The challenges of small animal veterinary anaesthesia in 2020

Veterinary anaesthesia may be facing new challenges during the COVID-19 pandemic, with the potential for shortages of cylinders of oxygen and some drugs in veterinary practice if resources are diverted to the NHS. This article prepares the veterinary surgeon in the event of such shortages, and discusses how to safely limit the use of oxygen in practice as well as the use of alfaxalone as an alternative induction and maintenance agent to propofol. Finally, the use of ephedrine to manage hypotension as an alternative to other vasopressors and inotropes that may be in short supply is described.

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Veterinary anaesthesia may be facing new challenges during the COVID-19 pandemic, with the potential for shortages of cylinders of oxygen and some drugs in veterinary practice if resources are diverted to the NHS. Oxygen supplementation is vital during anaesthesia of all patients to prevent hypoxaemia in the face of respiratory depression induced by anaesthetic drugs but there are ways to limit the use of oxygen and save this valuable resource in practice. Unlike other countries such as the USA, at the moment the UK is fortunate not to face shortages of μ opioid receptor analgesics such as buprenorphine, methadone, and fentanyl because specific veterinary licenced drugs are available in this country. However, preservative-free propofol may become less available in the veterinary sector as a result of diversion to the NHS and it is possible that manufacturing lines of some drugs will be taken over to produce drugs for the NHS in the future. This article prepares veterinary surgeons should such shortages occur and to discuss how to safely limit oxygen use in practice and think about alternative drugs to use in veterinary anaesthesia that are not likely to be affected by the pandemic.

Oxygen

In modern veterinary practice, maintenance of anaesthesia is generally achieved using an inhalant agent (commonly isoflurane or sevoflurane) vaporised in oxygen and delivered via an anaesthetic breathing system (*Figure 1*). This is for convenience, partly because limited practices have access to medical air supplies, and because a >30% inspired fraction of oxygen helps to prevent hypoxaemia should respiratory depression occur during anaesthesia. Oxygen supplementation is still required with total intravenous anaesthesia techniques because of respiratory depression caused by the agents used. Many practices use an oxygen generator as their source of oxygen; these practices are fortunate that they will not face oxygen shortages as a result of the pandemic. At the time of writing, there are not shortages of oxygen cylinders in practice but it is precautionary to think about how to limit use of oxygen should shortages occur at any stage in the future, while still following safe anaesthetic practice.

Figure 1. Oxygen.

Avoid the need for general anaesthesia using sedative techniques

Question whether a procedure involving general anaesthesia can be avoided. Some procedures can be carried out under sedation with adjunctive local anaesthesia techniques, potentially avoiding the need for oxygen supplementation. In some patients it may be possible to perform a wound closure, for example, using sedation with an opioid and alpha 2 agonist, combined with infiltration of the wound with local anaesthetic, such as lidocaine or bupivacaine. In the decision-making process it is important to assess the suitability of the patient for alpha 2 agonist administration; for example, alpha 2 agonists are contraindicated in patients with some types of cardiovascular disease. Caution should also be exercised inducing immobility via sedation in bracycephalic breeds (cats and dogs) because of the risk of upper airway obstruction when endotracheal intubation is not possible.

Reduce the duration of anaesthesia

Shorter anaesthesia times will result in less oxygen usage. This can be achieved by strategies such as pre-clipping awake patients before surgery (if tolerated by the animal) and carrying out preoperative radiography or computed tomography (CT) scans under sedation rather than under general anaesthesia. Making sure that everyone is prepared to start clipping and preparing an animal for surgery as soon as the animal is anaesthetised is also important to avoid delays. Surgery time will also vary depending on the experience and confidence of the surgeon; now it is better to delegate surgery to surgeons who have more experience and will be quicker at carrying out the procedure.

Not every sedated animal requires oxygen supplementation

Pulse oximetry is a valuable tool to determine which sedated patients require oxygen supplementation. If the SpO_2 is greater than or equal to 96% when the animal is breathing room air, it is reasonable to assume that the animal is adequately oxygenated without the need for supplemental oxygen. If supplemental oxygen is required because of a low SpO_2, then use a face mask (*Figure 2*) and an anaesthetic breathing system to deliver oxygen, rather than a flow-by technique.

Oxygenation is more effective with a low flow of oxygen (e.g. 1–2 litres/minute) using a face mask (Ambros et al, 2018; Wong et al, 2019) than a flow-by technique. Be aware that very tight fitting face masks should not be used for more than a few minutes because of the risk of build up of CO_2 within the mask. Some breeds of dog are more likely to require supplementation than others, for example brachycephalic breeds often need oxygen supplementation because of upper respiratory tract obstruction. Pulse oximetry can be unreliable when using alpha 2 agonists for sedation because the profound peripheral vasoconstriction caused by alpha 2 agonists disturbs the ability of the pulse oximetry probe to detect pulsatile changes in blood flow. Remember that pulse oximetry rarely gives falsely high readings, but if the SpO_2 reading is less than 96% it is better to err on the side of caution and provide supplemental oxygen. It may not be practicable to place a pulse oximetry probe on the tongue of some lightly sedated patients; in these cases, often placing the probe on the upper lip is well tolerated.

Is pre-oxygenation before premedication and induction of anaesthesia necessary?

Pre-oxygenation is necessary for some patients when endotracheal intubation is predicted to be challenging and apnoea post induction of anaesthesia will lead to hypoxaemia. However, this is not the case for most animals. In most cats and dogs, intubation is routine and apnoea post induction can be managed by intermittent positive pressure ventilation with 100% oxygen following endotracheal intubation. The subgroup of dogs and cats that will really benefit from pre-oxygenation is brachycephalic breeds. In this patient group, intubation can take a prolonged period of time which can lead to hypoxaemia, particularly if the patient is also apnoeic. Pre-oxygenation ensures that there is a buffer of oxygen in the lungs that prevents hypoxaemia until intubation is achieved. As discussed earlier, use a face mask to pre-oxygenate the patient and oxygen flows of around 1–2 litres/minute for approximately 3–5 minutes.

Use a rebreathing anaesthetic system (circle system) where possible

There are big differences in the flow of oxygen required to prevent rebreathing between the different anaesthetic breathing systems, with rebreathing systems (e.g. a circle system) (*Figure 3*) usually requiring the lowest flow rates of oxygen. The exception is the mini-Lack anaesthetic system, which is ideal for cats and requires oxygen flows of only 0.8–1.0 x minute volume. Modern circle breathing systems have low resistance one way and APL valves and therefore can be used on patients >10 kg bodyweight. Choose a rebreathing bag size that equates to 1 litre per 10 kg bodyweight of the patient. Some larger cats and smaller dogs will also cope well breathing on a circle breathing system if paediatric (15 mm narrow bore) tubing is used. When thinking about fresh gas flows of oxygen for a circle breathing system, remember that the metabolic requirement of oxygen for a dog or cat is approximately 10 ml/kg/minute, which is the minimum oxygen flow required to prevent hypoxaemia. Usually on a circle breathing system, higher flows are used for the following reasons:

Figure 2. Oxygen supplementation, if required, should be carried out using a face mask.

Figure 3. A circle breathing system.

Figure 4. A capnograph trace showing rebreathing (the inspired carbon dioxide concentration does not go down to zero during inspiration) in a cat attached to a T piece breathing system. Increasing the fresh gas flow will correct this problem.

- Some vaporisers and flowmeters are not calibrated to be accurate at very low rates of oxygen. However all vaporisers and flow metres should be accurate at flows of oxygen of 1 litre/minute.
- The time taken for changes in dialled inhalant agent concentration to be reflected in the inspired concentration of inhalant agent is slower with low flows of oxygen. Unless this is recognised, it can lead to an unstable plane of anaesthesia. However, keeping the flow of oxygen at 1 litre/minute minimises this effect. It can also be helpful to transiently increase the flow of oxygen to 2–3 litres/minute when a rapid change in inhalant concentration is required. If you have inhalant agent concentration monitoring on your multi-parameter monitor, it will tell you what the inspired and expired concentrations of inhalant are, making the difference between dialled and actual inhalant agent concentrations easier to understand.
- It is generally accepted that higher oxygen flows at the start of anaesthesia are useful to denitrogenate the patient when low flows of oxygen with a semi closed or closed APL valve are to be used during the rest of the anaesthetic. If you are not monitoring oxygen concentration in the breathing system then, to be safe, maintain the oxygen flow on 2 litres/minute for the first 5 minutes before dropping the flow to 1 litre/minute. Ideally use a multi-parameter monitor that can monitor inspired and expired concentrations of oxygen in the circuit to ensure that the inspired concentration of oxygen does not fall below 30%. However, at fresh gas flows of 1 litre/minute, as long as the equipment is not faulty, an inspired concentration of oxygen less than 30% is very unlikely.
- Ensure that there are no leaks in the breathing system and that the cuff on the endotracheal tube is adequately inflated to prevent inadvertent loss of oxygen from the system and a requirement for higher oxygen flows.

In summary, it is recommended to use a circle breathing system when possible at oxygen flows of 1 litre/minute for maintenance of anaesthesia. It may help to have slightly higher flows (e.g. 2 litres/minute) at the beginning of anaesthesia to ensure a rapid rise in inhalant agent concentration in the circuit to obtain a smooth transition from intravenous induction of anaesthesia to inhalant maintenance of anaesthesia. If nitrous oxide is used as part of the inspired gas mixture then it is important to stop the nitrous oxide 5–10 minutes before the end of anaesthesia and increase the oxygen flow to 2 litres/minute to prevent diffusion hypoxia.

Considerations for using non-rebreathing systems during anaesthesia

Animals <10 kg bodyweight will generally require a non-rebreathing system to maintain anaesthesia. Non-rebreathing systems rely on the fresh gas flow to prevent rebreathing of carbon dioxide and equations have been developed to determine the minimal fresh gas flow required dependent on the minute volume of the patient and the type of breathing system. However, these equations are somewhat conservative and generally a lower fresh gas flow can be used as long as monitoring using capnography is implemented to detect any evidence of rebreathing (when the inspired carbon dioxide concentration rises above zero).

For example, for a 5 kg cat the fresh gas flow required to prevent rebreathing on a T piece breathing system is generally accepted to be 2–3 x minute volume where minute volume can be taken as 200 ml/kg (minute volume = tidal volume x respiratory rate).

Required fresh gas flow is therefore: 2.5 x 200 x 5 = 2.5 litres/minute

However, often lower fresh gas flows are sufficient to prevent rebreathing dependent on the respiratory rate of the patient. Capnography can be used to detect rebreathing should it occur, and the fresh gas flow can be adjusted until it is just sufficient to prevent rebreathing. Inspired carbon dioxide concentration should be below 5 mmHg and expired carbon dioxide concentrations should be in the normal range (35–45 mmHg) (*Figure 4*).

A similar principle can be applied to Bain, Magill and Lack breathing systems. Remember that due to its design the Humphrey ADE breathing system also allows use of very low fresh gas flows during anaesthesia, even in cats and small dogs (*Figure 5*).

Table 1. A comparison of the properties of alfaxalone and propofol

	Propofol (PropoFlo Plus)	Alfaxalone (Alfaxan Multidose)
Induction dose in unpremedicated animals	6.5 mg/kg (dogs) 8 mg/kg (cats)	3 mg/kg (dogs) 5 mg/kg (cats)
Induction dose in animals premedicated with an alpha$_2$agonist	1–2 mg/kg in dogs and cats	1–2 mg/kg in dogs and cats
Use for maintenance of anaesthesia	Cannot be used by continuous rate infusion (CRI) for maintenance of anaesthesia due to the risk of benzyl alcohol toxicity	Can be used by CRI for maintenance of anaesthesia Cats (premedicated) 7–8 mg/kg/hour Dogs (premedicated) 6–7 mg/kg/hour
Use for anaesthesia on consecutive days	Heinz body formation has been reported in cats anaesthetised with propofol on consecutive days (Andress et al, 1995)	Heinz body formation has not been reported although studies on consecutive days of anaesthesia are not reported
Pain on injection	Pain on intravenous injection can sometimes be seen with propofol and is reported in people	Pain is not reported on intravenous injection in cats and dogs
Respiratory system effects	Hypoventilation or apnoea can be seen, particularly after rapid induction of anaesthesia	Hypoventilation or apnoea can be seen, particularly after rapid induction of anaesthesia
Cardiovascular system effects	Increases in heart rate after induction of anaesthesia to compensate for hypotension are uncommon	Increases in heart rate after induction of anaesthesia to compensate for hypotension are common, particularly if the animal was not premedicated with an alpha$_2$agonist; do not confuse with inadequate anaesthesia
Metabolism	Rapidly metabolised by the liver and lungs	Rapidly metabolised by the liver
Use for induction of anaesthesia for caesarean section in dogs	Puppy vitality for the first hour after delivery is reported to be better after induction of anaesthesia with alfaxalone compared with propofol. There are no comparable studies in cats (Doebeli et al, 2013)	Puppy vitality for the first hour after delivery is reported to be better after induction of anaesthesia with alfaxalone compared with propofol. There are no comparable studies in cats (Doebeli et al, 2013)
Intramuscular administration	Not recommended for administration by the intramuscular route	Although unlicensed by this route, alfaxalone can be used to provide a short period of sedation/anaesthesia after intramuscular administration. This route is suitable for cats and small dogs (dose 1–2 mg/kg intramuscularly) (Cruz-Benedetti et al, 2018; Rodrigo-Mocholí et al, 2018)
Recovery from anaesthesia	Recovery quality in unpremedicated patients is generally higher (smoother) than with alfaxalone	Recoveries from anaesthesia can be stormy in unpremedicated patients, ensure the patient is able to recover in a quiet, non stimulating environment
Shelf life	Solution is stable for 28 days after the vial has been broached	Solution is stable for 28 days after the vial has been broached

The mini Lack breathing system is worthy of a special mention because of the low fresh gas flows required for maintenance of anaesthesia with this system (0.8–1.0 x minute volume) even in cats. This breathing system has a very low resistance APL valve and smooth bore tubing so that the patient's breathing is not compromised.

Considerations for use of anaesthetic machines to conserve oxygen

- Although it sounds obvious, do not turn the anaesthetic machine oxygen flowmeter on until you are ready to connect the patient and make sure that the oxygen is not left on at the end of anaesthesia.
- Some anaesthetic machines have a residual flow of oxygen even when the flow metre is turned off. On these machines make sure that the oxygen supply is also turned off at the end of anaesthesia to stop the residual flow of oxygen.

Drug shortages

Drugs used in human medicine to manage ICU patients, particularly those on a ventilator, may also become less available as the pandemic continues. This potentially includes preservative free propofol, vasopressors such as norepinephrine (noradrenaline), inotropes such as dobutamine and midazolam. Fortunately, the veterinary sector has a licenced preparation of propofol that contains preservatives and is unsuitable for use in humans (PropoFlo Plus, Zoetis, UK) therefore propofol should be available to use as an induction agent throughout the pandemic. However, should there become a shortage of propofol, the licenced alternative product to use would be alfaxalone. If you are unfamiliar with using alfaxalone as an induction agent in cats and dogs, it is important to be aware of the small differences to using propofol. These are outlined in *Table 1*.

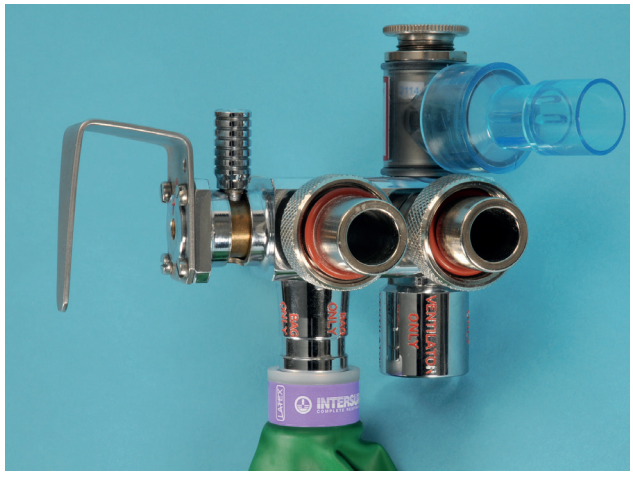

Figure 5. A Humphrey ADE breathing system.

Figure 6. Photo of a box of ephedrine 30 mg/ml.

Vasopressors and inotropes

Although use of constant rate infusions of noradrenaline, dopamine and dobutamine are relatively uncommon in general small animal practice, sometimes hypotensive patients during anaesthesia require more intensive drug administration to support blood pressure. Although not ideal as a replacement for noradrenaline, dopamine and dobutamine, which all have their own specific indications for use, an easy to use first line drug to support blood pressure which is less likely to become in short supply is ephedrine. Ephedrine (*Figure 6*) is a non-catecholamine sympathomimetic that can stimulate alpha and beta adrenergic receptors directly as well as indirectly by causing endogenous release of noradrenaline. It is administered as an intravenous bolus (0.1 mg/kg) to treat hypotension in dogs and cats and can cause an increase in mean arterial blood pressure and cardiac output (Chen et al, 2007). Practically most vials of ephedrine are 30 mg/ml, so it is useful to dilute a 1 ml vial of 30 mg/ml ephedrine to 30 ml with NaCl to make a 1 mg/ml solution, which is easier to administer accurately. Effects are relatively short lived (10–15 minutes) and tachyphylaxis occurs where subsequent doses become less effective, presumably as noradrenaline stores become exhausted. However, administration of ephedrine is a useful short-term measure to support blood pressure and cardiac output in anaesthetised animals and can be safely used when blood pressure is being measured non-invasively using Doppler or oscillometric techniques.

Conclusions

Challenges faced by veterinary anaesthesia at this time include the potential for shortages of oxygen and some drugs. There are ways to ration the use of oxygen in practice to make every cylinder last longer, probably the most significant of these is choosing to use a circle breathing system to limit fresh gas flow requirements during anaesthesia. A mini-Lack breathing system is also recommended for cats and dogs < 5 kg bodyweight. It remains to be seen whether propofol will become in short supply, but should this happen, then alfaxalone is a suitable alternative for induction of anaesthesia in cats and dogs.

KEY POINTS

- Oxygen supplementation is critical during anaesthesia but there are ways to safely ration use.
- In sedated patients use pulse oximetry to determine whether oxygen supplementation is needed.
- Use of a circle breathing system is ideal in patients >10 kg bodyweight.
- Consider using a mini-Lack breathing system in patients <5 kg bodyweight.
- Ephedrine is a useful drug for the support of blood pressure in anaesthetised patients.

Conflict of interest: none.

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