Capnography Review

The new 2010 American Heart Association Guidelines now endorse wave form capnography as a Level I recommendation for ET tube verification, a Level IIa reccomendation for detecting return of spontaneous circulation and a IIb for monitoring CPR quality.

Part 8: Adult Advanced Cardiovascular Life Support

Here are the excerpts:

On ET Confirmation

Continuous waveform capnography is recommended in addition to clinical assessment as the most reliable method of confirming and monitoring correct placement of an endotracheal tube (Class I, LOE A).

Notes:

Waveform capnography should be used "to confirm and monitor endotracheal tube placement in the field, in the transport vehicle, on arrival at the hospital, and after any patient transfer to reduce the risk of unrecognized tube misplacement or displacement."

Studies on wave form capnography "have shown 100% sensitivity and 100% specificity in identifying correct endotracheal tube placement."

Colormetric ETCO2 devices should only be used "when waveform capnography is not available (Class IIa, LOE B)."

On Monitoring CPR Quality

It is reasonable to consider using quantitative waveform capnography in intubated patients to monitor CPR quality, optimize chest compressions, and detect ROSC during chest compressions or when rhythm check *reveals an organized rhythm (Class IIb, LOE C).*

On Indicating ROSC

If PETCO2 abruptly increases to a normal value (35 to 40 mm Hg), it is reasonable to consider that this is an indicator of ROSC (Class IIa, LOE B).

0 comments

10 Things Every Paramedic Should Know About Capnography

Capnography is the vital sign of ventilation.

By tracking the carbon dioxide in a patient's exhaled breath, capnography enables paramedics to objectively evaluate a patient's ventilatory status (and indirectly circulatory and metabolic status), as the medics utilize their clinical judgement to assess and treat their patients.

Part One: The Science

Definitions:

Capnography – the measurement of carbon dioxide (CO_2) in exhaled breath.

Capnometer – the numeric measurement of CO_2.

Capnogram – the wave form.

End Tidal CO2 (ETCO2 or PetCO2) - the level of (partial pressure of) carbon dioxide released at end of expiration.

Oxygenation Versus Ventilation

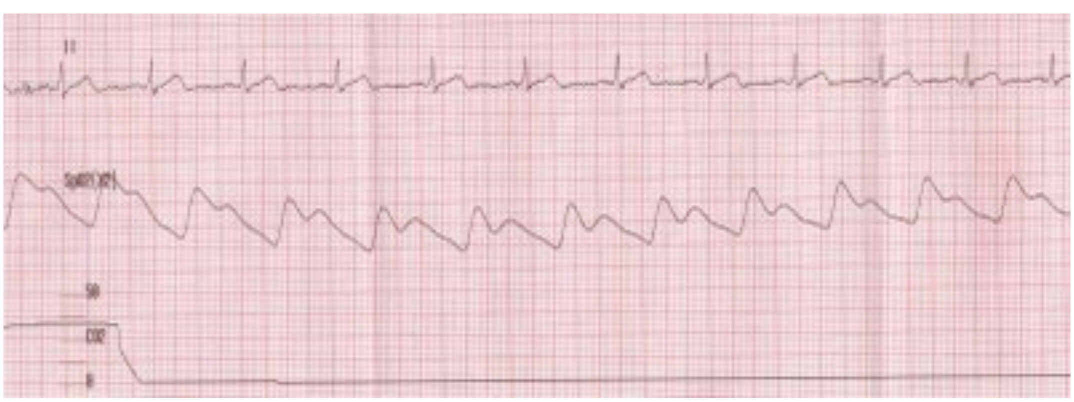
Oxygenation is how we get oxygen to the tissue. Oxygen is inhaled into the lungs where gas exchange occurs at the capillary-alveolar membrane. Oxygen is transported to the tissues through the blood stream. Pulse oximetry measures oxygenation.

At the cellular level, oxygen and glucose combine to produce energy. Carbon dioxide, a waste product of this process (The Krebs cycle), diffuses into the blood.

Ventilation (the movement of air) is how we get rid of carbon dioxide. Carbon dioxide is carried back through the blood and exhaled by the lungs through the alveoli. Capnography measures ventilation.

Capnography versus Pulse Oximetry

Capnography provides an immediate picture of patient condition. Pulse oximetry is delayed. Hold your breath. Capnography will show immediate apnea, while pulse oximetry will show a high saturation for several minutes.



Circulation and Metabolism

While capnography is a direct measurement of ventilation in the lungs, it also indirectly measures metabolism and circulation. For example, an increased metabolism will increase the production of carbon dioxide increasing the ETCO2. A decrease in cardiac output will lower the delivery of carbon dioxide to the lungs decreasing the ETCO2.

“CO2 is the smoke from the flames of metabolism.”– Ray Fowler, M.D. Dallas, Street Doc’s Society

PaCO2 vs. PeTCO2

PaCO2= Partial Pressure of Carbon Dioxide in arterial blood gases. The PaCO2 is measured by drawing the ABGs, which also measure the arterial PH.

If ventilation and perfusion are stable PaCO2 should correlate to PetCO2. In a study comparing PaCO2 and PetCO2 in 39 patients with severe asthma, the mean difference between PaCO2 and PetCO2 was 1.0 mm Hg, the median difference was 0 mm Hg. Only 2 patients were outside the 5 mg HG agreement (1-6, 1-12). -Jill Corbo, MD, et al, Concordance Between Capnography and Arterial Blood Gas Measurements of Carbon Dioxide in Acute Asthma, *Annals of Emergency Medicine*, October 2005

“Research has (also) shown good concordance...in patients with normal lung function, upper and lower airway disease, seizures, and diabetic ketoacidosis.” –ibid.

V/Q Mismatch

If ventilation or perfusion are unstable, a Ventilation/Perfusion (V/Q) mismatch can occur. This will alter the correlation between PaC02 and PetCO2.

This V/Q mismatch can be caused by blood shunting such as occurs during atelectasis (perfusing unventilated lung area) or by dead space in the lungs (Ventilating unperfused lung area) such as occurs with a pulmonary embolisim or hypovolemia.

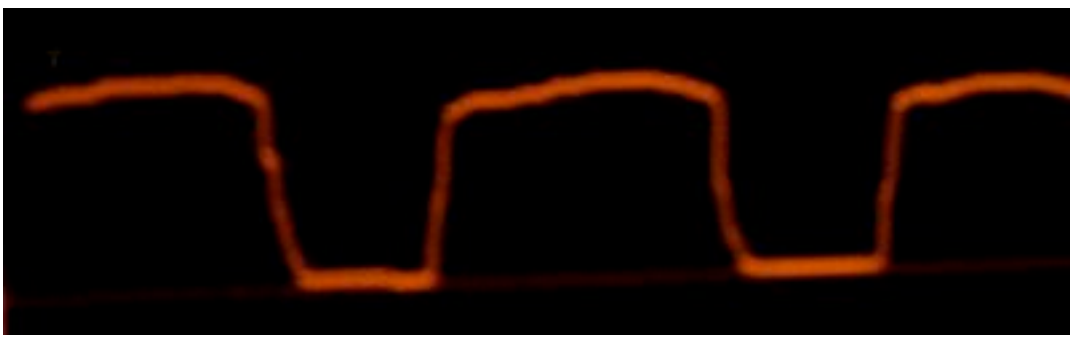
Normal Capnography Values

ETCO2 35-45 mm Hg is the normal value for capnography. However, some experts say 30 mm HG - 43 mm Hg can be considered normal.

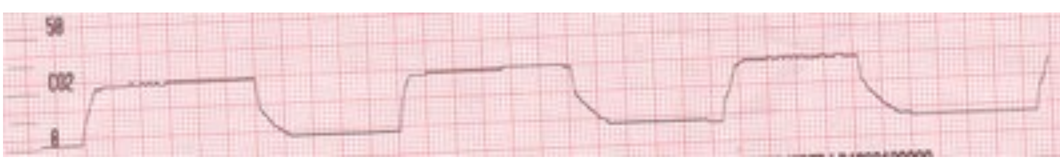
Cautions: Imperfect positioning of nasal cannula capnofilters may cause distorted readings. Unique nasal anatomy, obstructed nares and mouth breathers may skew results and/or require repositioning of cannula. Also, oxygen by mask may lower the reading by 10% or more.

Capnography Wave Form

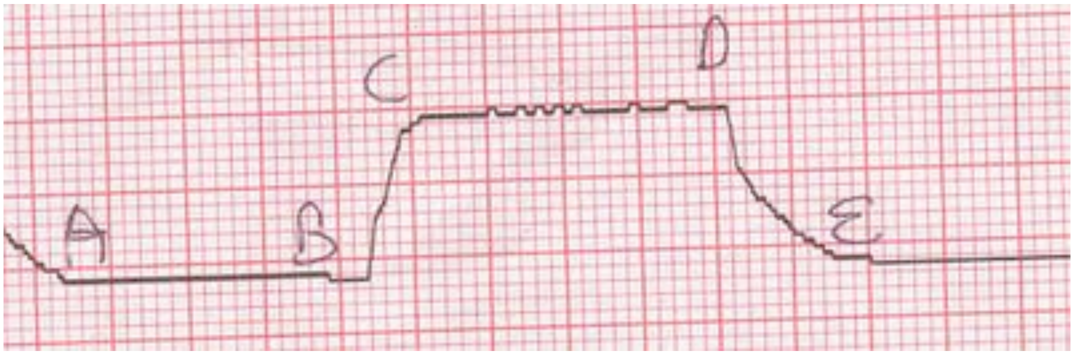
The normal wave form appears as straight boxes on the monitor screen:



But the wave form appears more drawn out on the print out because the monitor screen is compressed time while the print out is in real time.



The capnogram wave form begins before exhalation and ends with inspiration. Breathing out comes before breathing in.



A to B is post inspiration/dead space exhalation, B is the start of alveolar exhalation, B-C is the exhalation upstroke where dead space gas mixes with lung gas, C-D is the continuation of exhalation, or the plateau(all the gas is alveolar now, rich in C02). D is the end-tidal value – the peak concentration, D-E is the inspiration washout.

Abnormal Values and Wave Forms

ETCO2 Less Than 35 mmHg = "Hyperventilation/Hypocapnia"
ETC02 Greater Than 45 mmHg = "Hypoventilation/Hypercapnia"

Caution:

"End Tidal CO2 reading without a waveform is like a heart rate without an ECG recording." – Bob Page "Riding the Waves"

However, unlike ECGs, there are only a few capnography wave forms. The main abnormal ones -- hyperventilation, hypoventilation, esophageal intubation and obstructive airway/shark fin -- are described below.

Part Two: Clinical Uses of Capnography

1. Monitoring Ventilation

Capnography monitors patient ventilation, providing a breath by breath trend of respirations and an early warning system of impending respiratory crisis.

Hyperventilation

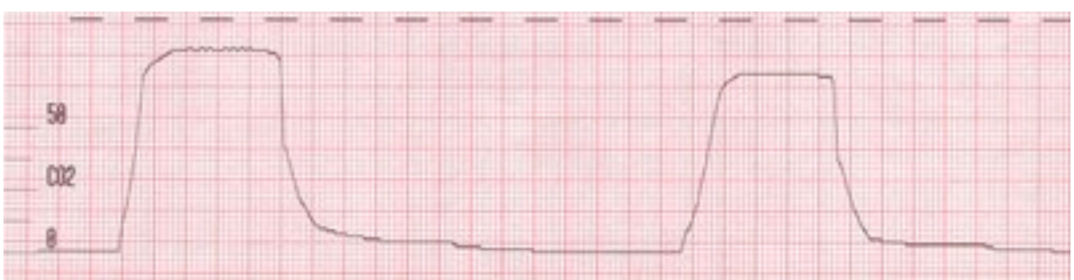
When a person hyperventilates, their CO2 goes down.

Hyperventilation can be caused by many factors from anxiety to bronchospasm to pulmonary embolus. Other reasons C02 may be low: cardiac arrest, decreased cardiac output, hypotension, cold, severe pulmonary edema.

Note: Ventilation equals tidal volume X respiratory rate. A patient taking in a large tidal volume can still hyperventilate with a normal respiratory rate just as a person with a small tidal volume can hypoventilate with a normal respiratory rate.

Hypoventilation

When a person hypoventilates, their CO2 goes up.



Hypoventilation can be caused by altered mental status such as overdose, sedation, intoxication, postictal states, head trauma, or stroke, or by a tiring CHF patient. Other reasons CO2 may be high: Increased cardiac output with increased breathing, fever, sepsis, pain, severe difficulty breathing, depressed respirations, chronic hypercapnia.

Some diseases may cause the CO2 to go down, then up, then down. (See asthma below).

Pay more attention to the ETCO2 trend than the actual number.

A steadily rising ETCO2 (as the patient begins to hypoventilate) can help a paramedic anticipate when a patient may soon require assisted ventilations or intubation.

Heroin Overdoses - Some EMS systems permit medics to administer narcan only to unresponsive patients with suspected opiate overdoses with respiratory rates less than 10. Monitoring ETCO2 provides a better gauge of ventilatory status than respiratory rate. ETCO2 will show a heroin overdose with a respiratory rate of 24 (with many shallow ineffective breaths) and an ETCO2 of 60 is more in need of arousal than a patient with a respiratory rate of 8, but an ETCO2 of 35.

2. Confirming, Maintaining , and Assisting Intubation

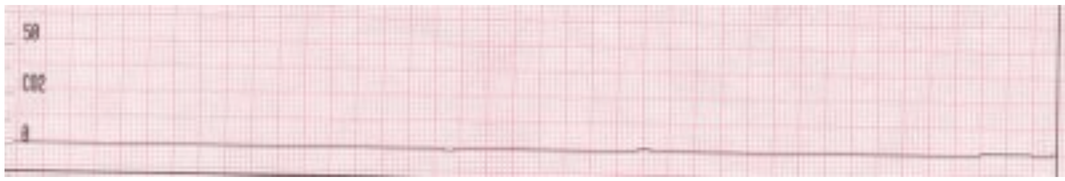
Continuous end-tidal CO2 monitoring can confirm a tracheal intubation. A good wave form indicating the presence of CO2 ensures the ET tube is in the trachea.

A 2005 study comparing field intubations that used continuous capnography to confirm intubations versus non-use showed zero unrecognized misplaced intubations in the monitoring group versus 23% misplaced tubes in the unmonitored group. -Silverstir, *Annals of Emergency Medicine*, May 2005

“When exhaled CO2 is detected (positive reading for CO2) in cardiac arrest, it is usually a reliable indicator of tube position in the trachea.” - The American Heart

Association 2005 CPR and ECG Guidelines

Reasons ETCO2 is zero: The tube is in the esophagus.*

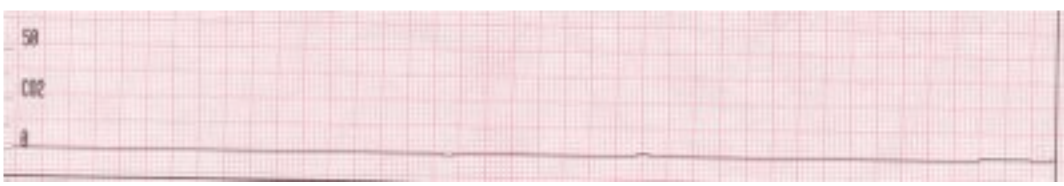


* True as a general rule, but may not hold for cases of greatly prolonged down time prior to initiation of CPR or cases of massive pulmonary embolism where blood flow to the lungs is completely blocked. Also, in patients in arrest, CPR is neccessary to generate a waveform.

Caution: In patients with a prolonged down time, the ETCO2 reading may be so low (sometimes less than 6mm HG) that some monitor's apnea alarms may go off even though the monitor is still providing an ETCO2 reading and a small wave form. If the apnea alarm goes off and you continue to bag without resistance and have equal lung sounds and negative epigatric sounds, do not automatically pull your tube. A small but distinct square wave form along with even a marginal EtCO2 reading is still verification the tube is in the trachea.

ETCO2 can also be used to assist in difficult intubations of spontaneously breathing patients.

Paramedics can attach the capnography filter to the ET tube prior to intubation and, in cases where it is difficult to visualize the chords, use the monitor to assist placement. This includes cases of nasal tracheal intubation.



You're out (missed the chords).

You're in.

Paramedics who utilize this method during cardiac arrests with cardiac compressions continuing while they intubate may see CPR oscillations on the monitor screen immediately upon intubating, replaced by larger wave forms once the ambu-bag has been attached and ventilations begun. The oscillations provide proof that compressions alone can produce some ventilation.

Note: You must still assess for equal lung sounds. Capnography cannot detect right main-stem intubations.

Capnography can also be used for combitubes and LMAs.

Paramedics should document their use of continuous ETCO2 monitoring and attach wave form strips to their PCRs. Print a strip on intubation, periodically during care and transport, and then just prior to moving the patient from your stretcher to the hospital table and then immediately after transfer. This will timestamp and document your tube as good.

Continuous Wave Form Capnography Versus Colorimetric Capnography

In colorimetric capnography a filter attached to an ET tube changes color from purple to yellow when it detects carbon dioxide. This device has several drawbacks when compared to waveform capnography. It is not continuous, has no waveform, no number, no alarms, is easily contaminated, is hard to read in dark, and can give false readings.

Paramedics should encourage their services to equip them with continuous wave form capnography.

3. Measuring Cardiac Output During CPR

Monitoring ETC02 measures cardiac output, thus monitoring ETCO2 is a good way to measure the effectiveness of CPR.

In 1978, Kalenda “reported a decrease in ETC02 as the person performing CPR fatigued, followed by an increase in ETCO2 as a new rescuer took over, presumably providing better chest compressions.” –Gravenstein, *Capnography: Clinical Aspects*, Cambridge Press, 2004

“Reductions in ETCO2 during CPR are associated with comparable reductions in cardiac output....The extent to which resuscitation maneuvers, especially precordial compression, maintain cardiac output may be more readily assessed by measurements of ETCO2 than palpation of arterial pulses.” -Max Weil, M.D., Cardiac Output and End-Tidal carbon dioxide, *Critical Care Medicine*, November 1985

With the new American Heart Association Guidelines calling for quality compressions ("push hard, push fast, push deep"), rescuers should switch places every two minutes. Set the monitor up so the compressors can view the ETCO2 readings as well as the ECG wave form generated by their compressions. Encourage them to keep the ETCO2 number up as high as possible.

Note: Patients with extended down times may have ETCO2 readings so low that quality of compressions will show little difference in the number.

Return of Spontaneous Circulation (ROSC)

ETCO2 can be the first sign of return of spontaneous circulation (ROSC). During a cardiac arrest, if you see the CO2 number shoot up, stop CPR and check for pulses.

End-tidal CO2 will often overshoot baseline values when circulation is restored due to carbon dioxide washout from the tissues.

A recent study found the ETCO2 shot up on average 13.5 mmHg with sudden ROSC before settling into a normal range.-Grmec S, Krizmaric M, Mally S, Kozelj A, Spindler M, Lesnik B.,*Resuscitation*. 2006 Dec 8

Note: Each bar represents 30 seconds.

“End-tidal CO2 monitoring during cardiac arrest is a safe and effective noninvasive indicator of cardiac output during CPR and may be an early indicator of ROSC in intubated patients.” - American Heart Association Guidelines 2005 CPR and ECG

Loss of Spontaneous Circulation

In a resuscitated patient, if you see the stabilized ETCO2 number significantly drop in a person with ROSC, immediately check pulses. You may have to restart CPR.

The graph below demonstrates three episodes of ROSC, followed by loss of circulation during a cardiac arrest:

4. End Tidal CO2 As Predictor of Resuscitation Outcome

End tidal CO2 monitoring can confirm the futility of resuscitation as well as forecast the likelihood of resuscitation.

"An end-tidal carbon dioxide level of 10 mmHg or less measured 20 minutes after the initiation of advanced cardiac life support accurately predicts death in patients with cardiac arrest associated with electrical activity but no pulse. Cardiopulmonary resuscitation may reasonably be terminated in such patients." -Levine R, End-tidal Carbon Dioxide and Outcome of Out-of-Hospital Cardiac Arrest, *New England Journal of Medicine*, July 1997

Likewise, case studies have shown that patients with a high initial end tidal CO2 reading were more likely to be resuscitated than those who didn't. The greater the initial value, the likelier the chance of a successful resuscitation.

"No patient who had an end-tidal carbon dioxide of level of less than 10 mm Hg survived. Conversely, in all 35 patients in whom spontaneous circulation was restored, end-tidal carbon dioxide rose to at least 18 mm Hg before the clinically detectable return of vital signs....The difference between survivors and nonsurvivors in 20 minute end-tidal carbon dioxide levels is dramatic and obvious." – ibid.

"An ETCO2 value of 16 torr or less successfully discriminated between the survivors and the nonsurvivors in our study because no patient survived with an ETCO2 less than 16 torr. Our logistic regression model further showed that for every increase of 1 torr in ETCO2, the odds of surviving increased by 16%." –Salen, Can Cardiac Sonography and Capnography Be Used Independently and in Combination to Predict Resuscitation Outcomes?, *Academic Emergency Medicine*, June 2001

Caution: While a low initial ETCO2 makes resuscitation less likely than a higher initial ETCO2, patients have been successfully resuscitated with an initial ETCO2 >10 mmHg.

Asphyxic Cardiac Arrest versus Primary Cardiac Arrest

Capnography can also be utilized to differentiate the nature of the cardiac arrest.

A 2003 study found that patients suffering from asphyxic arrest as opposed to primary cardiac arrest had significantly increased initial ETCO2 reading that came down within a minute. These high initial readings, caused by the buildup of carbon dioxide in the lungs while the nonbreathing/nonventilating patient's heart continued pump carbon dioxide to the lungs before the heart bradyed down to asystole, should come down within a minute. The ETCO2 values of asphyxic arrest patients then become prognostic of ROSC.-Grmec S, Lah K, Tusek-Bunc K,*Crit Care*. 2003 Dec

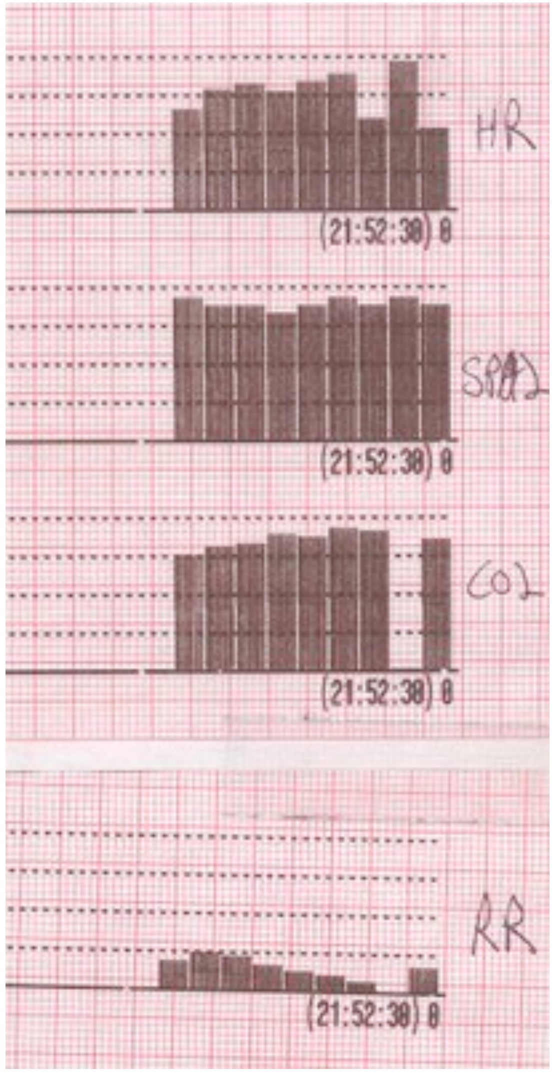
5. Monitoring Sedated Patients

Capnography should be used to monitor any patients receiving pain management or sedation (enough to alter their mental status) for evidence of hypoventilation and/or apnea.

In a 2006 published study of 60 patients undergoing sedation, in 14 of 17 patients who suffered acute respiratory events, ETCO2 monitoring flagged a problem before changes in SPO2 or observed changes in respiratory rate.

"End-tidal carbon dioxide monitoring of patients undergoing PSA detected many clinically significant acute respiratory events before standard ED monitoring practice did so. The majority of acute respiratory events noted in this trial occurred before changes in SP02 or observed hypoventilation and apnea." - -Burton, Does End-Tidal Carbon Dioxide Monitoring Detect Respiratory Events Prior to Current Sedation Monitoring Practices, *Academic Emergency Medicine*, May 2006

In the graph below, the respiratory rate decreases as the ETCO2 rises, and the patient suffers apnea, all the while the SPO2 remains stable.



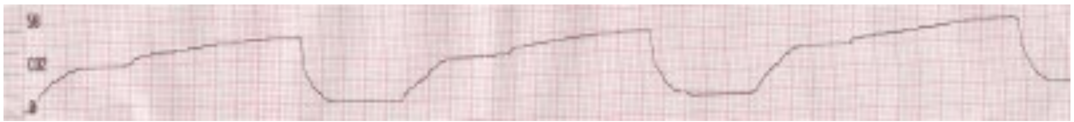
Note: Each bar represents thirty seconds.

Sedated, Intubated Patients

Capnography is also essential in sedated, intubated patients. A small notch in the wave form indicates the patient is beginning to arouse from sedation, starting to breathe on their own, and will need additional medication to prevent them from "bucking" the tube.

6. ETCO2 in Asthma, COPD, and CHF

End-tidal CO2 monitoring on non-intubated patients is an excellent way to assess the severity of Asthma/COPD, and the effectiveness of treatment. Bronchospasm will produce a characteristic “shark fin” wave form, as the patient has to struggle to exhale, creating a sloping “B-C” upstroke. The shape is caused by uneven alveolar emptying.



Multiple studies have confirmed the sloping shape correlates to bronchospasm and obstructive lung disease.

“The analysis of the capnogram’s shape is a quantitative method for evaluating the severity of bronchospasm.” –You, Expiratory capnography in asthma: evaluation of various shape indicies, *European Respiratory Journal*, Feb, 1994

Changing Asthma Values

Asthma values change with severity. With a mild asthma, the CO2 will drop (below 35) as the patient hyperventilates to compensate. As the asthma worsens, the C02 levels will rise to normal. When the asthma becomes severe, and the patient is tiring and has little air movement, the C02 numbers will rise to dangerous levels (above 60).

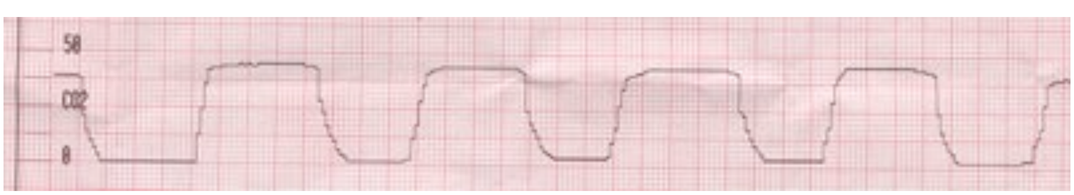
Successful treatment will lessen or eliminate the shark fin shape and return the ETCO2 to normal range (Patient below: capnogram on arrival, after start of 1st combi-vent, after two combivents).

Hypoxic Drive

Capnography will show the hypoxic drive in COPD "retainers." ETCO2 readings will steadily rise, alerting you to cut back on the oxygen before the patient becomes obtunded. Since it has been estimated that only 5% of COPDers have a hypoxic drive, monitoring capnography will also allow you to maintain sufficient oxygen levels in the majority of tachypneic COPDers without worry that they will hypoventilate.

CHF: Cardiac Asthma

It has been suggested that in wheezing patients with CHF (because the alveoli are still, for the most part, emptying equally), the wave form should be upright. This can help assist your clinical judgement when attempting to differentiate between obstructive airway wheezing such as COPD and the "cardiac asthma" of CHF.



(wave form of patient with cardiac asthma)

7. Ventilating Head Injured Patients

Capnography can help paramedics avoid hyperventilation in intubated head injured patients.

“Recent evidence suggests hyperventilation leads to ischemia almost immediately...current models of both ischemic and TBI suggest an immediate period during which the brain is especially vulnerable to secondary insults. This underscores the importance of avoiding hyperventilation in the prehospital environment.” --Capnography as a Guide to Ventilation in the Field, D.P. Davis, Gravenstein, *Capnography: Clinical Perspectives*, Cambridge Press, 2004

Hyperventilation decreases intracranial pressure by decreasing intracranial blood flow. The decreased cerebral blood flow may result in cerebral ischemia.

In a study of 291 intubated head injured patients, 144 had ETCO2 monitoring. Patients with ETCO2 monitoring had lower incidence of inadvertant severe hyperventilation (5.6%) than those without ETCO2 monitoring (13.4%). Patients in both groups with severe hyperventilation had significantly higher mortality (56%) than those without (30%). –Davis, The Use of Quantitative End-Tidal Capnometry to Avoid Inadvertant Severe Hyperventilation in Patients with Head Injury After Paramedic Rapid Sequence Intubation, *Journal of Trauma*, April 2004

“A target value of 35 mmHg is recommended...The propensity of prehospital personnel to use excessively high respiratory rates suggests that the number of breaths per minute should be decreased. On the other hand, the mounting evidence against tidal volumes in excessive of 10cc/kg especially in the absence of peep, would suggest the hypocapnia be addressed by lower volume ventilation.” – --Capnography as a Guide to Ventilation in the Field, D.P. Davis, *Gravenstein, Capnography: Clinical Perspectives*, Cambridge Press, 2004

8. Perfusion Warning Sign

End tidal CO2 monitoring can provide an early warning sign of shock. A patient with a sudden drop in cardiac output will show a drop in ETCO2 numbers that may be regardless of any change in breathing. This has implications for trauma patients, cardiac patients – any patient at risk for shock.

In the study cited below, 5 pigs had hemorrhagic shock induced by bleeding, 5 pigs had septic shock induced by infusion of e-coli, and 6 pigs had cardiogenic shock induced by repeated episodes of v-fib. The pigs' cardiac output was continuously measured as well as their PETCO2.

“Cardiac output and PetCO2 were highly related in diverse experimental models of circulatory shock in which cardiac output was reduced by >40 % of baseline values… measurement of PetC02 is a noninvasive alternative for continuous assessment of cardiac output during low flow circulatory shock states of diverse causes.” -Xiahua, End-tidal carbon dioxide as a noninvasive indicator of cardiac index during circulatory shock, *Critical Care Medicine*, 2000, Vol 28, No 7

“A patient with low cardiac output caused by cardiogenic shock or hypovolemia resulting from hemorrhage won’t carry as much CO2 per minute back to the lungs to be exhaled. This patient’s ETC02 will be reduced. It doesn’t necessarily mean the patient is hyperventilating or that their arterial CO2 level will be reduced. Reduced perfusion to the lungs alone causes this phenomenon. The patient’s lung function may be perfectly normal.” --Baruch Krauss, M.D, *JEMS*, November 2003

9. Other Issues:

DKA - Patients with DKA hyperventilate to lessen their acidosis. The hyperventilation causes their PAC02 to go down.

“End-tidal C02 is linearly related to HC03 and is significantly lower in children with DKA. If confirmed by larger trials, cut-points of 29 torr and 36 torr, in conjunction with clinical assessment, may help discriminate between patients with and without DKA, respectively.” –Fearon, End-tidal carbon dioxide predicts the presence and severity of acidosis in children with diabetes, *Academic Emergency Medicine*, December 2002

Pulmonary Embolus – Pulmonary embolus will cause an increase in the dead space in the lungs decreasing the alveoli available to offload carbon dioxide. The ETCO2 will go down.

Hyperthermia – Metabolism is on overdrive in fever, which may cause ETCO2 to rise. Observing this phenomena can be live-saving in patients with malignant hyperthermia, a rare side effect of RSI (Rapid Sequence Induction).

Trauma - A 2004 study of blunt trauma patients requiring RSI showed that only 5 percent of patients with ETCO2 below 26.25 mm Hg after 20 minutes survived to discharge. The median ETCO2 for survivors was 30.75. - Deakin CD, Sado DM, Coats TJ, Davies G. “Prehospital end-tidal carbon dioxide concentration and outcome in major trauma.” *Journal of Trauma*. 2004;57:65-68.

Field Disaster Triage - It has been suggested that capnography is an excellent triage tool to assess respiratory status in patients in mass casualty chemical incidents, such as those that might be caused by terrorism.

“Capnography…can serve as an effective, rapid assessment and triage tool for critically injured patients and victims of chemical exposure. It provides the ABCs in less than 15 seconds and identifies the common complications of chemical terrorism. EMS systems should consider adding capnography to their triage and patient assessment toolbox and emphasize its use during educational programs and MCI drills.”- Krauss, Heightman, 15 Second Triage Tool, *JEMS*, September 2006

Anxiety- ETCO2 is being used on an ambulatory basis to teach patients with anxiety disorders as well as asthmatics how to better control their breathing. Try (it may not always be possible) to get your anxious patient to focus on the monitor, telling them that as they slow their breathing, their ETCO2 number will rise, their respiratory rate number will fall and they will feel better.

Anaphylaxis- Some patients who suffer anaphylactic reactions to food they have ingested (nuts, seafood, etc.) may experience a second attack after initial treatment because the allergens remain in their stomach. Monitoring ETCO2 may provide early warning to a reoccurrence. The wave form may start to slope before wheezing is noticed.

Accurate Respiratory Rate - Studies have shown that many medical professionals do a poor job of recording a patient's respiratory rate. Capnography not only provides an accurate respiratory rate, it provides an accurate trend or respirations.

10. The Future

Capnography should be the prehospital standard of care for confirmation and continuous monitoring of intubation, as well as for monitoring ventilation in sedated patients. Additionally, it should see increasing use in the monitoring of unstable patients of many etiologies. As more research is done, the role of capnography in prehospital medicine will continue to grow and evolve.

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10 Things Every Paramedic Should Know About Capnography
Peter Canning, EMT-P
December 29, 2007 (Version 6.3)