



Ventilation in Zoo Animals

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Ventilation in Zoo Animals

- With such a diverse range it will be hard to generalise. Most principles can be applied across the board but there are huge differences in anatomy let alone physiology.











Ventilation in Zoo Animals

- In the following, *ventilation* is taken to mean manual (bag squeezing) or mechanical (ventilator). For the discussions on advantages, indications and dangers the two are largely indistinguishable.

Ventilation in Zoo Animals

- Why Ventilate?
- Indications for ventilation
- Dangers of ventilation
- Costs of ventilation
- How to ventilate
- Monitoring during ventilation

Why ventilate?

- Benefits of ventilation?
 - Reliable delivery of oxygen
 - Reliable delivery of agent
 - Removal of CO₂
 - Controlled anaesthesia
 - Anaesthesia-induced apnoea – dive reflex
 - Collection of data for reference (ECG, TV, RR, BP, TEMP etc)

Why Ventilate

- Delivery of oxygen – whether this is 21%, partially enriched, or 100%, ensuring that all available oxygen reaches the lungs optimises Hb saturation, avoids Hypoxaemia and hypoxia
- Delivery of agent – it takes a certain mass of agent to anaesthetise an animal. Can be breathing 2% or even 5% but if this is in 20% of lung volume, animal will not go to sleep or stay asleep

Why Ventilate

- Controlled removal of CO₂
 - To prevent Hyper or Hypo-capnia
 - To prevent acid-base imbalance
 - To prevent CO₂ narcosis (hypercapnia)
 - Blood pressure effects – cerebral vasodilation, peripheral vasodilation
 - Other effects - Sweating & tachycardia

Why Ventilate

- Controlled anaesthesia
 - Control over delivery of agent so have rapid control over depth of anaesthesia
 - Ventilation with agent will lead to rapid delivery and faster stabilisation
 - Ventilation without agent will lead to faster agent removal and more predictable recovery

Indications for ventilation

- Before anaesthesia
 - Poor SPO₂ – may be difficult but if it can be done then very helpful
 - Respiratory symptoms
 - Very young & very old and obese
 - Where rapid controlled recovery would be helpful
 - Where surgery itself will compromise respiration (chest compression)

Indications for ventilation

- During anaesthesia
 - Apnoea, hypoventilation, resp arrest
 - Dive reflex
 - Hyperventilation (light plane of anaes)
 - Hypercapnia
 - Variable depth of anaesthesia
 - Low SpO₂

Dangers of ventilation

- Inflict injury on the patient
- Removes some measures of depth of anaesthesia
- Over-ventilation

Dangers of ventilation

- Inflict injury on the patient
 - This is the biggest worry most people have
 - An inappropriate setting and the animal will blow up
 - I would equate this with learning to drive. Yes, the potential for disaster is high, it is a technically challenging thing to do and a wrong action could have severe consequences.
But as we all know the road is full of complete idiots who have apparently mastered at least the mechanics of driving. And like learning to drive, if you learn the principles and understand the consequences of your actions, you will be fine

Dangers of ventilation

- The fear of blowing animals up seems very real, so lets look at how we should approach ventilation to avoid lung damage.
- There are two main causes of lung damage during IPPV:
 - Barotrauma
 - Volutrauma

Barotrauma and Volutrauma

- Barotrauma
 - Lung damage (usually alveolar rupture) resulting from excessive alveolar transmural pressures
- Volutrauma
 - Lung damage resulting from alveolar hyperdistension
- Seemingly indistinguishable – how can you have one without the other?
- The answer lies in the compliance of the respiratory system being ventilated
- Compliance = Volume change per unit of Pressure change: $C = \Delta V / \Delta P$

Barotrauma and Volutrauma

- If a normal tidal volume is delivered to a mammalian lung in a closed, unrestricted chest then normal lung expansion and normal lung pressures will result
- If a normal tidal volume is delivered to a lung in a restricted chest (low compliance) then reduced lung expansion will occur but a very high pressure will result and so barotrauma may occur
- If a normal tidal volume is delivered to a lung in an open chest (high compliance) then excessive lung expansion will occur but only a low pressure will be reached and so volutrauma may occur

Barotrauma

- The excessive pressure leads to popping of alveoli and subsequent escape of gas from the lung causing pneumothorax, pneumomediastinum and sub-cutaneous emphysema
- The pressures required to cause this are high, typically in excess of 50cm H₂O pressure and it has not been recorded in humans at less than 30cm

Volutrauma

- The excessive distension (alveolar hyperdistension) leads to a shearing and tearing action of the alveoli along the basement membrane with resultant damage to blood vessels and inflammatory response
- Note that this can occur at relatively low pressures
- Will be seen in high-compliance lungs (large volume, small pressure change)

Barotrauma & Volutrauma – how does this relate to ventilating zoo animals?

- As described above, the possible damage inflicted depends on the compliance of the target lung
- In the animal kingdom there are basically three types of lung structure, each with different levels of compliance
 - Mammalian
 - Avian
 - Reptilian

Barotrauma & Volutrauma – how does this relate to ventilating zoo animals?

- Mammalian lungs
 - Surrounded by a chest wall and a diaphragm
 - Limited volume expansion so compliance is not too high (not excessively elastic)
 - To avoid barotrauma do not use excessive pressures
 - Volutrauma would require high pressure because lung expansion is restricted
 - Therefore BT and VT rarely seen
 - Must adjust thinking if diaphragm ruptured or chest is open as this changes (raises) the compliance markedly

Barotrauma & Volutrauma – how does this relate to ventilating zoo animals?

- Avian lungs
 - Not bounded by a diaphragm
 - Rigid alveolar structure (parabronchi) with little expansibility (low compliance)
 - Terminated by air sacs with marked expansibility (high compliance)
 - Since we are not interested in ventilating the air sacs we should look at the lung structure
 - This has a unique one-way flow system that is very efficient
 - Pressure is not required to 'open' alveoli. All that is required is to flow air through the lungs and allow it to be exhaled for efficient gas exchange. Pressure is neither required nor desirable.
 - Although I can find no reference to this it seems logical to allow some minimal air sac expansion to maintain the one-way air flow system
 - Thus minimal chest movements are required. Ventilating pressures of less than 10cm should be adequate

Barotrauma & Volutrauma – how does this relate to ventilating zoo animals?

- Reptiles/Amphibians
 - Normal alveolar structure
 - No bounding diaphragm
 - Very high compliance lungs (similar to mammalian lungs in an open chest)
 - For this reason they are susceptible to Volutrauma
 - Emphasis should be placed on moderate chest/abdominal expansion since it is only abdominal contents and their back-pressure that adds to the resistance



Costs of Mechanical Ventilation

- Financial
- Physiological
- Time
- Emotional

Costs of Ventilation

- Financial
 - Equipment costs (Mechanical)
 - Time to learn techniques (Mechanical & Manual)

Costs of Ventilation

- Physiological
 - Apart from amphibians, IPPV is not natural. The dynamics are all changed and this must have consequences at some level
 - Increase in mean intra-thoracic pressure hinders return of blood to heart – fall in preload and CO. But species without a diaphragm do not suffer from this because heart is not compartmentalised, so in birds and reptiles this is less of a concern.
 - Reduced respiratory drive – a cost or a benefit depending on your aim

Costs of Ventilation

- Time
 - Time taken to learn how to use the ventilator or master manual IPPV techniques
 - Time taken to set up ventilator for use. Increases with patient size but this is in line with the increase in preparation time for these procedures anyway. With e.g. SAVo3/Merlin the ventilator can be left in patient circuit and only used when required
 - Mechanical IPPV will free time up for a nurse, so has a positive effect on time costs

Costs of Ventilation

- Emotional
 - Listed last but possibly one of the most important factors in assessing the impact of moving to mechanical ventilators
 - There is a fear of setting an incorrect value and killing the animal instantly
 - With manual IPPV you 'know' what to do.
 - "We don't need one" "haven't needed one up until now".
I agree. We don't need a lot of things – lifts in buildings, TV remote controls but they make life easier.
 - Fear is based on the unknown and is understandable. Before starting on a live patient practice on a dummy patient to see how the machine works, what happens if I do this? Etc.

How to Ventilate

- Manual
- Mechanical

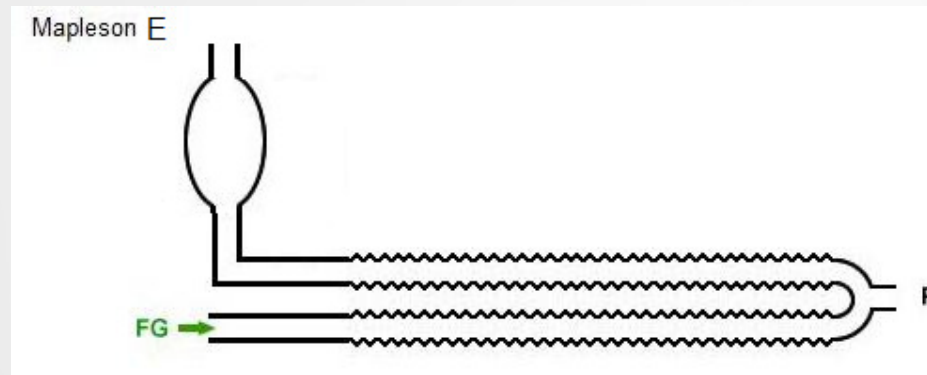
How to Ventilate

- Manual
 - Not as simple as it might appear
 - Must understand the circuit being used
 - Easy to force rebreathing – e.g Magill/Lack (bag in inspiratory limb and valve in expiratory limb)
 - T-piece : ensure FGF is high enough and will be very unlikely to get problems
 - Circle: valves prevent rebreathing

Manual Ventilation

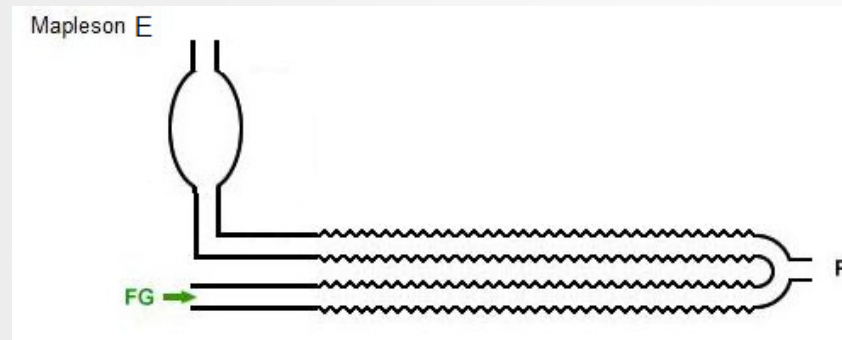
- There are 2 basic circuits to consider
 - Reservoir bag in the expiratory limb
 - Reservoir bag in the inspiratory limb
- Circle systems – these are easy because two one-way valves prevent rebreathing

Reservoir in Expiratory Circuit



- Typically seen with a T-piece or a Bain
- All gas flow is controlled by pressure
- Because of the circuit type, the FGF is typically quite high
- The FGF flushes out the waste gas
- Difficult to re-introduce waste gas

Reservoir in Expiratory Circuit

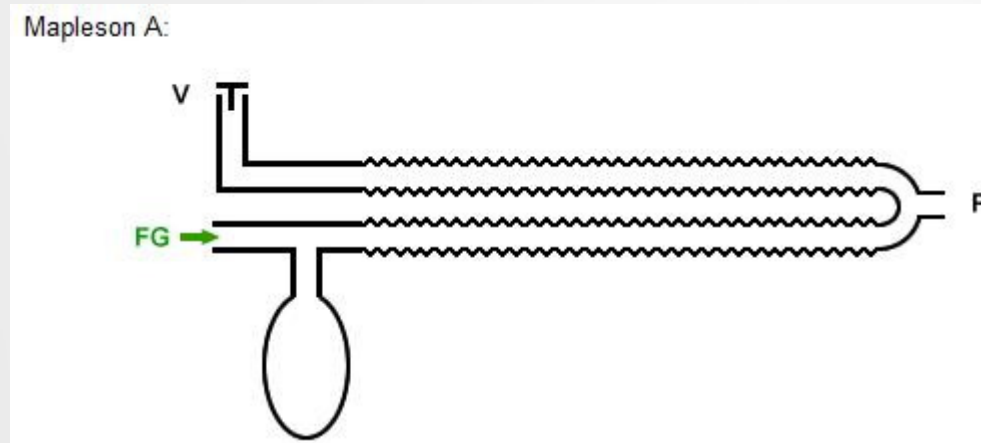


- When you occlude the bag it fills up with fresh gas
- Squeezing it forces fresh gas into the patient – both from the bag/exp limb and incoming fresh gas
- When you release the bag the patient exhales and incoming FGF ensures it goes out of expiratory limb

IPPV with a T-Piece or Bain

1. Occlude the end of the reservoir bag (T-piece) or close the valve (Bain)
2. Allow gas to fill the bag
3. Squeeze the bag to inflate the chest
4. Release bag or open valve and allow patient to exhale
5. Repeat

Reservoir in Inspiratory Circuit

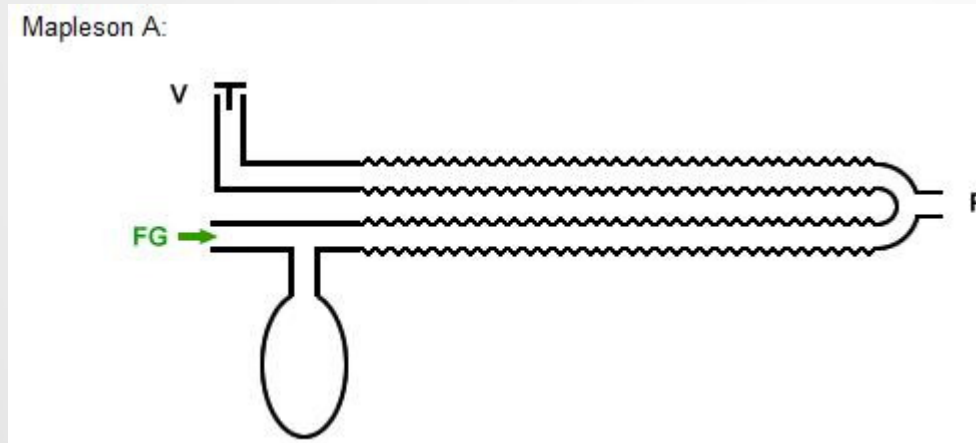


Magill or Lack (Mini-Lack) circuit

- Typically seen with a Magill or a Lack
- Gas flow is controlled by pressure and a one-way valve. Valve is always on the expiratory limb.

Reservoir in Inspiratory Circuit

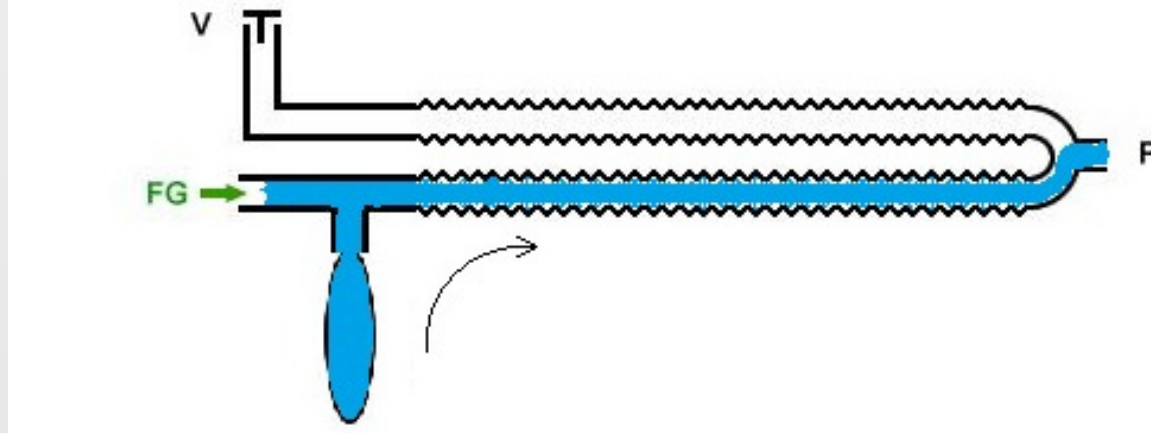
Magill or Lack (Mini-Lack) circuit



- FGF is much less than T-piece circuit
- Circuit is efficient for spontaneous breathing but **bad** for IPPV

Manual ventilation with a Lack

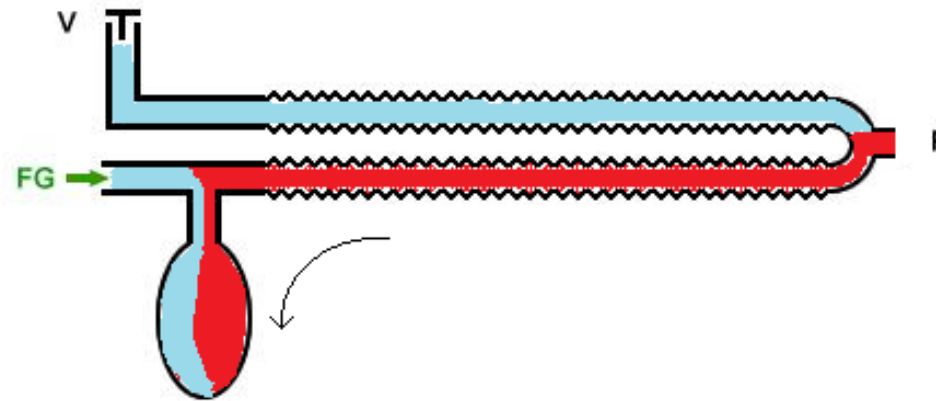
Mapleson A:



- First time you squeeze the bag – fresh gas forced in to animal.

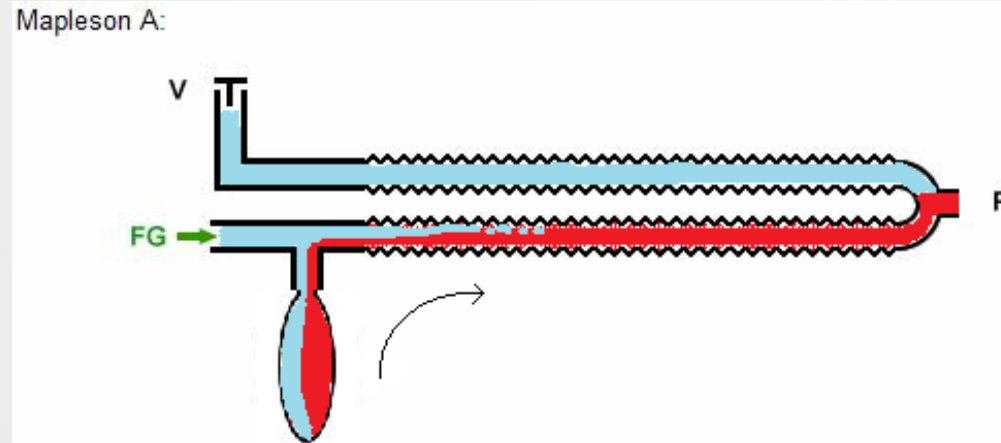
Manual ventilation with a Lack

Mapleson A:



- Then when you release the bag, waste gas preferentially goes back into bag

Manual ventilation with a Lack



- Second time you squeeze the bag, you force waste gas back into patient.
- Very easy to cause rebreathing
- Cannot be repeated at speed without rebreathing

IPPV with a Magill

- After patient has exhaled, close the valve
- Let bag fill up with fresh gas
- Squeeze the bag to inflate the chest
- Maintain the pressure on the bag and open the valve – the patient breathes out
- Close the valve and THEN release pressure on the bag
- Let the bag fill up with fresh gas....

IPPV with a circle system

- Circle system has its own valves
- If you close the exit valve it is a closed system
- Squeezing the bag forces fresh gas (no CO₂) into the patient.
- Releasing the bag allows waste gas to go to circle
- Can give IPPV several times before opening valve, squeezing bag and re-filling with fresh oxygen

Manual IPPV summary

- Much safer with a bag in the expiratory circuit such as a T-piece or Bain. Can perform faster IPPV
- When using a Lack/Magill make sure you allow exhaled gas to leave before releasing the bag
- With either system, increasing FGF will reduce chances of rebreathing
- If you are using a circle then one-way-valves ensure that rebreathing cannot occur. Close the waste valve to give IPPV. Replenish oxygen every 10 breaths

Ventilators -How to Ventilate

- There are 4 fundamental things you need to know before you can ventilate your patient

- 1) Tidal Volume
- 2) Minute Volume
- 3) Inspiratory Flow
- 4) Metabolic oxygen requirement

Knowing just these four things will allow you to set the appropriate flow rates for any ventilator

Ventilators -How to Ventilate

- Do I need a muscle relaxant?
 - No. It is possible to override the inherent spontaneous respiratory drive by stimulating two systems:
 - Lung stretch receptors
 - Respiratory centre via CO₂

Ventilators -How to Ventilate

- **Tidal Volume** = $Wt \text{ in kg} \times 10$. This gives you the tidal volume in mls. Divide by 1000 for L.
- **Minute Volume** = Tidal Volume $\times$ Resp Rate
- **Inspiratory Flow**. To calculate this you need to know Inspiratory Time, I_t .
This is not something that can be calculated but a good approximation can be made: Mouse = 0.2, cat = 0.7, medium dog = 1.0, Horse = 2.0.
Then, $\text{Insp Flow} = (TV(L) \times 60) / I_t$
- **Metabolic requirement** = 10mls/kg/min

Ventilators -How to Ventilate

- Example "Rex"

10kg Patient. Resp rate = 15. Insp Time = 1.0

$$TV = 10 \times 10 = 100\text{mls or } 0.1\text{L} = A$$

$$MV = TV \times RR = 100 \times 15 = 1500\text{mls}/1.5\text{L} = B$$

$$\text{Insp Flow} = (0.1 \times 60) / 1.0 = 6\text{L/min} = C$$

Metabolic requirement:

$$10 \times 10 = 100\text{mls/min} = D$$

Now, however you choose to ventilate this is all you need to know...

Ventilators -How to Ventilate

- Merlin on a non-rebreathing system - the FGF just needs to match the Minute Volume = B. If volume cycling, $TV = A$
- SAV₀₃/SAV₀₄ – T-piece circuit so, we must meet patient's maximum inspiratory flow, which we have calculated = C
- Merlin on a rebreathing system – just need to supply metabolic requirement = D

Ventilators -How to Ventilate

- If you are Volume cycling the TV has been calculated
- If you are Pressure cycling with e.g. SAV_{03/04} the FGF has been calculated
- If you are using a non-rebreathing circuit for ventilation the FGF is the minute volume
- If you are using a circle the FGF has been calculated

Ventilators -How to Ventilate

- Rex on SAVo₃/SAVo₄
 - FGF must match max insp flow = 6L/min
 - Set Target Pressure according to species/age
 - 10kg Mammal ~ 10-15cm H₂O
 - 10kg Bird ~ 6-9cm H₂O
 - 10kg Reptile ~ 8-10cm H₂O

Suggested values Mammals (6-20) mice – horses, Birds 6-10, reptiles/amphibians 6-15

Ventilators -How to Ventilate

- Rex on Merlin with non-rebreathing circuit
 - The FGF must match only the Minute Volume (B). Merlin will drive in the gas at the high Insp Rate required, so do not need the high FGF
 - If volume cycling set the TV to 100mls and the Insp Time to 1.0
 - If pressure cycling set the pressures as in the previous slide

Ventilators -How to Ventilate

- Rex on Merlin with rebreathing circuit
 - The FGF needs only to match the metabolic requirement = 100mls/min
 - If volume cycling set the TV to 100mls and the Insp Time to 1.0
 - If pressure cycling set the pressures as in the previous slide



Ventilators -How to Ventilate

- To make things easier use a Ready-To-Ventilate sheet before you start..

How to stop ventilating

- The aim is to return the patient to a state of spontaneous breathing at a convenient time
- Need to reduce the suppression of respiratory drive on the two main pathways – stretch receptor and CO_2
- Reduce TV by 10%-20% this will reduce stretch receptor activity and reduce MV leading to a rise in End-tidal CO_2
- Will also be dependent on the level of anaesthesia, which should be reduced

Monitoring during ventilation

- For monitoring to be effective, must be able to:
 - Understand the information from the monitor
 - Adapt the anaesthetic and/or ventilation accordingly

If neither of those are possible then monitoring is of no benefit

Monitoring during ventilation

- What can we monitor & why?
 - Lung sounds
 - Capnography
 - Oxygen saturation
 - ECG
 - Blood Pressure
 - Temperature

Monitoring during ventilation

- Lung sounds
 - Use a stethoscope to listen to the lungs during ventilation
 - Patient should be receiving full breaths
 - So there should be good lung sounds over the entire chest. If not, there could be a leaking ET tube or a postural problem
 - Listen for tracheal noise suggestive of fluid and or mucous in the ET tube or trachea

Monitoring during ventilation

- Capnography
 - Very closely tied in with Minute Volume delivery
 - Know your normals – 40mmHg or 5% or 5kPa
 - Gives information on efficiency of breathing
 - If an animal is hypercapnic then Minute Volume delivery is too low
 - If an animal is hypocapnic then Minute Volume delivery is excessive
 - For anaesthesia aim for normo/hypocapnia
 - For recovery aim for normo/hypercapnia

Monitoring during ventilation

- Pulse-Oximetry/Oxygen saturation
 - Compared to CO₂, Oxygen diffuses much less readily across the alveolar tissue and is therefore a better indicator of pulmonary problems
 - Especially useful for pre-op or immediate post-induction evaluation where hypoxaemia is a potential problem
 - Low values are an indication for oxygen supplementation and/or ventilation

Monitoring during ventilation

- ECG
 - Easy to apply. Oesophageal ECG can save a lot of time and avoid unnecessary clutter
 - Provides heart rate as well as indications of arrhythmias, heart block
 - Variations in heart rate may indicate changes in depth of anaesthesia, circulating blood volume or drugs, so care must be taken when interpreting a change in heart rate

Monitoring during ventilation

- Blood Pressure
 - Invasive is definitely more accurate than Oscillometric
 - But.. Accuracy may not be the over-riding requirement.
 - May be better to accept an approximation of the blood pressure than spend a long time trying to insert an arterial line
 - May be better just to assess the systolic value with a Doppler system and listen to (quantify?) blood flow
 - How will you respond to variations in blood pressure? Fluids, drugs, reduce volatile agent concentration?
 - Need to be prepared with fluids and drugs

Monitoring during ventilation

- Temperature
 - Will affect recovery rate
 - Especially so in cold-blooded animals
 - Difficult to increase a patient's temperature. Better to stop it falling in the first place
 - Hypothermia will lead to effects in blood distribution. Warming may then lead to redistribution and hypotension

Problems of the very small patient

- Dead space becomes a real problem
- Excessive flows in small tubes cause pressure drops that must be taken into account
- Estimation of tidal volume is unreliable so pressure-cycled ventilation is preferred- with the understanding of the type of lung structure being ventilated

Ventilating a very small patient

- Example: 50g bird. $RR = 40$, $I_t = 0.5$
 - $TV = 0.5\text{mls}$
 - $MV = 20\text{mls/min}$
 - $I_{\text{flow}} = 60\text{mls/min}$
 - $\text{Metabolic} = 0.5\text{mls/min}$
 - Use a cut down tom-cat catheter or similar
- Note the effect of excessive flow on the pressure drop along the tube and subsequent fall in patient ventilation

Ventilating a very large patient

- Requires some serious mechanical ventilation equipment and its physical size may be a problem
- Posture has a big impact on effectiveness of ventilation
- Myopathies due to recumbency must be protected against
- Shear bulk can make patient positioning difficult
- Abdominal mass/recumbency will change (reduce) lung compliance
- Manual ventilation can be extremely difficult and wearing especially in the larger animals and keeping Inspiration time short is also difficult

Summary

- Know your ventilation parameters before you start
- Use monitoring as an aid to controlling ventilation
- If manually ventilating, understand the implications of IPPV with the circuit you are using
- On balance, ventilation has positive benefits to the patient and yourself