced airway (Ward & Yealy, 1998).

Figure 1

Normal Capnogram

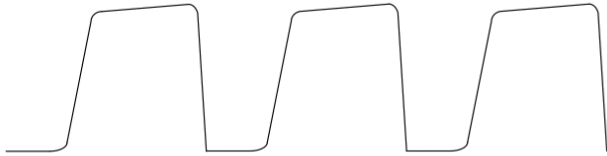
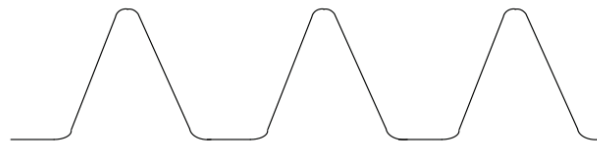


Figure 2

Kinked Endotracheal Tube Capnogram



A leak in an endotracheal tube's distal cuff or a supraglottic airway's seal will result in a waveform like that shown in Figure 3 (Ward & Yealy, 1998).

Respiratory Management

Apnea detection is an application of capnography that is potentially, and immediately, lifesaving. It can take minutes for a patient's oxygen (O_2) levels to desaturate below the usual pulse oximeter oxygen saturation (SpO_2) alarm settings. Since capnography monitors patient ventilation in real-time, it can detect bradypnea and apnea in seconds, allowing the clinician to quickly restore ventilation and perfusion to prevent patient deterioration (Cacho et al., 2010).

We need to ensure that our intubated patients are properly oxygenated and sedated. A capnogram like that shown in Figure 4, sometimes referred to as a "curare cleft", indicates that the patient is inhaling prematurely during exhalation. This may indicate that the patient is hypoxic or that the patient's sedation is wearing off (Ward & Yealy, 1998).

Interestingly, non-intubated patients may also present with this waveform, which may indicate hypoxia or unmanaged pain (Greenbaum, 2024).

Cardiac Emergencies

American Heart Association (AHA) guidelines suggest that $ETCO_2$ measurements of at least 10 mmHg (1.33 kPa) during cardiopulmonary resuscitation (CPR) indicate adequate compressions and ventilation (American Heart Association, 2020). A sudden rise of $ETCO_2$ of 10 mmHg (1.33 kPa) or more indicates that return of spontaneous circulation (ROSC) has been achieved (Kodali & Urman, 2014).

Metabolic Emergencies

Low $ETCO_2$ measurements, lacking a ventilatory disturbance (e.g., hyperventilation), may indicate either an abnormally low metabolic level or that the patient is suffering from a metabolic acidosis. For example, a patient presenting with an $ETCO_2$ measurement of 25 mmHg (3.3 kPa) with blood glucose measurements greater than 16.7 mmol (300 mg/dl) and a history of diabetes strongly suggests that our patient has progressed from

Figure 3

Leaky Endotracheal Tube Cuff Capnogram

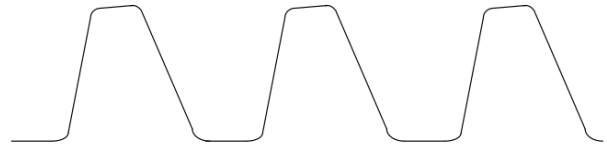
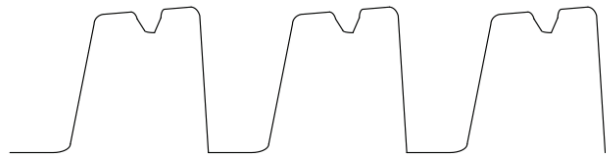


Figure 4

Gasping Capnogram



simple hyperglycemia into diabetic ketoacidosis. A rapid bedside diagnosis allows treatment to begin sooner, relative to waiting for blood tests to be completed (Kamel & Halperin, 2017).

High $ETCO_2$ measurements, lacking a ventilatory disturbance (e.g., bronchospasm, respiratory failure), may indicate an abnormally high metabolic level. For example, a patient presenting with recent sedation by EMS personnel for delirium and violent behaviour secondary to a suspected phencyclidine (PCP) overdose presents with increasing $ETCO_2$ measurements, the last of 55 mmHg (7.3 kPa). This suggests that the patient is developing malignant hyperthermia. Capnography allows providers to see the increasing metabolic activity before it results in potentially lethal temperature levels (Gupta & Hopkins, 2017).

Shock

Shock is (by definition) a systemic disruption in perfusion (Ward, 2011). Cells that are inadequately perfused switch to anaerobic metabolism, which produces lactic acid and little to no CO_2 . The lactic acid is buffered by HCO_3 , which reduces the amount available for removing CO_2 from the blood stream. The reduced production and removal of CO_2 , and thus shock, can be detected by monitoring $ETCO_2$ measurements. Since capnography is a continuous measurement process, shock can be detected sooner than using other vital signs.

Compensated shock can be recognized with $ETCO_2$ measurements of 28–35 mmHg (3.7–4.7 kPa) with an appropriate history. Decompensated shock can be recognized with $ETCO_2$ measurements 13–27 mmHg (1.7–3.6 kPa). $ETCO_2$ measurements below 12 mmHg (1.6 kPa) imply irreversible shock has set in (Kheng & Rahman, 2012). At this stage, treatment must be rapid and aggressive if the patient's life is to be saved.

Trauma

Capnography can assist in managing patients with traumatic brain injuries (TBIs). Hyperventilation of TBI patients improves oxygenation but reduces cerebral blood flow. Hypoventilation improves blood flow but reduces oxygenation. Maintaining

ETCO₂ between 30 and 35 mmHg (4.0 and 4.7 kPa) provides a healthy balance of these two competing priorities (Frakes, 2011).

Conclusion

Capnography provides continuous, non-invasive monitoring that provides insights into a patient's perfusion, metabolic, and ventilatory status. In conjunction with other diagnostic tools, capnography can help emergency department providers recognize potentially life-threatening problems earlier, and monitor the effectiveness of related patient treatment.

Implications for Emergency Nursing Practice

- Capnography allows for rapid assessment of the patient's ventilatory, perfusion, and metabolic status at the bedside.
- Capnography changes with potentially life-threatening conditions much more quickly than other diagnostic tools.
- Capnography supplements, but does not replace, other diagnostic modalities.

REFERENCES

- American Heart Association. (2020). *Advanced cardiovascular life support*. American Heart Association.
- Cacho, G., Pérez-Calle, J. L., Barbado, A., Lledó, J. L., Ojea, R., & Fernández-Rodríguez, C. M. (2010). Capnography is superior to pulse oximetry for the detection of respiratory depression during colonoscopy. *Revista Espanola de Enfermedades Digestivas*, 102(2), 86–89. <https://doi.org/10.4321/S1130-01082010000200003>
- Frakes, M. A. (2011). Capnography during transport of patients (inter/intra-hospital). In J. S. Gravenstein, M. B. Jaffe, N. Gravenstein, & D. A. Paulus (Eds.), *Capnography* (2nd ed.). Cambridge University Press.
- Greenbaum, H. (2024). *Emergency capnography* (1st ed.). CRC Press. <https://doi.org/10.1201/9781003491576>
- Gupta, P. K., & Hopkins, P. M. (2017). Diagnosis and management of malignant hyperthermia. *BJA Education*, 17(7), 249–254. <https://doi.org/10.1093/bjaed/mkw079>
- Kamel, K. S., & Halperin, M. L. (2017). *Fluid, electrolyte, and acid-base physiology* (5th ed.). Elsevier USA.
- Kheng, C. P., & Rahman, N. H. (2012). The use of end-tidal carbon dioxide monitoring in patients with hypotension in the emergency department. *International Journal of Emergency Medicine*, 5(1). <https://doi.org/10.1186/1865-1380-5-31>
- Kodali, B. S., & Urman, R. D. (2014). Capnography during cardiopulmonary resuscitation: Current evidence and future directions. *Journal of Emergencies, Trauma, and Shock*, 7(4), 332–332. <https://doi.org/10.4103/0974-2700.142778>
- Ward, K. R. (2011). The physiological basis for capnometric monitoring in shock. In J. S. Gravenstein, M. B. Jaffe, N. Gravenstein, & D. A. Paulus (Eds.), *Capnography* (2nd ed., pp. 231–238). Cambridge University Press.
- Ward, K. R., & Yealy, D. M. (1998). End-tidal carbon dioxide monitoring in emergency medicine, Part 1: Basic principles. *Academic Emergency Medicine*, 5(6), 628–636. <https://doi.org/10.1111/j.1553-2712.1998.tb02473.x>

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