CAPNOGRAPHY 101

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Capnography is an extremely useful, non-invasive tool used for estimating $PaCO_2$ in intubated patients. As an anesthetist, it is important to be able to recognize common capnograms and initiate treatment with the attending clinician. Capnography can guide ventilation strategies in anesthetized patients especially when arterial blood gas sampling may not be available.

INTRODUCTION

Capnography provides a non-invasive method for measuring end-tidal carbon dioxide ($ETCO_2$). There are a few terms used to describe the various aspects of capnography. Capnometry is the numerical display of end-tidal CO_2 ($ETCO_2$). The capnogram is the graphical display of $ETCO_2$ and capnography or the capnograph is the technique or instrument used to measure $ETCO_2$. In many cases, people use the term capnography as an all-inclusive term for all of the above.

Capnography is a good tool to help assess ventilation in many species. Capnography is an indirect measurement of arterial CO_2. $ETCO_2$ correlates well with $PaCO_2$ (direct arterial measurement of CO_2). In mammals, the measurement of $ETCO_2$ can read about 2 to 5mmHg lower than actual $PaCO_2$. In birds the opposite is true. The anatomy and physiology of the avian lung is quite different than that of mammals. Bird lungs create an efficient cross-current exchange system which produces a higher concentration of CO_2 in expired gas compared to the actual arteries. This means that the $ETCO_2$ reading on the capnogram will be higher than the actual $PaCO_2$. In birds, it is estimated that the $ETCO_2$ reading will be about 5mmHg higher than the $PaCO_2$ reading.

In summary, $ETCO_2$ in the avian patient overestimates actual $PaCO_2$ by about 5mmHg which is opposite of what is observed in mammals. Capnography has many uses all species and can actually yield a lot of information if you understand and know how to read the numbers and graph. The website www.capnography.com is an excellent source for learning about capnography. This site is human based, but translates well to veterinary medicine.

The usefulness of capnography in reptiles may be limited. Unfortunately, there is evidence that suggests capnography in reptilian species may not demonstrate the same relationship as seen with birds and mammals. Does this mean capnography doesn't have a place in reptile anesthesia? No it doesn't. Capnography can still be extremely useful as it can demonstrate leaks in the endotracheal tube or circuit, airway obstruction, ventilator malfunction, potential V/Q mismatch, etc. Trends can be monitored and assessed over time. One phenomenon seen during reptile anesthesia is cardiac shunting. Reptiles can intermittently shunt blood away from the lungs. This can be observed during prolonged periods of apnea and during diving or a diving reflex/response. This response can be seen numerically on the capnograph. When this occurs, the $ETCO_2$ will start out in the "normal" range and then drop to numbers somewhere between 0 and 10 mmHg. In other species this would be a serious emergency. When this occurs, the anesthetist should check the overall vitals of the patient, ensure the endotracheal tube is still properly connected and that there are no major malfunctions with the equipment. If everything is in working order, this drop in $ETCO_2$ is most likely due to cardiac shunting.

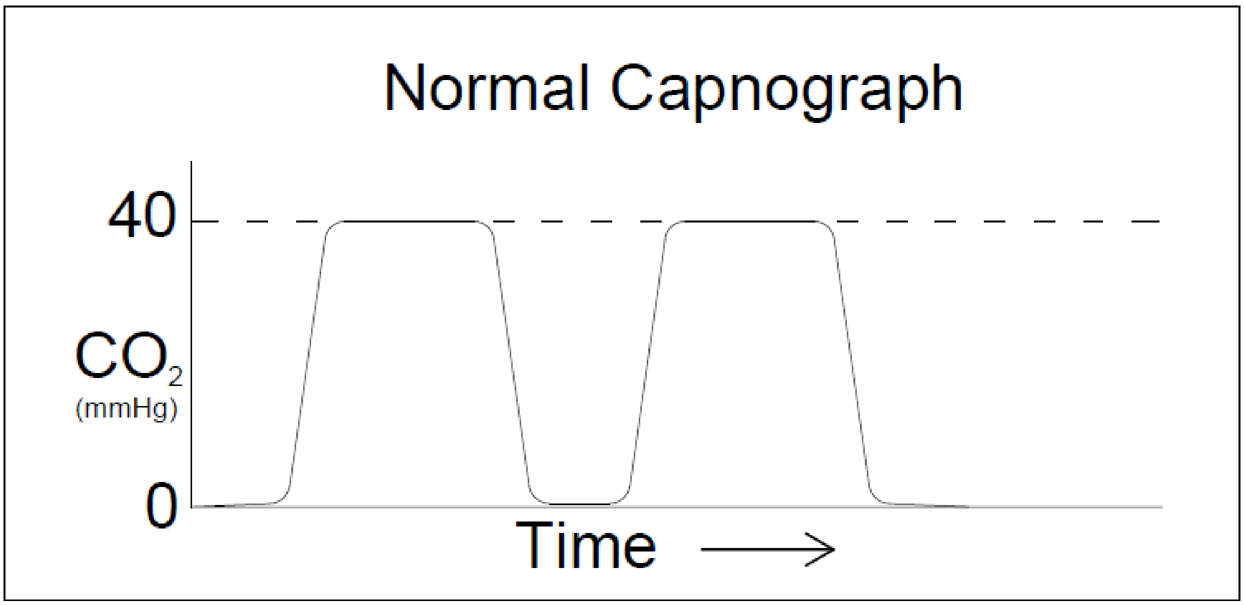
Patients are considered hypercapnic (too much CO_2) when $ETCO_2$ is greater than 45 mmHg. Increased values indicate inadequate ventilation, rebreathing of CO_2, or hypoventilation. Prolonged values reading above 60 mmHg can lead to hypoxemia. Hypoxemia predisposes patients to arrhythmias, myocardial depression, respiratory acidosis, and is rare cases, heart failure. In these cases, patients should be manually or mechanically ventilated to decrease $ETCO_2$. Hypoventilation can also indicate too deep of an anesthetic plane. Vitals and depth should be assessed and anesthetic depth adjusted as needed.

$ETCO_2$ values that are less than 35 mmHg can indicate hyperventilation. These patients are considered hypocapnic (not enough CO_2). Ventilation may also be required to help regulate erratic breathing patterns such as tachypnea. Hyperventilation can also indicate a light anesthetic plane or pain. This should obviously be assessed and dealt with accordingly. Hypocapnia can also indicate other issues such as V/Q mismatch, decreased cardiac output, esophageal intubation, extubation of the patient, kink or mucus plug in the tube, apnea, and hypothermia.

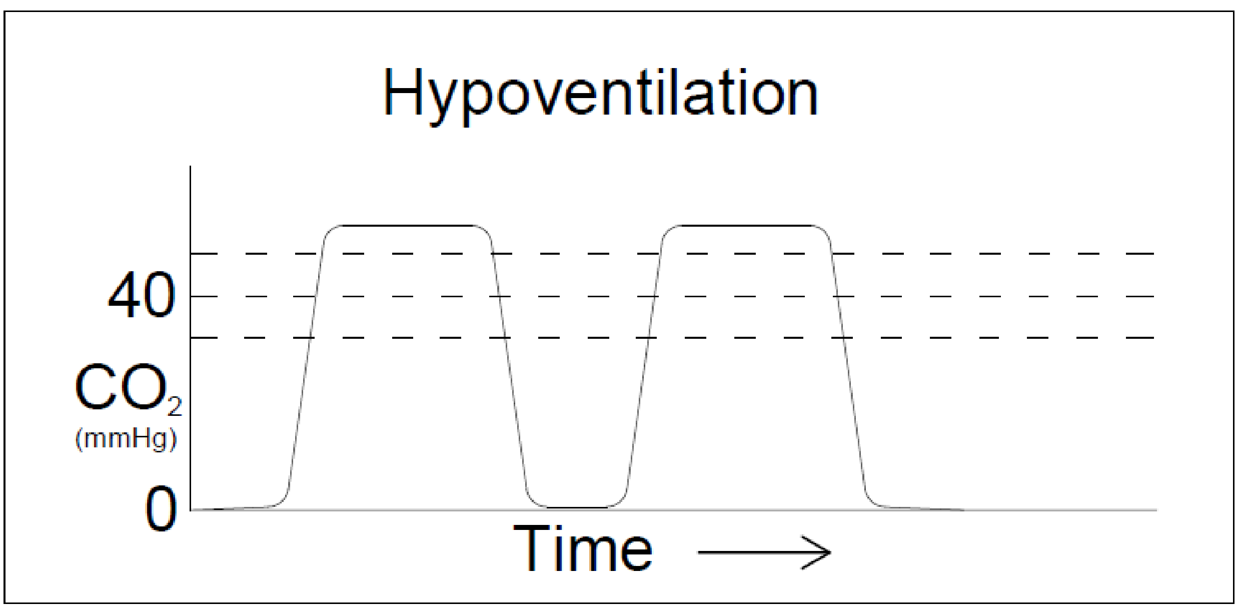
There are two types of caponographs on the market; sidestream and mainstream. Sidestream capnography requires a sample line to be connected directly to the airway. This method offers continuous sampling by pumping gases through tubing into the measurement chamber. This is very effective but does have a higher chance of becoming kinked or clogged with blood, mucus, or moisture.

Mainstream capnography analyzes gas directly at the endotracheal tube where the device is attached. The mainstream device can increase dead space so it is important to use a pediatric piece when working with small patients. Mainstream monitors are less likely to become clogged and are often cheaper to maintain. The downside is that they are larger than side stream monitors and can pull or kink the endotracheal tube.

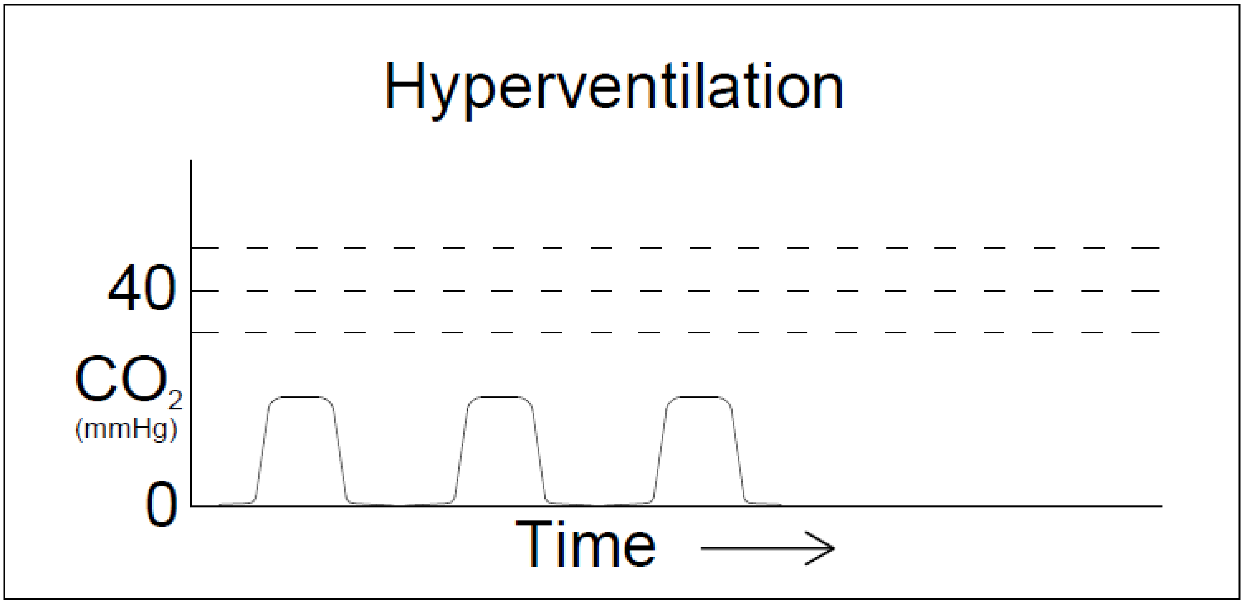
NORMAL CAPNOGRAPH WAVEFORMS



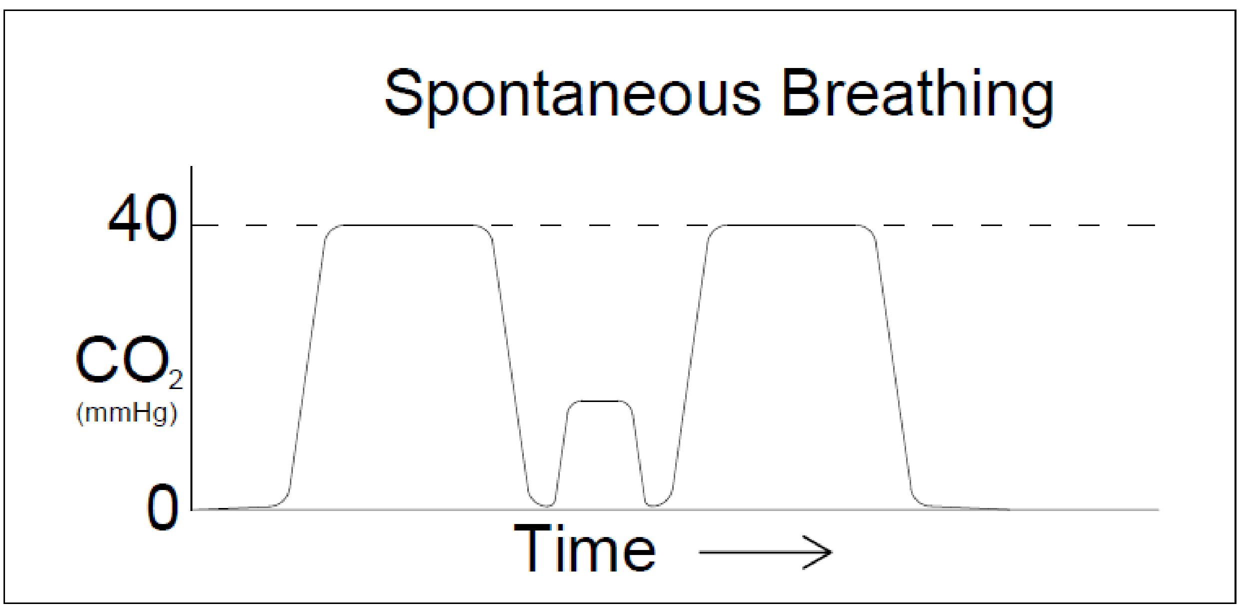
The capnogram above depicts a normal waveform. In birds and mammals, the range for $ETCO_2$ is between 35-45mmHg.



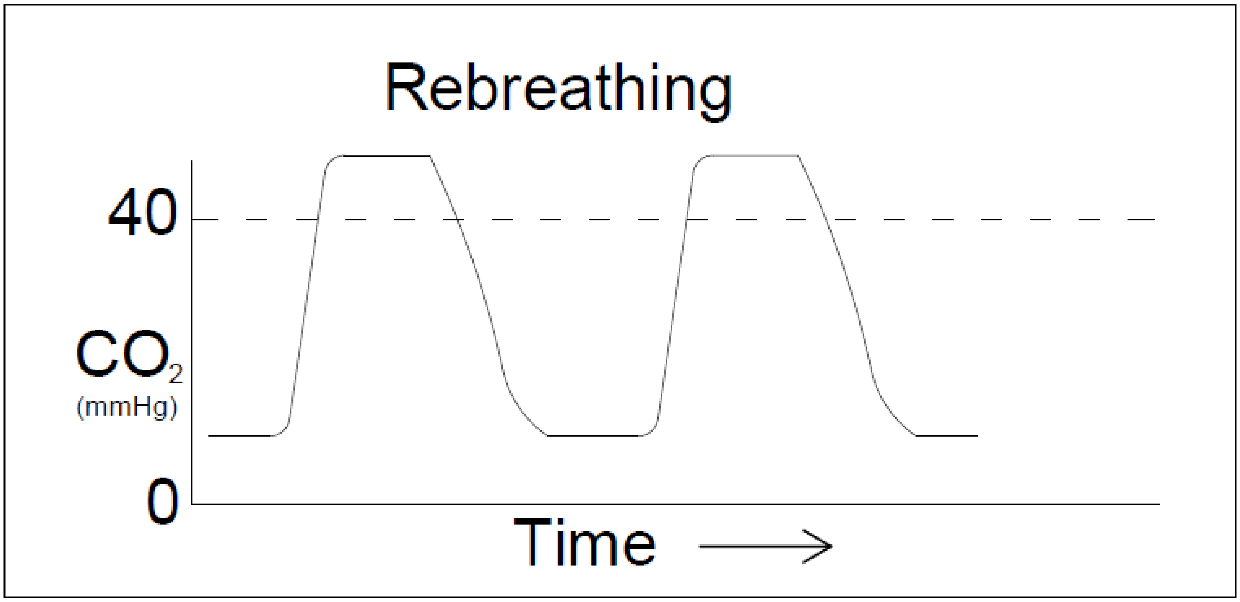
The normal range for $ETCO_2$ in most mammals and birds is 35-45mmHg. A capnograph reading above 45mmHg is called hypercapnia (too much CO_2) and is often caused by hypoventilation as seen above. Some common causes for hypoventilation include a deep plane of anesthesia, various diseases, and respiratory and/or metabolic disturbances.



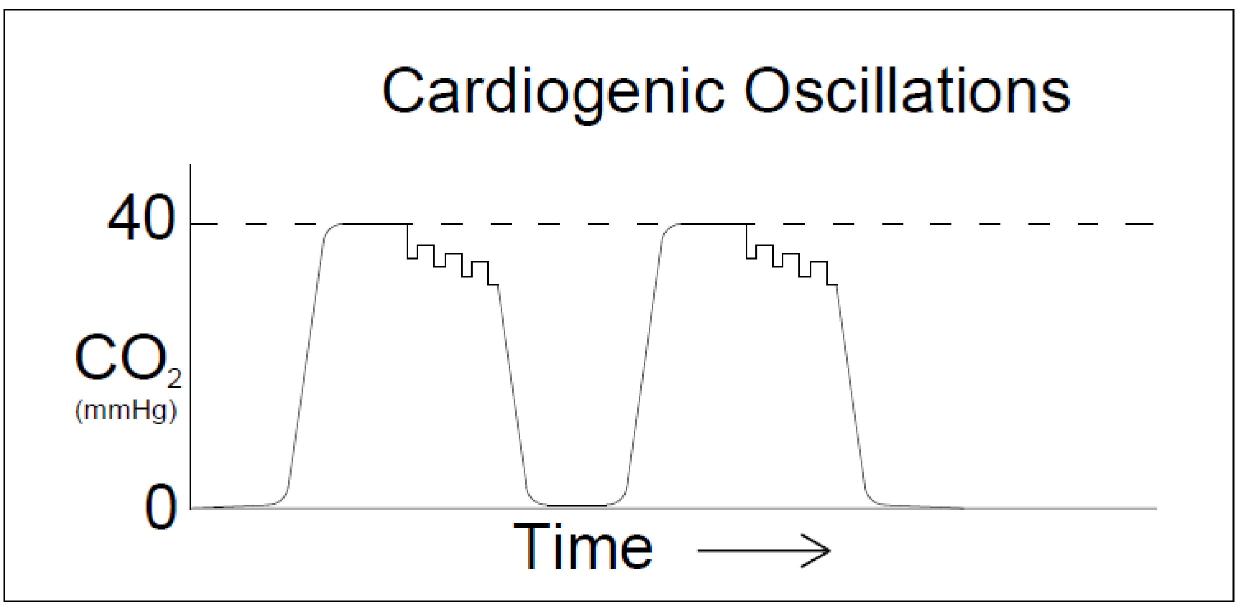
The normal range for $ETCO_2$ in most mammals and birds is 35-45mmHg. A capnogram reading below 35mmHg is called hypocapnia (not enough CO_2) and is often caused by hyperventilation as seen above. Some common causes for hyperventilation can be pain, light plane of anesthesia, tachypnea, and respiratory or metabolic disturbances.



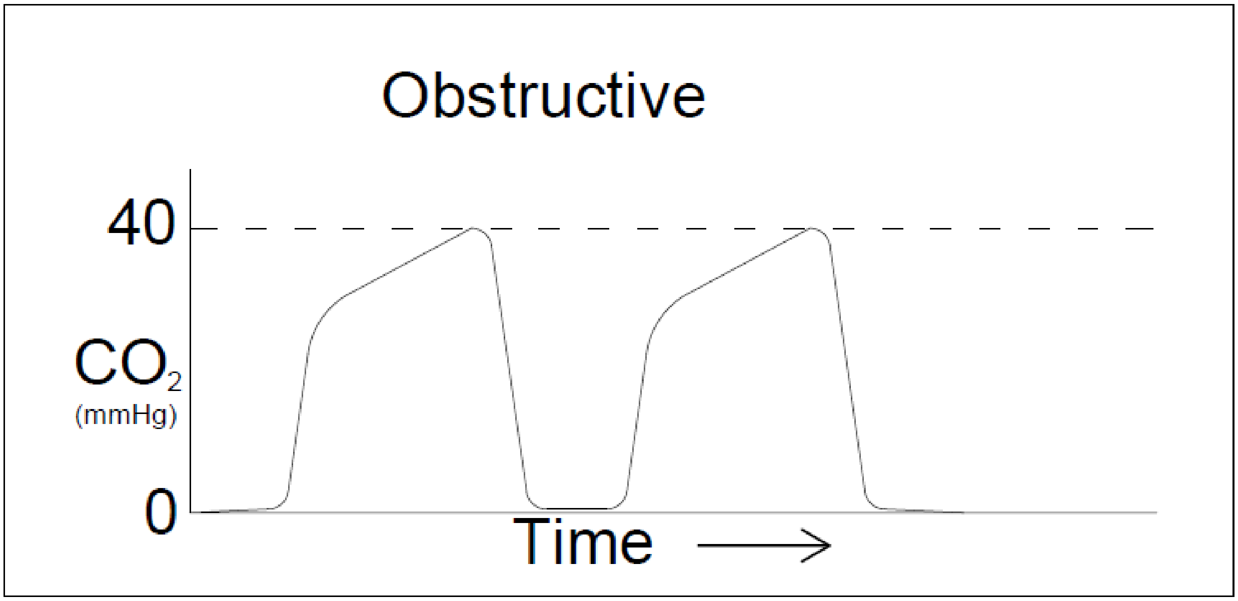
The capnogram above depicts a patient being ventilated via a mechanical ventilator (intermittent positive pressure ventilation - IPPV). The small breath between the ventilated breaths is the patient spontaneously breathing around the ventilator.



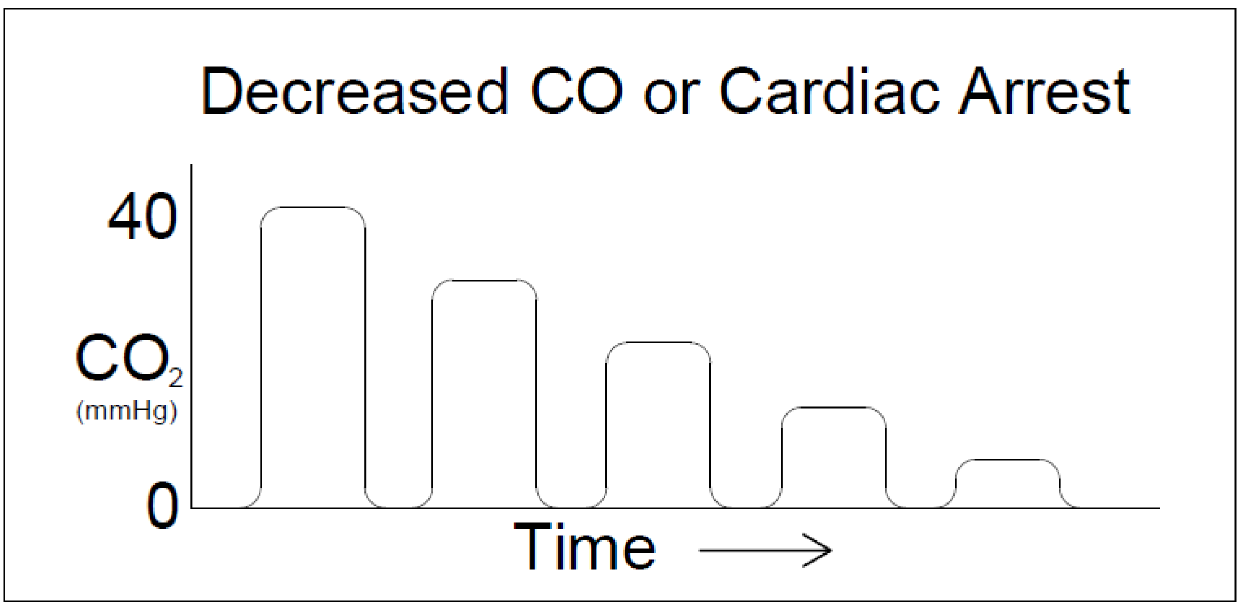
The capnogram above shows the baseline not returning to zero after each breath. This waveform indicates rebreathing of CO_2. Some common causes for this include exhausted soda lime, no oxygen flow or flow too low, hyperventilation and flutter valve not closing properly.



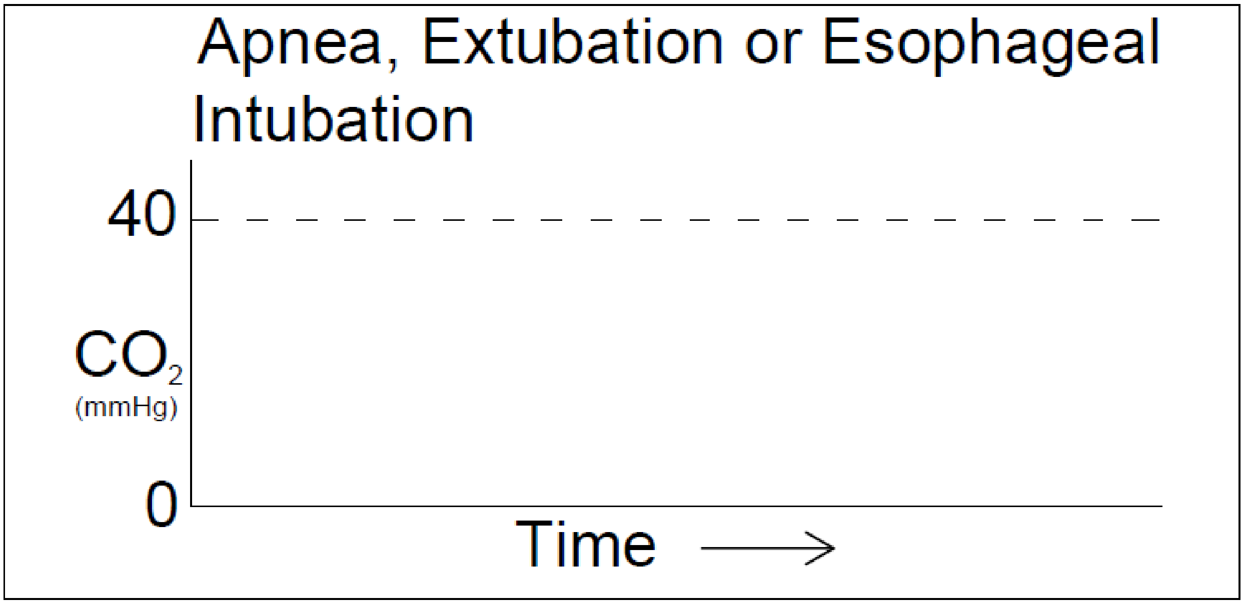
The capnogram above depicts cardiogenic oscillations. This is an artifact due to a strong heartbeat. Each "blip" represents a single heartbeat.



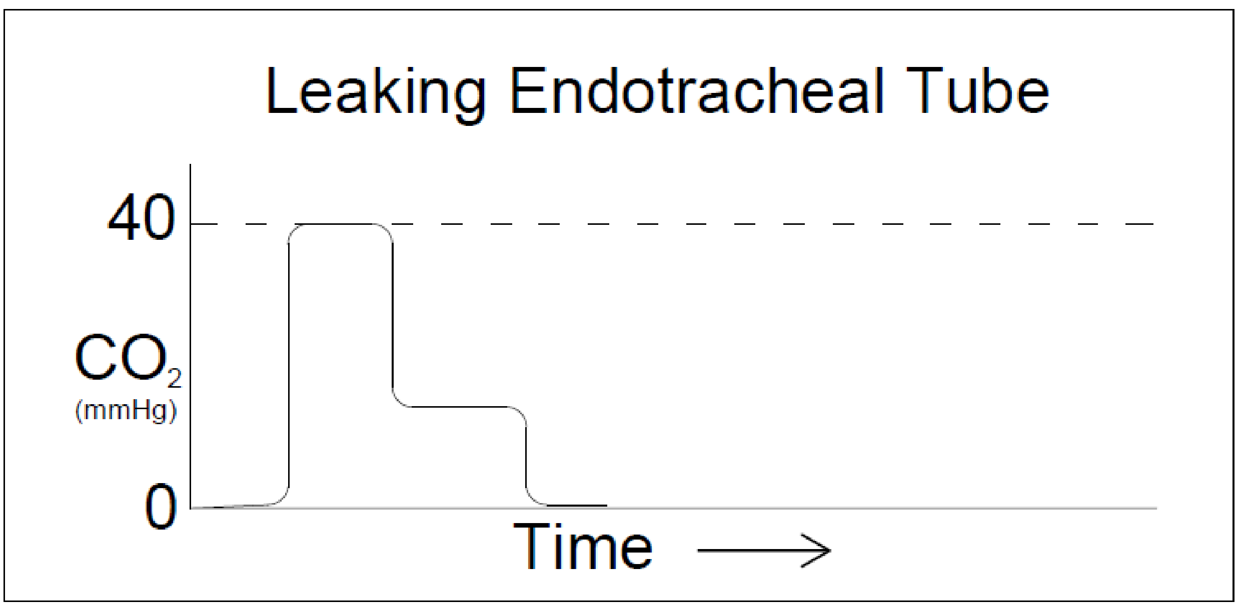
The capnogram above depicts airway obstruction, for example a kinked tube or mucous plug.



The capnogram above depicts cardiac output decreasing and an impending cardiac arrest.



The capnogram above depicts a zero reading. The lack of a waveform indicates apnea, extubation or an esophageal intubation.



The capnogram above depicts a leaking or deflated cuff on an endotracheal tube.

SUGGESTED READING

Bryant, S. (2010). Anesthesia for Veterinary Technicians. Wiley and Sons.
Seymour, C. & Duke-Novakovski, T. (2007) BSAVA Manual of Canine and Feline anaesthesia and Analgesia. 2nd ed. British Small Animal Veterinary Association.