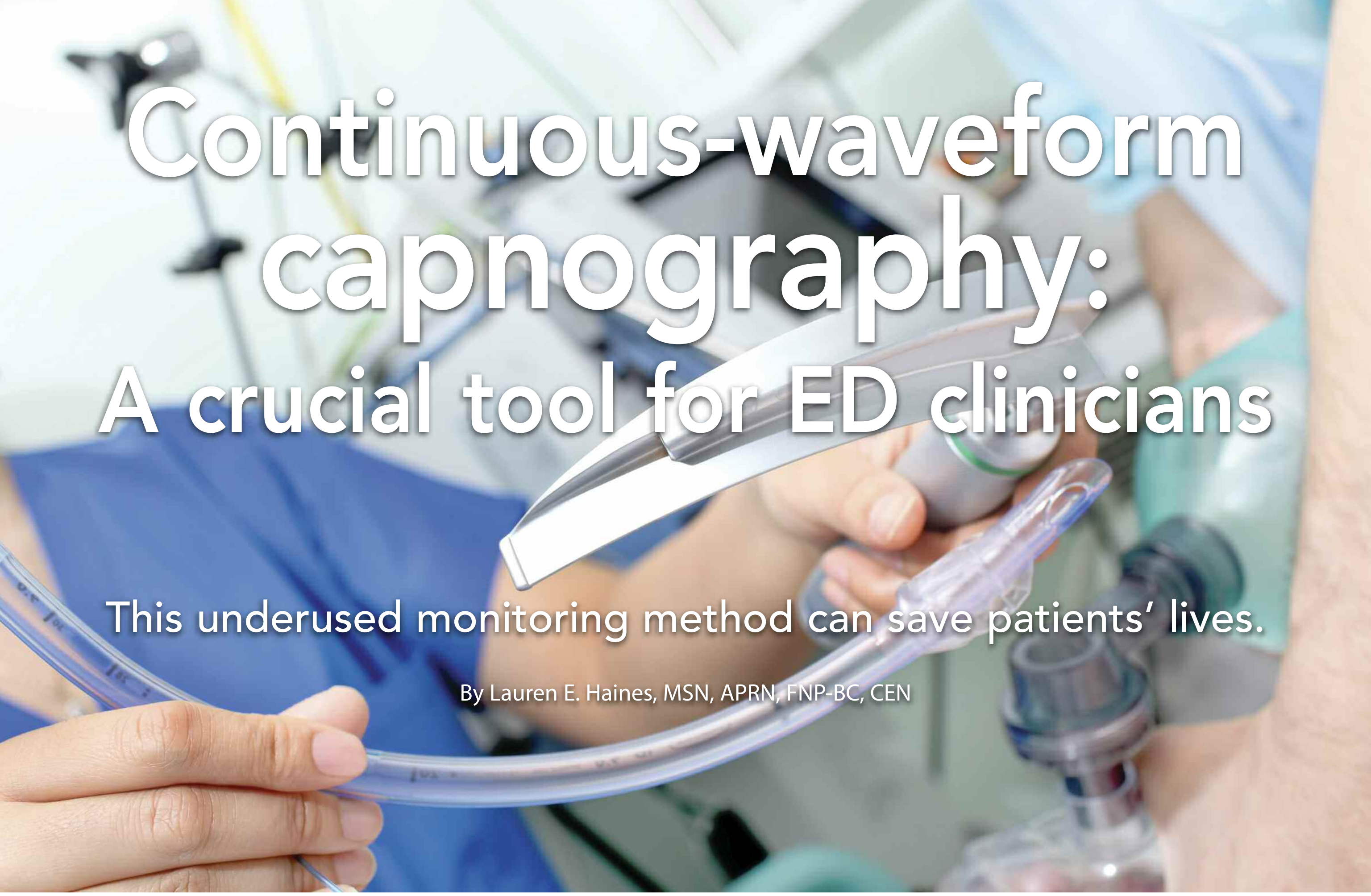


Continuous-waveform capnography: A crucial tool for ED clinicians

This underused monitoring method can save patients' lives.

By Lauren E. Haines, MSN, APRN, FNP-BC, CEN

MANY emergency department (ED) patients are at risk for complications associated with airway management and ventilator problems. Continuous-waveform capnography (CWC) is a critical method clinicians can use to monitor patients' respiratory function. By means of a specialized nasal cannula or attachment for an endotracheal or tracheostomy tube, this noninvasive technique measures end-tidal carbon dioxide ($ETCO_2$) over time and displays it as a CO_2 waveform. Despite its important benefits, though, CWC is underused.

$ETCO_2$ is the percentage concentration of CO_2 at the end of exhalation. It reflects CO_2 production and elimination as well as ventilatory function and pulmonary perfusion. $ETCO_2$ monitoring helps ensure correct endotracheal tube placement during intubation and helps evaluate respiratory and ventilatory status during procedural sedation or mechanical ventilation. It's also valuable in monitoring the effectiveness of cardiopulmonary resuscitation (CPR) and determining return of spontaneous circulation (ROSC) after cardiac arrest. (See *Capnography basics*.)

This article discusses CWC use during procedural sedation, intubation and mechanical ventilation, and CPR. It also describes troubleshooting and compares the benefits and drawbacks of capnography and pulse oximetry.

Procedural sedation

Medications commonly given during procedural sedation, like sedatives and analgesics, can cause respiratory depression leading to hypoventilation, apnea, hypoxia, or a combination. CWC can be used before the sedation procedure to identify baseline respiratory function, and during the procedure to identify airway complications and hypoventilation. Obese patients and those with sleep apnea are especially prone to these complications and should be monitored appropriately.

Intubation and mechanical ventilation

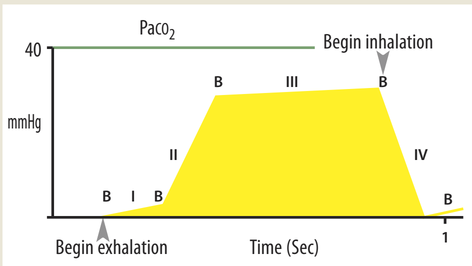
In newly intubated patients, ED clinicians can use capnography, capnometry (CO_2 measurement alone without a continuous written record or waveform), or both to verify correct endotracheal tube placement. Colorimetric capnometry, a qualitative method, identifies correct tube placement initially by confirming $ETCO_2$ presence with a pH-sensitive filter. (See *How a colorimetric capnometer works*.)

The American Heart Association's Advanced Cardiac Life Support (ACLS) and Pediatric Advanced Life Support guidelines recommend using CWC during patient transport and procedures involving patient movement. CWC significantly improves prompt identification of endotracheal tube dislodgment over pulse oximetry alone. A study of patients with such dislodgments found approximately 48% of those monitored by capnography had improper tube

Capnography basics

A simple, noninvasive procedure appropriate for all age groups and many settings, continuous-waveform capnography (CWC) measures and provides a graphic depiction of end-tidal carbon dioxide ($ETCO_2$) as a waveform, or capnogram. Measurements can be made via sidestream sampling through a nasal cannula or via attachments to an endotracheal or a tracheostomy tube.

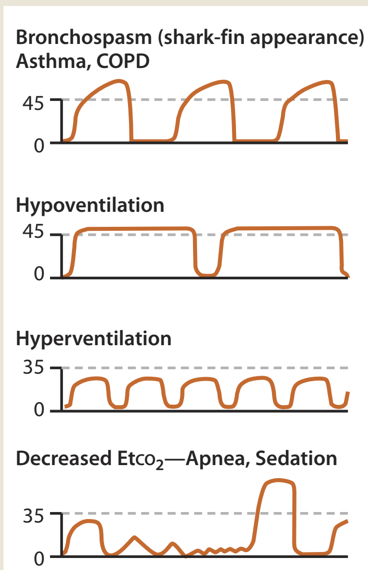
The capnogram corresponds to the patient's respiratory cycle. Normally, it displays an almost-square waveform, indicating a clear airway. A nonsquare waveform may indicate a partial airway obstruction or impaired ventilation, while an absent waveform indicates complete airway obstruction or absence of pulmonary perfusion.



During inspiration, the waveform tracing stays at zero as the patient inhales fresh air. Its highest point corresponds with the $ETCO_2$ level, defined as peak partial pressure reached at the end of exhalation. Normally, $ETCO_2$ ranges from 35 to 45 mm Hg.

- Levels above 45 mm Hg can result from hypoventilation, respiratory acidosis, fever, bronchospasm, ventilation of a previously unventilated lung, or an adrenergic response.
- Levels below 35 mm Hg may stem from hyperventilation, respiratory alkalosis, partial airway obstruction, pulmonary embolus, cardiac arrest, hypotension, hypovolemia, or hypothermia.

When monitoring patients with CWC, always consider the numeric reading and waveform display as well as the patient's physiologic condition. The waveforms to the right show how various conditions affect the tracing.



How a colorimetric capnometer works

A colorimetric capnometer consists of a pH-sensitive impregnated paper that attaches to the end of an endotracheal tube. The color of the pH paper changes from purple to yellow when the capnometer detects carbon dioxide, suggesting proper endotracheal tube placement.

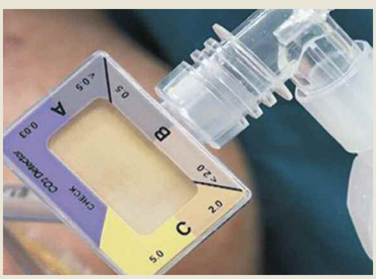


Photo: Nellcor™ adult colorimetric CO_2 detector.

Benefits of CWC during resuscitation

Using continuous-waveform capnography (CWC) can make a lifesaving difference during cardiac resuscitation. It can:

- indicate the quality of chest compressions
- provide good predictability of correct endotracheal tube position during placement
- detect return of spontaneous circulation without the need to interrupt resuscitation to check the patient's pulse
- predict survivability.

placement corrected before pulse oximetry levels declined, compared to just 12% of patients without CWC monitoring.

CWC also can be used to monitor the ventilator status of mechanically ventilated patients. $ETCO_2$ readings alert clinicians to the need to adjust ventilator settings, including tidal volume and respiratory rate. Capnography has become the standard for confirming ventilation after intubation and is recommended for all ventilator-dependent patients.

Cardiac resuscitation

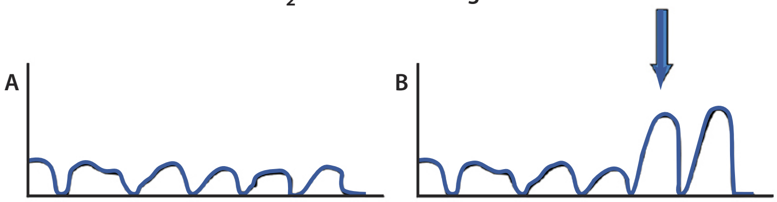
For patients in cardiac arrest, high-quality CPR is essential for survival. Because CWC measures pulmonary blood flow during cardiac arrest, it indicates the quality of chest compressions. A low $ETCO_2$ level indicates poor CPR quality and is linked to a reduced chance of ROSC. Studies show $ETCO_2$ levels below 10 mm Hg after 20 minutes of CPR portend poor survival odds. Conversely, levels above 25 mm Hg at 5 to 10 minutes after CPR initiation indicate a greater chance of ROSC. (See *Benefits of CWC during resuscitation*.)

Also, CWC use during cardiac resuscitation helps clinicians recognize ROSC without having to interrupt CPR to check for a pulse. Minimizing such interruptions is crucial for maintaining adequate

Using CWC to identify ROSC

Continuous-waveform capnography (CWC) helps clinicians eliminate unnecessary interruptions in cardiopulmonary resuscitation, thus improving the patient's survival odds. As this waveform shows, an abrupt increase in end-tidal carbon dioxide ($ETCO_2$, indicated by an abrupt rise in the waveform) suggests return of spontaneous circulation (ROSC).

CO_2 waveform during CPR



An abrupt increast in $ETCO_2$ may indicate return of spontaneous circulation. Increase in pulmonary circulation brings more CO_2 into lungs for elimination.

perfusion and improving survival odds. An abrupt $ETCO_2$ rise indicates ROSC from a sudden increase in pulmonary perfusion. (See *Using CWC to identify ROSC.*)

Troubleshooting

CWC is simple to use—but it's not perfect. Condensation can obstruct the sampling line; if this happens, the line may need to be disconnected and flushed with an air-filled syringe until clear. If this fails to fix the problem, the line may need to be replaced. Know that an obstructed or disconnected sampling line may cause a flat tracing instead of a square waveform on the capnogram. This can also occur if the patient isn't breathing, the ventilator becomes disconnected, or the endotracheal or tracheostomy tube becomes occluded or dislodged.

CWC is simple to use— but it's not perfect.

Also, the waveform may not return to zero during inspiration. This may indicate the patient is rebreathing CO_2, which may signal ventilator malfunction or inadequate patient oxygenation.

Capnography vs. pulse oximetry

Pulse oximetry is widely used in EDs, both for one-time oxygenation evaluation and continuous monitoring in more critical patients. Pulse oximetry detects hypoxia—but hypoxia can be a late sign of inadequate ventilation.

In contrast, CWC detects early signs of respiratory depression and ventilatory complications and is more sensitive in detecting respiratory compromise in patients undergoing procedural sedation. What's more, it identifies endotracheal tube dislodgment faster than pulse oximetry, allowing more timely tube correction. Additionally, in patients receiving supplemental oxygen, pulse oximetry may appear normal despite obvious respiratory impairment or hypoventilation. (See *Comparing CWC with pulse oximetry.*)

Nursing implications

CWC is the standard of care for monitoring pulmonary function in ED patients. Besides yielding insight into the patient's metabolic, circulatory, and respiratory status, it identifies respiratory complications faster than pulse oximetry. All nurses should be able to use this simple but effective tool to provide the highest-quality care. ★

Comparing CWC with pulse oximetry

Continuous waveform capnography (CWC) has crucial benefits over pulse oximetry.

- It detects hypoventilation before hypoxia onset—in many cases, minutes before pulse oximetry shows decreased partial pressure of oxygen.
- It provides more information about the patient's overall respiratory function.
- It's more reliable in patients with hypothermia or poor distal perfusion.

Capnography, on the other hand, doesn't measure oxygenation. However, it's a good tool to use in conjunction with pulse oximetry.

When Lauren E. Haines wrote this article, she was a critical care clinical nurse education specialist at Eastern Connecticut Health Network in Manchester.

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