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Anaesthesia Refresher and Update for Veterinary Nurses Mini Series

Session Three: Peri-anaesthetic Monitoring

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CPD SOLUTIONS – ANAESTHESIA REFRESHER AND UPDATE FOR VETERINARY NURSES
MODULE 3: MONITORING, RECOVERY AND POSTOPERATIVE CARE

PART 1: PERIANAESTHETIC MONITORING

Monitoring the sedated or anaesthetised patient is crucial in the entire perianaesthetic period. Undesirable events can occur at any time after any drug is given. The anaesthetic death period in veterinary medicine extends from the time of premedication until 48 hours after recovery from sedation or anaesthesia.

The level of monitoring will depend on the equipment available, but a basic minimum should be performed for every patient. The anaesthetic record is a legal document and readings should be recorded in indelible ink every 5-15 minutes. Displaying certain information as a graphical representation is useful as this allows trends to be detected – for example, whether heart rate and blood pressure are slowly decreasing. In turn, this allows the person monitoring the anaesthetic to act on abnormal readings by taking corrective action. In this way, a crisis may be avoided.

Basic monitoring

Basic monitoring consists of “hands on” monitoring, and the value of this should never be underestimated. It is important to look at and touch the patient, because much information can be gained in this way.

There are several ways in which the cardiovascular system can be assessed without using expensive equipment. The mucous membranes are examined for colour and by assessing capillary refill time, which should be less than 2 seconds. Listening to the heart with a stethoscope is only of value if a pulse cannot be detected, and little meaningful information is gained in the majority of cases. Palpation of central pulses cannot be relied upon to indicate normotension, and some animals can retain their central pulses and be significantly hypotensive. Peripheral pulses are more sensitive to change, and it is these pulses that should be palpated in the anaesthetised patient wherever possible. A pulse that is difficult to palpate or one that is weak and thready can indicate hypovolaemia, hypotension or a deep plane of anaesthesia. It is important to palpate the peripheral pulse in the conscious patient, before anaesthesia is induced, so changes can be detected in the anaesthetised patient. The peripheral pulses that can be accessed include the:

- Dorsal pedal
- Palmar metacarpal
- Digital
- Lingual
- Coccygeal
- Facial

Heart and pulse rates should be the same. An increase in heart rate is seen if nociception (pain) occurs, or when the patient is lightly anaesthetised – at the beginning and end of anaesthesia. Conversely, the heart rate decreases in line with the depth of anaesthesia. Other factors should also be considered, if a change in heart rate is noticed. If the patient is hypotensive or hypercapnic, an elevated heart rate may be a compensatory mechanism. Some drugs affect heart rate: the alpha-2 agonist agents, such as medetomidine and dexmedetomidine, cause bradycardia, whereas ketamine maintains or increases the heart rate.

Temperature is one of the easiest parameters to assess, yet it remains one that is often overlooked. A rectal thermometer can nearly always be used and most digital thermometers can be left in situ and turned off between readings, to avoid having to keep introducing the thermometer into the anus. If a multiparameter monitor is available, the temperature probe can be inserted down the oesophagus to give the core temperature. Alternatively, it can be covered and placed in the rectum. The readings are displayed continuously on the monitor. The majority of heat is lost in the first 30 minutes of anaesthesia, so patients for even quick, routine procedures are likely to become hypothermic. In addition, some premedication drugs cause a decrease in body temperature, so warming may be needed immediately after premedication, to prevent heat loss before induction.

There are many warming aids that are cheap and simple to use, such as bubble wrap and socks, as well as active warming methods such as the HotDog and HotBody Warming systems or circulating warm air (Bair Hugger/Cocoon and other similar devices). Some animals are particularly susceptible to hypothermia, such as the very young, the elderly, those that are underweight or cachexic, sick patients and small animals because of their high surface area to body weight ratio. Temperature also decreases during preparation for surgery, due to clipping of hair, skin preparation and from lack of insulation of the table. If a rectal (or ear) thermometer is used, low readings may not be reliable as the animal becomes cold, due to vasoconstriction.

Using a humidity and moisture exchanger (HME) of suitable size between the endotracheal tube and breathing system will help prevent heat loss, especially when a non-rebreathing system is used. The gas flow rate should be decreased, according to capnography, to keep it low and prevent further loss of heat. If capnography is not available, the flow rate should be recalculated as the respiratory rate decreases, to avoid using excess gas flow. Direct heat on the body using wheat bags should be avoided, as this is likely to cause further loss of core body temperature, as heat causes vasodilation. The warm bags may be wrapped around the inspiratory tube of the breathing system.

There are many harmful consequences of hypothermia, such as bradycardia with decreased cardiac output and venous return, coagulopathies, decreased perfusion of the brain and depression of the central nervous system, increased risk of surgical site infection (due to poor tissue perfusion), increased oxygen demand due to shivering, and delayed recovery. Recovery may not be smooth due to the discomfort caused by shivering. Anaesthetised animals that are hypothermic need less inhalant agent to maintain them in the same plane of anaesthesia, as the MAC (minimum alveolar concentration) of the inhalant agent decreases with temperature loss.

There are some patients who will not require additional warmth. Some husky-type dogs, with thick coats, are prone to hyperthermia in the summer months, and patients with airway problems, that are tachypnoeic or panting before anaesthesia, often have an increased temperature. Many brachycephalic breeds suffer from heat stress because of the work of breathing and poor heat exchange in the nasal cavity. Pyrexic patients, such as those with septic joints, are also prone to hyperthermia. However, many patients that start out with a high temperature may lose heat when anaesthetised, and the temperature of all patients, whether sedated or under general anaesthesia, should always be monitored.

Respiratory rate, depth and pattern can all be assessed by looking at the animal’s chest excursions and bag movements, which should be similar. Respiratory rate decreases as the plane of anaesthesia deepens. Listening to breathing and lung sounds, as well as the heartbeat, can be accomplished by using an oesophageal stethoscope.

Cranial nerve reflexes can be assessed by examining the position and size of the pupil, although some drugs will affect this so it is not always reliable. After ketamine administration, the pupil will be dilated and the animal may look awake. If atropine has been given, the pupil will again be dilated (and the heart rate increased), which can give a false impression of the depth of anaesthesia. Opioids cause different pupillary responses in cats and dogs. Opioid administration causes the pupils to dilate in cats (mydriasis) and constrict in dogs (miosis).

At the beginning of anaesthesia, the eye is in a central position but the pupil should be constricted (depending on drug administration). As consciousness is lost and the plane of anaesthesia deepens, muscles relax and the eye starts to rotate downwards into a ventromedial position. If the patient becomes excessively deep, the eye rotates back again (dorsally) but the pupil will be dilated, due to complete relaxation of the ocular muscles. This is seen in anaesthetic overdose and patients who are in a coma. When death is imminent, the pupil is fixed, dilated and the eye is dry, due to lack of secretions.

The pupillary light reflex is useful and works in two ways. When a light is shone in one eye and the pupil of that eye constricts, the direct pupillary reflex and optic nerve control are assessed. When the pupil of the opposite eye also constricts, which is a normal response, the consensual reflex and oculomotor nerve control are assessed. If the patient is very deeply anaesthetised, these responses will not be seen.

Generally, a strong palpebral reflex indicates a light plane of anaesthesia. The palpebral reflex should not be over-stimulated as it becomes refractory and will eventually not respond.

A strong pedal withdrawal reflex is seen at the beginning and end of anaesthesia, when the patient is in a light plane. Assessment of jaw tone is a good indicator of the depth of anaesthesia. A strong jaw tone suggests a light plane of anaesthesia, whereas a loose jaw tone indicates a deep plane. Loss of the anal reflex (which can be assessed by introducing a rectal thermometer) indicates a deep plane of anaesthesia and generally, anal tone should not be completely flaccid.

Advanced monitoring

Pulse oximetry

Pulse oximetry measures the saturation of haemoglobin with oxygen in arterial blood. It measures how much oxygen is carried by haemoglobin as a percentage of the maximum it could carry. The unit of measurement is therefore percentage. It is a non-invasive monitor and gives a guide to oxygen saturation. SpO_2 denotes the non-invasive method of oximetry, whereas SaO_2 refers to the invasive measurement, whereby a sample of arterial blood is taken and blood gas analysis performed to measure saturation. Neither of these methods is the same as PaO_2, which is an invasive way of monitoring the partial pressure of oxygen in arterial blood, and which is measured in millimeters of mercury – mmHg. There is no linear relationship between SpO_2 and PaO_2 and a high SpO_2 reading does not mean that oxygenation is necessarily good, nor will it equate to a satisfactory PaO_2 reading. An SpO_2 of 95% can indicate the beginning of desaturation and the onset of hypoxaemia, and it is important that the reading remains higher than 95%. Even so, this does not guarantee sufficient oxygenation.

The waveform or bar that is often also shown on pulse oximeters is knows as the plethysmograph, and the shape of the waveform gives important information and can be more important than the number displayed. There are several considerations to take into account when using pulse oximetry. The technology in the oximeter varies, and this can affect the validity of the result. Some oximeters only measure a few red blood cells as they pass the detector, using only two wavelengths of light, and it may be that those red cells are fully saturated with oxygen, displaying a high reading, where the next cells may not be fully saturated. Similarly, anaemic animals can show very good oximetry readings because even though they may have reduced numbers of red cells or haemoglobin, the haemoglobin that is present may be fully saturated with oxygen. However, the decreased numbers of erythrocytes may not be enough to allow sufficient oxygenation. On the other hand, other machines use more wavelengths of light and measure more red cells, giving more reliable readings. Some machines calculate oxygen saturation from each pulse, rather than across a range of pulses, giving highly accurate results. The pulse rate can be checked manually against that shown by the oximeter, and this will give an indication as to whether the reading is reliable or not. The type of probe can be a clip-type transmittance probe, which can compress the tongue or tissue, resulting in an invalid or absent reading, or a reflectance probe, such as that which is placed in the rectum, and likely to give more consistent readings. The light must be able to shine through the tissue, and pigmented membranes prevent this. Readings are likely to be inaccurate in states of hypovolaemia, hypothermia and hypotension, due to peripheral vasoconstriction.

The oximeter probe should be the last piece of monitoring equipment that is removed at the end of anaesthesia. When the patient is disconnected from the breathing system, the decrease from breathing 100% oxygen to 21% in room air can result in desaturation and it may be necessary to “wean” them off of pure oxygen back onto room air, until saturation can be maintained.

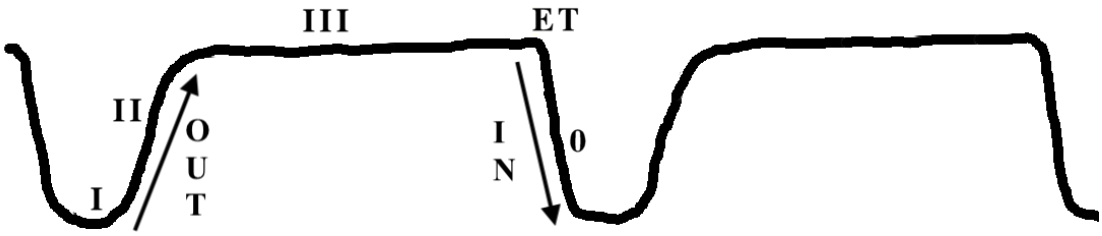
Capnography

Capnography is the measurement of concentration of carbon dioxide in respiratory gases. End-tidal carbon dioxide ($ETCO_2$) is the concentration of carbon dioxide at the end of a breath, and the fraction of inspired carbon dioxide ($FICO_2$) is the concentration of carbon dioxide in inspired gases. Carbon dioxide is the waste product of tissue metabolism, and capnography is the best way to monitor ventilation. Normal $ETCO_2$ readings (normocapnia) in dogs and cats are in the range of 35-45 mmHg, although realistically, in anaesthetised patients, these values may be higher but should be maintained at less than 60 mmHg.

There should be no or very little carbon dioxide in inspired gas, so $FICO_2$ should be 0 mmHg (or close to 0). End-tidal carbon dioxide readings are very similar to $PaCO_2$ readings – those in arterial blood – so capnography provides a reliable, non-invasive way of assessing ventilation.

Examination of the capnograms (waveforms) provides useful information. A normal capnogram has a distinct shape and consists of four phases, as shown in the diagram below.

Normal capnogram



At each phase of the capnogram, a different part of the respiratory cycle can be assessed. Abnormalities are identified by examination of the shape of the capnograms. Table 1 describes what is happening at each of the four phases of the normal capnogram.

Table 1: Capnogram phases and the respiratory cycle

Phase	Line shape	Description
I	Parallel with base line	Dead space gas exhaled
II	Expiratory upstroke	Dead space and alveolar gas exhaled
III	Expiratory plateau	Mixing of gas from different parts of the lungs results in the average concentration of CO_2 from all alveoli. The end of the plateau represents $ETCO_2$
0	Inspiratory downstroke	Inhalation of fresh, CO_2-free gas

Hypercapnia – a high $ETCO_2$ reading – results from hypoventilation or a fresh gas flow that is too low. Hypocapnia – a low $ETCO_2$ reading – results from hyperventilation, an undersized endotracheal tube or one with a leaking cuff.

When a value outside the normal range is seen, the cause should be found if possible, and suitable action taken. Performing intermittent positive pressure ventilation will bring end-tidal carbon dioxide levels to within normal parameters, whether they are too high or too low.

If the monitor gives inspiratory CO_2 readings, this can be used to set the fresh gas flow rate. As $FICO_2$ should be 0 mmHg, the fresh gas flow is lowered until this reading creeps up to 1 or 2 mmHg.

Blood pressure

Arterial blood pressure is the force exerted on the arterial walls. It is the driving force for blood flow through the vessels that supply oxygen to the organs and tissues of the body. Vital organs must remain perfused with blood under anaesthesia to allow them to continue functioning normally. Systolic arterial pressure is the maximum pressure in the artery when the heart contracts, diastolic pressure is the lowest pressure in the artery, between cardiac contractions, and the mean arterial pressure (MAP)

is the average pressure over one complete cardiac cycle. This is equivalent to the perfusion pressure, and it is this reading that is most reliable when using oscillometry to measure blood pressure and the most significant in the anaesthetised patient. Approximate normal values of arterial blood pressure in dogs and cats are shown in Table 2.

Should hypotension occur, which is a common phenomenon in anaesthetised patients, and remain untreated, the consequences can of serious significance to the patient and may play a part in organ damage in later life. Kidney injury and blindness are likely sequelae, as is damage to the central nervous system, heart and lungs.

Anaesthetised patients become hypotensive for a variety of reasons, including pharmacological effects of anaesthetic and analgesic drugs, positioning of the patient during anaesthesia, cardiac arrhythmias, compromised venous return, administration of intermittent positive pressure ventilation, manipulation of the viscera during surgery, and human error.

Hypotension in dogs and cats is defined as a mean arterial pressure of less than 60 mmHg or a systolic pressure of less than 80 mmHg. Blood pressure can be measured using a non-invasive method or invasively. Invasive blood pressure monitoring involves cannulating an artery (usually a peripheral artery), and having specialised equipment, to give a continuous digital display and waveform. Details relating to invasive blood pressure monitoring are outside the scope of this course and the focus is on non-invasive methods.

Non-invasive blood pressure is measured using standard oscillometry or high definition oscillometry, both of which give systolic, diastolic and mean arterial pressure values, or using Doppler, which gives systolic pressure only. There are several drawbacks to non-invasive blood pressure monitoring. It is important to use the correct size cuff, measurement of which should be approximately 40% the circumference of the limb or tail (30% in cats). Cuff placement is also important. It should not be secured with a tight piece of tape, nor should it be bandaged in place, and it should be level with the heart. Some common errors and their consequences are shown in Table 3.

Oscillometric readings are often underestimated and the systolic reading may be lower by as much as 15 mmHg than the actual systolic pressure. Trends are important, as this allows detection of deterioration or improvement. Standard oscillometry does not work well with small vessels (cats and small dogs) or in states of hypotension, hypovolaemia, high heart rates, compromised blood flow or where there is movement. Doppler blood pressure measurement gives one reading only. This is the systolic reading, although in cats and small dogs, the reading obtained is thought to be somewhere between the systolic and mean arterial pressures. The piezoelectric crystals used in the probe are very sensitive, so this is a suitable method for cats, small dogs or any patient with a low blood pressure. As an audible signal is emitted, it provides an excellent, hands-free monitor of peripheral pulse, and can be used together with oscillometric blood pressure devices.

Table 2: Approximate normal arterial blood pressure values in dogs and cats

Measurement	Value (mmHg)
Systolic pressure	80-140
Diastolic pressure	55-90
Mean arterial pressure	80-120

Table 3: Common errors in BP measurements

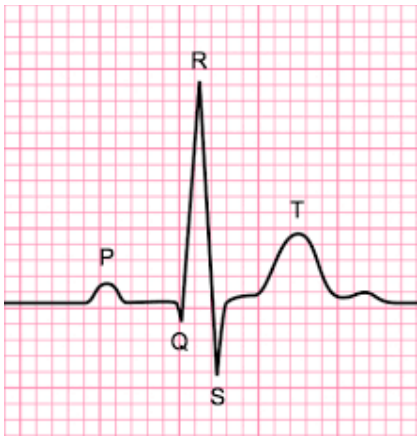
Cuff error	BP
Too large or too tight	Underestimated
Too small or too loose	Overestimated
Lower than the heart	Overestimated
Higher than the heart	Underestimated

For most routine anaesthetics, if a patient becomes hypotensive and there is no immediate obvious reason, the first action is to decrease the vaporiser setting. The reason for this is that all the inhalant agents cause a dose-dependent vasodilation, and will therefore lower blood pressure. Decreasing the concentration of the inhalation agent will often be sufficient to correct hypotension due to vasodilation from the inhalant agent. It is sometimes necessary to give a bolus of crystalloid fluid, or start intravenous fluid infusion, to correct hypotension that is due to hypovolaemia. Treatment with drugs may also be required in some instances, although many general practices do not stock the necessary drugs or equipment for their administration, if CRI (constant rate infusion) is required. Hypotension and hypothermia are often linked, so monitoring body temperature and warming the patient if necessary, are also important.

ECG

Electrocardiography is a measure of the heart's electrical activity. An ECG trace is a graph that plots electrical activity as voltage on the y-axis and time on the x-axis. There is no information on cardiac output, so the ECG trace does not show how well the heart is performing mechanically and cannot ever be relied upon to confirm the anaesthetised patient is alive, as it is possible to obtain an electrical trace after death. The rate and rhythm of the heart are assessed under anaesthesia. Various arrhythmias can be identified, and this is significant as stroke volume and cardiac output can be compromised as a result. Impending crises can also be detected from examination of the ECG trace. Lead II is used to monitor ECG activity in anaesthetised animals. This is not a diagnostic tool, and lead II is used as it measures the voltage difference between the right forelimb and the left hindlimb, so it is in a line with the direction of the heart's activity. Three or four electrodes are used. Placement and colour system used in the UK are shown in Table 4. The electrodes are placed on the feet, using adhesive pads, or on the limbs, using crocodile clips. When two forelimb and one other (hindlimb or alternative location) electrodes are used in lead II, the ECG waves and complexes will look like those in the diagram. However, if two hindlimbs and one forelimb are used for electrode placement, the trace will be inverted.

Normal ECG trace in lead II



The P wave is a positive/upward deflection, and represents contraction of the atria – atrial depolarisation. The QRS complex represents ventricular contraction (depolarisation) and the T wave, which may be a positive or negative deflection in small animals, (above or below the baseline), represents the resting phase, or ventricular repolarisation.

Table 4: Placement of ECG electrodes (UK colours) in lead II

Electrode	Position
Red	Right forelimb
Yellow	Left forelimb
Green/black	Hindlimb – or if both electrodes present: green LH, black RH

Electrical interference may be a problem when assessing the ECG. Interference from equipment such as diathermy or heat pads is common, and although the heart rate may be accurate, the ECG trace is often of no value. Heart rate is calculated by counting the R waves but occasionally, the machine counts the T wave as a separate beat. This is referred to as ‘double counting’ and can explain a sudden increase or decrease in the heart rate displayed by the monitor. There are many abnormal ECG rhythms that can be identified, but it is important to be familiar with a normal ECG and to report abnormalities when they arise. Most multiparameter monitors have a Freeze button, which freezes all the waveforms on the monitor but continues monitoring and displaying numerical values. Pressing the Freeze button a second time will resume waveform display mode.

PART 2: RECOVERY AND POSTOPERATIVE CARE

At the end of anaesthesia, the vaporiser is turned off and pure oxygen is administered. How long oxygen is given depends on several factors, but the administration of 100% oxygen should be given to all patients for at least several minutes. It will be necessary to increase the fresh gas flow rate at the end of anaesthesia when using a circle system. Monitoring aids are left in place until signs of regaining consciousness are observed, then they can be removed as necessary. The last piece of monitoring to be removed is generally the pulse oximeter. It is useful to know that the patient is maintaining saturation when breathing room air – that is, after discontinuation of pure oxygen, and if necessary, weaning off of oxygen back onto room air may be necessary. If oxygen is required after extubation, it can be given by mask, flow-by, nasal prongs or nasal catheter. It is wise to check the size of the urinary bladder and empty it if it is full. This will improve patient comfort and aid a smooth recovery.

The airway must be protected until the time of extubation, so the cuff of the endotracheal tube remains inflated until immediately prior to tube removal. Extubation should be performed at the correct time for the species. Non-brachycephalic dog breeds are extubated after the swallow reflex has returned and some people prefer to wait for two good swallows. Brachycephalic breeds are extubated much later, usually when they are conscious. They are usually not able to bite on the tube because of their jaw and facial conformation. However, they must never be left unattended with an endotracheal tube in place. Extubation in the cat should take place before they start to swallow, to avoid laryngospasm occurring. It is not always easy to judge when this will be, but generally, if they have a strong palpebral reflex or start to twitch the ears when stimulated or move their limbs, the endotracheal tube can be removed. The cuff is deflated and the tube gently removed, ideally when the patient is breathing out. A downward arc motion minimises the risk of trauma to the trachea, especially when preformed tubes are used. As with intubation, the process should be performed gently as any damage incurred can manifest later as oedema, which has consequences such as discomfort, anorexia or inappetence, or airway obstruction. Gagging and coughing during extubation should be avoided as this increases the risk of regurgitation. Occasionally, extubation is required earlier than normal; for example, in patients with raised intracranial or intraocular pressure, or following airway surgery, where coughing and gagging will further increase the pressure or cause damage to the surgical site. In these cases, the airway is unprotected until consciousness is regained, and the patient must not be left unattended, and the head should be kept slightly raised to avoid aspiration, should regurgitation occur.

A wheeled trolley should be used to transfer the patient back to the kennel or recovery area, as this is safer than carrying it, for both the animal and personnel. A warm, comfortable area must be provided for recovery and the patient positioned appropriately. Sternal recumbency allows both lungs to inflate fully and simultaneously, improving oxygenation. However, it may be that lateral recumbency is more comfortable. If the animal was in lateral recumbency during anaesthesia, the contralateral recumbency during recovery allows the dependent (down) lung to re-inflate. Sternal recumbency is required for certain breeds, such as brachycephalics, and following some procedures, including airway surgeries or when regurgitation is a risk.

The CEPSAF report showed recovery from anaesthesia to be the most dangerous phase and the one when most anaesthetic deaths occur. Most deaths that occur during recovery do so in the first three hours of regaining consciousness and although there is no real evidence to support theories in the veterinary profession, it is thought that lack of monitoring during recovery is a contributing factor. It is therefore optimal for all patients recovering from general anaesthesia to be assigned a designated nurse to monitor them until they are fully conscious and ambulatory. The transition from unconsciousness to consciousness can be stressful for the patient, with some patients showing exaggerated responses. Geriatric animals show more emergence delirium than other animals and appreciate reassurance during recovery, as confusion is common. Similarly, very young animals require reassurance.

How long an individual animal takes to recover from anaesthesia depends on several different factors, such as the breed, size, body condition and disease state, drugs used, time spent under anaesthesia, and body temperature. Should emergence delirium occur, a low-dose alpha-2 agonist drug will often be given to aid a smooth recovery. This is something that can be pre-agreed, either prior to or during anaesthesia, and form part of the anaesthetic plan. This means the drug can be given without delay, if instructions by the veterinary surgeon have already been recorded, and the correct dose can be calculated and recorded on the anaesthetic plan and/or record prior to recovery.

There should be a full and detailed handover from the person who was monitoring the anaesthetic to the person who will be responsible for monitoring the patient during recovery. It will be necessary for certain information to be explained verbally, as well as having written notes. The body temperature at the end anaesthesia must be recorded and if necessary, active heat supplied. The reason for anaesthesia must be known, together with any surgical or medical procedures performed. It is especially important to relay information relating to abnormalities or concerns that arose during anaesthesia and whether any action was taken, such as giving a fluid bolus or drugs to treat hypotension, whether additional analgesia was required, whether local nerve blocks were used and if so, whether they were effective, and so on. There must also be a clear forward plan, regarding fluid therapy, analgesia, other drug therapy and feeding instructions. Intravenous fluids are usually continued during the postoperative phase, generally at maintenance rate following routine procedures, until the animal eats and drinks. Food and water can be offered when the animal is fully conscious. Feeding after approximately two hours of regaining consciousness has many advantages and is rarely contraindicated. Body temperature returns to normal, blood glucose levels increase and morale is improved. It has also been shown that healing times are faster for the surgical patient, with less risk of surgical site infection and wound dehiscence. Morbidity and mortality rates are reduced if nutritional support is given early in the recovery phase, and recovery time is reduced. Any expected or possible complications must be explained verbally and recorded on the patient's hospitalisation chart, together with interventions that have been instructed by the veterinary surgeon. Pain scoring is good practice and there are many methods and systems that can be used. Timely intervention with analgesia is crucial to a patient's recovery and breakthrough pain must be avoided.

Monitoring after anaesthesia is as crucial as monitoring during anaesthesia, and many complications can be prevented if a diligent observer remains with the patient until it is fully recovered, acting on irregularities and therefore increasing the chances of a smooth and uneventful recovery.

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