Capnography Monitoring in the LifeWindow 6000V

1. Introduction to Capnography

Capnometry is defined as the measurement and numerical display of the CO2 concentration, in the expired air, during the respiratory cycle (inspiration and expiration). It’s most commonly used to monitor end-tidal CO2 and has become standard care for intraoperative monitoring of ventilation efficiency in human anesthesia. End-tidal CO2 (ET CO2) is the partial pressure of CO2 at the end of exhalation. Normally end-tidal CO2 reflects the partial pressure of CO2 in the alveoli. EtCO2 is not the same as PaCO2 (Partial pressure of CO2 in the arterial blood). Even though that the numbers should be close, a difference in the numbers is expected and it can also indicate an adverse clinical condition. The normal difference of PaCO2 and EtCO2 in a healthy patient is approximately 2–6mmHg.

The measurement of end-tidal CO2 is useful for determining optimal minute ventilation, hypoventilation, airway disconnection or airway obstruction. This technique is finding increased use in veterinary anesthesia as it is a relatively inexpensive, continuous method to document ventilation adequacy and limits the need for invasive procedures such as arterial blood gas analysis. Capnometry can be performed using either a capnometer or a capnograph. A capnometer measures and displays the readings without a graphic presentation. A Capnograph is capable of displaying the numerical values as well as the wave form, also referred as capnogram.
There are four distinct phases of the capnogram (see figure of capnogram).

1. Phase I is the inspiratory baseline. This phase represents fresh gas flow, anesthetic plus oxygen, past the CO2 sensor during inspiration. The baseline should have a value of zero otherwise the patient is rebreathing CO2.
2. Phase II is the expiratory upstroke. This represents the arrival of CO2 at the sensor just as exhalation begins. It is usually very steep.
3. Phase III is the expiratory plateau, which represents exhaled CO2. The peak of this exhaled CO2 is called the end-tidal CO2.
4. Phase IV is the inspiratory downstroke. This is the beginning of the inhalation and the CO2 graphic curve falls steeply to zero.
5. End-tidal CO2 concentrations between 35 and 45 mmHg are considered normal in anesthetized animals.
6. There is only one normal shape of capnogram. Clinically any deviations from this shape should be investigated.

The Normal Capnogram

- A-B: exhalation of CO2 free gas contained in dead space at the beginning of exhalation
- B-C: respiratory upstroke, representing the emptying of connecting airways & the beginning of emptying of alveoli
- C-D: Expiratory (or alveolar) plateau, representing of emptying of alveoli - due to uneven emptying of alveoli, the slope continues to rise gradually during the expiratory pause
- D: End-tidal CO2 level - the best approximation of alveolar CO2 level
- D-E: Inspiratory downstroke, as the patient begins to inhale fresh gas
- E-A: Inspiratory pause, where CO2 remains at 0.
2. Clinical implication of the Capnogram

In the anesthetized patient, normal end-tidal CO2 concentrations together with normal capnogram appearance indicate normal function of patient’s metabolism, circulation, ventilation, and of the anesthetic machine.

This is because CO2 is produced by tissue metabolism, carried to the lungs by the blood, and subsequently exhaled by alveolar ventilation.

Increases in end-tidal CO2 concentrations may be due to impaired alveolar ventilation (anesthetic induced respiratory depression), increased metabolism (malignant hyperthermia or sepsis), or the addition of CO2 to the circulatory system as a result of rebreathing CO2.

Rebreathing CO2 can be due to soda lime exhaustion, incompetent expiratory valve on the anesthetic machine allowing exhaled CO2 to be re-inhaled (even with normal function of soda lime), or intravenous bicarbonate injection.

Decreased or abolished ET CO2 concentrations may be due to hyperventilation, low cardiac output (low blood volume deliver to the lungs), respiratory arrest (no alveolar ventilation), or cardiac arrest (no circulation).

Capnogram monitoring in anesthetized patients also provides vital information regarding the patient's airway patency. A depressed or absent capnogram may be due to a dislodged endotracheal tube, misplaced endotracheal tube (i.e., esophageal intubation), obstructed endotracheal tube or airway, a leak around endotracheal tube cuff or, disconnection of the endotracheal tube from the anesthetic machine. Qualitative analysis of capnogram morphology provides detecting and diagnosing patient and anesthesia machine abnormalities.

The capnogram below shows a rebreathing of CO2 due to a possibility of incompetent expiratory valve or exhaustion of soda lime.
This capnogram shows a kinked endotracheal tube. Note the prolonged expiratory upstroke (A) and a slanted expiratory plateau (B) due to the slower gas flow rate during these two phases.

3. Mainstream and Sidestream Capnography

**Mainstream sampling** - CO2 analysis chamber is in line between the patient airway and the ventilator circuit.

**Sidestream sampling** – CO2 analysis chamber is within the device. Patient’s expired gas is aspirated from the airway and drawn to the device through a sampling line.
3.1 Sidestream capnography:

In sidestream capnography, the CO2 sensor is located in the main unit itself (away from the airway) and a tiny pump aspirates gas samples from the animal's airway through a 10 feet long capillary tube into the main unit. The sampling tube is connected to a T-piece inserted at the endotracheal tube. The gas that is withdrawn from the patients often contains anesthetic gases and so the exhausted gas from the capnograph should be routed to a gas scavenger or returned to the patient breathing system. The optimal gas flow is considered to be 90-175 ml/min, which ensures that the capnographs are reliable in both low and high respiration rate situations. In the LifeWindow CO2 menu, the flow rate can be adjusted to 90, 150 or 175 ml/min. The sidestream capnographs have a unique advantage: they allow monitoring of non-intubated subjects, as sampling of the expiratory gases can be obtained from the nasal cavity using nasal adaptors.

Our Sidestream system uses a revolutionary sampling system technology, called Sure CO2. The moisture is totally removed from the gas sample with occlusions being practically nonexistent due to an in line filter. The Sure CO2 sampling system is a low cost component designed to last 100 hours of operation and then it should be replaced. The use of this sampling system eliminates the possibility of occlusions to happen inside of the machine.

**SureCO2 Sampling System**

- Improved accuracy and clearer waveforms
- Lasts longer in high humidity applications
- Compatible with all DIGICARE CO2 Systems

The Sure CO2 Sidestream Sampling System
3.2 Mainstream capnography.

In the Mainstream capnograph, an airway adapter containing the CO2 sensor is inserted between the breathing circuit and the endotracheal tube. The IR rays traverse the respiratory gases to an IR detector within the airway adapter, eliminating the need for gas sampling and scavenging. Therefore the CO2 analysis is performed within the airway. To prevent condensation of water vapor, which can cause falsely high CO2 readings, all Mainstream sensors are heated above body temperature to about 39 degrees. Mainstream Capnography can be used in low weight animals for better accuracy and frequency response. Advantages include the ability to monitor CO2 in very small tidal volumes without concern for gas containing anesthetic agents in the OR or occlusion problems.

Mainstream Sensor with Multiuse Airway Adapter  Low Dead Space Airway Adapter  Disposable Airway Adapter

3.3 DualCap

The LifeWindow™ 6000V also offers the option of both Sidestream and Mainstream Capnography in the same unit. The advantage of this option is that the clinician has the best of both worlds. Sidestream can be selected in cases where it is more applicable and Mainstream can be used in those applications where it’s technology is deemed necessary. The DualCap Capnography option in the LifeWindow™ 6000V is totally calibration free.

Selection of either Sidestream or Mainstream in the LifeWindow CO2 Menu
4. Top Reasons to use Capnography

4.1 Confirm and verify tracheal intubation placement.
4.2 Evaluate ventilator settings and circuit integrity.
   • Circuit leaks
   • Disconnect
   • Faulty exhalation valve
4.3 Assess cardiopulmonary status and changes in pulmonary blood flow.
   • Pulmonary embolism
   • Decreased cardiac output
   • Cardiac arrest
4.4 Assess airway management and changes in airway resistance.
   • Occlusion or kinking of ET tube
4.5 Monitor ventilatory status of the respiratory impaired patient.
   • Identify hypo or hyperventilation
   • Airway management
4.6 Monitor effectiveness of ventilator weaning process. Response to changes in ventilator settings, i.e., respiratory rate, flow and/or volume
4.7 Monitor effectiveness of Noninvasive Positive Pressure Ventilation (NIPPV) commonly delivered via a BiPAP ventilator.
   • Response to changes in flow and pressure settings
4.8 Evaluation and interpretation of hemodynamic waveforms.
   • Use end expiration to determine timing of arterial pressure readings
4.9 Assess response and effectiveness of cardiopulmonary treatments.
   • Bronchodilator and/or surfactant

Reduce the number and/or frequency of arterial blood gas drawing.

5. Capnography operation in the LifeWindow 6000V

Please refer to the section CO2 Monitoring in the LifeWindow 6000V Operator’s Manual for detailed operation of the Capnography function.