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CAPNOGRAPHY– GETTING STARTED

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Capnometry – Getting started

Capnometry and Capnography

The gold standard method of assessing the adequacy of ventilation is measuring the partial pressure of carbon dioxide (PaCO2) in the arterial blood by blood gas analysis. However, this is an invasive, technical and expensive method compared to capnography which measures the amount of end-tidal (exhaled) carbon dioxide during ventilation (ETCO2). End-tidal carbon dioxide gives a reading that is close to that obtained through blood gas analysis and is usually maintained between 35-45mmHg.

Capnometry provides a continuous measurement of ETCO2 and gives a numerical value; capnography provides us with a waveform of the respiratory cycle.

The ETCO2 value gives us information:

- Adequacy of patient ventilation
- Systemic metabolism
- Cardiac output
- Pulmonary perfusion
- Equipment failure

A change in ETCO2 values suggests an alteration in one or more of these parameters.
Capnography is far superior than pulse oximetry at identifying apnoea and airway issues promptly as any changes will be seen on the capnograph almost instantly.

Indications for Use

Indications for capnography in veterinary patients are numerous, including:

- Monitoring of ventilation in spontaneously breathing anaesthetised patients
- Monitoring of patients undergoing mechanical ventilation
- Monitoring of patients undergoing CPR
- Monitoring of ventilation in intubated comatose patients
- Confirmation of endotracheal tube placement
- Confirmation of naso-oesophageal feeding tube placement

Veterinary Capnography Equipment

Capnometers are available as either small hand held monitors, or large multiparameter monitors. Multiparameter monitors display a numeric value as well as a waveform and

respiratory rate, whilst most hand-held monitors only display a numeric value. A sensor or sampling tube (dependent upon monitor type), is attached to the end of the endotracheal tube between the breathing circuit, and the endotracheal tube. A sensor may also be attached to a tightly fitting face mask, though results are less accurate when compared with an intubated patient.

There are two different methods by which capnography equipment can measure ETCO2. These are determined by the type of monitor used:

Sidestream Monitors

A sampling tube from the monitor is attached to the endotracheal tube.

A sample of expired gas is collected close to the exit of the endotracheal tube, and sent up the small-bore sampling tube to the capnometer, where the ETCO2 level is measured. This avoids dead space and drag produced by a mainstream analyser but results in a time delay of a few seconds for the reading to appear on the monitor screen.

A numeric value and a waveform are displayed on the monitor. The waveform is a graphic display of the changes in ETCO2 over time, and provides important information about patient ventilation, respiratory patterns, and technical problems (e.g. ET tube occlusion, leak in breathing circuit).

Some sidestream monitors require increased oxygen flow rates, as the capnometer draws off a portion of the gas flow to take its measurement. The small-bore size of the sampling tube used in sidestream type monitors can become occluded with respiratory secretions or becoming kinked, causing incorrect readings. Moisture caused by condensation from the endotracheal tube can also interfere with readings.

Mainstream Monitors

Mainstream capnometers; the analyser connects between the endotracheal tube and the breathing circuit. It gives an immediate reading visible on the monitor making it a very rapid method of measuring ETCO2 and can be useful for small patients that have rapid respiratory rates. The disadvantage of mainstream capnography is the analyser causes increased dead space and can be increase drag on the breathing system and ET tube.

Interpretation of capnography

Capnometry reports the maximum and minimum carbon dioxide levels associated with expiration and inspiration respectively in a numerical format. ETCO2 is the partial pressure of CO2 in the expired air obtained at the end of respiration. The production of CO2 is determined by:

- The rate CO2 produced by the tissues
- The rate of exchange of CO2 from the blood to the alveoli
- The rate CO2 is removed by alveolar ventilation

This means that ETCO2 can provide us information on metabolism, ventilation and circulation

A more complete picture of carbon dioxide transfer can be obtained from a capnogram, like an ECG tracing. A capnogram provides a continuous waveform that reflects the changes in airway carbon dioxide levels throughout inspiration and expiration.

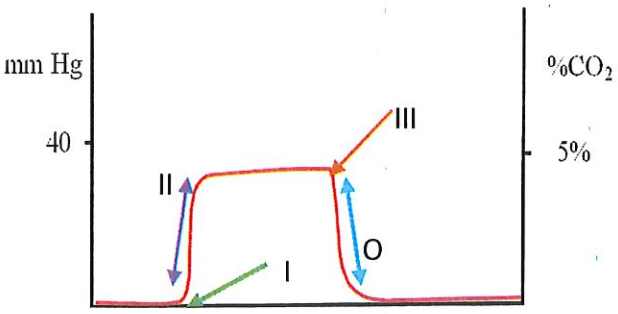
Numerical Reading

The normal ETCO2 is **35-45mmHg** (28 – 35mmHg in cats) and is approximately 5mmHg below PaCO2 (arterial partial pressure of CO2) in normal dogs.

Hypercapnia	Potential causes
>45mmHg begin to ask why **>50mmHg take some action – probably caused by anaesthesia** **>60mmHg patient will be experiencing acidosis**	• Increased depth of anaesthesia • Hypoventilation (depth, weight, positioning, pregnancy etc) • Endobronchial intubation • ETT against tracheal wall • Rebreathing • Increased cardiac output (tachycardia) • Increased CO2 production (increased metabolism) – Shivering hyperthermia, seizuring
ETCO2 of 45- 60mmHg can cause stimulation of the nervous system; increased heart rate, slight increase in blood pressure and inadequate ventilation. Ventilation assistance should be initiated via manual or mechanical ventilation.	
ETCO2 >60mmHg can cause cardiac depression, vasodilation, reduced BP, metabolic acidosis and CNS depression.	

Hypocapnia	Potential causes
<35mmHg	• Hyperventilation – too light/pain • Decreased metabolism – hypothermia, hypothyroidism • Decreased cardia output • Hypotension • Cardiac arrest • Pulmonary embolism • Drug induced (alpha2) • Disconnection of the breathing system, sampling line • Leaky ETT • Oesophageal intubation
Sudden fall in ETCO2	A capnography that shows a sudden unexplained decrease in ETCO2 is an indicator that the patient may be suffering a cardia arrest

The Waveform



I: Inspiratory baseline

II: Alveolar gas mixes with dead space

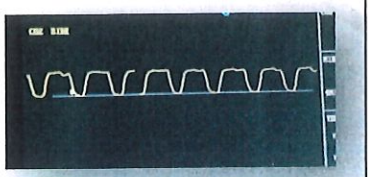
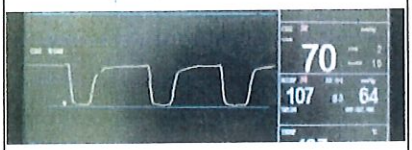
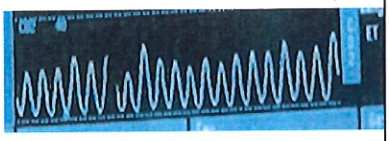
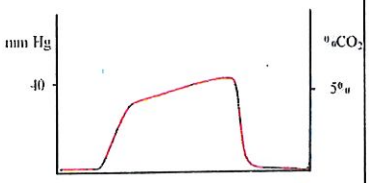
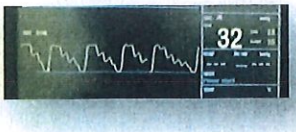
III: Main component of expiration

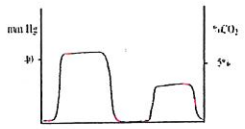
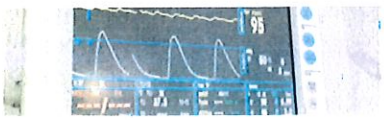
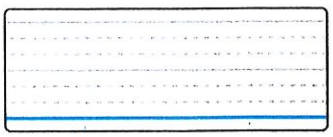
O: Inspiratory downstroke - rapid fall in CO2 levels as new breath take

The waveform displayed has a unique shape that provides us with information about the patient's respiration and ventilation status:

- Absence of a waveform (see Zero ETCO2 above)
- If the baseline is above zero, it usually indicates rebreathing of exhaled gases from expired soda lime, or inadequate gas flow rate.
- A gradual rise in ETCO2 without a plateau may indicate a partial or complete airway obstruction.
- A sharp peaked wave may indicate a leak in the breathing circuit, or tachypnoea.
- A sudden drop in the waveform (to low or zero) may indicate a large leak in the circuit, disconnection of the breathing circuit, an airway obstruction, extubation or cardiac or respiratory arrest.

Capnography quick reference guide

Capnogram Trace	Appearance	Common causes
Normal		- Normal ventilation pattern - 35-45mmHg - 28-35mmHg (cats)
Hypoventilation		- Hypoventilation (? positioning) - Low tidal volume - Excessive anaesthetic depth - >50mmHg indicates inadequate ventilation
Hyperventilation		- Hyperventilation - Tachypnoea - Painful - Light plane of anaesthesia - <30mmHg
Skewed output		- Reduced ability to expire - Partially obstructed ET tube (mucus plug) - Kinked ET tube - Upper airway obstruction - Bronchoconstriction
Increased inspiratory CO2		- Excessive dead space - Insufficient fresh gas flow (especially T pice and Bain) - Exhausted soda lime - Malfunctioning inspiratory valve in a circle system - Insufficient time of exhaled breath in soda lime (large dog with small canister)
Cardiac oscillations		- Normal cardiogenic oscillations - Often seen with a low respiratory rate, deep chested dogs with slower respiratory rates

Steep expiratory upstroke		- Difficulty exhaling - Obstructed ETT - Bronchospasm (anaphylaxis, asthma) - Expiratory valve malfunction - APL valve closed
Dips in alveolar plateau		- Pressure on thorax of anaesthetised patient – pushing air out of the lungs - Spontaneous ventilation against a ventilator (too light (waking up), pain, hypoxaemia, hyperthermia)
Reduced cardiac output		- Reduced cardiac ouput, patient may be pale, cyanotic and/or hypotensive - ETT too small or cuff not inflated properly (CO2 produced, but not reaching the detector) - Hypothermia (reduction in CO2 production)
Reduced cardiac output/ cardiac collapse		- Check patient - Check there is no leak in the ETT cuff - Be prepared for CPR
Sloping inspiratory slope	 	- Inspiratory resistance - Pressure on the thorax - Abdominal contents compressing thoracic cavity - Malfunctioning inspiratory valve - Fresh gas flow too low - Leak around the ETT cuff
Flat line		- Oesophageal intubation - Apnoea - Respiratory arrest - Cardiac arrest - Sensor disconnection from patient - Machine calibration

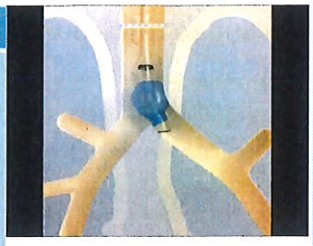
Capnography use during CPR

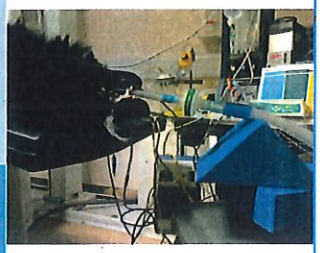
Capnography is considered the best tool for assessing the effectiveness of cardio pulmonary resuscitation due to its responsiveness and sensitivity to the return of spontaneous circulation (ROSC). ETC02 will be between 0 and 10mmHg in an arrested patient. CO2 will almost immediately increase upon return of spontaneous circulation. ROSC (ETCO2 increases to 18-24mmHg). If ETC02 is not moving above 10mmHg despite optimal CPR technique a different method of CPR should be considered.

The decision to terminate CPR should be based on the original prognosis of the disease process and the owners' wishes. Outcome is likely to be poor if you have been unable to get ETC02 >10mmHg or efforts have gone on for longer than 20 min. It was noted that human patients who could not be resuscitated had significantly lower ETC02 levels than those who were successfully resuscitated.

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Normal ETCO2: 35-45mmHg dogs/ 28-35mmHg cats	
Hypercapnia >45mmHg	• Increased depth of anaesthesia • Hypoventilation (depth, weight, positioning, pregnancy etc) • Endobronchial intubation • ETT against tracheal wall • Rebreathing • Increased cardiac output (tachycardia) • Increased CO2 production (increased metabolism) – Shivering hyperthermia, seizuring





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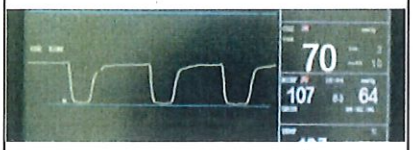
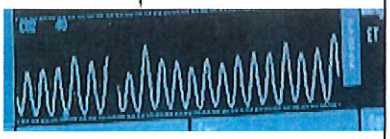
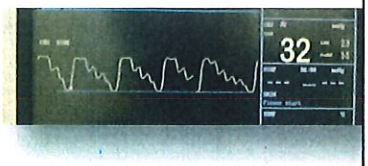
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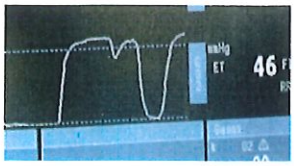
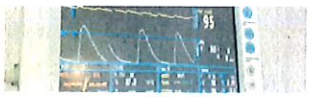
Capnography waveform guide

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Capnography waveform guide

Dips in alveolar plateau		- Pressure on thorax of anaesthetised patient – pushing air out of the lungs - Spontaneous ventilation against a ventilator (too light (waking up), pain, hypoxaemia, hyperthermia)
Leak or reduced cardiac output		- Reduced cardiac output, patient may be pale, cyanotic and/or hypotensive - Check ETT – may be a leaky or underinflated cuff, tube too small (CO2 produced but not reaching the detector) - Damaged or kinked sample line - Hypothermia (reduction in CO2 production)
Reduced cardiac output/cardiac collapse		- Check patient - Be prepared for CPR
Sloping inspiratory waveform	 	- Inspiratory resistance - Leakage at level of ETT or breathing circuit - Pressure on the thorax - Abdominal contents compressing thoracic cavity - Malfunctioning inspiratory valve - FGF too low
Flat line		- Oesophageal intubation - Apnoea - Respiratory arrest - Cardiac arrest - Sensor disconnection from patient - Machine calibration

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