LINNAEUS
SUSTAINABILITY

We go for lower flow

Date issued: 19 April 2022

Lower flow anaesthesia for sustainability

The benefits of lower flow anaesthesia for efficiency, increasing airway humidity and reducing patient cooling and are understood, but we are increasingly aware of the impact of volatile anaesthetic agents as greenhouse gases. Higher fresh gas flows will vaporise (and release more gases after scavenging to the atmosphere) proportionately more anaesthetic agents. For example, one hour of isoflurane anaesthesia in a dog is equivalent to driving 12 miles in an average European car (if using 1.3% isoflurane delivered in 1L/min oxygen: Jones & West 2019). Veterinary professionals using anaesthetic agents should therefore show responsible stewardship of these drugs. These guidelines will help you to conserve volatile anaesthetic agent whilst performing general anaesthesia in animals.

These best-practice guidelines are intended for use by qualified veterinary professionals and should not replace clinical decision-making or discretion. Alterations to veterinary anaesthetic protocols should be overseen by a qualified veterinary surgeon working within their competency.

Key Points:

1. Avoid prolonged or unnecessary anaesthesia
2. Manage your anaesthetic to conserve fresh gas flow (FGF)
3. Use circle breathing systems in animals over 5-10kg
4. Use non-rebreathing systems and capnography to reduce FGF in animals under 5-10kg

Avoid prolonged or unnecessary anaesthesia

- Only use general anaesthesia where necessary; consider sedation where suitable
- Rather than one longer anaesthetic, consider separate sedations for diagnostic procedures, and then general anaesthesia for surgery alone
- Be efficient in managing workflow while the animal is anaesthetised
    - prepare equipment for cases
    - ensure the appropriate people are ready for smooth and timely case management without delays
    - facilitate prompt decision making where possible

Manage your anaesthetic to conserve fresh gas flow

Drugs and techniques which allow reduction in volatile agent use

- Reviewing sedative, premedication and analgesic drugs may allow reduction of the amount of oxygen and volatile anaesthetic agent required to maintain a stable depth of anaesthesia. Consider contraindications to any drugs before use, and consult an ECVAA Diplomate in Veterinary Anaesthesia and Analgesia for more advice if needed
- Regional anaesthesia (e.g. epidural anaesthesia for hindlimb surgeries or local anaesthetic blocks for dental procedures) can be used if available and if you are familiar with a safe technique, but not at the expense of substantially increasing the length of anaesthesia. Decide on a maximum time for nerve blocks/epidurals e.g. 10 minutes

Equipment maintenance and checking

- Regularly service your anaesthetic machine and leak test your machine and breathing systems. Ensure there are no leaks resulting from inadequate endotracheal tube cuff inflation or cracks in capnograph (or gas sampling) lines
- Use stoppers/bungs on the patient end of the breathing system after disconnection from the patient. These preserve oxygen and volatile agent in the breathing system, and prevent anaesthetic gases contaminating the room

Use circle breathing systems in animals over 5-10kg

Lower flow and circle basics

- Animals under anaesthesia require only ~10ml/kg/min of oxygen for cellular metabolism. We commonly supply more than this for the following reasons:
    - to speed up changes in the depth of volatile agent anaesthesia
    - to de-nitrogenate the body at the start of anaesthesia
    - as some rotameters and vaporisers are not accurate or calibrated for FGF below 1 L/minute
    - and for non-rebreathing systems only; to remove exhaled carbon dioxide from the breathing system during the expiratory pause of the breathing cycle
- When we are using circle breathing systems (soda-lime or carbon-dioxide absorbent containing) in animals over 5-10kg, under most circumstances we can reduce the FGF to 1L/min once a stable depth of anaesthesia is achieved (see details of use below)
- Patients over 5-10kg, including some cats, can usually tolerate the extra resistance to breathing due to the valves and soda lime in the circle breathing systems, depending on the system in use. Please check the manufacturer's recommendations or talk to a Linnaeus Specialist Anaesthetist if unsure.
- At lower FGF through a circle breathing system, (after breathing system) you may see accidental inadequate depth of anaesthesia, and unstable depths of anaesthesia. This is because the concentration of inspired anaesthetic agent being delivered with the FGF can be diluted by the

circulating mix of gases from the breathing system and patient's body (the 'dilution effect'). As a result of this dilution effect, changing the anaesthetic depth at lower FGF will take more time

Equipment required

- A circle breathing system with leak testing of the anaesthetic machine and breathing system before anaesthesia. Appropriate-sized reservoir (or rebreathing) bags and paediatric hosing should be used for animals under 10 kgs. Also ensure there are no leaks resulting from inadequate endotracheal tube cuff inflation or cracks in the capnograph (or gas sampling) lines. Pre-anaesthetic safety checklists should be used to increase compliance.
- Capnography is recommended to monitor for equipment faults such as valve defects and soda lime exhaustion, or for patient factors such as hypoventilation (see capnography resources). The gas sample rate for most side-stream capnographs is 250 ml/minute, which should be added to the FGF if used
- Monitoring the fraction of inspired oxygen (FiO_2) is recommended, and the FiO_2 should always be over 30% under general anaesthesia. Delivery of a hypoxic mix is unlikely at FGF of 1 L/minute and over, unless gases other than oxygen are delivered, or the equipment is faulty. If FGF is less than 1L/minute, FiO_2 should be monitored

Monitoring anaesthetic depth

- Careful monitoring of anaesthetic depth – be aware of the dilution effect
- Check the rebreathing bag – it should always contain enough gas for your patient to breathe in without any risk of collapsing the bag, and the APL valve should be sufficiently open to prevent distension of the rebreathing bag

How to use lower FGF with a circle breathing system:

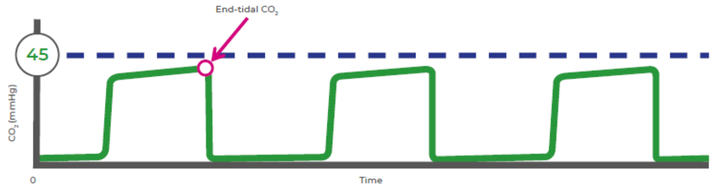
- **Start of anaesthesia or when moving to a new breathing system:** Set the FGF to 2 L/minute for 5-10 minutes with a higher vaporiser setting (e.g. isoflurane vaporiser 2-2.5%) to prime and fill the breathing system and patient
- **Maintenance of anaesthesia:** Reduce the FGF to 1 L/minute if the anaesthetic depth is stable; bear in mind that the vaporiser setting will need to be higher than when using higher FGF. Always monitor depth of anaesthesia carefully when using lower FGF and have sufficient injectable anaesthetic agent ready to administer via an intravenous catheter.
- **End of anaesthesia:** Set the FGF to 2 L/minute for 5 minutes and empty the rebreathing bag
- **To change the depth of anaesthesia rapidly**
    - Consider using propofol boluses e.g. increments of 20% of the anaesthetic induction dose used, or boluses of a sedative or analgesic drug. Ensure pain relief is adequate, and repeated during anaesthesia if required
    - Increase to 2 L/minute and increase vaporiser concentration for 5 minutes
    - Then reduce FGF back to 1 L/minute but with a higher vaporiser setting than previously
    - Empty the rebreathing bag when changing depth (only if needed; avoid venting waste gases if possible)

Use non-breathing systems and capnography to reduce FGF in animals under 5-10kg

- **Non-rebreathing system basics**
  - Patients under 5-10kg usually breathe more easily with lower resistance (non-rebreathing) systems
  - A higher FGF is needed with non-rebreathing systems (which have no soda lime) to prevent rebreathing of carbon dioxide by flushing exhaled carbon dioxide from the breathing system during the expiratory pause

- **Choose lower flow non-rebreathing systems for animals under 5-10kg during spontaneous ventilation**
  - A Mini-Lack or Lack breathing system (Mapleson A systems; FGF ≈ 200 ml/kg/minute) will require lower fresh gas flows to prevent rebreathing of carbon dioxide than a Bain or T-piece breathing system (Mapleson D, E or F systems; FGF ≈ 500ml/kg/minute).
  - The Mini-lack and Lack are not suitable systems for providing sustained periods of positive pressure ventilation
  - Circle breathing systems should be used for patients over 5-10kg; non-rebreathing systems such as Bain or Lack breathing systems are not recommended due to the high FGF which they require in larger patients.
  - Make sure that you are using systems with pressure relief valves for safety

- **Use the minimum FGF for your patient**
  - Use the minimum FGF for your patient
  - For non-rebreathing systems, FGF rates are either calculated as a multiple of average minute ventilation, or can be judged using a capnograph
  - If a capnograph is NOT available, calculate your minute ventilation based on the weight of your patient and the breathing system you are using (see calculations above)
  - If a capnograph IS available, you can use your capnograph to just prevent rebreathing of carbon dioxide (see figures A and B). This is easily detected using the capnography trace. This is easily detected using the capnography trace; decrease the FGF until rebreathing of CO_2 is detected by an increase in the $FiCO_2$, or an elevation of the trace from the baseline during inspiration. Then, increase the FGF until this rebreathing is eliminated.
  - The flow required to prevent rebreathing may vary during the course of the anaesthetic, as the patient changes their ventilation rates and depth.
  - Other potential causes of rebreathing of exhaled carbon dioxide include; exhausted soda lime and faulty rebreathing system valves (for rebreathing systems only), and excessive equipment dead space (for both rebreathing and non-rebreathing systems)



A. Normal capnogram. The end-tidal CO_2 should be between 35 – 45 mmHg.

B. Capnogram showing rebreathing of carbon dioxide. Note that the inspired CO_2 is increased; $ETCO_2$ may be normal initially, but will rise with time and increasing inspired CO_2 concentrations

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