Practical Use of Capnography in Exotic Animal Anesthesia

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Respiratory monitoring is vital for the safe anesthesia of exotic animals, but it can frequently be challenging due to the patients' small size. The ideal assessment of respiratory gas exchange is blood gas analysis measuring the degree of oxygenation (oxygen assay) and ventilation (carbon dioxide [CO_2] assay), but this is either too invasive or expensive in most cases. The arrival of pulse oximetry, which assesses oxygenation, and capnography, which assesses ventilation, has provided noninvasive, economic methods of monitoring both respiratory and cardiovascular function in exotic animal patients.

Pulse oximeters indicate both the pulse rate and percentage oxygen saturation of hemoglobin ($SP0_2$). A probe transmits light of two different wavelengths to measure the absorption of oxygenated and deoxygenated blood passing through a pulsating vascular bed. The $SP0_2$ is determined by a photoreceptor measuring the ratio of these infrared and red light wavelengths. This is a useful indicator of the degree of oxygenation of blood, but it requires direct connection of the probe to an area of the body overlying adequate vasculature for a reading, which is frequently difficult with small reptiles and birds. Failure to find and directly connect the probe to a significantly vascular area renders pulse oximetry results inaccurate. Probes are normally designed for the tongue or ear vessels in larger animals and people and are often too large for small exotic patients. Even if an adequate reading is obtained, pulse oximetry can be unreliable with arterial oxygen concentrations often falling significantly before any changes in $SP0_2$ are reported. Pulse oximetry can give an indication of the degree of hypoxemia, which may lead to tissue hypoxia, but it offers limited information as to the cause.

In human medicine, the use of capnography to measure end tidal CO_2 concentrations ($PetCO_2$) in expired air is a standard anesthetic monitoring technique used in combination with pulse oximetry. The $PetCO_2$ is a very useful indicator of arterial carbon dioxide concentrations, which are very similar. Capnography can produce evidence of inadequate ventilation as well as suggest a cause by evaluation of the capnogram trace. It can also provide useful information regarding lung perfusion.

Capnography has not been available for routine anesthetic monitoring in veterinary medicine until recently due to the high cost of mainstream capnographs, but economic sidestream portable units have now become available on the veterinary market. These machines are designed for animals with small tidal volumes. This paper discusses the use and performance of a new capnograph available for use with exotic animal anesthesia.

Types of Capnographs

The two types of capnographs use either a mainstream or sidestream sensor. Both machines measure the CO_2 content of expired air by optical means. A mainstream sensor sits in line with the patient's airway and measures the CO_2 concentration of each breath. This sensor can be used in small animals, but it is prohibitively expensive for routine veterinary use except in referral centers. Machines using a sidestream sensor are more economic and thus capable of bringing capnography withinin reach of the veterinary community. The sidestream sensor continuously removes a small stream of expired air from the patient's airway, using a small tube and pump, for CO_2 analysis. Sidestream capnographs have some immediate disadvantages. The sidestream method creates an unavoidable time delay between sampling and reporting. More significantly, because sidestream sensors require the removal of small volumes of gas (50-200 mls per minute), there is a minimum limit on patient size. In very small animals, the sampling volume can be similar to the tidal volume of the patient. The sensor of many capnographs is unable to detect individual breaths in smaller animals due to

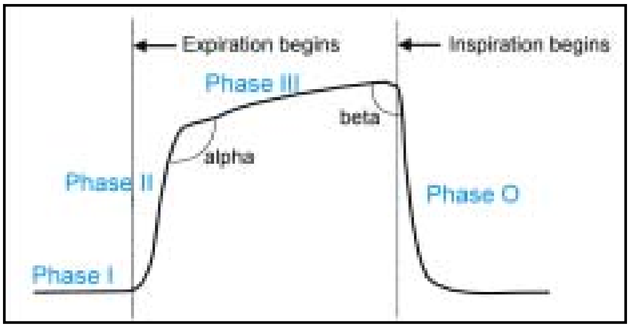

Fig 1. Diagrammatic representation of a normal capnogram reading. The y-axis measures PCO_2, and the x-axis reports time (moving left to right). Four phases are recognized in the capnogram. Interpretation of the shape and angle of the tracing is often more important than just reading the $PetCO_2$.

their increased respiratory rates. The Capnovet-10 is an exception in that it uses small sampling volumes and is capable of monitoring animals with respiratory rates up to 120 breaths per minute.

Explanation of Normal Capnogram

Capnographs noninvasively and continuously measure the PCO_2 in expired air. On expiration, the machine displays the maximum PCO_2 found throughout the expiratory phase. This is known as the end tidal CO_2 value. The capnograph will also display the PCO_2 measured against time. This waveform is known as the capnogram. The capnogram consists of 4 phases (**Figs 1, 2**):

- **PHASE 0 -** Inspiration. Inspired air does not contain a high PCO_2.
- **PHASE 1 -** Expiration of air from the anatomic dead space. This air has not been in contact with alveolar air and should not contain a high PCO_2.
- **PHASE 2 -** Expiration of alveolar air mixed with air from the dead space. This contains an increasing PCO_2 and is responsible for the upstroke of the capnogram.
- **PHASE 3 -** Expiration of purely alveolar air. This eventually forms a plateau in the capnograph, representing the maximum $PetCO_2$. The animal inspires again, creating the swift downstroke on the capnogram, and the cycle repeats.

The third phase is the most important, indicating lung performance and giving information about both perfusion and ventilation. The alpha angle is a measurement of the rate of transition from phase 2 to 3. This angle gives an idea of the ventilation/perfusion ratio of the lungs.

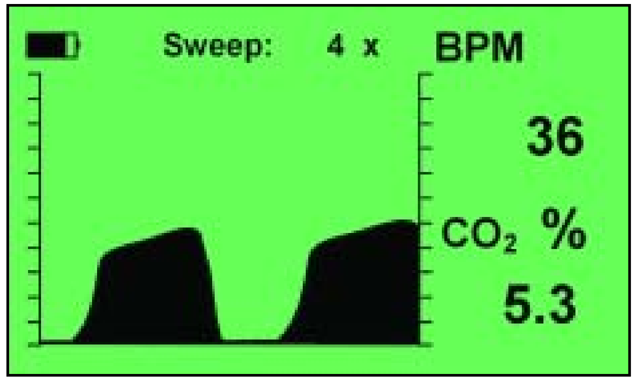

Fig 2. A normal capnogram as depicted on the Capnovet-10.

Fig 3. The Capnovet-10 is a microprocessor-controlled, portable, sidestream capnograph.

Use of Capnovet-10

The Capnovet-10 is a hand-held, portable (runs on rechargeable batteries) microprocessor-controlled PCO_2 monitoring device (**Fig 3**), which uses side stream technology to sample the PCO_2 of expired air. It allows the operator to set the sampling volume at any point between 50-200 ml per minute to suit the size of the patient. The display indicates $PetCO_2$, apnea time and a graphic depiction of the expiratory CO_2 waveform. The author uses this capnograph in a variety of exotic patients, including ferrets, rabbits, parrots, raptors and reptiles (**Figs 4, 5**). The sidestream sensor can use one of two different housings, depending on the patient's size. A simple connector in line with the endotracheal tube is used in all patients weighing ≥400 g (**Fig 6**), and a smaller adapter is used in smaller patients (**Fig 7**). The smaller piece connects directly to the endotracheal tube, both reducing dead space and being less bulky to use than if it were set off to the side. The author has not been able to achieve adequate readings with the Capnovet-10 in animals weighing <75 g.

Fig 4. A rabbit connected to the Capnovet-10 and a pulse oximeter.

Fig 5. The Capnovet-10 connected to a snake.

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Fig 6. An African grey parrot attached to the Capnovet-10 using the standard inline sensor. The connector simply fits in line between the anesthetic circuit and the endotracheal tube.

Fig 7. Adapter designed for smaller patients. This fits directly onto the endotracheal tube and acts as both the endotracheal tube connector and capnograph sampling tube.

The capnograph can also be used in a nonintubated patient by employing a nasal tube. A waste line from the capnograph is connected directly to the anesthesia scavenging system for dispersement of gas after sampling.

The Capnovet-10 has been used in the author's practice for 6 months in over 200 exotic animal anesthetic protocols. After induction and intubation, sevoflurane is the anesthetic most routinely used. It is administered via a nonrebreathing mini T-piece for all exotic animal anesthesias. The majority of patients are ventilated mechanically.

Introduction to Abnormal Capnograms

REBREATHING - If a patient is rebreathing expired air, the $PetCO_2$ will rise. Inspired air will now have a significant PCO_2, so the baseline will rise (**Fig 8**). This is useful information for exotic animals, which are frequently artificially ventilated.

RESPIRATORY OBSTRUCTION - If phases 2 and 3 of the capnogram are elongated, and the alpha angle is decreased, one should suspect obstruction in the expiratory gas flow (**Fig 9**). [AU/LH: The alpha angle in Fig 9 appears to be increased in this case.cjo] In the author's experience with small exotic patients, this is most commonly due to mucus obstruction of the endotracheal tube. Because of the small diameter, kinked endotracheal tubes are also commonly problematic in small birds and reptiles.

ASSESSMENT OF VENTILATION - The height of the capnogram plateau in phase 3 will gradually rise in the hypoventilated animal but fall in one that is hyperventilated. The baseline will remain steady if no rebreathing is taking place. This information can be used to adjust the settings on the ventilator to provide a better-balanced anesthetic protocol with optimal ventilation and perfusion.

ASSESSMENT OF CARDIAC OUTPUT - The height of the capnograph can be a useful assessment of cardiac output. If cardiac output is increased, the height will rise. This is commonly seen during thoracotomies in mammals. If there is a fall in cardiac output, the height of the capnograph will fall due to poor lung perfusion. This differentiation can potentially be useful with exotic animals in which small blood volumes lead to significant concerns regarding hemostasis.

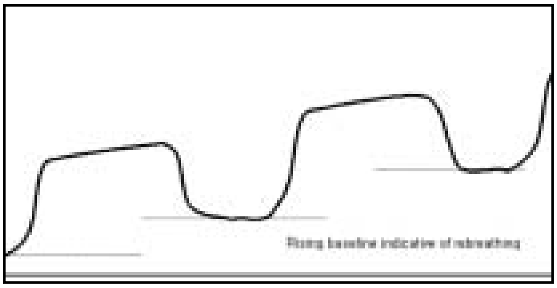

Fig 8. The raised baseline in this capnogram indicates that the patient is rebreathing expired air.

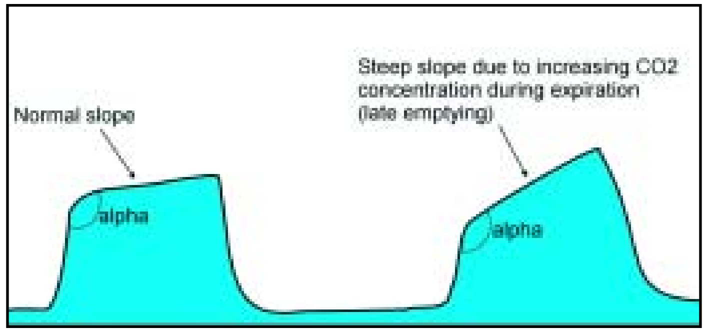

Fig 9. This capnogram reveals an increased $PetCO_2$ in phases 2 and 3. This is seen in cases of respiratory obstruction.

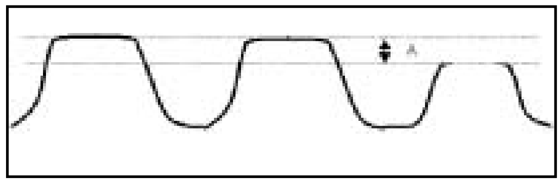

Fig 10. A lowering of the height of the plateau in phase 3 of the capnogram indicates a fall in cardiac output.

Conclusion

The Capnovet-10 is simple to use and obtains valuable readings in a variety of exotic pets. The main advantage of capnography over pulse oximetry is the ease of obtaining reliable readings, as the machine does not depend on direct attachment to the patient's body. It is the author's experience that pulse oximetry has limited use in small exotic patients due to the present size of the probes, so capnography is potentially of far more use. Its most significant application is assessing the effectiveness of the ventilator and indicating the possibility of a blocked endotracheal tube. Experience suggests that the $PetCO_2$ should lie between 1.5-3.5% (12-30 mmHg). Any persistent deviation from this concentration requires further investigation. As our skill as surgeons improves and surgical procedures become lengthier, capnography in combination with pulse oximetry should aid in monitoring our small patients.

The size limit of the machine for producing reproducible readings was found, in our experience, to be around 75 g in reptiles, although readings in birds were obtained down to 50 g. At the lower weights, the capnograph would not detect breathing. The monitor was found to be very useful in smaller birds where the risk of tube obstruction is greater. Although high PCO_2 is not considered to be the trigger for respiration in reptiles, any excessive deviations from the normal $PetCO_2$ would still be significant. Capnography is a rapidly developing science in human anesthesia, and with the development of economic units, its use in veterinary medicine should expand.

Acknowledgement

The author is grateful to Keith Simpson, Vetronic Services Ltd, UK, for the images of the Capnovet-10 for this paper.

References and Further Reading

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Useful website: www.capnography.com

Resources at a Glance

The Capnovet-10 is supplied in the US by:

- Dan Scott and Associates <www.danscottandassociates.com>
- Longview Veterinary Equipment <www.lveco.com>

and in the UK by:

- Vetronic Services LTD <www.vetronic.co.uk>