# Capnography – What can it tell us?

Keith Simpson BVSc MRCVS MIET(Electronics)

Torquay, Devon.

# What is Capnography?

- Capnography is the science of monitoring carbon-dioxide levels in the respiratory gases of an animal
- Capno = Greek for smoke/vapour
- Two main equipment variants:
  - Capnometer
  - Capnograph

# Capnography – Sidestream or Mainstream

- 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.

# Capnography – Sidestream


# Capnography –Mainstream

IRMA mainstream CO2 Monitor

# Why look at $CO_2$?

- Measurement is a relatively non-invasive technique and depending on the method used can be performed with conscious animals
- Exhaled carbon dioxide levels give an easy way of assessing the state of the respiratory and or cardiovascular system
- Capnography is probably the single most useful monitoring modality
- Virtually no false errors – high reliability

# What information do we get?

- Information from Capnography can be broken down into 4 levels, each with increasing degrees of information

# Capnography - Information

- Level 1:
  - Breathing or not, i.e apnoea monitor
  - Respiratory rate

# Capnography - Information

- Level 2:
  - Expired $CO_2$ levels
  - Inspired $CO_2$ levels
- From these parameters we can now begin to deduce the state of the patient with regard to respiration i.e normocapnic, hypocapnic or hypercapnic
- Expired $CO_2$ is taken to be equivalent to arterial $CO_2$ levels

# Capnography - Information

- Level 3:
  - Waveform profile
  - There are 4 recognised parts to a typical capnogram, each one having characteristics that impart specific information
  - The waveform can be referenced to time as a time capnogram, or to volume (SBT)

# Capnography - Information

- Level 4:
  - Combination of level 2 or level 3 information with blood gas information
  - Can determine e.g. lung dead space using Bohrs equation or take it a stage further and look at components of the lung dead space, e.g. alveolar dead space using the SBT

# Capnography - Information

- So there is a huge amount of information available from a standard capnograph.
- In viewing the wealth of information from a capnograph we should not lose sight of the most basic information..

# Capnography – the science

- Boils down to the fundamental fact that respiring cells consume oxygen and produce carbon dioxide as a by-product and that this carbon dioxide is removed by the lungs
- This continuous production of carbon dioxide is the essence of determining patient status
- The summary of the above is that all situations can be reduced to a balance of production and removal of CO2

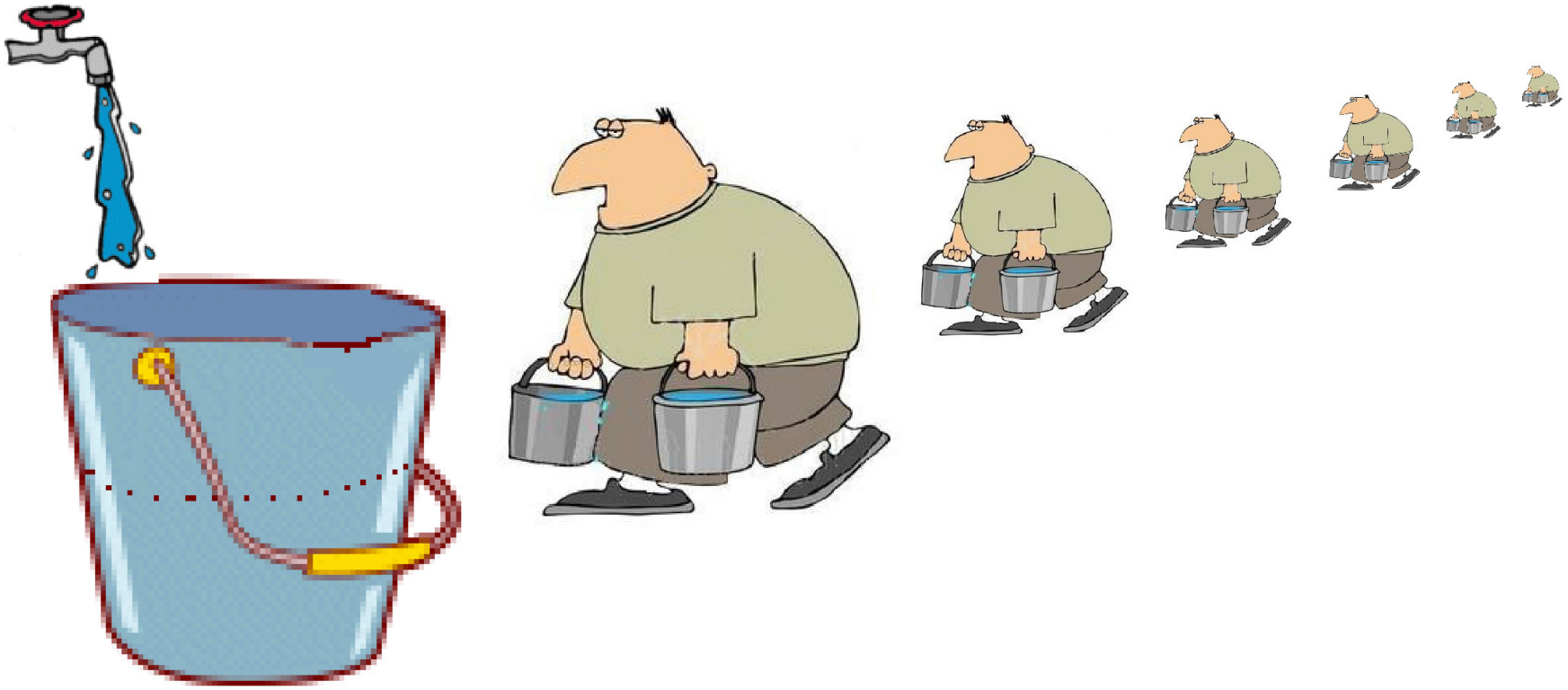
# Capnography – the science

- Essentially for a resting animal the rate of production of CO2 is constant. It is varied by the metabolic rate of the animal, so in some circumstances can change.
- Hyperthermia will lead to an increase in CO2 production.
- Conversely hypothermia will lead to a reduction in CO2 production

# Capnography - visualisation

- Consider the production of CO2 as an open water tap filling a large vessel
- In this concept the vessel is the lungs and the open tap is the constant production of CO2
- Consider the removal of CO2 as a man removing water from the vessel with a bucket

# Capnography - visualisation

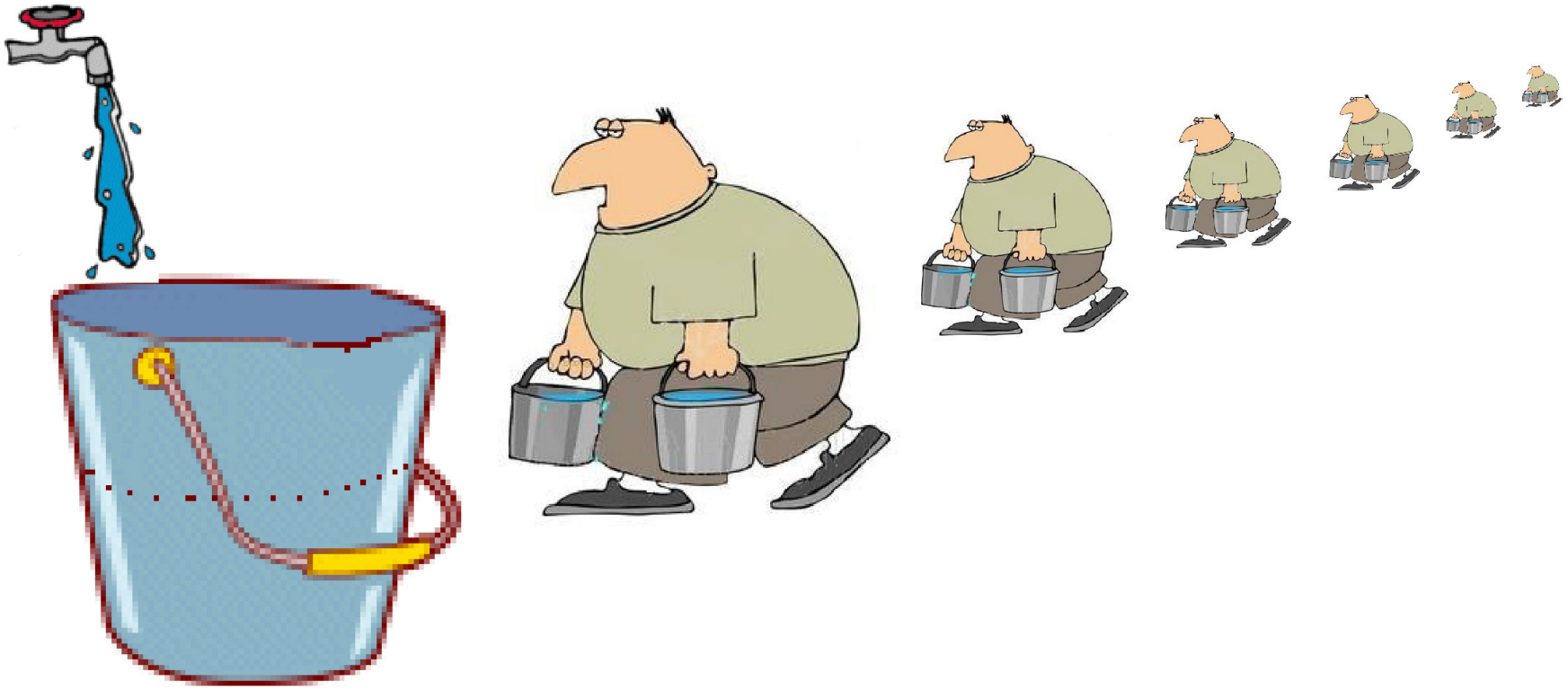


Rate of removal = rate of delivery  NORMOCAPNOEA

# Capnography - visualisation

- In the previous slide:
  - The running tap represents a constant delivery of $CO_2$
  - The big bucket represents the level of $CO_2$ in the lungs
  - The men represent the rate of removal of $CO_2$ from the lungs

# Capnography - visualisation



Rate of removal = rate of delivery  NORMOCAPNOEA

# Capnography – the science

- Therefore to keep an animal normocapnic we must ensure that the rate of breathing is sufficient to remove the CO2 delivered to the lungs
- We will return to this concept later

# Capnography

- Now that we understand where the information is coming from, what can we do with this information, and what does it mean for the animal?

# Capnography – Level 2 information

- Normal values

- Inspired $CO_2$ : 0%
- Expired $CO_2$:  4.5% (35 mmHg)

- The following slides assume a zero level for inspired $CO_2$. We will come to the effects of increased inspired $CO_2$ later

# Capnography – Hypercapnia

- Increased levels of end-tidal (alveolar) $CO_2$.
  - 5-6% begin to question why
  - > 6% take some action
- This means that the level of $CO_2$ in the lungs after equilibration with pulmonary blood is too high, which itself means that the removal of $CO_2$ is insufficient
- This usually means that the animal is under-ventilated. This may indicate respiratory depression or some other cause (lung pathology)
- Rarely does it reflect an increase in metabolic $CO_2$ production

# Capnography - Hypercapnia

Rate of removal < rate of delivery:  Hypercapnia

# Capnography - Hypercapnia

- What's wrong with hypercapnia?

- Indicates hypo-ventilation, so reduced oxygen exchange, and anaesthetic exchange
- Cerebral vasodilation increasing cerebral blood flow and intracranial pressure
- Peripheral vasodilation by direct effect on vessels
- Cellular acidosis develops rapidly affecting cellular function
- Central depression at very high levels of pCO2
- Stimulation of the sympathetic nervous system resulting in tachycardia, peripheral vasoconstriction and sweating

# Capnography - Hypercapnia

- In a clinical situation this indicates a patient that has insufficient minute volume ventilation.
- It can indicate a patient is too deep
- This patient needs an increase in minute volume ventilation: Give supplementary breaths by hand by squeezing the bag or begin mechanical ventilation

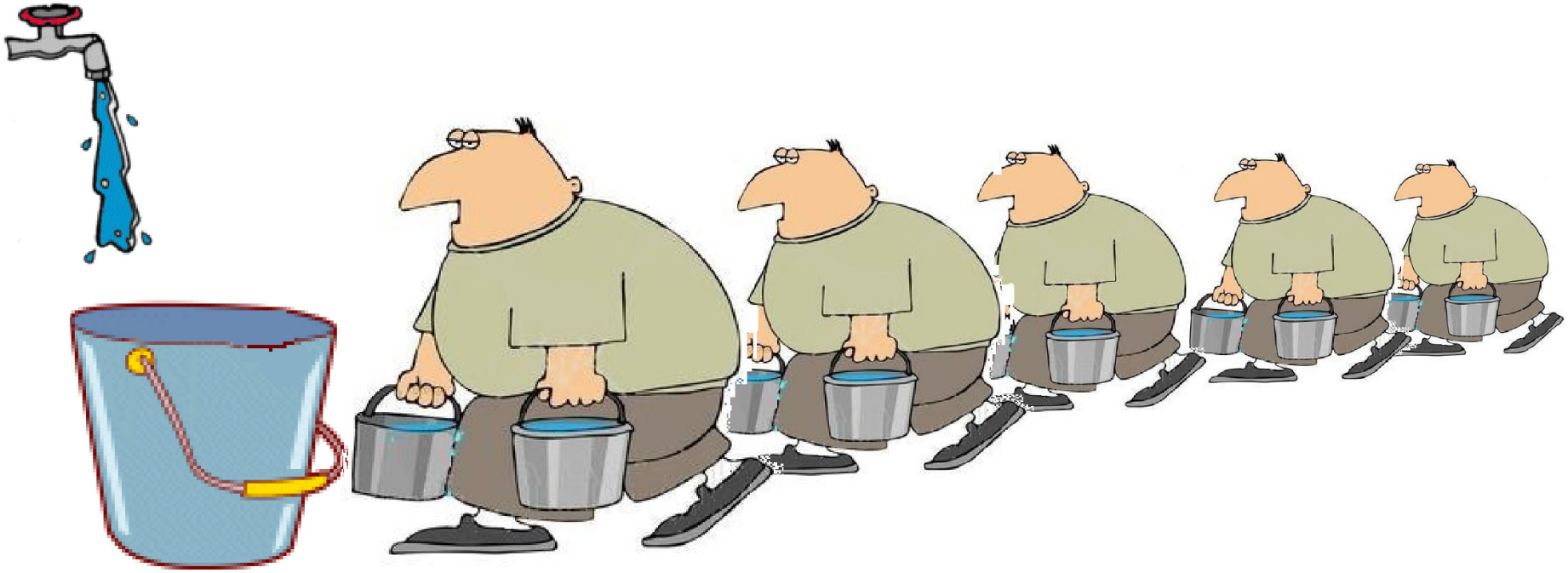
# Capnography - Hypocapnia

- Decreased levels of end-tidal (alveolar) $CO_2$.
- This means that the level of $CO_2$ in the lungs after equilibration with pulmonary blood is too low, which itself means either that the removal of $CO_2$ is excessive or that $CO_2$ delivery is reduced

# Capnography - Hypocapnia

- Possible causes:
  - Excessive ventilation
  - Reduced $CO_2$ production – hypothermia
  - Reduced delivery of $CO_2$ to the lungs

# Capnography - Hypocapnia



Rate of removal > rate of delivery:  Hypocapnia

# Capnography - Hypocapnia

Reduced delivery of $CO_2$: Hypocapnia

# Capnography - Hypocapnia

- Reduced delivery of CO2
  - Can be either reduced cardiac output or decreased production
  - Differentiate between the two by degree of change. With a change in cardiac output the effect on the capnogram is dramatic

# Capnography - Hypocapnia

- What's wrong with Hypocapnia?

- Inhibition of respiratory drive
- Shift of the haemoglobin oxygen dissociation curve to the left (impairing peripheral oxygen unloading)
- Depression of myocardial contractility
- Cardiac arrhythmias
- Less of an evil than Hypercapnia

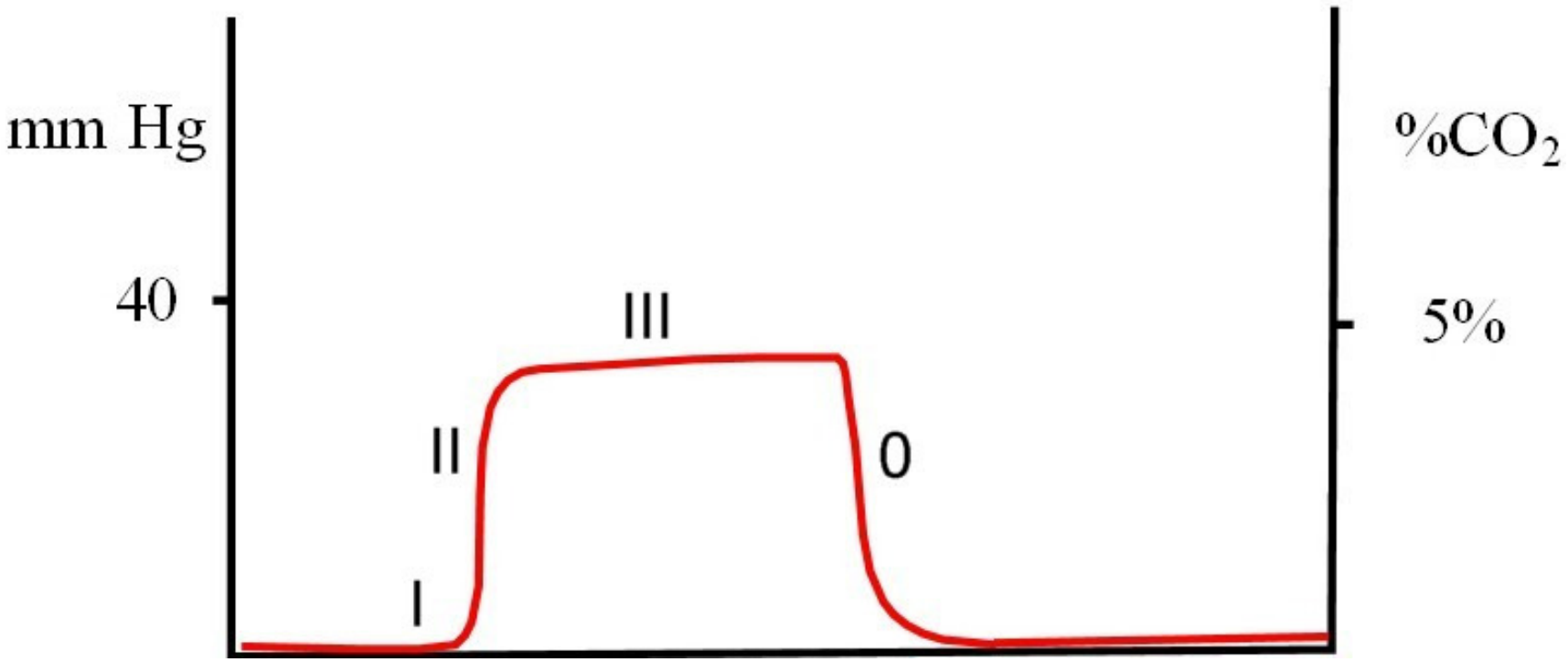
# Capnography - waveforms

- So far all the information discussed has been available from a capnometer, i.e. the information has been purely numerical.
- We will now look at the information imparted by the capnogram itself

# 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

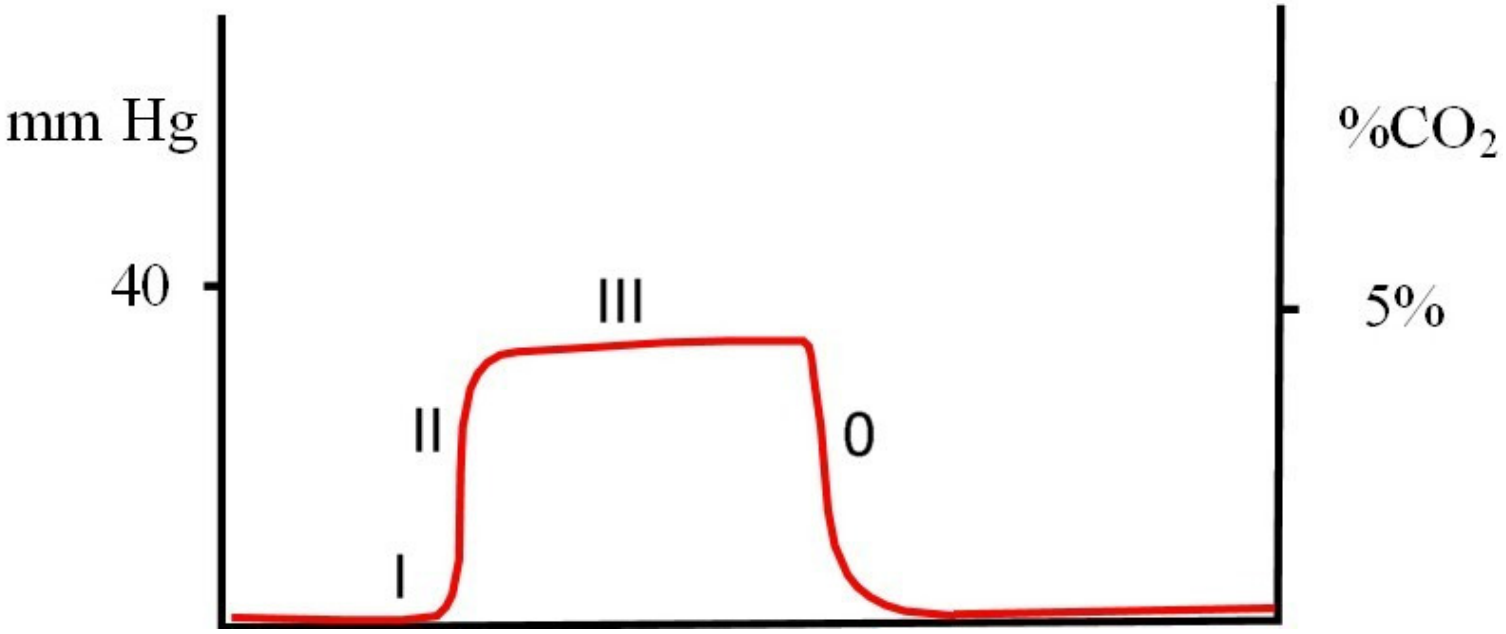
# Typical Capnogram



# Typical Capnogram

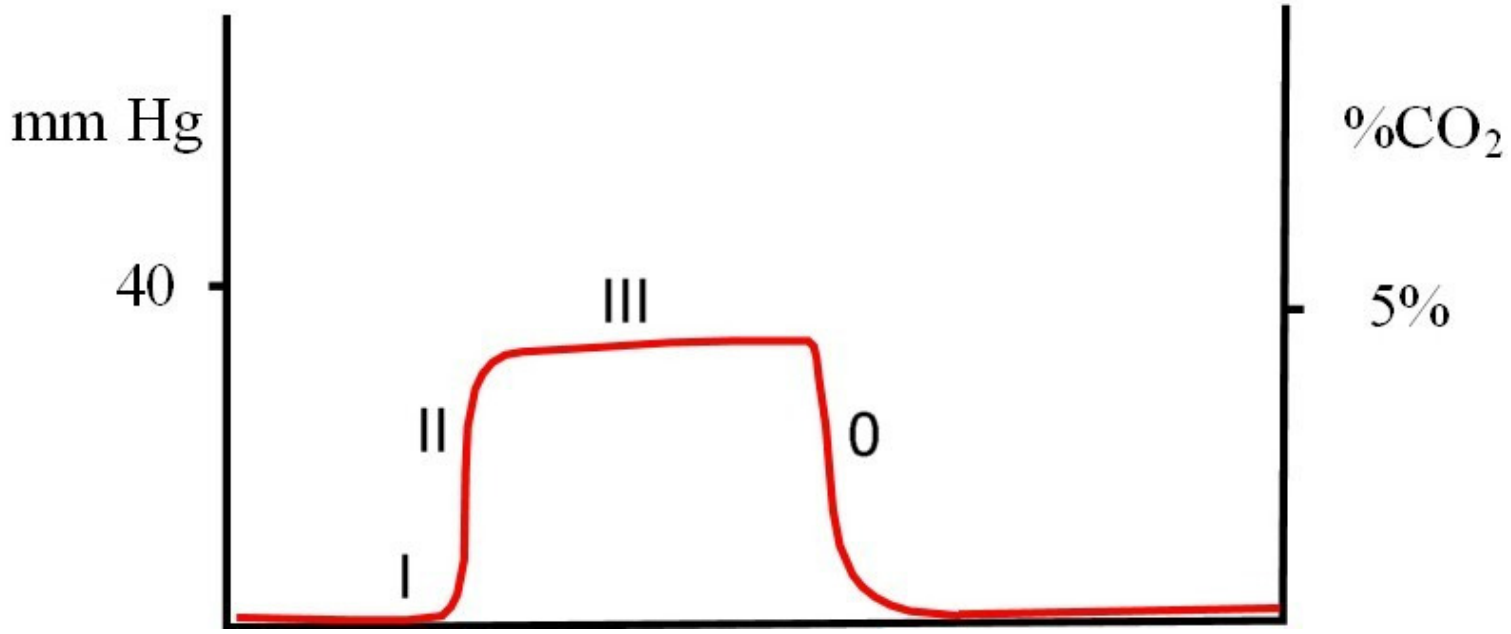
- Mainstream & Sidestream
- Live demo..

# What do the different phases represent?



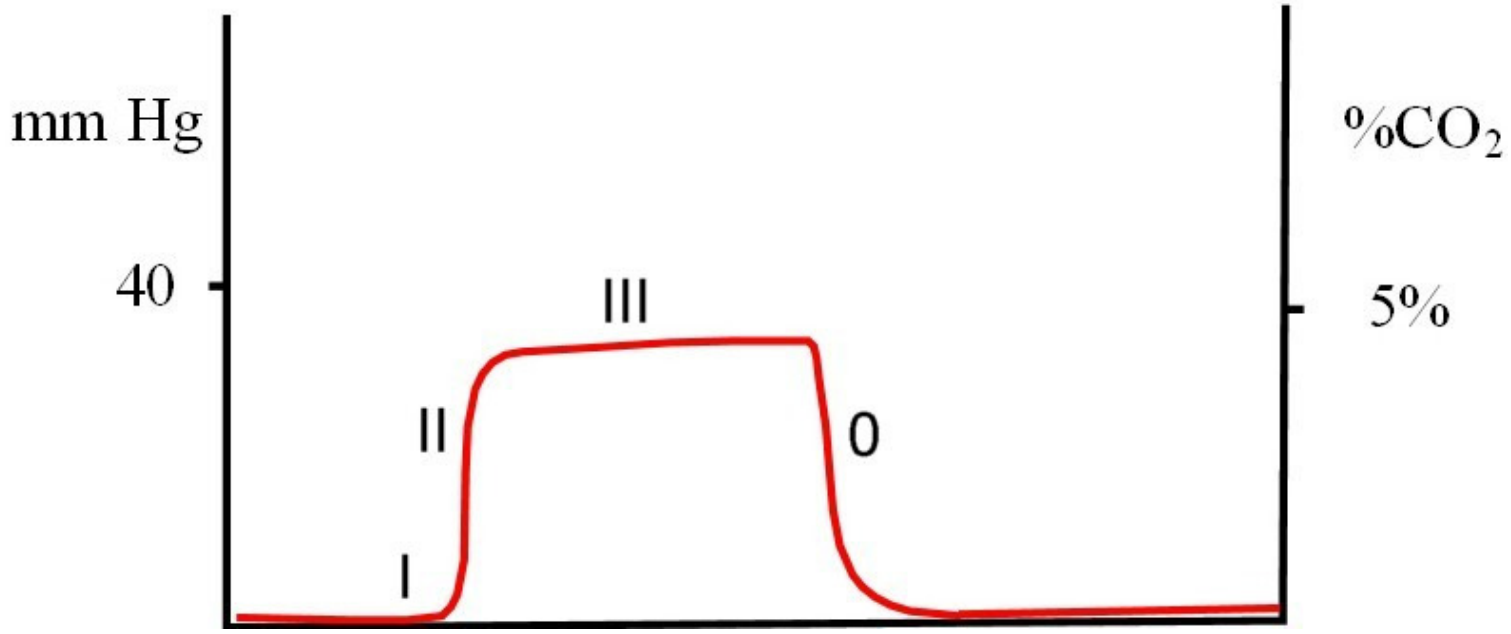

- Phase 0 – Inspiration. Rapid fall in CO2 levels as new breath taken

# Phase I



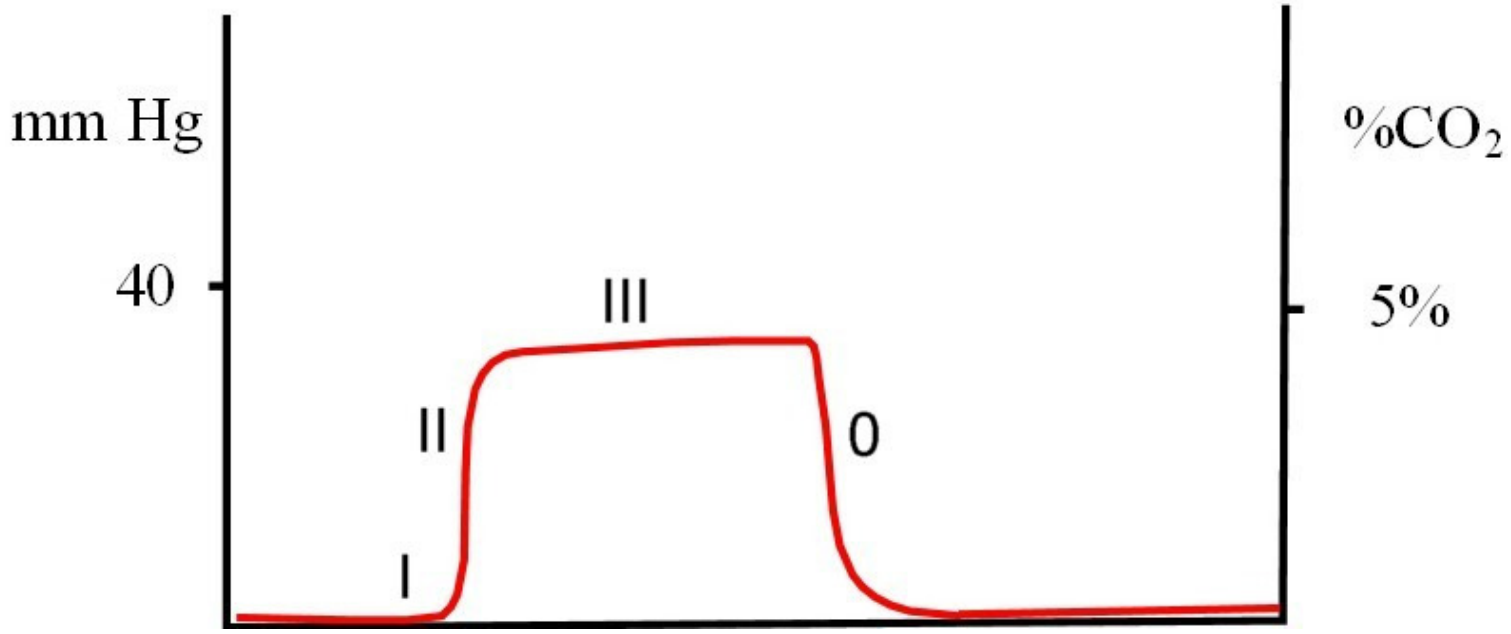

- Phase I – Beginning of expiration and the elimination of gas from anatomical dead space

# Phase II



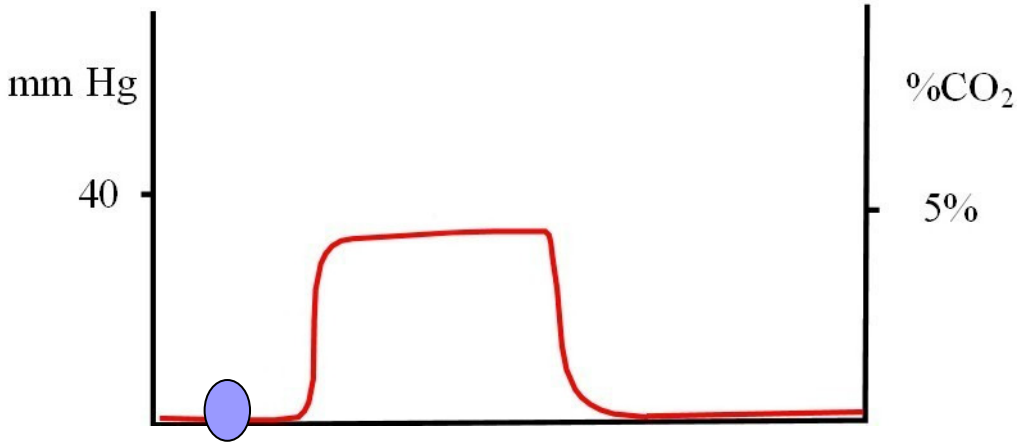

- Phase II – Alveolar gas mixes with dead space

# Phase III




- Phase III – Main component of expiration. Has a typical positive slope

# Normal Capnogram




Expired CO2: 5% 38mmHg
Inspired CO2: 0% 0 mmHg
Exp – Insp: 5% 38 mmHg

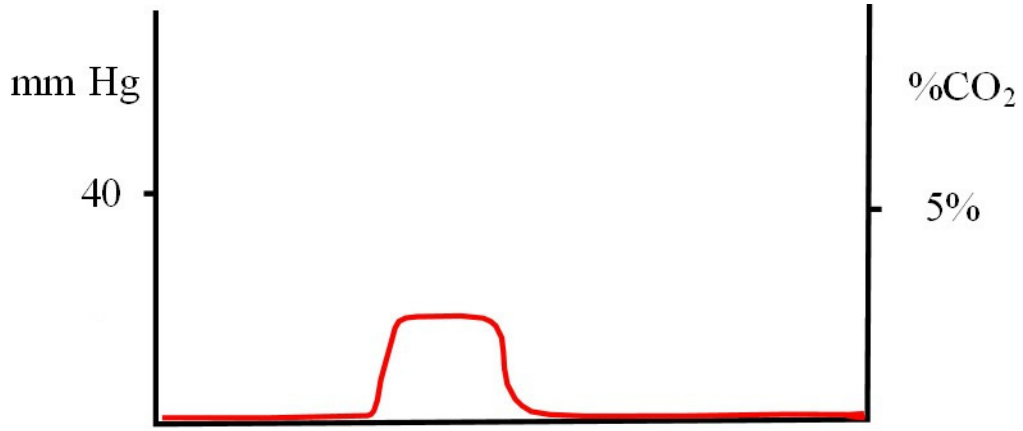
# Capnogram 2


Expired CO2: 7.5% 55 mmHg
Inspired CO2: 0% 0 mmHg
Exp – Insp: 7.5% 55 mmHg

# 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

# Capnogram 3

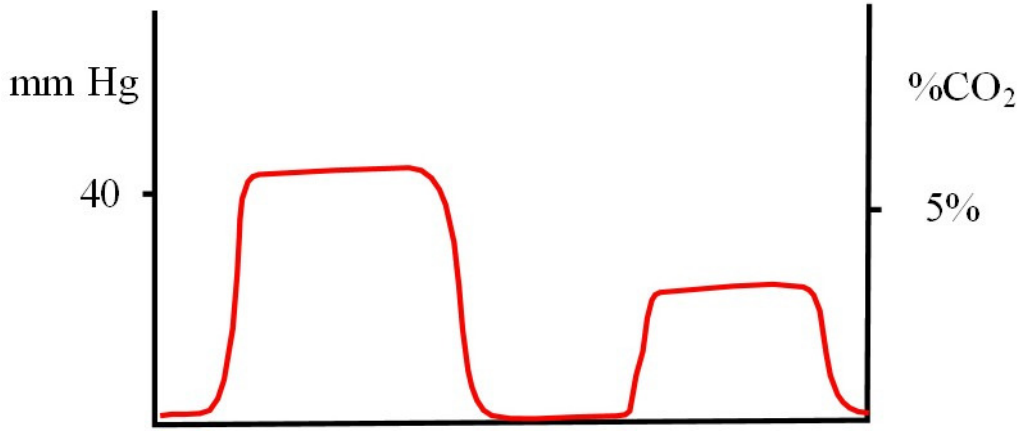



Expired CO2: 3%  25mmHg
Inspired CO2: 0%  0 mmHg
Exp – Insp:  3%  25 mmHg

# Falling End-Tidal $CO_2$

- $CO_2$ 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 $CO_2$ to the lungs is decreased. Causes – compression of pulmonary artery by surgeon, PEEP, shock
- Hypothermia. Results in reduced $CO_2$ production

# Capnogram 4

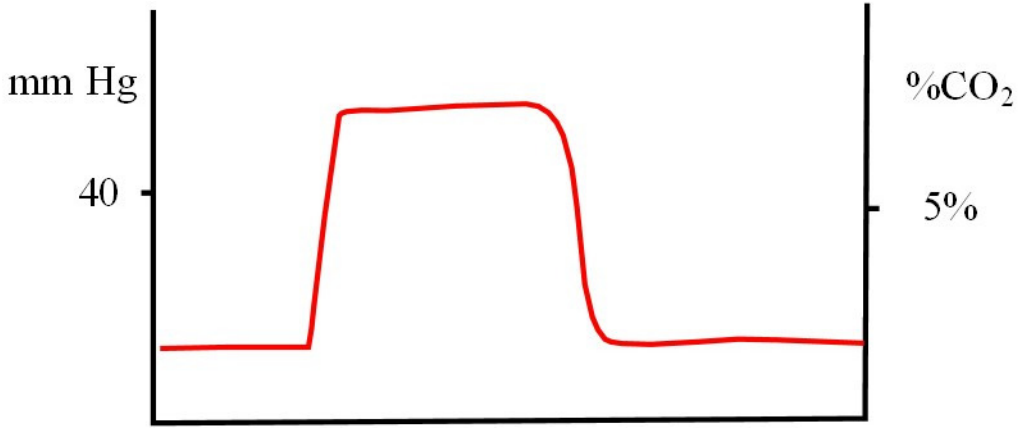



Expired CO2: 6% 45 mmHg then 3% 25 mmHg
Inspired CO2: 0% 0 mmHg

# Dramatic drop in $CO_2$ level between 2 breaths

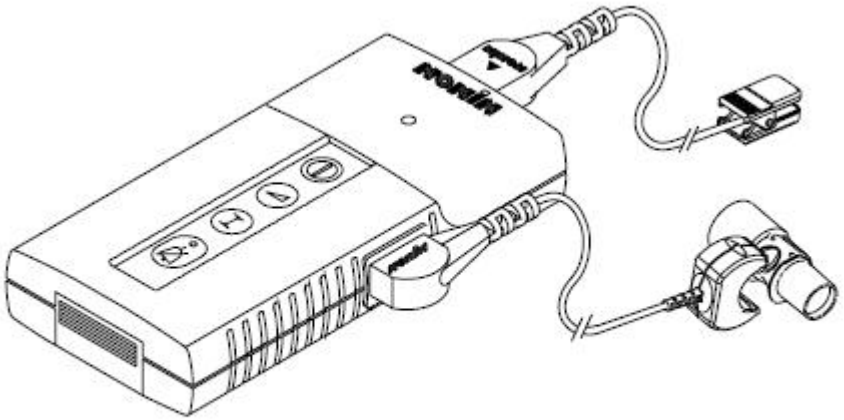
- Such a sudden fall in $CO_2$ level must be associated with a fall in cardiac output. This can happen when the surgeon “embarrases” heart function or occludes the pulmonary artery.
- Something to look out for in ruptured diaphragm repair

# Capnogram 5



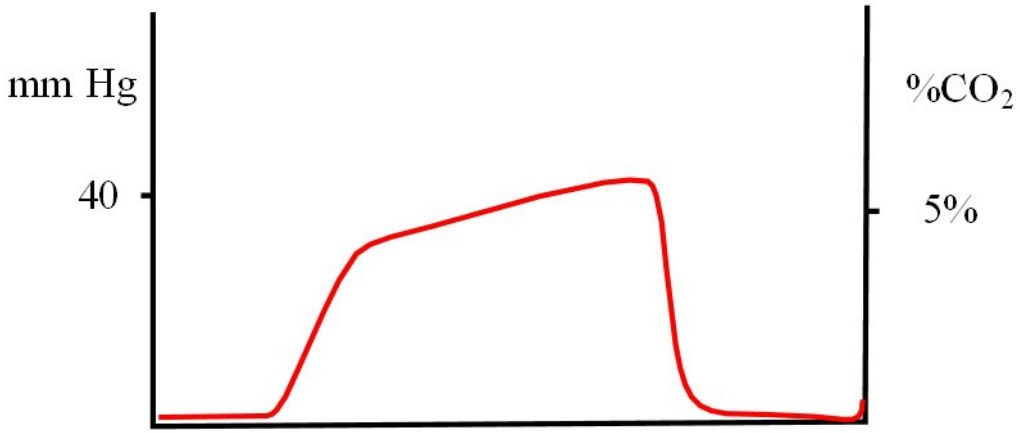

Expired CO2: 7%  55 mmHg
Inspired CO2: 2% 17 mmHg
Exp – Insp:  5%  38 mmHg

# Delta Capnography - Nonin 9847V




*The Model 9847V Veterinary Pulse Oximeter and Carbon Dioxide Detector*

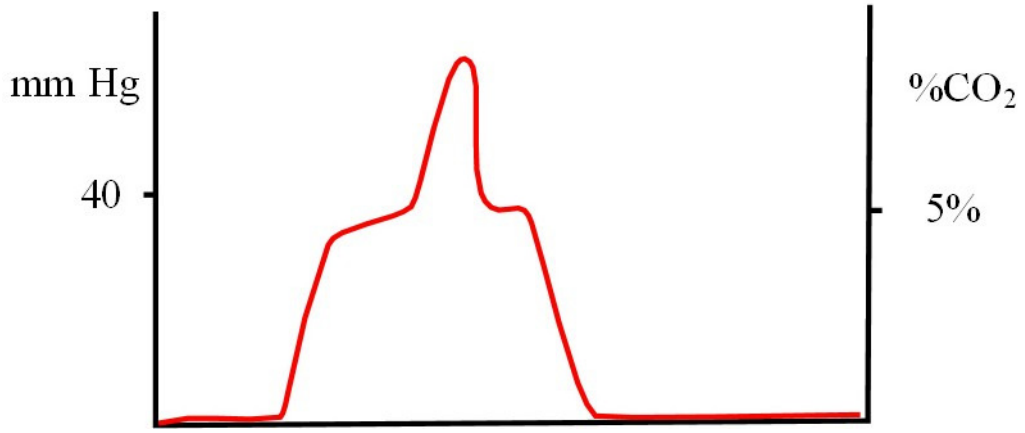
# Capnogram 6



# Skewed Capnogram

- The Capnogram is skewed.
- The total cycle time is unchanged but the time for phase II is extended
- Phase II is the expiration of gas from the lungs, mixing with dead space gas.
- Elongation of phase II is most commonly caused by obstruction in the expiratory circuit

# Spiked Capnogram



# Spiked Capnogram

- The spike represents an isolated pocket of high percentage CO2 gas during the expiratory period.
- Known as gas trapping this can be due to:
  - Single-bronchus intubation
  - Mucus plugs

# Capnography - Summary

- Easy to use
- Lots of information available from basic through to detailed
- The single most informative piece of equipment for anaesthetised animals
- Remember to consider production versus removal in all cases where CO2 output changes