Reducing oxygen use during general anaesthesia

These guidelines will help you to conserve this precious resource by safely minimising the oxygen and volatile anaesthetic agent you use in animals.

Key Points to Conserve Oxygen:

1. **Reduce the duration of anaesthesia**

2. **Use oxygen generators for supplemental oxygen where available**

3. **Use less oxygen during general anaesthesia and sedation**
    a. **Only provide oxygen to sedated patients if clinically indicated**
    b. **Only pre-oxygenate animals before general anaesthesia if clinically indicated**
    c. **Manage your anaesthetic to conserve oxygen**
    d. **In animals >10kg, use circle breathing systems with lower fresh gas flows (FGF)**
    e. **In animals <10kg, when using non-rebreathing systems, use capnography to titrate the FGF and just prevent rebreathing of carbon dioxide**

1. Reduce the duration of anaesthesia

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

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2. Use oxygen generators for supplemental oxygen where available

- Oxygen generators should be used in preference to compressed oxygen supplies for longer-term provision of oxygen, in particular for critically ill patients under intensive care, in incubators, or during recovery from anaesthesia
- Using electric power, these can provide up to 5 L/minute of 95% oxygen
- The machines can be noisy, and are not appropriate for use with most modern anaesthetic machines
- Humidified oxygen can be provided by attaching bubble humidifier bottles

3. Use less oxygen during general anaesthesia and sedation

a. Only provide oxygen to sedated patients if clinically indicated

- Provide oxygen only if clinically indicated or deeply sedated
- If a pulse oximeter reliably reads SpO_2 over 95% when breathing room air, supplemental oxygen may not be required

b. Only pre-oxygenate animals before general anaesthesia if clinically indicated

- Pre-oxygenation is indicated in patients at risk of hypoxaemia, or prolonged periods of apnoea e.g. deeply sedated patients prior to anaesthesia, patients with impaired cardiorespiratory systems, critically ill patients, BOAS patients
- Pre-oxygenation is most effective when using a facemask (without the rubber seal is adequate and better tolerated) for a period of 3 minutes directly before inducing anaesthesia. The oxygen flow should be sufficient to prevent rebreathing of carbon dioxide (2 – 4L/minute by face mask should be adequate for most veterinary patients)
- If used as 'flow-by', pre-oxygenation is unlikely to increase inspired oxygen concentrations significantly

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c. Manage your anaesthetic to conserve oxygen

- Do not turn on oxygen until the breathing system is attached to the patient
- Use of additional sedative and analgesic agents (e.g. medetomidine boluses or ketamine infusions) will reduce the amount of oxygen and volatile anaesthetic agent required to maintain a stable depth of anaesthesia. Consider contraindications to any drugs before use
- Regional anaesthesia (e.g. epidural anaesthesia for hindlimb fracture repairs) can be used if available and if you are familiar with a safe technique, but not at the expense of increasing the length of anaesthesia. Allow a maximum of 10 minutes for nerve blocks/epidurals
- It is not desirable to reduce use of oxygen by adding nitrous oxide to the anaesthetic protocol; this is due to its extremely potent greenhouse gas effects and the risk of a hypoxic mixture being delivered
- If clinically possible, minimise the use of ventilators which are powered by compressed oxygen supplies
- If your anaesthetic machines have an anti-hypoxic /residual flow system, remember to turn the anaesthetic machine OFF after the patient is disconnected, to stop wastage from the 'residual' flow
- Use stoppers/bungs on the patient end of the breathing system after disconnection from the patient. This preserves oxygen and volatile agent in the system, and prevents anaesthetic gases contaminating the room

d. In animals >10kg, use circle breathing systems with lower FGF

Lower flow and circle basics:

- Animals under anaesthesia require only ~10 ml/kg/min of oxygen for cellular metabolism. We 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
  - some rotameters and vaporisers are not accurate or calibrated for FGF below 1 L/minute
  - 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 containing) in animals over 10kg, under most circumstances we can **reduce the FGF to 1 L/min** once a stable depth of anaesthesia is achieved (see details of use below). Patients over 10kg can usually tolerate the extra resistance to breathing due to the valves and soda lime in circle breathing systems
- At lower FGF through a circle breathing system, the concentration of inspired anaesthetic agent (being delivered with the FGF) can be diluted by, and therefore very different to, the re-circulated concentration of anaesthetic agent in the patient's body and in the breathing system (the '*dilution effect*'). In addition, changing the anaesthetic depth will take more time. These factors may result in accidental light anaesthesia, and unstable depths of anaesthesia

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d. In animals >10kg, use circle breathing systems with lower FGF *continued*…

Equipment required:

- A circle breathing system; check the anaesthetic machine and breathing system for leaks before anaesthesia. Also ensure there are no leaks resulting from inadequate endotracheal tube cuff inflation or cracks in the capnograph (or gas sampling) lines
- 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 capnographs is 250 ml/minute, which should be added to the FGF if used
- If you have FiO_2 monitoring, the FiO_2 should be over 30% at all times 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 1 L/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 it should never be distended

How to use lower oxygen flows with a circle breathing system:

START: Set the FGF to 2 L/minute for 5-10 minutes with higher vaporiser setting (e.g. isoflurane vaporiser 2-2.5%) to prime and fill the breathing system and patient. If you can monitor anaesthetic agents, aim for an initial end-tidal isoflurane concentration of ~1.1% (dog) - 1.3% (cat) and end-tidal sevoflurane concentration of ~2.1% (dog) – 2.3% (cat)

MAINTENANCE: Reduce the FGF 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. Monitor depth of anaesthesia carefully when using lower FGF

END: Set the FGF to 2 L/minute for 5 minutes, particularly if nitrous oxide is used (to prevent diffusion hypoxia)

TO CHANGE THE DEPTH OF ANAESTHESIA RAPIDLY:

- Consider using propofol boluses e.g. increments of 20% of the anaesthetic induction dose used, or fentanyl boluses. 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 bag when changing depth (but only if needed, avoid if possible as this is wasteful)

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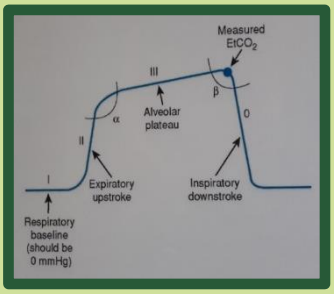
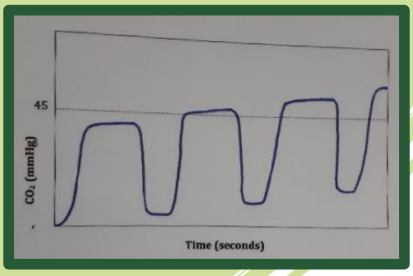
e. In animals <10kg, when using non-rebreathing systems, use capnography to titrate the FGF and just prevent rebreathing of carbon dioxide

- Patients under 10kg usually breathe more easily with lower resistance (non-rebreathing) systems
- We use a FGF far higher than 1 L/minute with non-rebreathing systems (i.e. no soda lime) to flush exhaled carbon dioxide from the breathing system during the expiratory pause
- For these non-rebreathing systems, FGF rates are calculated as a "*circuit factor (1-2.5) X minute ventilation (~200 ml/kg/minute)*"
  - If a capnograph is not available, calculate your minute ventilation based on the weight of your patient and the breathing system you are using e.g. T-piece ≈ 500ml/kg/minute and mini-lack ≈ 200ml/kg/minute
  - For moving animations to explain the gas flow during the respiratory cycle, see here https://www.frca.co.uk/SectionContents.aspx?sectionid=149

- For patients under 10kg and during spontaneous ventilation, a mini-lack or lack breathing system (circuit factor ~1) will require lower FGF to prevent rebreathing of carbon dioxide than a Bain or T-piece breathing system (circuit factor ~2.5). However, the limitations of these systems should be appreciated e.g. the Mini-lack and Lack are not suitable systems for providing sustained periods of positive pressure ventilation, and you should make sure that you are using systems with pressure relief valves for safety
- For patients over 10kg, avoid using Bain or Lack breathing systems; these systems use very high flow rates, and can be replaced by circle breathing systems
- **You can use your capnograph to just prevent rebreathing of carbon dioxide**. This will reduce oxygen FGF to the safest minimum (for more information, see capnography resources on Teams)
- The flow required to prevent rebreathing may vary during the course of the anaesthetic, as the patient changes their ventilation rates and depths. This is easily detected using the capnography trace.
- 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.

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Further resources

- **Live Q & A session** on Tuesday 7th April at 14:00 with Sarah Gibson, RCVS Specialist in Anaesthesia and Analgesia – to book, contact Chloe Roberts (Linnaeus Clinical & Education Development Manager) or Becky Timmons (Referral Relations Manager, Davies Veterinary Specialists)
- **Low Flow Anaesthesia webinar** (accessible in the Linnaeus Webinar series on Teams)
- **Reducing oxygen use blog** **https://vetspecialists.co.uk/blog-post/reducing-anaesthetic-gas-for-environmental-benefit**
- Jones, RS & West, E (2019) Environmental Sustainability in Veterinary Anaesthesia. Veterinary Anaesthesia and Analgesia 46 (4) 409-420, and the accompanying podcast
- **Dealing with isoflurane shortages** blogs:
  - **https://ava.eu.com/managing-the-isoflurane-shortage/**
  - **https://www.bsava.com/News/ArticleID/2535/Isoflurane-supply**
- **Contact for further information**: Chloe Roberts (Linnaeus Clinical & Education Development Manager)

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