Quality Anaesthetic monitoring and Ventilation equipment

VSL

Vetronic Services Ltd

Capnography - Principles & Pitfalls

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What is Capnography?

- Capnography is the science of monitoring carbon-dioxide levels in the respiratory gases of an animal

- Capno = Greek for smoke/vapour

- The equipment used is a Capnograph

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Capnography – Sidestream or Mainsteam?

•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.

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Capnography - Sidestream

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Capnography - Mainstream

IRMA mainstream CO2 Monitor

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Sidestream/ Mainstream

- Demonstration

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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

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What information do we get?

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

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Capnography - Information

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

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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

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Capnography - Information

- **Level 3:**
  - Waveform profile

  - There are 4 recognised parts to a typical capnogram, each one having characteristics that impart specific information

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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..

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Capnography - Principles

- 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 CO_2

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Capnography - Principles

- Essentially for a resting animal the rate of production of CO_2 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 CO_2 production.

- Conversely hypothermia will lead to a reduction in CO_2 production

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Capnography - Visualisation

- Consider the production of CO_2 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 CO_2

- Consider the removal of CO_2 as a man removing water from the vessel with a bucket

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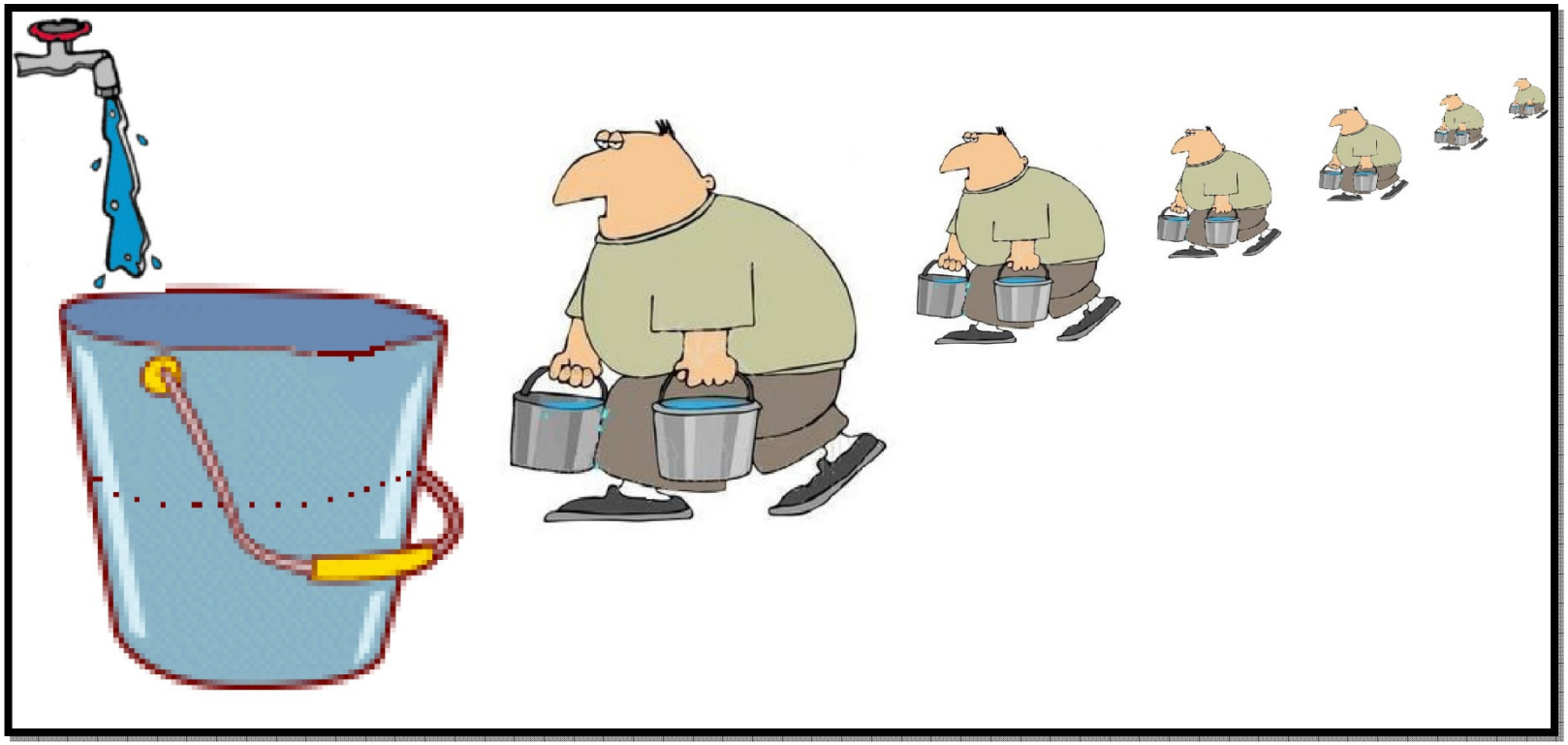
Capnography - Visualisation



Rate of removal = rate of delivery NORMOCAPNOEA

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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

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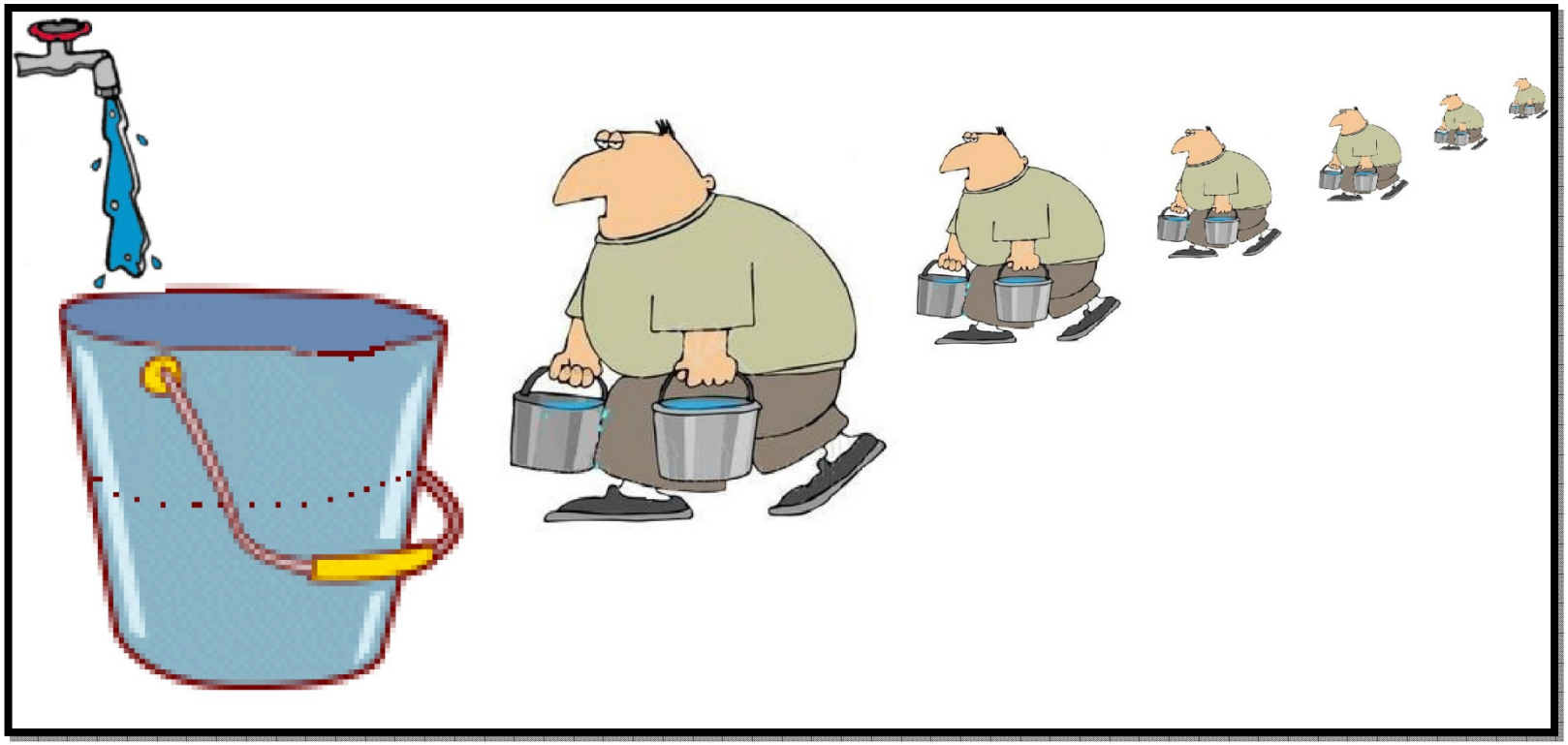
Capnography - Visualisation



Rate of removal = rate of delivery NORMOCAPNOEA

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Capnography – the science

- Therefore to keep an animal normocapnic we must ensure that the rate of breathing is sufficient to remove the CO_2 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?

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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

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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

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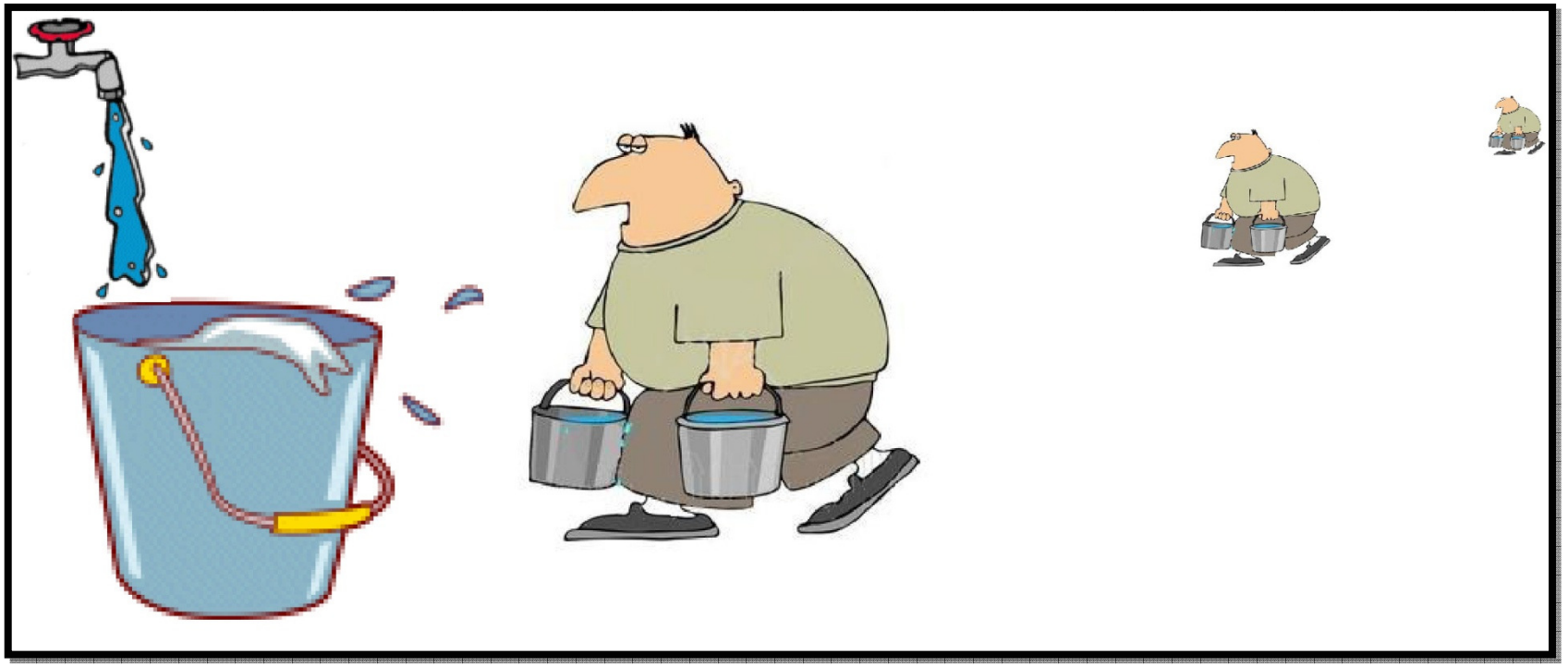
Capnography - Hypercapnia



Rate of removal < rate of delivery: Hypercapnia

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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 pCO_2
- 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

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Capnography - Hypercapnia

- 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

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Capnography - Hypercapnia

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

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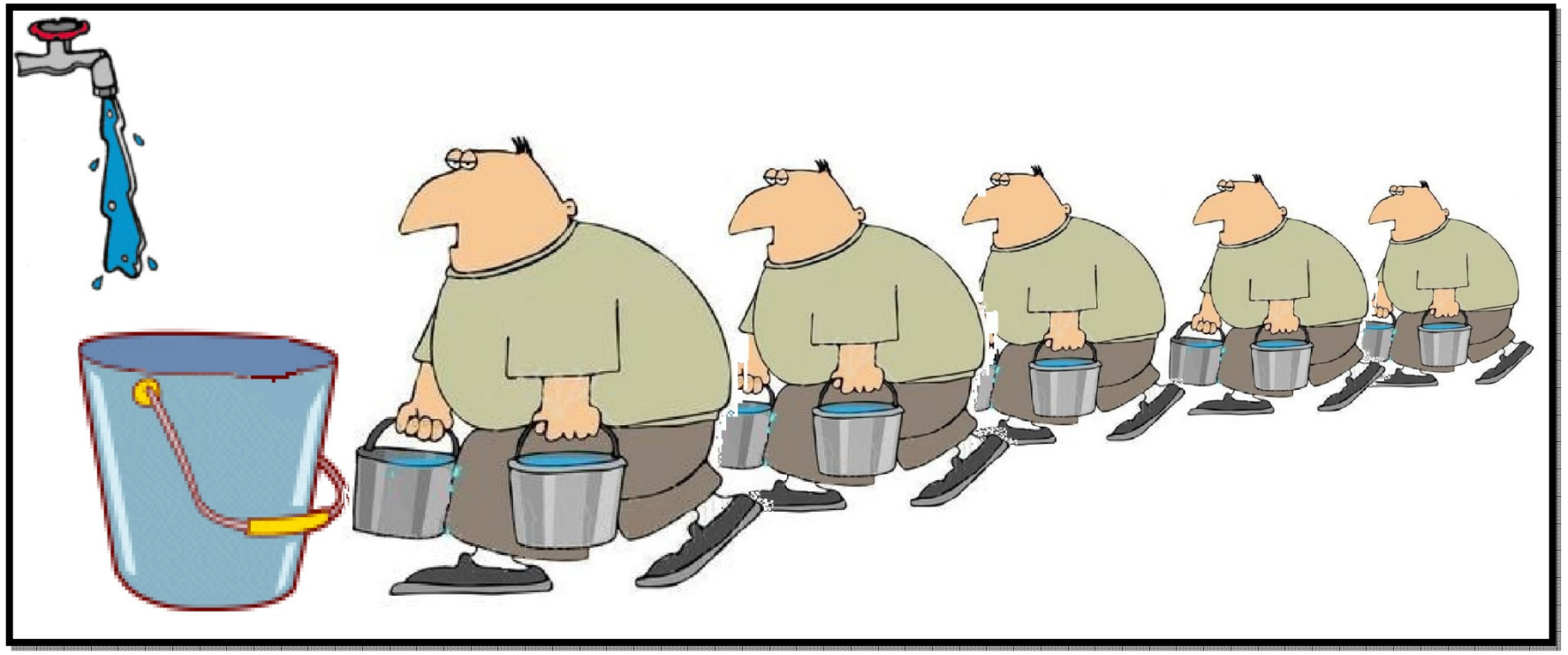
Capnography - Hypercapnia



Rate of removal > rate of delivery: Hypocapnia

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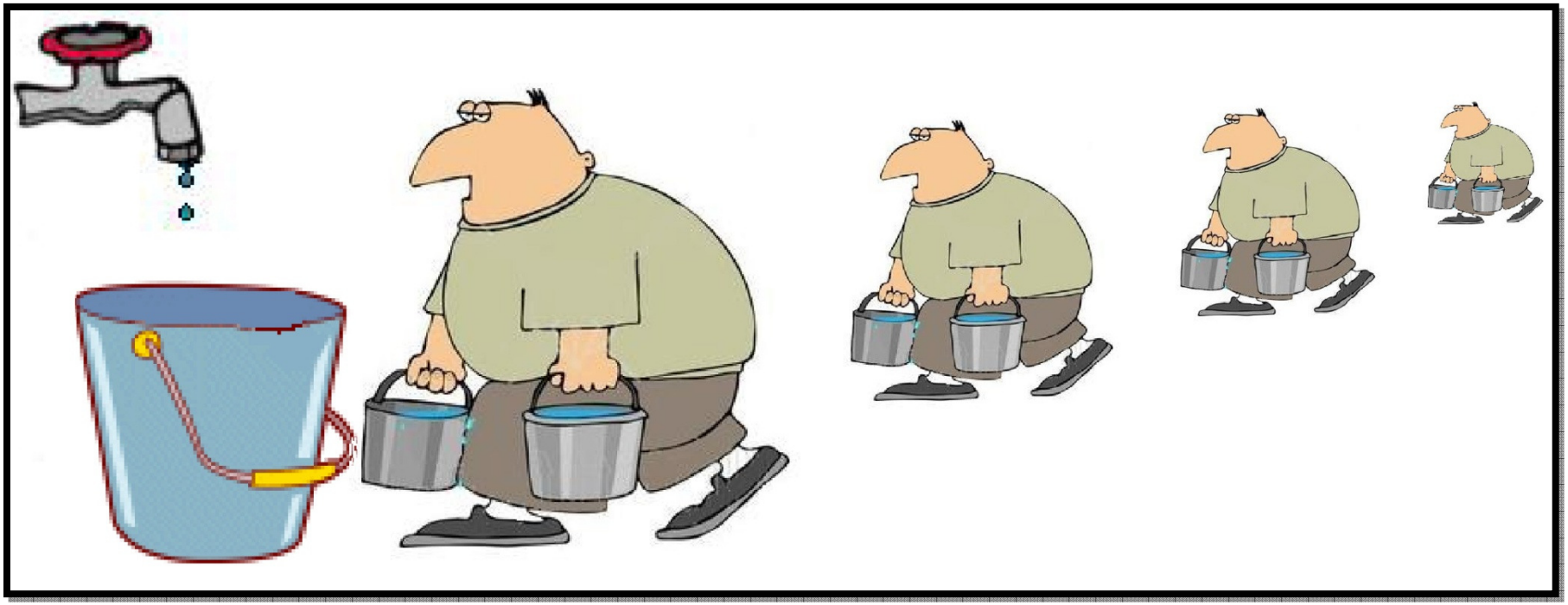
Capnography - Hypercapnia



Reduced delivery of CO2: Hypocapnia

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Capnography - Hypercapnia

- **Reduced delivery of CO_2**
  - 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

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Capnography - Hypercapnia

- **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

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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 CO_2 during the complete respiratory cycle

- The Capnogram waveforms provide a lot of information

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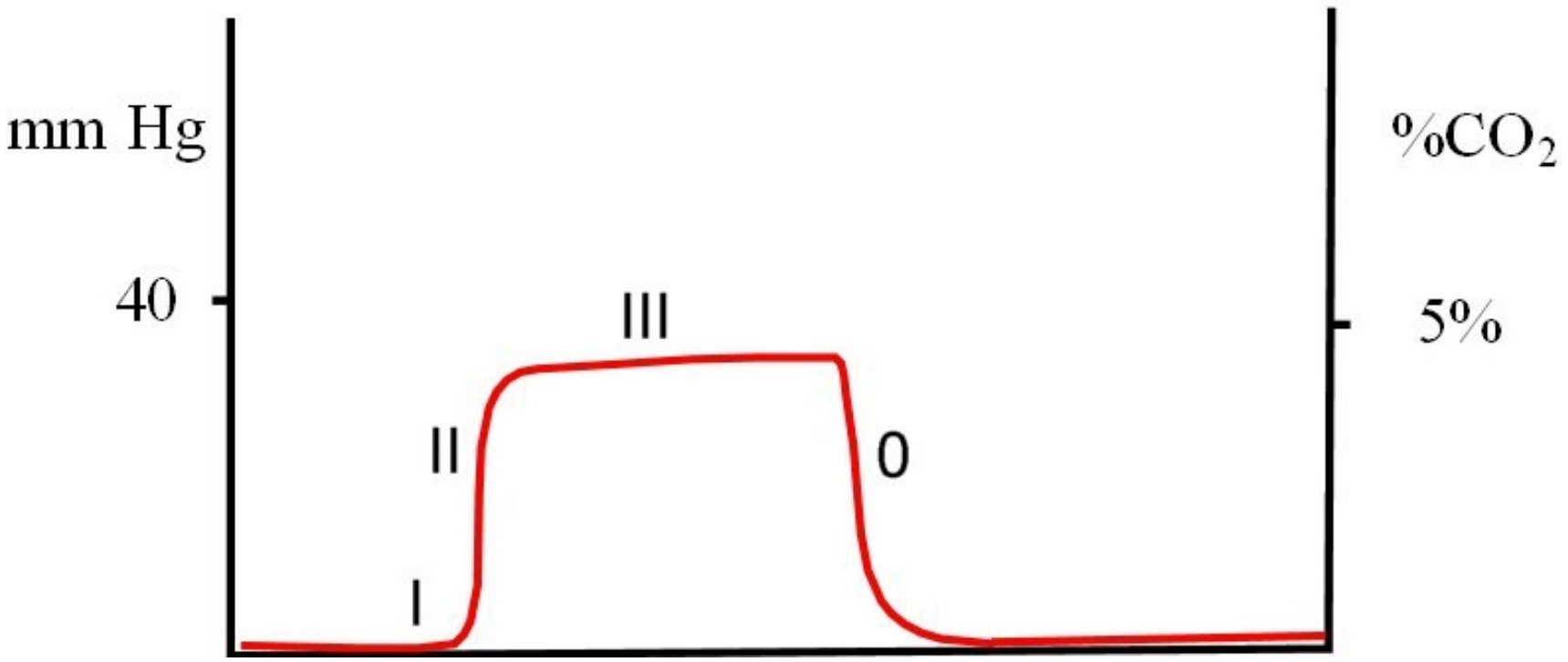
Typical Capnogram



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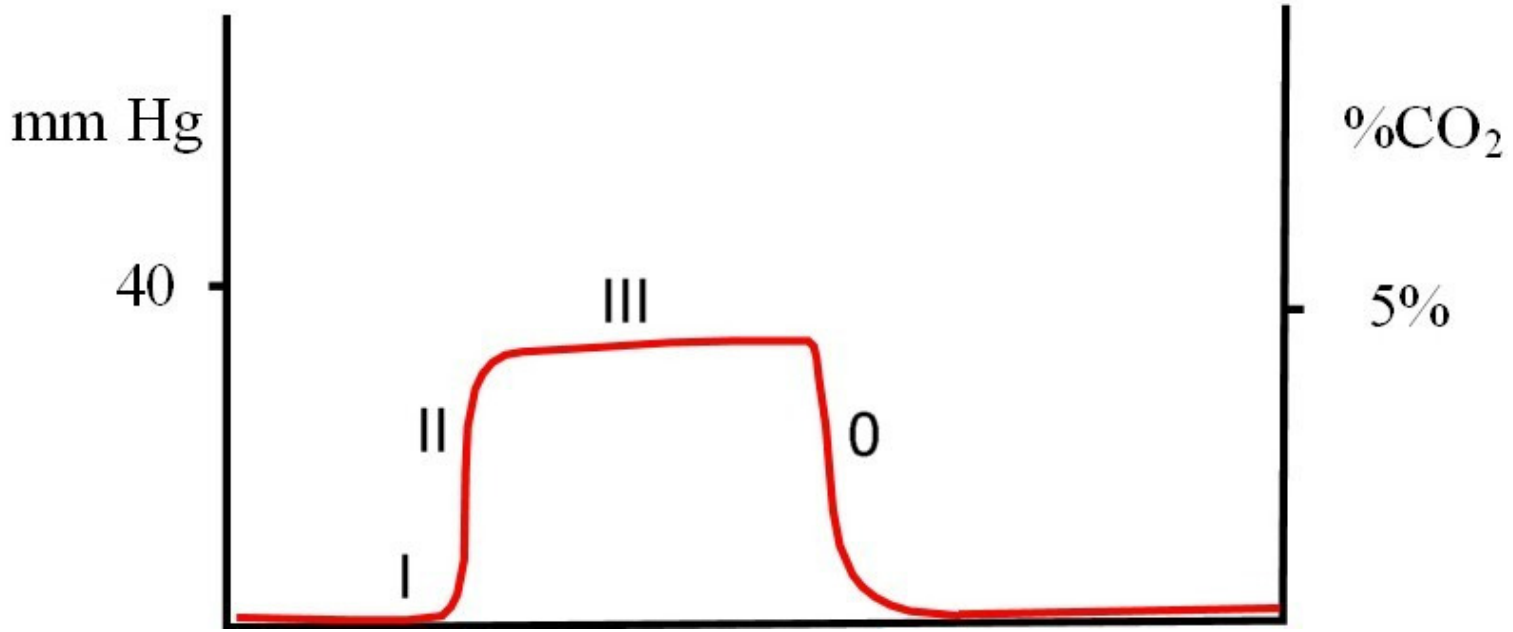
What do the different phases represent?



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

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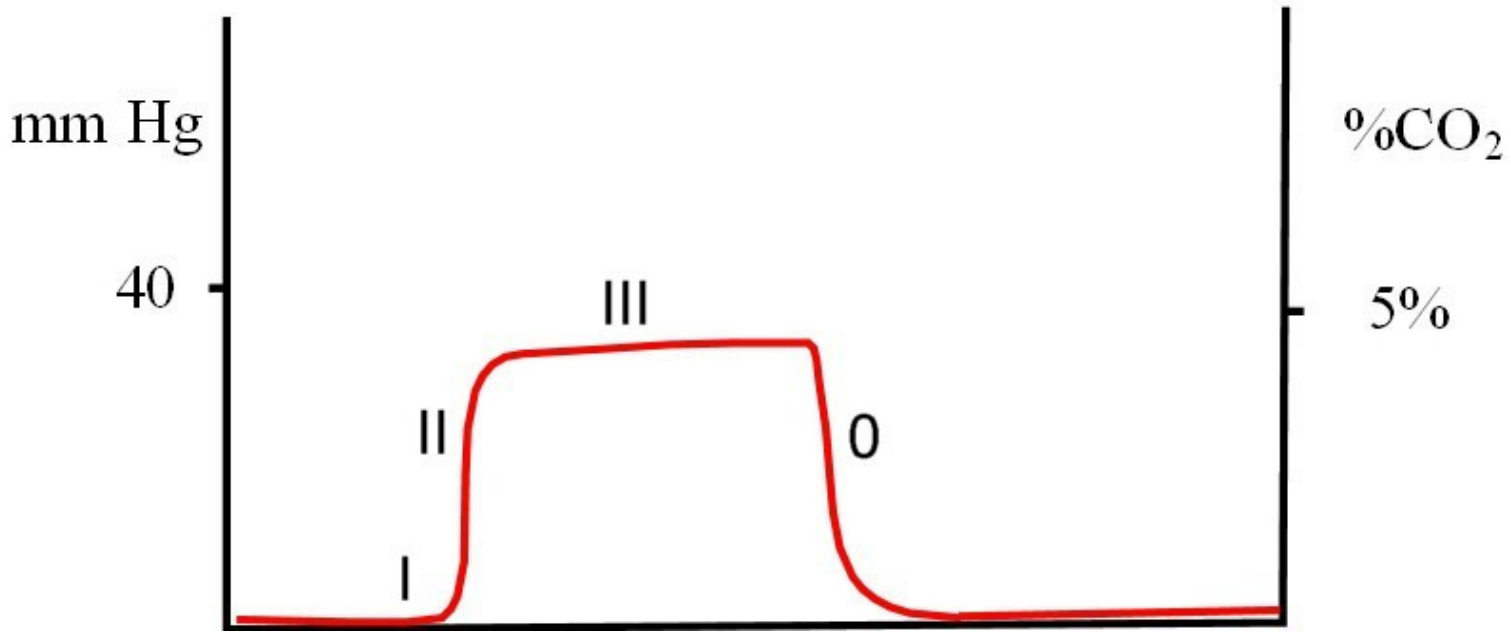
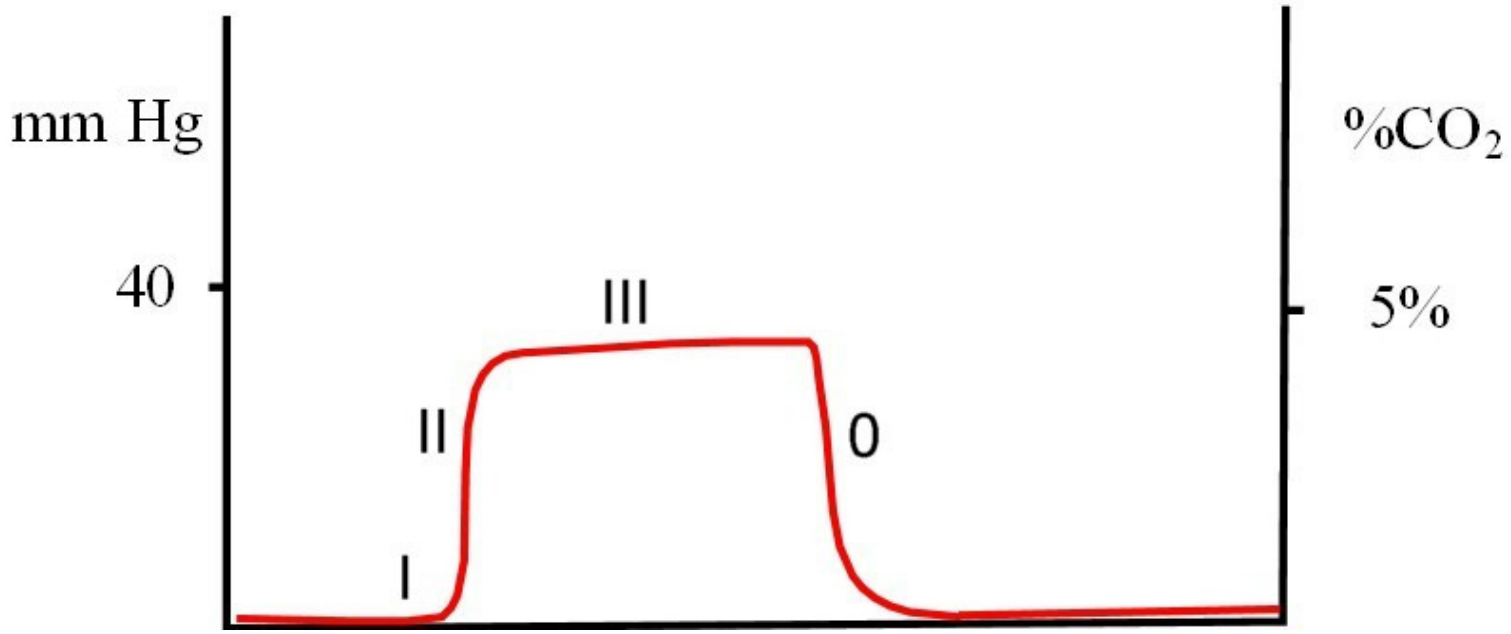
Phase I



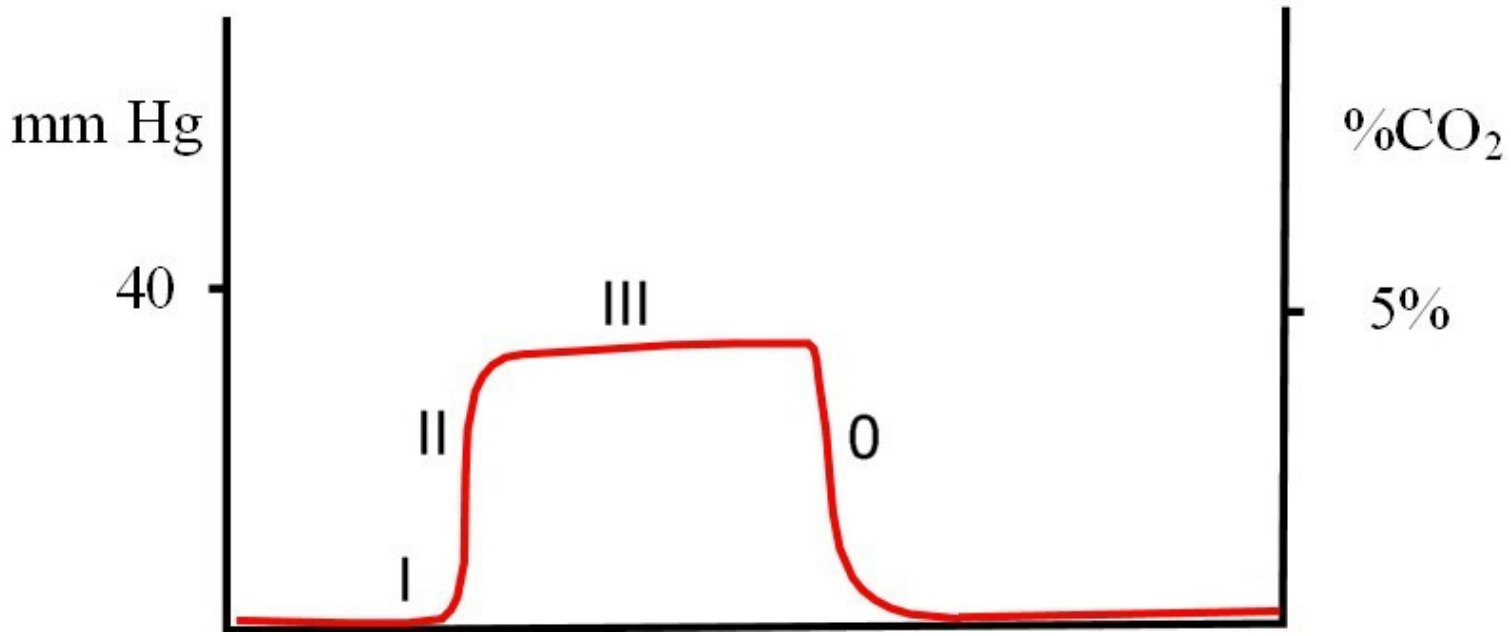
Phase I – Beginning of expiration and the elimination of gas from anatomical dead space

Phase II



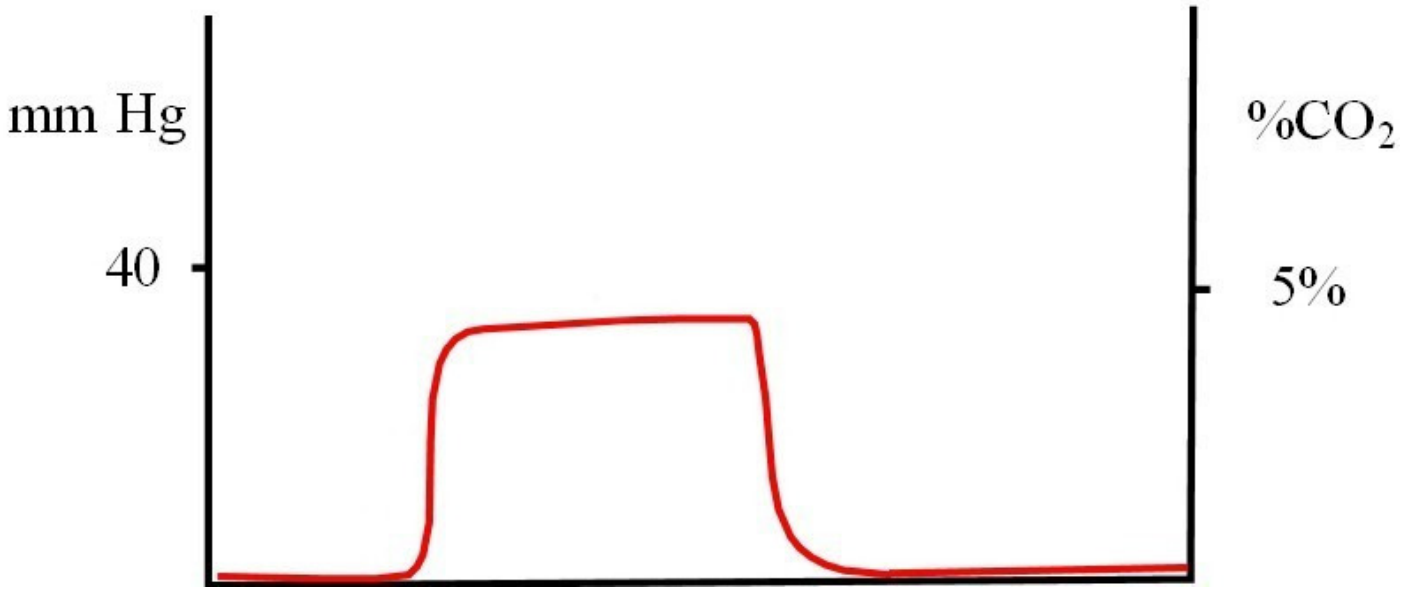
Phase II – Alveolar gas mixes with dead space

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

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Increasing End-tidal CO_2

- CO_2 delivery to the lungs exceeds removal
- Need to increase the minute volume to “blow off” more CO_2
- If animal is not on a ventilator, then start IPPV
- If animal is on a ventilator then increase the Respiratory Rate
- 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

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Capnogram 2

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

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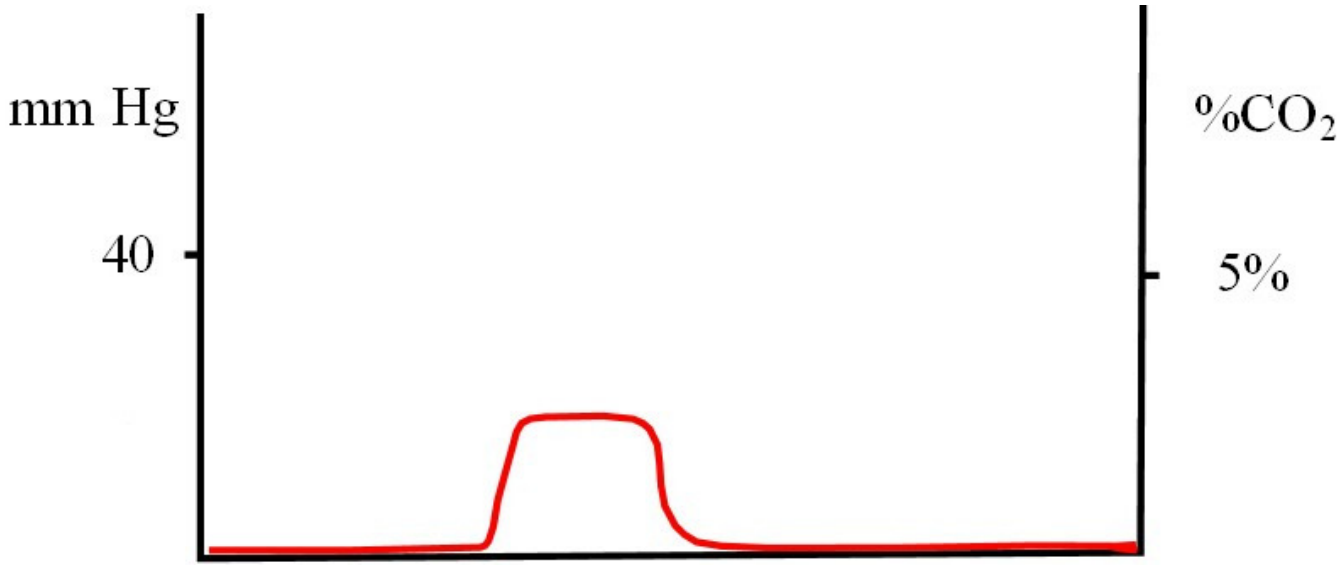
Falling End-Tidal CO_2

- 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 3



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

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Dramatic Drop in CO_2 level between 2 breaths

- Such a sudden fall in CO2 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

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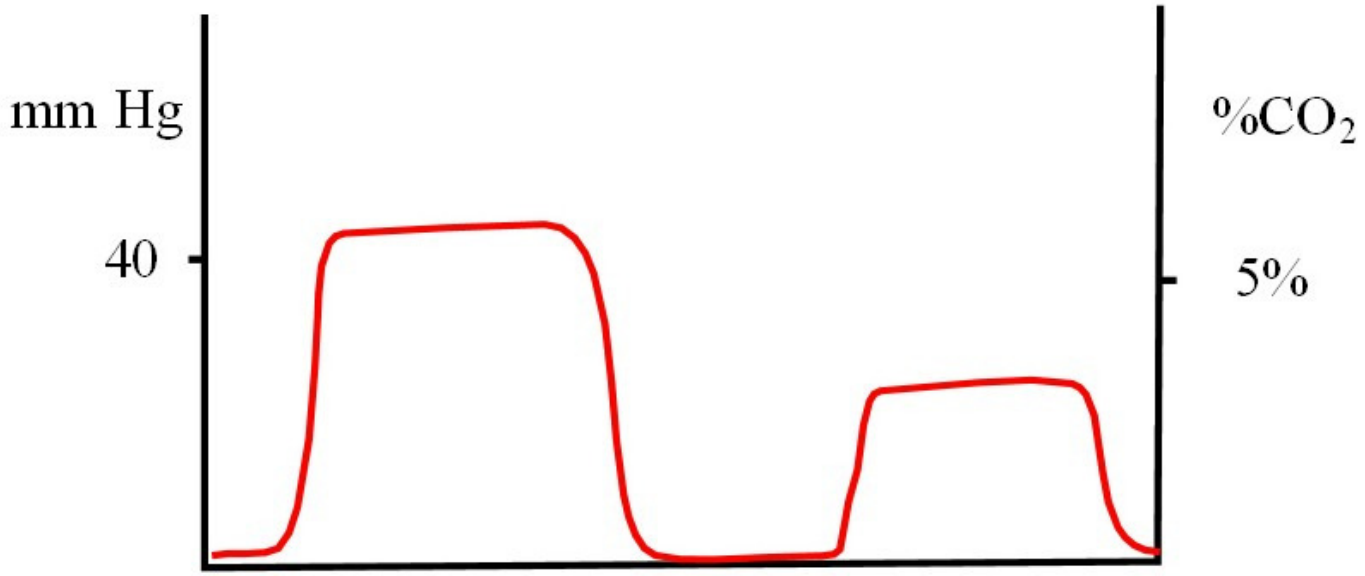
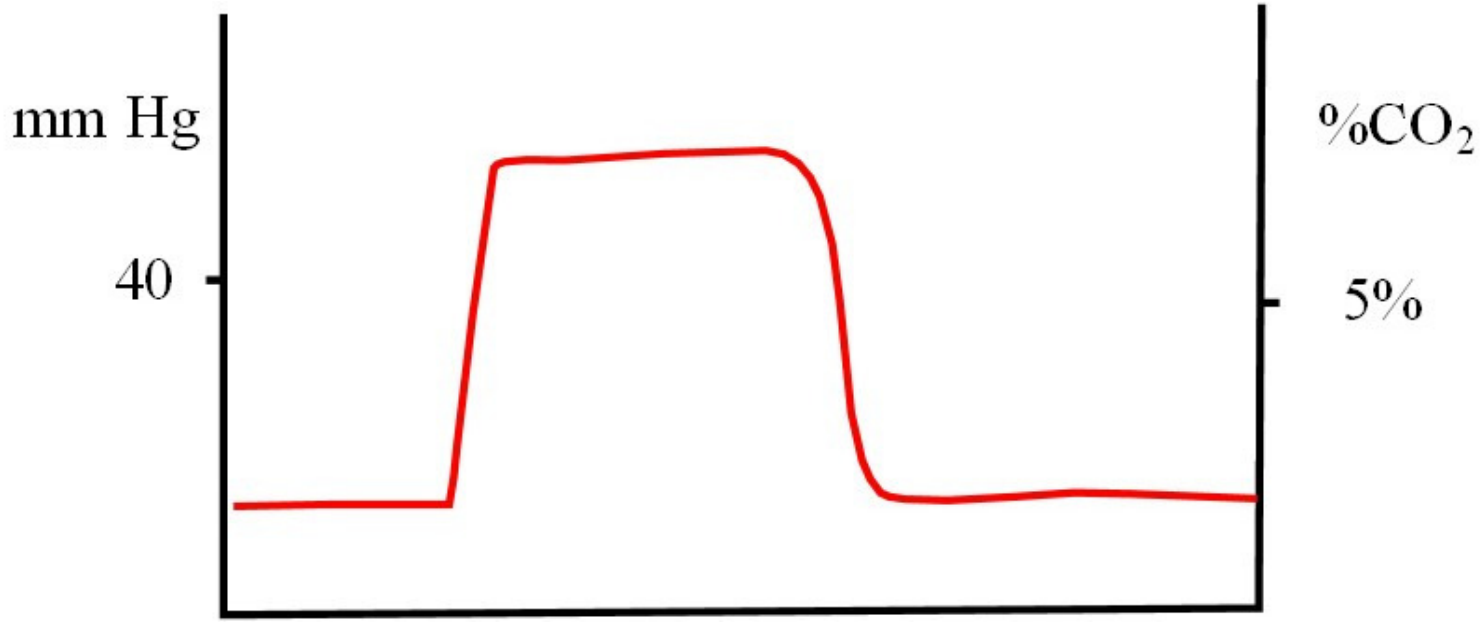
Capnogram 4



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

Capnogram 5



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

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Rebreathing

- **Live Demo on a standard Y-piece..**

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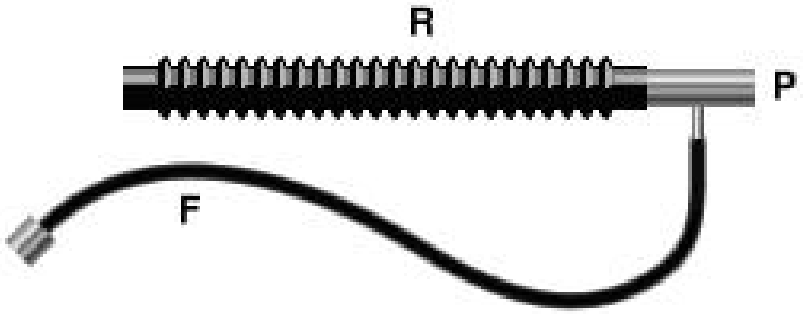
The T-piece and gas flow



The FGF must be sufficient to meet the needs of the patient during the inspiratory phase, otherwise rebreathing will occur.

It is very easy to under-estimate the FGF requirement.

How do you calculate the required FGF?

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The T-piece and gas flow

- To calculate the FGF needed for inspiration:

- Calculate the volume required in 1 second and then x 60

- e.g. 5kg cat. T.V. 50mls. Inspiratory time (IT) 1 second = 50mls/second x 60 = 3000mls/minute = 3.0L/minute

- Note that it IT is actually 0.8s: 3.75L/min

The T-piece and gas flow

- If you have a Capnograph you can use it to set the required FGF.

- Note that the FGF will vary over the course of a procedure because tidal volume will change

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Beware hand ventilation

- You must be aware of the type of anaesthetic circuit in use when hand ventilating.

- Two basic types:

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Hand Ventilation

- Re-breathing bag in supply limb e.g. Magill or Lack. High risk of re-breathing when performing IPPV

- Re-breathing bag in waste limb e.g. T-piece or Bain (modified Bain). Less risk of re-breathing during IPPV.

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Hand Ventilation

- Check the Capnograph profile during IPPV and increase FGF if there is any sign of re-breathing.

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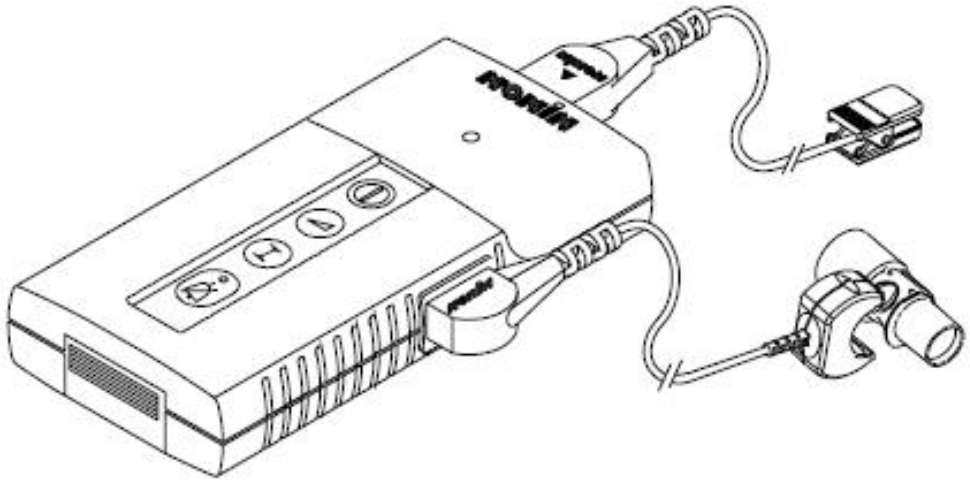
Delta Capnography – Nonin 9874V



The Model 9847V Veterinary Pulse Oximeter and Carbon Dioxide Detector

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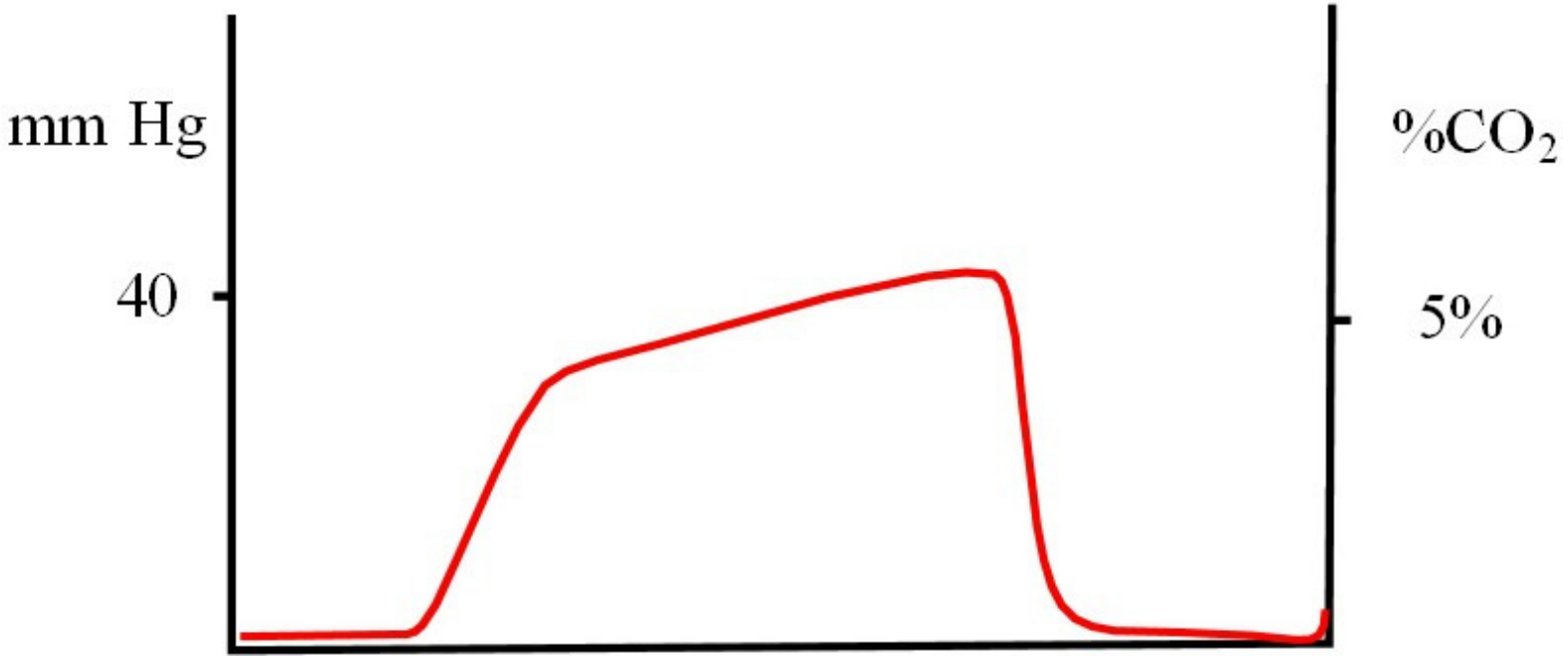
Capnogram 6



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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

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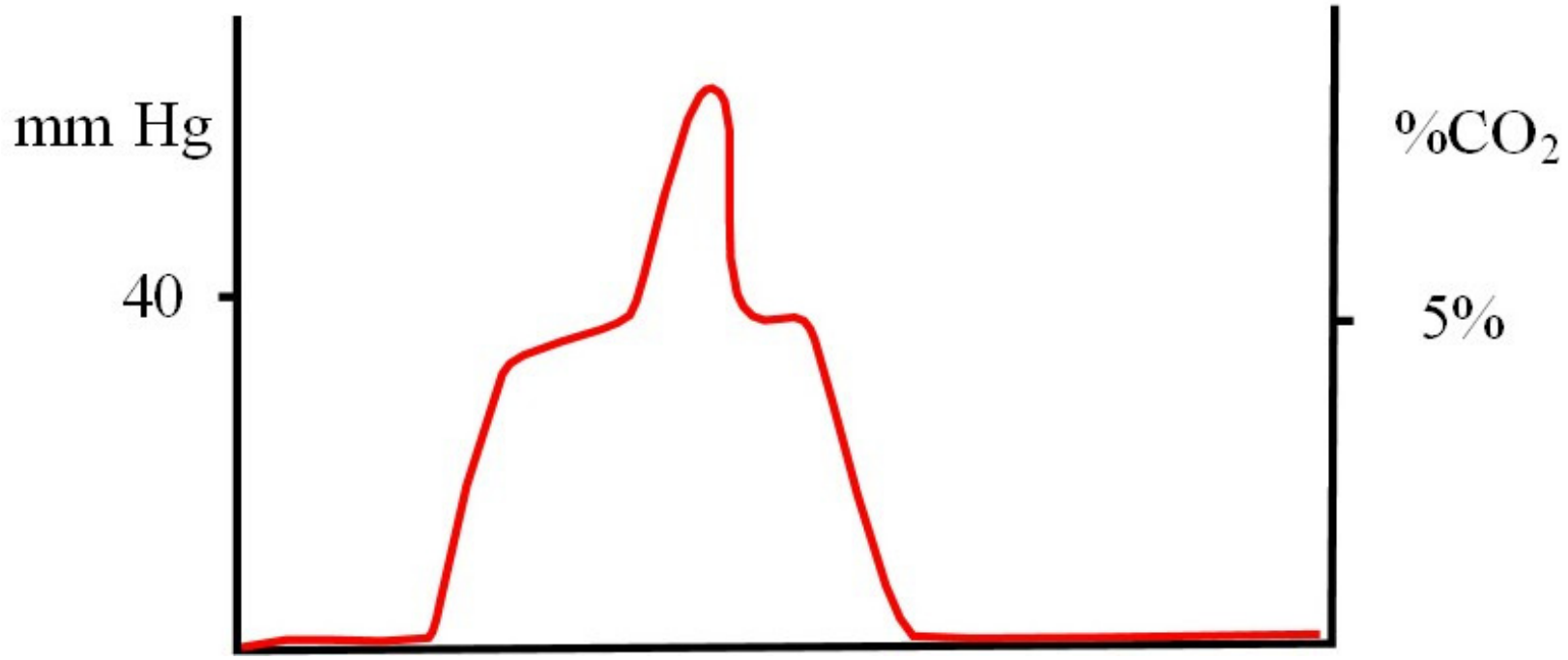
Spiked Capnogram



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Spiked Capnogram

- The spike represents an isolated pocket of high percentage CO_2 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 CO_2 output changes

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Thank-you for Listening

If you have any further issues or enquiries about Vetronic Services LTD and their products please do not hesitate to contact us on the below contact details:

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Fax: 0870 129 4705

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