Capnography in the Veterinary Technician Toolbox

Katie Pinner BS, LVT
Bush Advanced Veterinary Imaging
Richmond, VA
What are Respiration and Ventilation?

• Respiration includes all those chemical and physical processes by which an organism exchange gases with its environment.

• Ventilation The act of bringing air in and expelling air from the lungs.
Respiratory System

- Nares or Nostrils
- Nasal cavity
- Pharynx
- Trachea
- Bronchi
- Bronchioles
- Alveoli
**Important Terms**

- **Tidal volume**: is the lung volume representing the normal volume of air displaced between normal inhalation and exhalation when extra effort is not applied (10 ml/kg).
- **Total lung capacity**: the volume in the lungs at maximal inflation.
- **Residual volume**: the volume of air remaining in the lungs after a maximal exhalation.
- **Expiratory reserve volume**: the maximal volume of air that can be exhaled from the end-expiratory position.
- **Inspiratory reserve volume**: the maximal volume that can be inhaled from the end-inspiratory level.
- **Functional residual capacity**: the volume in the lungs at the end-expiratory position.
- **Vital capacity**: the volume of air breathed out after the deepest inhalation.
- **Inspiratory capacity**: the sum of inspiratory reserve volume and tidal volume.
Graphic representation

- Inspiratory reserve volume
- Tidal volume
- Expiratory reserve volume
- Residual volume
- Inspiratory capacity
- Vital capacity
- Functional residual capacity
- Total lung capacity
Respiratory Physiology

- Carbon dioxide is produced in the tissues by metabolic processes.
- This CO2 diffuses into venous blood and is transported to the lungs to be removed from the body by ventilation.
- Ventilation replaces CO2 rich gas from the alveoli with CO2 free gas from the or breathing circuit.
- The partial pressure of CO2 in the alveoli (PaCOs) reflects a balance between the CO2 delivered to the alveoli by the cardiovascular system and its removal by ventilation.
Gas Exchange

Gas Exchange in the Lungs

Air sac of the lungs (alveolus)

Air

Blood from the heart

Oxygen

Carbon dioxide

Blood returning to the heart

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Oximetry vs Ventilation

• Oximetry (SPO2) is a measurement of oxygen concentration in the bloodstream
• Ventilation is the process of inhaling and exhaling
• Capnography helps us assess the quality of the patient’s ventilation
Pulse Oximetry

- Pulse oximetry is a measurement of the percentage of hemoglobin saturated with oxygen (SpO2). SpO2 can give an indication of the partial pressure of oxygen in arterial blood (PaO2), although under anesthesia a normal SpO2 may not necessarily indicate adequate ventilation given the fact that the patient is on 100% oxygen.

- An SpO2 > 95% only indicates a PaO2 > 80 mmHg.

- Patients on 100% oxygen should have a PaO2 of 400-500.
Oxygen-hemoglobin dissociation curve
What is Capnography?

- Capnography is the monitoring of the concentration or partial pressure of carbon dioxide (CO2) in expired gases.
- The waveform that is generated from its measurement is called a capnogram.
Why do we measure ETCO2?

• A good indicator of anesthetic depth of patients
• Gives us a good estimate of PaCO2 in circulating arterial blood
• Helps us assess cardiac output, systemic metabolism, and pulmonary perfusion in patients
• Often a first indicator of an impending anesthetic emergency
• Insure proper tube placement
• Alerts us of apnea
What is a normal ETCO2?

- **35-45 mmHG** in the normal patient
- **30-35 mmHG** in the patient with possible increased intracranial pressures
- **ETCO2** below 30 can reduce cerebral blood flow
What is PaCO2?

- PaCO2 is the partial pressure of carbon dioxide in circulating arterial blood
- Usually expressed in mmHg
How do ETCO2 and PaCO2 compare?

- ETCO2 is the level of expired CO2
- PaCO2 is the partial pressure of CO2 in arterial blood
- ETCO2 typically underestimates PaO2 by about 2-5mmHg
- If my patient’s ETCO2 is 55, I can estimate that my patient’s PaCO2 is 60
Types of CO2 Monitors

- Mainstream monitoring
- Side stream monitoring
Main-stream CO2 Monitoring

• In the mainstream monitor a sample cell or airway adapter is inserted directly in the airway between the breathing circuit and the endotracheal tube. A lightweight infrared sensor is then attached to the airway adapter. The sensor emits infrared light through the adapter windows to a photodetector typically located on the other side of the airway adapter. The light which reaches the photodetector is used to measure ETCO₂. Mainstream technology eliminates the need for gas sampling and scavenging as the measurement is made directly in the airway. This sampling technique results in crisper waveforms which reflect real-time ETCO₂ in the patient airway.
Side-stream CO2 Monitoring

• In side-stream capnography, the CO₂ sensor is located in the main unit itself (away from the airway) and a tiny pump aspirates gas samples from the patient's airway through a 6 foot long capillary tube into the main unit. The sampling tube is connected to a T-piece inserted at the endotracheal tube or anesthesia mask connector.
Hypercapnia

- Patients with a ETCO2 of greater than 45
- This patient has inadequate ventilation
- Causes
  - Endotracheal tube too far in
  - Obesity
  - Respiratory depression from anesthetic drugs
  - Anesthetic plane is too deep
  - Increased metabolism from sepsis, hyperthermia, or respiratory acidosis
  - Impaired ventilation from alveolar collapse or collapsed lung
  - Increased intracranial pressure
Hypercapnia caused by equipment

- Soda lyme is exhausted limiting CO2 removal
- Expiratory flutter valve is stuck in the open position
- Oxygen flow rate is too low
- There is too much dead space in the system allowing the rebreathing of expired CO2
Treating Hypercapnia

• Increasing the respiratory rate or volume of the patient will decrease ETCO2

• Accomplished by manual or mechanical intermittent positive pressure ventilation

• If ETCO2 remains high after initiating IPPV, look for other causes such as equipment issues
Hypocapnia

- ETCO2 of less than 30-35mmHG
- This patient is experiencing hypoventilation

**Causes**

- Low cardiac output
- Hypothermia
- A rapid decrease in ETCO2 is often the first indication of cardiac arrest
Treating Hypocapnia

• Make sure to investigate and treat the cause of decreased cardiac output. This includes a reduction in inhaled anesthetic gases and the use of injectable drugs if necessary

• If the patient is cold do whatever is possible to warm the patient (heat support and wrapping extremities)
The Normal Capnogrpah

Figure 2. Four distinct phases of capnogram
Phases of the Capnogram

- Phase I: Inspiratory baseline, which 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.
Phases of the Capnogram

- Phase II: expiratory upstroke, which represents the arrival of CO2 at the sensor just as exhalation begins.
Phases of the Capnogram

- Phase III: expiratory plateau, which represents exhaled CO2. The peak of this exhaled CO2 is called the end tidal CO2.
Phases of the Capnogram

- Phase 0: inspiratory down stroke, which is the beginning of inhalation and the CO2 graphic curve falls steeply to zero.
Phases of the Capnogram

- **A-B**: Exhalation of CO2 free gas contained in dead space at the beginning of exhalation. (Phase I)

*Figure 2. Four distinct phases of capnogram*
Phases of the Capnogram

- B-C: Respiratory upstroke, representing the emptying of connecting airways and the beginning of emptying of alveoli. (Phase II)
Phases of the Capnogram

- C-D: Expiratory plateau, representing of emptying of alveoli- due to uneven emptying of alveoli, the slope continues to rise gradually during the expiratory pause. (Phase III)
Phases of the Capnogram

- D: End tidal CO2 level - the best approximation of alveoli CO2 level

*Figure 2. Four distinct phases of capnogram*
Phases of the Capnogram

- D-E: Inspiratory down stroke, as the patient begins to inhale fresh gas. (Phase 0)
Phases of the Capnogram

- E-A: Inspiratory pause, where CO2 remains at 0

*Figure 2. Four distinct phases of capnogram*
Troubleshooting the Capnograph

- Hyperventilation
- Short waveform indicating that patient’s ETCO2 is too low
Troubleshooting the Capnograph

- Hypoventilation
- The wave form is tall indicating a ETCO2 of \(~ 50\text{mmHg}\)
Troubleshooting the Capnograph

- Patient is too light
Troubleshooting the Capnograph

- Rebreathing of CO2
- Baseline is not returning to 0
- Check flutter valves
Troubleshooting the Capnograph

- Cardiogenic Oscillations
- This artifact is due to a strong heartbeat
Troubleshooting the Capnograph

- Obstructive waveform
- Mucous plug, kinked tube, etc.
Troubleshooting the Capnogrpah

• Rounded edges of the capnogram indicate a leaky endotracheal tube
• Check cuff inflation/cuff integrity
Capnography in Emergencies

• A sharp decline in ETCO2 is often the first indication of an impending cardiac arrest

• Monitoring of ETCO2 is imperative in updated CPR protocols
ETCO2 in CPR

- ETCO2 is considered a baseline monitoring tool in the RECOVER initiative protocols for CPR
- ETCO2 of greater than 15mmHg indicate effective chest compressions
Questions?