Monitoring, Ventilation & Capnography

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Why do we need to monitor?

- Under anaesthesia animals no longer have the ability to adequately control their normal homeostatic mechanisms
- Loss of respiration control
- Loss of temperature control
- Loss of blood pressure control

What is the point of monitoring?

- To detect ***early*** changes from the normal
- To enable corrective action to be taken

- To do this we ***must know*** what corrective action to take
- E.g. falling heart rate and pulse-ox values in an intubated (100% O2) dog

What can we monitor?

- **Heart rate** – stethoscope, pulse-ox, ecg
- **Oxygen saturation** – pulse-ox, observation
- **Blood pressure** – IBP, oscillometric or Doppler
- **Inspired & expired gases** – capnography, oxygen and agent monitoring

What is the relative merit of each monitoring technique?

- We'll look at ease of use, reliability and usefulness for each type

Heart Rate

- Easy to detect,
- Relatively fast response
- Limited information about patient status – changes can be for a variety of reasons: Pain, depth of anaesthesia, blood volume changes, drugs
- Heart rate in combination with an ECG is much more useful

Oxygen Saturation – Pulse-Ox

- Measures the % saturation of haemoglobin ***only! Indicates Hypoxaemia NOT Hypoxia***
- Easy to use. Non-invasive
- Very slow/late response in animals receiving 100% oxygen
- Clamp-type probes prone to false errors, poor reliability.
- Reflectance types much better
- Much more useful in air-breathing animals

Pulse-Oximetry and anaemia

- In a severely anaemic animal with perhaps even clinical cyanosis, what will be the reading from a pulse-oximeter? Low, normal or “high”?

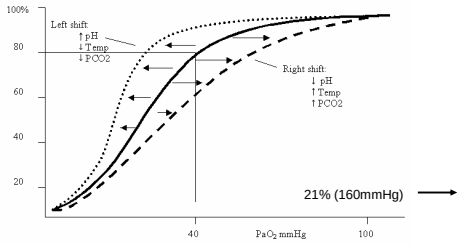
Transmission Probe

- Any transmission probe will, after a period of time, exsanguinate the underlying tissue

Reflectance probe

- Once fixed in place there is no deterioration of signal

Why Pulse-ox has a slow response



Blood pressure

- More difficult to set up for reliable results.
- Gives good information on cardiovascular status
- 3 types – IBP, Oscillometric & Doppler
- Markedly affected by anaesthetic agents
- Interpretation of results must be made with care. Systolic pressure **alone** is not a reliable indicator - Need to look at the pulse waveform

Inspired and expired gases

- CO_2 – capnography
- Inhalation agents – Halo, Iso, Sevo
- Gases – O_2, N_2O

- All were traditionally expensive but now CO_2 is well within reach of the general practitioner

Capnography

- Rapid response to changes in ventilation and perfusion
- Easy to use
- Virtually no false errors – high reliability
- Single most useful monitoring technique in the anaesthetised patient

Summary

- Heart rate useful but better in conjunction with ECG
- Pulse-Ox of limited value and reliability in 100% oxygen. Much better for room air
- Blood pressure – can be very useful
- Capnography – easy to use, reliable and full of information

End of Introduction

Mechanical ventilation

- How easy is it to use?
- Why not just squeeze the bag?
- What benefits does it offer?
- Different types?

How easy is it to use a mechanical Ventilator?

- When you are used to it and know what you are doing it is very easy to use. *But…*
- Good use of a mechanical ventilator comes with an understanding of the principles of gas exchange and ventilation modes.

What's wrong with manually squeezing the bag?

- Volume delivery estimation is difficult
- Pressure delivery estimation is almost impossible – this can lead to under-inflation but more likely to over-inflation and its subsequent problems
- It takes up 100% of the Nurse/Assistant's time
- Can be difficult to remain consistent during a 2 or 3 hour procedure

What benefits does a Ventilator offer?

- Reliable oxygen delivery to the patient
- Reliable carbon dioxide removal from the patient
- Reliable anaesthetic agent delivery
- All the above mean a much smoother anaesthetic
- Can be used in rebreathing circuits without the worry of circuit resistance

Additional benefits

- Nurse/Assistant is free to hold/fetch/carry as well as control the ventilation
- Hyper/Hypocapnia can be avoided
- High risk/long term patients can be ventilated consistently and safely

When should you use a ventilator?

- On nearly all cases – there is no harm in doing so and it provides a better, smoother, more controllable anaesthesia.
- Why restrict it to "special cases" ?
- Infrequent use can cause problems because there is not then the familiarity with the ventilator.

"Must Ventilate" cases

- Thoracotomy
- Ruptured diaphragm
- Muscle relaxant surgery
- Gastric Torsion
- Toxic cases – e.g. pyo
- Reptiles - tortoises

Ventilating modes

- Volume cycling
- Pressure cycling – use particularly for the smaller patients
- What do these modes mean?

Volume cycling

- Simplest means of ventilation
- The inspiratory phase is terminated once a preset volume has been delivered.
- Easy to calculate average TV – 10 mls/kg body weight.
- Slightly underestimates the smaller animals < 5kg
- Set the TV. Set the Inspiratory time or Respiratory rate and begin

Pressure cycling

- The inspiratory phase is terminated once a preset pressure has been reached.
- Much safer for smaller animals
- How do you determine target pressure?
- Animal compliance means calculation not possible.
- Most animals properly ventilated between 6 and 12 cm H2O

Consequences of mechanical ventilation….

- Patient assessment is more difficult
- Needs external monitoring
- Pulse-Ox much less useful than Capnography
- Capnography is a VERY reliable indicator of patient status. Can adjust the minute volume in line with end-tidal CO2 values

Thinking in terms of Minute Volume

- May not immediately be intuitive but is very helpful in controlling patient status
- Minute Volume = Tidal Volume x breaths per minute
- If animal is hypocapnic then reduce the minute volume
- If animal is hypercapnic then increase the minute volume

Some helpful formulae

- Tidal Volume (mls) = Bodywt (kg) x 10
- Minute Volume = Tidal Volume x Breaths per minute
- Oxygen consumption = 10 mls/kg per minute
- Patient compliance = Volume delivered/Pressure rise (mls/cm H_20)

The use of Capnography in practice

- Now easily affordable
- Easy to use
- Good reliable results
- Much more information than e.g. pulse-ox

What we need to cover

- What does capnography measure?
- What does this represent?
- What are the implications of this information?
- How do you use this information?
- What does the waveform represent?

Capnography - Definitions

- Capnometer – a device for displaying the numerical values only of Carbon Dioxode monitoring
- Capnograph – a device for displaying graphical and numerical data from Carbon Dioxide monitoring

Definitions

- Mainstream Unit – a device that samples the CO2 levels in line. There is no delay in the capnogram trace. Gives a fast response. Fixed volume of dead space
- Sidestream Unit – a device that extracts a sample of the airway gas and performs the analysis inside the machine. Can be very small dead space. Needs a low sampling rate for tiny animals. Tend to be less expensive

What information do we get from Capnography?

- Capnography gives us continuous information on Expired and Inspired CO2 concentrations
- Expired CO2 (PetCO2) is a reflection of the PaCO2.
- There will always be a gradient between PetCO2 and PaCO2 but other than in extreme circumstances, this is usually only 1-2mmHg

So why monitor CO2 ?

- Carbon Dioxide production is constant and its expired level reflects both cardiovascular and respiratory efficiency
- All the Capnograph profiles and End-Tidal values you will see can be explained by remembering the above statement
- It is an early warning system for hypoxia
- Simply put it tells you that the animal *IS* breathing and how well it is breathing

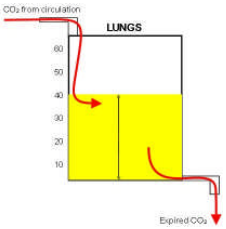
Why is it important?

- If arterial CO2 concentrations rise too much then this can have effects on the brain leading to CO2 narcosis and death
- If arterial CO2 concentrations fall too much then this will eventually lead to an alkalaemia, with resultant tetany and muscle spasms

What can a Capnometer tell us ?

- Expired and Inspired CO2 concentrations
- Although this is limited information it still says a lot about ventilation efficiency
- The heart is constantly returning blood with CO2 to the lungs. If the animal is breathing normally then this is removed and end-tidal CO2 is between 35-40mmHg

Representation of CO2 levels in the lungs

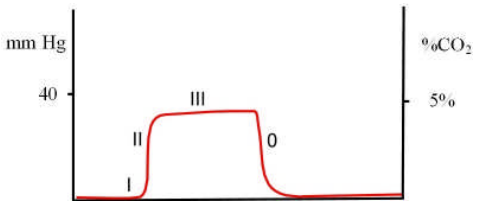


- If the animal is breathing too slowly (hypoventilating) then the constant delivery of CO2 but the slow removal means CO2 will build up in the lungs producing a high End-Tidal CO2 reading
- If the animal is hyperventilating the CO2 will be removed quicker than it is delivered and the animal will have a low End-Tidal CO2
- Remember, this does not have to be an anaesthetisd animal – could be sedated, toxic, collapsed

What can a Capnogram tell us ?

- In addition to the End-Tidal value the Capnogram shows the levels of CO2 during the complete respiratory cycle
- The Capnogram waveforms provide a lot of information

Typical Capnogram



What do the different phases represent?

- Phase 0 – Inspiration. Rapid fall in CO2 levels as new breath taken
- Phase I – Beginning of expiration and the elimination of gas from anatomical dead space
- Phase II – Alveolar gas mixes with dead space
- Phase III – Main component of expiration. Has a typical positive slope

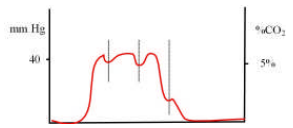
Remember what the capnogram represents

- The Capnogram represents levels of CO2 and NOT necessarily inspiration and expiration
- A simple example will illustrate this

Capnogram

- The capnogram shows a biphasic profile. This patient was continuously breathing out but the trace went down. Why?
- A downward trace shows a fall in CO2 levels, which could be inspiration but could also be differential (temporal) emptying of the lungs

Biphasic Capnogram – need different picture here!



How to respond ?

- Before going on to look at some capnograms and their features we need to know how to respond to the changes we detect

Increasing End-tidal CO2

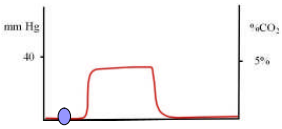
- CO2 delivery to the lungs exceeds removal
- Need to increase the minute volume to “blow off” more CO2
- If animal is not on a ventilator, then start IPPV
- If animal is on a ventilator then the simplest way to do this is to increase the respiratory rate. Leave Inspiratory time unchanged and decrease the Expiratory time
- Could increase the Tidal Volume but that might change the degree of lung inflation
- Why has this occurred? Was Minute Volume too low or is there another factor? Hyperthermia, changes in Cardiac Output

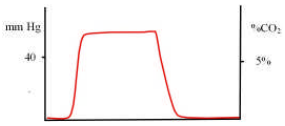
Falling End-Tidal CO2

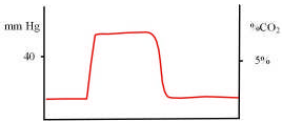
- CO2 removal rate exceeds the delivery rate to the lungs
- Need to reduce the minute volume
- If the animal is not on a ventilator then it is probably hyperventilating. Possible response to pain - may need increased depth of anaesthesia
- If the animal is on a ventilator then the minute volume is too high. Reduce the minute volume by decreasing the respiratory rate.
- Another cause could be….
- Fall in cardiac output so delivery of CO2 to the lungs is decreased. Causes – compression of pulmonary artery by surgeon, PEEP, shock
- Hypothermia. Results in reduced CO2 production

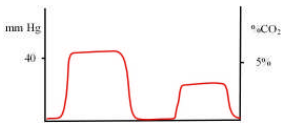
A look at some capnograms

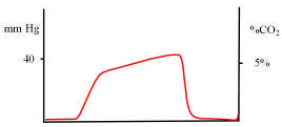
Normal Capnogram

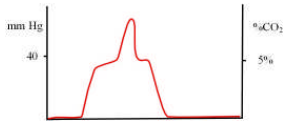








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