Capnography 101: A Primer

By Marcos Díaz, D.D.S.

Since its introduction in anesthesia thirty years ago, capnography has demonstrated its usefulness in detecting respiratory events which has helped tremendously in the delivery of safe, routine anesthesia for the benefits of our patients. Since most anesthesia complications occur due to airway complications, airway management is therefore probably the most important aspect of safe anesthesia delivery. Capnography has the ability to detect critical respiratory problems, such as hypoventilation much earlier than pulse oximetry can, and allows in my opinion, the ability to diagnose and troubleshoot airway issues quicker and better than any other monitor available.

The Basics

Capnography, also referred to sometimes as end tidal CO_2 or $ETCO_2$ monitoring, allows one to measure the concentration of carbon dioxide (CO_2) in a mixture of expired gases and it is expressed as the partial pressure of CO_2. Capnometry and capnography are sometimes used synonymously as both analyze and record carbon dioxide, with the latter including a waveform. A "normal" capnograph reading is the result of the integrated function of production of CO_2 in the tissues, its carriage in the blood, exchange in the lungs and its exit through the airway space.

Normally, the $ETCO_2$ is 2 to 5 mm Hg lower than arterial CO_2 pressure. The typical range for end-tidal carbon dioxide during general anesthesia is 30 - 40 mm Hg. The capnograph waveform (Figure No. 1) of the $ETCO_2$ contains the expiratory portion (Phases I, II, II and occasionally IV) and the inspiratory portion (Phase 0). It also contains two angles, the alpha angle (α) between Phase II and III and the beta angle (β) between Phase III and 0 which is also used to aide in the waveform interpretation.

A) Phase 0 is the inspiratory segment.

B) Phase I is the CO_2-free gas that is not involved in the gas exchange (dead space).

C) Phase II is the rapid upswing and includes both alveolar gas and dead space gas.

D) Phase III is a plateau segment that involves alveolar gas and has a small positive slope. The $ETCO_2$ is measured at the end of Phase III.

E) Phase IV (occasionally seen) is a terminal upswing present in patients with reduced chest compliance.

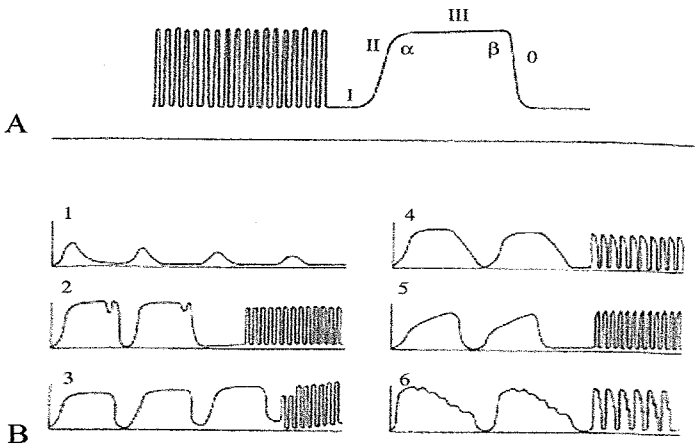
F) Alpha angle (α) is between Phases II and III is related to ventilation:perfusion matching of the lungs.

G) Beta angle (β) is between Phases III and 0 and is usually about 90°; it can be used to reassess rebreathing.

Uses And Applications

Anesthesia Delivery Machine or Apparatus:
Abnormal capnography readings may indicate inadequate anesthetic delivery or faulty equipment. Capnography monitors may help adjust and calibrate fresh gas flows and detect circuit disconnects, leaks and one-way valve malfunctions and other device problems as well **(see Figure 1 – Capnograph B:3)**. Widening of the β angle with elevation of both Phases 0/I and III is a sign of the machine's inspiratory valve failure, while elevation of Phase 0/I and Phase III is a sign of expiratory valve failure or absorbent malfunction.

Figure 1.



A: Normal capnograph.
I: Dead space expiration; **II:** Mixed dead space and alveolar gas expiration; **III:** Alveolar gas expiration and plateau; **0:** Inspiration. Phase IV is a terminal upswing that occurs at the end of Phase III seen in obese and pregnant patients with reduced thoracic compliance.

B: Capnographs that may be seen in practice.
1: Rapid extinguishing uncharacteristic waveform compatible with esophageal intubation; **2:** Regular dips in end-expiratory plateau seen in underventilated lungs or in patients recovering from neuromuscular blockade "Curare Clefts"; **3:** Upward shift in baseline seen with rebreathing of CO2, miscalibration, etc.; **4:** Restrictive pulmonary disease; **5:** Obstructive pulmonary disease; **6:** Cardiogenic oscillations usually seen with sidestream capnographs for spontaneously breathing patients at the end of each exhalation. The cardiac action causes a to-and-fro movement of the interface between exhaled and fresh gas.

Airway
The capnograph was originally developed to aid intubation by confirming the proper positioning of the endotracheal tube since the presence of CO_2 confirms tracheal intubation. If the tube is inadvertently positioned in the esophagus, or at any time gets displaced, the monitor will detect no CO_2 and one can accurately know such event is happening. This still remains one of the most vital applications for anesthesia. Due to swallowed gas, esophageal intubation may result in CO_2 return similar to that of the endotracheal intubation, except that the $ETCO_2$ diminishes to zero within a few breaths **(see Figure 1 – Capnograph B:1)**. Even when used with laryngeal mask airways (LMA), it can help detect dislodgement, malpositioning or hypoventilation.

Breathing - Ventilation
End Tidal CO_2 is a useful indication of how well the patient is breathing. Abnormal readings may help detect distal airway obstructions, such as bronchospasm, and other breathing complications while patients are under sedation or general anesthesia **(see Figure 1 – Capnograph B:4&5)**. Carbon dioxide can be measured either at the breathing circuit (mainstream capnograph) or via aspiration of a gas sample by the capnograph (sidestream capnograph.) Sidetream capnograph may also be used on a nonintubated patient to give a qualitative assessment of respiration **(see Figure 1 – Capnograph B:6)**. Airway obstructions will result in diminishing $ETCO_2$ with alterations of the wave forms. These would return to normal once the obstruction is resolved.

Circulation
Another basic use of capnography is estimating cardiac output. It detects certain circulatory abnormalities. A sudden drop in the $ETCO_2$ concentration may indicate a possible pulmonary embolism, shock or system leaks. Diminishing $ETCO_2$ occurs with low perfusion, auto-PEEP (positive end expiratory pressure) or airway obstruction.

Malignant Hyperthermia
A rapidly increasing $ETCO_2$ value along with other signs is considered one of the first and most important warning signs of malignant hyperthermia, especially if it is unresponsive to hyperventilation.

Homeostasis
Capnography can detect a variety of complications associated with general anesthesia and sedation, including awareness, acid-base balance disorders and sepsis.

Neuromuscular Function
In anesthesia, the capnograph will change as the patient's neuromuscular function is altered **(see Figure 1 – Capnograph B:2)**. If the muscle relaxant wears off during anesthesia, curare clefts will been seen as part of the waveform. Towards the end of the anesthetic, as the patient's neuromuscular function returns to normal, the capnograph demonstrates the adequacy of spontaneous respirations by showing normal waves. In conjunction with other parameters, extubation of the patient is done when the capnograph returns to normal.

Non-Perioperative Situations
There are instances in which practitioners outside of the OR or operatories use capnography to their advantage. In the ER and the ICU, tracheal intubation as a measure airway protection or for ventilation during transport of the critically ill patient, capnography is used. In addition, sleep studies use capnography to assist in assessing the degree of gravity of the apnea as well as the need for asleep ventilation requirements.

Conclusion

Although many of the parameters, applications and uses of capnography used today might not all be applicable to the dental setting, it is important to understand that this monitoring will allow one to become aware of many of the anesthetic problems quicker and with much more accuracy than any other monitor. This in turn will more likely direct the anesthesia provider to a specific action to correct such problem or concern. I have been using capnography now for over ten years, and I know my anesthetic cases are less stressful and safer because of the greater airway monitoring capability that capnography provides. I would encourage consideration by those who administer any level of IV sedation to use capnography. Although capnography is not yet a standard of care in the sedated patient in the dental field, in my opinion, it should soon become the standard of care because of the wealth of information it provides.

Florida Dental Society of Anesthesiology
P.O. Box 444,
Orange Park, FL 32073
904-703-4083

www.fdsahome.org