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Anaesthesia Refresher and Update for Veterinary Nurses Mini Series

Session One: Anaesthetic Equipment and Drugs

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PART 1: EQUIPMENT

ANAESTHETIC MACHINE

Anaesthetic machines vary in type and appearance, but all consist of the same basic parts. Some machines have gas cylinders that are fixed to the machine, and the machine is on wheels, so it is portable. Others have components mounted on a rail, known as the back bar. For these, the gases are piped in from larger cylinders kept externally.

Components of the anaesthetic machine

Regardless of the type of machine, it will have the following components:

1. A common gas outlet
2. Gas supply – either cylinder or via pipes
3. Pressure gauges for cylinders and pipelines
4. Pressure reducing valves for each gas
5. Flowmeters
6. Vaporiser (one or more)
7. Emergency oxygen flush valve

Common gas outlet

This is where the gases leave the machine and where the breathing system attaches.

Gas supply

Gases are supplied in cylinders or tanks. The actual gas comes either directly from cylinders that are attached to the machine or from larger cylinders that are piped in from an external source to the machine. Various different sizes of medical gas cylinders exist, but for veterinary anaesthesia, small cylinders that fit onto the machine are generally size E and the larger cylinders that are stored externally are usually size J, although other sizes may also be used. It is essential that the gas contained in the cylinder can be easily identified, and there are several ways of ensuring this happens. A label around the cylinder neck shows all the relevant information pertaining to that specific gas. Cylinders are colour coded and in the UK and most European countries, the colours are standardised, although they differ in the United States of America.

The way in which small cylinders attach to the yoke of the machine is by a system of pins, which are spaced at varying intervals, depending on the gas contained in the cylinder. This is a safety feature that prevents the wrong cylinder being fitted, and is called the **pin index system**. The bullnose fitting has a similar safety component, in that there is a threaded outlet that is specific to each gas, so again, it is not possible to inadvertently attach the wrong cylinder to the wrong yoke.

To ensure a gas-tight fit between cylinder and yoke, there is a neoprene seal, called the Bodok seal.

Gases that are piped from an external source travel from a large cylinder to a connector that is attached to the machine. Schrader connections are found at the source and anaesthetic machine, to enable attachment of the pipes. The Schrader probe from the pipeline is fixed securely to the Schrader valve. A safety system exists, whereby the pipeline for a specific gas will only attach to the corresponding Schrader socket.

Cylinder colour	Pipeline colour	Gas	Cylinder contents
Black body with white shoulders or all white	White	Oxygen	Gas
Blue body and shoulders	French blue	Nitrous oxide	Liquid
Grey body with black and white shoulders or white body with black and white shoulders	Black	Medical air	Gas

Pressure gauges

Cylinders contain gas (or liquid) under high pressure. In the cylinder, oxygen and medical air are gases, but nitrous oxide is a liquid under pressure. Pressure gauges for cylinders that contain gas (oxygen and medical air) allow estimation of the contents of the cylinder and enable the user to tell when the contents are running low. However, as nitrous oxide is a liquid under pressure, the gauge only measures the saturated vapour pressure. Whilst there is some liquid in the cylinder, regardless of how much liquid there is, there will always be a pressure reading of saturated vapour, so the gauge of a nitrous oxide cylinder does not give any information relating to how much liquid that can be used as a gas remains in the cylinder. The cylinder must be weighed in order to estimate its contents.

Pressure gauges are situated on the cylinder yoke but some modern machines have panel-mounted pressure gauges. The pressure of piped gases is lower than that of gas in the cylinder and for piped gases, there is also a pressure gauge that shows the pipeline pressure.

Pressure reducing valves

Cylinder pressure is very high and must be reduced to a safe pressure before it can leave the machine. There is a pressure reducing valve for each gas, to carry out this function.

Flowmeters

Gas must be delivered safely and reliably to the patient, and fine control is necessary. This is accomplished using a flowmeter, which is a graduated tube containing a float. The float is necessary to ensure consistent gas flow, and should be spinning in the column of gas. It is either a bobbin or a ball. The fresh gas flow reading is taken from the top of the bobbin, not the dot in the middle. Where the float is a ball, the reading is taken from the middle.

Most flowmeters are calibrated to read in litres per minute (L/min), although some machines also have narrower flowmeters, which are calibrated in millilitres per minute (ml/min), up to 1000 ml or 1 litre.

Flowmeters vary in their appearance, as each one is calibrated specifically for an individual gas, so some appear to be wider than others. As with gas cylinders and pressure gauges, the flowmeter control knob is colour coded accordingly. Oxygen is white and is found on the left hand side of the block (in the UK). Medical air is next to oxygen, and is black and white. Where present, nitrous oxide is on the right hand side and is blue.

Vaporisers

Inhalant anaesthetic agents are presented in a liquid form and must be converted into a gas for the patient to inhale. This process occurs in the vaporiser. Each inhalant agent has a specific vaporiser and with modern safety devices, it should not be possible to add the wrong agent to the wrong vaporiser. A vaporiser that is calibrated to deliver 2% isoflurane, for example, would not deliver 2% sevoflurane, and vice versa. The safest way possible of filling the vaporiser should be used, although this is largely dictated by the vaporiser itself. The key filling system is safer than directly pouring the liquid into the vaporising chamber, although some leakage is still possible. Sevoflurane vaporisers in the UK have their own unique filling system, and spillage of fluid is not possible.

The sevoflurane bottle is self-sealing, which is an added safety feature. Vaporisers lock into place on the anaesthetic machine. Some machines have the facility to accommodate more than one vaporiser.

Plenum vaporisers are commonly used in veterinary anaesthesia. The term ‘Tec’ comes from the fact that they allow for temperature compensation. The vaporising chamber holds the anaesthetic liquid agent, and it is important that this chamber is not overfilled, otherwise accurate concentrations of inhalant gas cannot be delivered. When the carrier gas enters the vaporiser, it splits into two streams. Some of the gas flows into the vaporising chamber that contains the liquid agent, and some flows into the bypass channel – an area that bypasses the vaporising chamber. The amount of gas in each of these two streams is governed by the concentration set on the vaporiser dial. If the dial is set to 3%, more gas passes through the vaporising chamber than if the dial were set to 2%.

Emergency oxygen flush valve

Activation of this valve allows 100% oxygen to leave the machine at a high flow rate – usually 30-70 litres/minute. This valve should only ever be used to purge the breathing tubes and system of anaesthetic gas, which is diverted into the scavenge system. It should never be used with a patient attached to the system, as the high flow and pressure will cause barotrauma and volutrauma to the lungs.

AIRWAY EQUIPMENT

Endotracheal tubes

Different types of endotracheal tube exist, depending on the material the tube is made from, and the type of cuff. Soft tubes are made from silicone and often require a rigid stylet for placement. PVC and red rubber tubes are themselves rigid and can be placed without the use of a stylet.

The cuff of an ET tube is present to allow air to be instilled to create a pharyngeal seal. The cuff profile can be one of two types. High pressure profile cuffs are more likely to cause tracheal damage, whereas low pressure profile cuffs are less likely to damage the trachea. The larynx of cats is particularly sensitive, and it is recommended that red rubber tubes are avoided, due to the propensity for causing laryngeal and tracheal trauma.

Cuff profile	Description	Examples
Low volume, high pressure LVHP	High pressure is exerted over a small area of tracheal wall: more risk of damage	Magill red rubber tubes
High volume, low pressure HVLP	Lower pressure is exerted over a larger area of tracheal wall: less risk of damage	PVC tubes

A safety feature that is found in modern tubes is the Murphy eye. This is an opening at the tracheal end, on the side of the tube, and allows airflow to continue if the end of the tube is temporality occluded during the intubation process. This can sometimes occur due to the anatomy of the trachea and the shape of the tube.

Laryngeal mask airway/supraglottic airway devices

A veterinary adaptation of the human laryngeal mask airway is available for cats, dogs and rabbits, in the form of v-gel devices. This precludes the need for endotracheal intubation, as there is no contact with the trachea. Gases are delivered via the pharynx. These devices are quick to insert and placement requires little skill, as opposed to that which is needed for placing an endotracheal tube. The airway diameter is wider than could be accomplished with an ET tube. Different sizes are available, and it is imperative that the correct size is used. The canine v-gel is the newest addition to the market, and is available for dogs of different weights and head shapes. This type incorporates an integrated gastric channel, down which a suction tube can be passed, enabling suctioning of the oesophagus, should regurgitation and aspiration occur. The v-gel has a finite life and it is recommended that they are not used more than 40 times.

ANAESTHETIC BREATHING SYSTEMS

A breathing system delivers fresh gases to the patient and removes waste gases from them. Alveolar gas contains carbon dioxide, and it is important that this is not rebreathed, otherwise a respiratory acidosis can occur. There are two main types of breathing system, the classification depending on how the waste gases are removed:

1. Non-rebreathing systems
2. Rebreathing systems

Non-rebreathing systems

The removal of waste gases relies on high flow rates to ensure alveolar gas is not rebreathed. Fresh gas from the machine is the only gas the patient breathes in. To ensure rebreathing does not occur, each system has a circuit factor. This is a multiplication of the patient's minute volume.

Respiratory terminology

Tidal volume: the volume of air breathed in and out in one breath. In dogs and cats, this is approximately 10-15 ml/kg (although figures vary, according to age, size, health, condition etc)

For cats and dogs weighing less than 10 kg: approximately 15 ml/kg
For dogs weighing more than 10 kg: approximately 10 ml/kg

Minute volume: the volume of air breathed in and out in one minute. It is the tidal volume multiplied by the resting respiratory rate.

Functional Residual Capacity (FRC): the amount of air left in the lungs at the end of normal exhalation. This air allows gaseous diffusion to continue between breaths.

<u>To find the fresh gas flow (FGF) for a patient using a non-rebreathing system</u>

1. Calculate the tidal volume (ml): body weight x 10-15 ml
2. Calculate the minute volume (ml): tidal volume multiplied by respiratory rate
3. FGF (litres/minute) = minute volume multiplied by the circuit factor

When capnography is available, the fresh gas flow can be set according to the inspiratory carbon dioxide reading, which should be 0 mmHg, or very close to 0. It will be seen that fresh gas flows are much lower than those calculated using the formulae quoted.

There are different configurations of tubing and the position of the bag. Those systems that have the bag on the inspiratory limb have a low circuit factor, so they are more efficient. However, this means that long-term IPPV (intermittent positive pressure ventilation) cannot be performed without causing rebreathing. Those systems that have the bag on the expiratory limb have a higher circuit factor, so they are less efficient, but IPPV can safely be performed.

Non-rebreathing systems

System	Bag position	Circuit factor	Ideal weight	IPPV
Parallel Lack	Inspiratory limb	0.8	> 8 kg	No
Mini Lack	Inspiratory limb	1	2-10 kg	No
Magill	N/A as only one tube	0.8	> 8 kg	No
Modified Bain	Expiratory limb	1-2	> 8 kg	Yes
Jackson-Rees modified Ayre's T-piece	Expiratory limb	2.5-3	Up to ~ 8 kg	Yes

Rebreathing systems

Soda lime removes carbon dioxide from alveolar gas and the air is then rebreathed, meaning this system can correctly be called a circuit, as the gas goes round in the manner of a circuit. Heat and moisture are retained, so the inhaled gas is warm and moist. One-way valves are present to ensure unidirectional gas flow in the system. As there is no reliance upon fresh gas flow to flush carbon dioxide from the system, much lower flows can be used. Gas flow is related to minute oxygen consumption and not to minute volume, so no calculations are required when setting the FGF for a circle system. Minute oxygen consumption is approximately 5-10 ml/kg and if the system were to be used as a closed system, this could mean the flow rate would be as low as 200 ml/minute. However, usual practice is to use it as a semi-closed system, with higher flows and a semi-open valve. At the beginning of anaesthesia, a higher flow rate is needed (100 ml/kg/min) in order to denitrogenate the lungs and also to achieve an appropriate plane of anaesthesia. The FGF can then be lowered, either according to capnography or if this is not available, to around 1-2 litres/minute. The APL valve will need to be opened and partially closed accordingly. Towards the end of anaesthesia, the valve is opened and the flow rate increased, in order to lighten the plane and to purge anaesthetic gases from the system. If the plane of anaesthesia needs to be changed quickly at any time, the valve must be opened, the bag purged and the flow rate increased, as changes in concentration occur slowly at low flows.

As long as the bag is on the expiratory limb, IPPV can safely be performed. There are usually only three main types of circle system in the UK: the semi-disposable circle, the Cyclo-Flo and the Humphrey ADE with a soda lime canister.

The semi-disposable circle is suitable for animals weighing over 8-10 kg (ideal weight). However, the traditional wide corrugated circle tubing can be replaced with low resistance tubing, which means that some circle systems may be suitable for animals weighing even less than 8 kg. The Cyclo-Flo system is low resistance and is marketed for patients weighing 7 kg and over (ideal weight).

Soda lime must be changed when it is approximately 66-75% exhausted. There are different types of soda lime, with different colour changes:

- Pink soda lime (fresh) changes to white when exhausted
- White soda lime (fresh) changes to purple when exhausted
- Green soda lime (fresh LoFloSorb) changes to purple when exhausted

The **Humphrey ADE** is a hybrid system and can be used with or without the soda lime canister. The unique feature is the valve. This is a PEEP valve – positive end expiratory pressure – and it conserves dead space gas, such that approximately 50% of each breath is composed of dead space gas that has been preserved in the inspiratory limb and bag. The action of PEEP is to maintain patent pulmonary alveoli and prevent their collapse.

When used in non-rebreathing mode (< 7 kg), the bag is on the inspiratory limb. The circuit factor is 0.5-0.75 times the minute volume. The lever must be in the upright position and the system works like a Lack. The lever is only ever set to the down position when a ventilator is attached to the ventilator port, otherwise the bag and the valve are not active and the patient will not be able to breathe.

For animals weighing over 7 kg, the soda lime canister is added to the system. IPPV can safely be performed in either non-rebreathing or rebreathing mode, due to gas flow configuration. Specific flow rates are published by Anequip, on their website, and this is updated regularly. However, as with all breathing systems, the flow should be set and altered as necessary, according to capnography if possible.

The bag of any breathing system must be of suitable size. Generally, this is said to be 3-6 times the patient's tidal volume. Using a tidal volume of 10 ml/kg, multiplying the animal's weight by 60 gives a good estimation of the correct bag size to use.

A suitable scavenging system must be used to ensure all waste gases are removed and that environmental pollution does not occur. When using activated charcoal systems, the container must be weighed regularly, to ensure it is not exhausted (the depleted weight is shown on the label). These systems do not scavenge nitrous oxide.

Safety checking the anaesthetic machine and breathing system

It is good practice to perform safety checks prior to **every** anaesthetic. The breathing system is attached to the machine, the exhaust valve closed, the patient end occluded and the system filled with oxygen using the flowmeter. This assesses the low pressure part of the machine. The bag is filled until it is turgid, with no creases, then gently squeezed to ensure there are no leaks. Repeating this process, using the emergency oxygen flush to fill the bag, assesses the high pressure part of the machine. The oxygen flush valve can also be used to flush any stale waste anaesthetic gas into the scavenge system, so when preoxygenation occurs, the patient breathes in oxygen, not waste anaesthetic gas that has been dormant in the tubes.

The bags should be checked visually to ensure they are not perished. For non-rebreathing systems, the bag must be connected to the bag port, not to the valve port. This mainly relates to the Bain system, where the APL valve and bag fit either port. The bag port has a lip and the word ‘bag’ is usually written on this lip. This is on the expiratory limb and it is crucial that the bag is attached correctly. The inner tube of the coaxial Bain should also be assessed to establish it has not been disconnected. If this were to happen, dead space in the system is increased hugely, with potentially fatal consequences. There are several methods for testing correct connection. One method is to attach the system to the machine, turn on the oxygen to about 4 litres/minute and occlude the inner tube at the patient end with a syringe plunger. If the inner tube is correctly connected and intact, the back pressure of oxygen will push the float down, so it will fall. If it does not fall, the inner tube has become disconnected and the system should be discarded.

Endotracheal tubes should be checked to ensure they are clean, intact and that the lumen is patent. The cuff is checked by inflating with air and the tube is then left for at least several minutes. If deflation occurs, there is a leak and the tube should be replaced.

PART 2: ANAESTHETIC AND ANALGESIC DRUGS

A wide variety of drugs is used in veterinary anaesthesia and those that are most often used in general practice are covered in this course, although it should be noted that not all of them are licensed for veterinary use.

PREMEDICATION DRUGS

Drugs used in the preoperative period include sedatives and analgesic agents.

Acepromazine is a phenothiazine drug that is used to sedate the animal. Sedation is enhanced when an opioid agent is also administered. Effects of acepromazine include peripheral vasodilation, causing a decrease in blood pressure and body temperature, so careful monitoring after administration is needed, and supplemental warmth should be provided. Syncope may occur in Boxer dogs so acepromazine is used with caution in this breed. The drug has a long duration of action and cannot be antagonised.

Medetomidine and **dexmedetomidine** are alpha-2 adrenergic agonist agents. In addition to causing sedation, these agents also cause analgesia. Their effects are antagonised with atipamezole. They can be used to provide effective preanaesthetic medication when used at low doses and combined with an opioid drug. The amount of induction agent required will be significantly reduced. Soon after administration, peripheral vasoconstriction occurs, and this accounts for the increase in blood pressure and bradycardia, which is a compensatory mechanism to vasoconstriction. Blood is directed to the central organs to maintain perfusion, causing cyanosis of the mucous membranes. After approximately 30 minutes, blood pressure normalises or decreases as the vasoconstriction lessens. Oxygen should be given to all patients after administration of an alpha-2 agonist drug. The respiratory rate is slow and often deep. Hyperglycaemia is frequently noted and this is because there is reduced secretion of endogenous insulin. These agents are either avoided or used with caution in known diabetic patients.

Midazolam and **diazepam** are benzodiazepine agents that are tranquillisers, rather than sedatives. They do not cause analgesia and these drugs are combined with others for optimal effects. When combined with an opioid drug, they can be used for premedication, but they can also be used on their own at induction, to act as a co-induction agent with the main induction drug. Their effects can be antagonised with flumazenil.

Opioid drugs are often used in combination with other drugs or as a sole agent in the preanaesthetic period. The aim is to provide analgesia and to control nociception during the entire perioperative period. It is important that peripheral and central sensitisation are reduced. The term used to describe this process is ***preventive analgesia***.

Full mu agonist agents include **morphine, methadone, pethidine** and **fentanyl**. The partial mu agonist agent used in small animal veterinary anaesthesia is **buprenorphine**, and the mixed agonist/antagonist agent is **butorphanol**, which provides good sedation but weak analgesia.

Bradycardia may be seen after opioid administration. Decreased respiratory rate is reported in people, but at clinical doses, this is not seen in veterinary patients. Dogs often pant, and this is because the set point for temperature is altered. Cats may become hyperthermic.

Opioid agents can be antagonised with naloxone. However, although its onset of action is rapid, it wears off quickly (after about 30-40 minutes) and the effects of the opioid will then be exerted again unless repeat naloxone is given, until the opioid effects have left the receptors. All effects of the opioid will be antagonised, including analgesia, so consideration must be given as to how analgesia can be replaced before or immediately after administering naloxone.

Carprofen and **meloxicam** are the non-steroidal anti-inflammatory drugs used perioperatively to provide multimodal analgesia. They are either given in the preanaesthetic period, at induction or during recovery. They act by inhibiting the action of cyclooxygenase (COX) enzymes 1 and 2. As well as providing analgesia, NSAIDs also have anti-inflammatory, antipyretic and antitoxaemic properties. The undesirable effects of NSAIDs, that may preclude their administration in some patients, include:

- Renal dysfunction
- Intestinal ulceration
- Blood dyscrasias
- Antithrombotic effects

Ketamine is an NMDA antagonist agent from the cyclohexanone group. It is used as a sedative, to induce anaesthesia and it also provides analgesia. It must be combined with another agent to provide muscle relaxation, so a benzodiazepine or alpha-2 agonist drug is given with ketamine.

Ketamine has few cardiovascular effects, and heart rate and blood pressure are not negatively affected. Ketamine is the only anaesthetic drug that does not depress the central nervous system. It causes stimulation and for this reason, some cranial nerve reflexes are retained. The patient may salivate, the pupil of the eye is dilated and the palpebral reflex may persist.

INDUCTION AGENTS

Propofol is a phenol-based anaesthetic agent. It is presented as an emulsion, so the bottle should be shaken before use. When given quickly, apnoea occurs. The drug should ideally be given slowly, over 60 seconds. The preparation without preservative should be discarded 6 hours after opening, whereas propofol that contains preservative can be used for up to 28 days after broaching the bottle.

Alfaxalone is a neurosteroid anaesthetic agent. It can be administered intramuscularly as well as intravenously. When given by the intramuscular route, sedation is achieved. This is useful for aggressive patients that will not allow handling, although an intravenous catheter should be placed as soon as possible. As with propofol, the drug should be given slowly over 60 seconds. Alfaxalone provides cardiovascular stability and is the drug of choice for sick patients or those with cardiovascular disease.

Alfaxalone that does not contain preservative should be discarded after use (some literature says it may be kept for up to 6 hours). The preparation with preservative can be used for up to 28 days after broaching the bottle.

Ketamine provides dissociative anaesthesia. When used in combination with other agents, it causes general anaesthesia and is sometimes used in sick patients. ‘Triple combination’ refers to the combination of an alpha-2 agent, an opioid and ketamine, usually given by intramuscular injection for cat neuter procedures. ‘Kitten quad combination’ is the triple combination with the addition of midazolam. The opioid is often methadone, so there is better pain relief, and body surface area dosing is used, resulting in a lower volume of the alpha-2 drug.

MAINTENANCE INHALANT AGENTS

Isoflurane and **sevoflurane** are the two volatile inhalant agents used in small animal veterinary anaesthesia in the UK. Of the two, isoflurane is more potent, as it has a lower MAC (minimum alveolar concentration) value than sevoflurane. It also takes slightly longer to exert its effects and for the effects to wear off, as it is more soluble in blood than sevoflurane. Conversely, sevoflurane has a higher MAC value and is therefore less potent (the vaporiser is calibrated up to 8%, whereas the isoflurane vaporiser is only calibrated up to 5%). Both agents cause vasodilation, resulting in hypotension and hypothermia. These effects are dose-dependent, so 2.5% isoflurane will cause more hypotension and heat loss than 2%.

Desflurane is not currently used in veterinary anaesthesia in the UK (2019).

Total Intravenous Anaesthesia (TIVA)

If anaesthesia cannot be maintained using an inhalant agent, TIVA may be employed. This technique involves the administration of a suitable induction agent by constant rate infusion (CRI), using a syringe driver. Alfaxalone can be used in both dogs and cats, but propofol should only be given as a CRI to dogs, due to its cumulative effects in cats and the propensity for causing oxidative injury to red blood cells with the formation of Heinz bodies.

Triple/quad injection combinations

Used in cats, the triple or quad combinations will sometimes provide sufficient general anaesthesia for neuter procedures, although some inhalant agent may also be required, especially for spay surgeries.

Whichever technique is used, the trachea should always be intubated wherever possible, and oxygen administered during the anaesthetic period.

Carrier gases

One or more carrier gases are needed to vaporise the volatile agent. Oxygen is the main carrier gas and is usually given at 100%. Medical air may be given with oxygen as it is beneficial in preventing absorption atelectasis, which can occur when 100% oxygen is administered.

Nitrous oxide was traditionally another popular carrier gas that was used to provide analgesia until some years ago, when its popularity waned, as analgesia is now provided using drug combinations and various techniques. Certain precautions must be taken when using nitrous oxide:

- The maximum ratio of nitrous oxide to oxygen is 2:1 to avoid hypoxia
- Activated charcoal does not scavenge nitrous oxide so a different scavenging method must be used
- The use of nitrous oxide must be avoided in certain procedures, including GDV surgery, repair of ruptured diaphragm, pneumothorax and pneumoperitoneum, head injuries and cases where there is increased intraocular pressure
- Pulse oximetry should be monitored when using nitrous oxide and a circle breathing system
- At the end of anaesthesia, 100% oxygen should be given for at least 3 minutes in order to avoid diffusion hypoxia

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