ZEVN Talk May 2016 - Notes to PowerPoint

Key objectives:
Use Minute Volume to predict the best circuit
Understand the difference in performance between T-piece, Lack, Bain and a circle

Opener - so you've got a 12kg monkey to anaesthetise. What is your preference, a Lack a Bain, circle or a T-piece?
Why ???

At the end of this talk you will all be able to answer that question comfortably...

Fundamentally there are only 3 objectives:

Easy to breathe in
Easy to breathe out
No rebreathing of carbon dioxide - to do this you need to feed in a source of fresh gas and get rid of the expired gas.

It is all easy until you start using connectors and pipes to achieve the above

Before we start there are two fundamental facts that we must be aware of:
Expired gas has two ffactions - Dead Space Gas and Alveolar Gas
Dead Space Gas is unchanged in its composition and can be safely rebreathed.

Start:
Get a pipe and try to breathe in and out - rebreathing+++, so this approach will not work. Needs another pipe to get rid of the exhaled gas.

Two-pipe system:
No better and can see immediately what is wrong with this - both pipes are used so there is always rebreathing
Introduce a FGF down one limb - see how this improves the situation
See how the expiration pipe is only used for expiration as long as the flow of gas into the inspiration pipe is sufficient to meet the demand
Now we have a functioning T-piece but it is inefficient. If there is a pause between the end of the breath and the next inspiration then the exp pipe is full of fresh gas that I could actually use - permissive back-flow. So this is good for smaller animals where the FGF is modest because there is virtually no resistance to inspiration or expiration. But for larger animals we need really high gas flow rates which becomes difficult and wasteful.
By looking at the CO2 content using a Capnograph we can see how much the effect of MV has on rebreathing. Between each breath the CO2 in the

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expiratory pipe is removed by the FGF. If the FGF is too low it will not be removed and rebreathing will occur.
We have created a Mapleson E circuit. It has no valves, it has no need for a reservoir bag and offers virtually no resistance to breathing. Of all the circuits it is the simplest, safest and easiest for the animal to breathe through.

BUT!!! It is wasteful of gas for the large patients.
e.g. 75kg patient needs a FGF of approx 60L/min
A typical E cylinder contains 680L of oxygen. At 18L/min that will only provide about 35 minutes of supply.

The following adaptations are employed to make the circuits more efficient in terms of gas flow, since this reduces costs not only of gas but of volatile anaesthetic agents.

One way to improve efficiency is to re-use the gas that has taken no part in the gas exchange mechanism.

Maybe we could improve efficiency by putting the reservoir bag in the expiratory circuit. You can see that during inspiration gas is pulled from the bag as well as the FGF and the room air. This looks to be working much better but we need to look at what's actually happening by using a capnograph.
We could improve things further by putting a one-way valve after the bag. Now we have what looks like a T-piece but with an expiratory valve. This is called a Mapleson D (Modified Bain)
How has this helped?

During inspiration, the patient inhales fresh gas from the FGF plus gas from the expiratory limb and the reservoir bag, which deflates. During expiration the dead space gas fills the expiratory tube and the reservoir bag until they are full when the valve opens and the alveolar gas is removed. During the pause between breaths the FGF flushes out the alveolar gas so that at the beginning of inspiration the patient draws in fresh gas again. For this to happen the FGF must be sufficient and this must match the Minute Volume requirement x 2.5-3. For this to work well the bag must be full at the end of expiration and remain full during the expiratory pause while the FGF flushes out the alveolar gas. Because of the higher flow rates this circuit is better for IPPV and more forgiving if the bag is not filled during expiration. But the valve and expiratory tubing increase the work of breathing so this circuit is not suitable for the smaller animals. For animals under 10kg use a T-piece.

Maybe it would be more efficient to put the reservoir bag in the inspiratory circuit. So, now we introduce a bag in the inspiratory circuit to make it more efficient.

This bag can hold the fresh gas so that when there is demand for gas it can supply it. Why would this be more efficient? The first part of each breath contains Dead Space gas, which has the same composition as initially breathed in, so we could re-use it.
Let's add a bag and see if it helps. Not really because a lot of the expired gas goes out of the expiratory limb so we need to prevent that somehow but only initially. How do we do that? Add a lightly loaded valve at the end of the expiratory limb so that not until the bag fills up will it go out of the expiratory limb.
Much better, but now you can see the importance of the reservoir bag. We only want the first part of the breath to go down to the bag and we want the bag to help with the demand at inspiration so it needs to match your patient. Ideally the bag should be full at the end of expiration. In practice you should match the bag size to the tidal volume, so that it is at least equal to the tidal volume. For the system to work efficiently the bag should be full during, or at the end of expiration. And you should match the FGF to the Minute Volume of the patient with the adjustment of a circuit factor - 1.5 for a Mapleson type A, which is what we have here.
Why 1.5 ? That makes the circuit most efficient in terms of FGF and non-rebreathing. During the expiratory pause period, the FGF washes out the expired gas before the next inspiration.
Note that there is a slight improvement in performance between a Lack and a Magill due to the position of the valve. The siting of the valve away from the patient improves the efficiency by preserving more of the Dead Space gas.

What are the possible problems here?

- The expiratory valve trip pressure must not be too high, otherwise too much expired gas will go down to the reservoir bag and the result will be a lot of rebreathing and extra respiratory effort.
- The reservoir bag if too large and/or under-inflated too much expired gas will go down to the reservoir bag and the result will be a lot of rebreathing. (theoretically, once the bag is full it shouldn't matter but if it isn't full then it will have a large effect).
- The FGF must be high enough to ensure too much rebreathing doesn't occur.
- Emptying the bag causes no back-pressure and so rebreathing will occur until the system stabilises again. So should always flush/increase FGF after emptying the bag until bag is full again.

The above has focused on spontaneous breathing but one very important consideration when choosing a circuit is how the circuit will operate when giving manual IPPV.

Mapleson A - Magill and Lack are very poor at IPPV. A strict regime must be used to prevent rebreathing

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Mapleson D - Bain/Modified Bain. This is an efficient circuit for IPPV because the relatively high FGF prevents rebreathing and the bag in the expiratory circuit is more efficient.

The ONLY reason we need to get rid if the exhaled gas is that we can't allow it to be breathed back in because it is full of CO_2. So what if we remove all the CO_2 by passing it through some soda lime before it comes back into the inspiratory circuit again. This is a circle circuit.

Circle circuits:

For animals over 10kg and certainly over 20kg a circle circuit can be considered. This is more efficient than the previously discussed circuits but a circle circuit does have some inherent restrictions.

The work of breathing is increased because the patient has to draw gas through the circle (absorber and valve) and exhale through the circle (absorber and valve). So consider the patient. Is it weak and moribund or fit, well and strong ? If it is weak and moribund, consider using a Modified Bain instead, unless of course it is quite large (in which case the resistance is less of an issue).

Heat loss
Can be significant with non-rebreathing systems such as a T-piece. Less so with a Lack or Bain but smaller animals tend to use a T-piece and these are more susceptible to heat loss. If heat loss is an issue consider using a HME unit.

Now we know how the systems work we can make some deductions about which one to use and when.

In the exotic world I do not think economy and efficiency are paramount. More important is minimising morbidity and mortality.

For animals with a minute volume under 1L use a T-piece or Bain (not a modified Bain) CF = 2.5-3
For animals with a minute volume over 1L and less then 4L use a Lack or a Modified Bain but be aware of the implications of IPPV between the two types. (MB CF = 1.5-2, Lack CF = 1.5)
For animals with a Minute Volume over 4L a circle circuit looks more efficient and practical if a prolonged outside surgery is envisaged. The metabolic oxygen requirement is approximately 10mls/kg/min. A 20kg animal breathing 20 breaths per minute has a MV of 4L/min. If this animal was on a Lack the FGF would need to be 6L/min. If it was on a circle the FGF would only need to be 200mls/min. But you can only run it at 200mls/min once it is stable and often you need to run gas a lot faster to get anaesthetic concentration levels up so it becomes much more like 1-2L/min. In practice I suspect this is how

the system is run and it is probably better to run it like this than try and use a non-rebreathing system at higher flow rates. Running a circle like this is poor use of a circle but good safe clinical practice - the FGF is minimised, the consumption of Agent is minimised, the exhaustion of Soda Lime is minimised but it isn't exactly what the circuit was designed to do.
When using a circle system it takes time for the circuit to respond and this is known as the time constant and is the result of circuit volume divided by flow. If the circuit volume is say 3L and the FGF is 1L/min, then the time constant is 3 minutes. It will take 5 time constants (15 minutes in this case) to fully replace the gas in the system. If your patient starts to wake up you either need to give some intravenous drug or markedly increase the FGF. Of course in practice you would simply squeeze out the bag and turn op the FGF to speed things along but in any event this circuit will not react quickly to changes in agent concentration.

Now that we understand all that let's collate this all together into some sort of decision tree:

Remember the ease of breathing through these systems is in the order:

T-piece
Lack/Bain
Circle

Assess your patient to obtain its respiratory rate and body weight
Calculate the patients Minute Volume (MV = RR x Wt(kg))

Healthy fit patient:
If the MV is less than 1L --> T-piece
If the MV is more than 1L but less then 4L use a Lack (Mini or standard) or a Modified Bain
If the MV is more than 4L consider a circle system

Now consider these modifying factors:

- Patient is weak/moribund: use a circuit which fits the criteria above but look at the circuit below it on the scale. It may be better to use a T-piece with some extra wasted gas rather than the slightly more complex 'valve' circuits which increase the work of breathing and risk rebreathing
- Patient may need IPPV. If the patient is suited to a Modified Bain/Lack, opt for a Modified Bain as inappropriate IPPV is less likely
- Procedure may be lengthy and 'outside'. Consider a circle if the patient size permits, as less gas is required

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