Practical guide to monitoring anaesthetised small animal patients

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Anaesthesia – a reversible and controlled coma-like state – is an art based on an understanding of many contributing factors: pharmacology, the patient and its varied physiological processes or disease states, the procedure being undertaken and the potential complications arising as a result of all of these. Monitoring a patient at this time can be challenging but the increasing use of multiparameter monitors reduces the incidence of morbidity and mortality in both people and animals. Understanding the data displayed on these monitors is important, but it is vital not to lose sight of the whole picture as well. This article focuses on the main parameters that are monitored when small animals undergo general anaesthesia (including the patient itself) and explains how the data acquired should be considered in relation to other information.

Why monitor?

Monitoring an animal under anaesthesia allows timely and informed responses to changes in the patient's status. Because body systems are part of an interactive and constantly adapting organism, it is important to monitor more than one variable per body system and more than one body system at the same time. For example, heart rate (a cardiovascular system variable) may be increased in cases of hypotension or pain, and if looking at the blood pressure (another variable for the cardiovascular system), this may be low if the heart rate has increased in response to hypotension or high in response to pain. In a recent study, hypoventilation and hypotension were among the most common complications in dogs under general anaesthesia (Redondo and others 2007).

Writing parameters and observations down on an anaesthetic record is important because as well as being used as a legal document, it helps to visualise trends and is part of the anaesthetic history for that patient.

Monitoring the patient

The depth of anaesthesia in a patient can be assessed by monitoring the parameters listed in Table 1, although these are only indicative of the plane of anaesthesia and are in no way exhaustive or cover every eventuality that may occur under general anaesthesia. When interpreting the information, several other factors must be taken into account, including the drugs being administered to the patient and what is happening to the patient at that time. For example, when using isoflurane as an inhalant anaesthetic, the patient may develop hypotension and the heart rate may increase as a compensatory mechanism during deep anaesthesia.

It is also worth noting that some parameters may behave differently from as described in Table 1; for example, when a dog is lightly anaesthetised, its heart rate may decrease, possibly due to vagal stimulation (which may be related to the presence of the endotracheal tube [ETT]).

Table 1: Parameters used to assess depth of anaesthesia

Parameter	Light anaesthesia	Adequate anaesthesia	Deep anaesthesia	Comments
Eye position	Central	Rotated	Central	Can be central with dissociative anaesthetics (DA)
Palpebral reflex	Present	Absent	Absent	Can be present with DA Repeated poking will cause this reflex to disappear
Jaw tone	Present	Absent	Absent	Can be present with DA
Movement	Possible	Absent	Absent	
Cornea	Moist	Moist	Dry	
Heart rate	Usually increased		Usually decreased	
Respiratory rate	Usually increased		Usually decreased	
Response to surgical stimulation	Yes	Possible	No	

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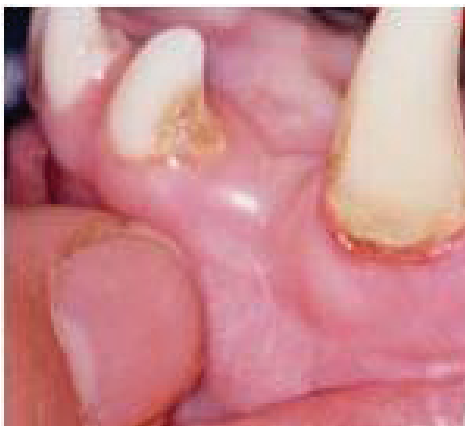


Fig 1: Normal pink mucous membranes in a dog

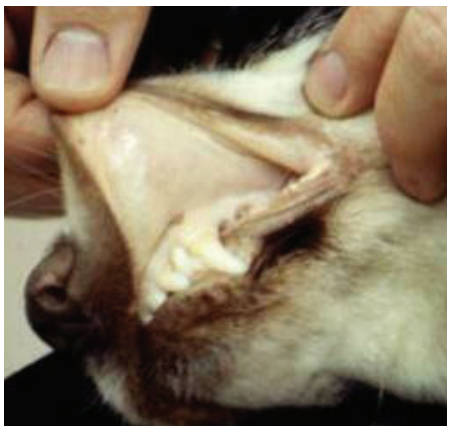


Fig 2: Pale mucous membranes in a dog, suggesting hypoperfusion, anaemia or vasoconstriction

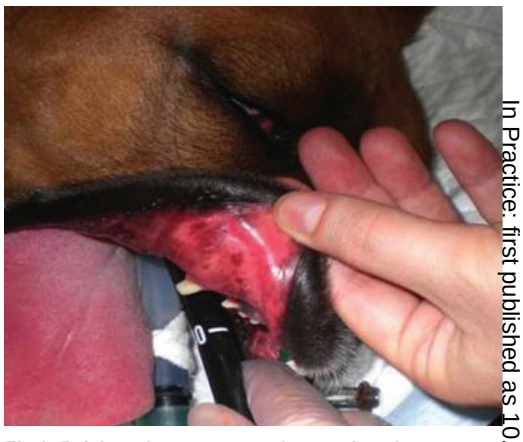


Fig 3: Brick-red mucous membranes in a dog, indicating haemoconcentration or hypercapnia

Reflexes and jaw tone

In my opinion, the globe position in a cat is often unreliable and cats can 'jump off the table' with ventrally rotated eyes, so jaw tone appears to be a more reliable parameter for monitoring in this species.

Mucous membrane colour

When monitoring the colour of the mucous membrane, pink is normal (Fig 1) and a pale colour suggests hypoperfusion, anaemia or vasoconstriction (Fig 2). If the mucous membrane is red, this implies vasodilation or local congestion, whereas a brick-red colour indicates haemoconcentration or hypercapnia (Fig 3). A blue mucous membrane is indicative of cyanosis (Fig 4) and yellow means it is icteric so the patient will need oxyglobin (Fig 5).

Capillary refill time

The capillary refill time (CRT) gives an indication of peripheral perfusion. A CRT of less than two seconds is normal, whereas an extremely quick CRT suggests congestion; a CRT of more than two seconds indicates peripheral hypoperfusion.

Peripheral pulses

The rate, rhythm, quality and synchronicity of peripheral pulses with heartbeats should be assessed (Fig 6) and fast, slow or abrupt changes in pulse rates should be

Table 2: Causes of an increased pulse rate

Cause of increased pulse rate	How to rule this out?
Drug related (atropine, ketamine, adrenaline)	Look at the patient's history
Light anaesthetic plane	Check eye position, palpebral reflex and jaw tone. Often blood pressure will be increased as well
Pain	Check the analgesics you have given have not worn off. If in doubt provide more analgesia. Normally blood pressure will be increased as well
Hyperthermia	Check temperature and end tidal carbon dioxide ($EtCO_2$)
Hypotension	Check blood pressure and depth of anaesthesia, decrease the percentage of isoflurane given
Hypovolaemia	Look at the patient's history Check blood pressure (although in early phases the heart rate will increase to maintain blood pressure), assess pulses (are they bouncy?), give a fluid bolus if not contraindicated and see if pulse rate decreases
Hypoxaemia	Check the saturation of haemoglobin with oxygen (SpO_2) percentage, inspired oxygen and ventilation
Hypercapnia	Check $EtCO_2$ and provide positive pressure ventilation (PPV) if this is high
Hyperthyroidism	Look at the patient's history
Anaemia	Look at the patient's history Check the packed cell volume (PCV)
Pheochromocytoma	Look at the patient's history, usually blood pressure will vary widely
Cardiac disease	Check ECG to look for tachyarrhythmias, feel pulses (are they regular and of a constant strength?), listen for a heart murmur. Pulse rate should have been increased also in the preoperative assessment

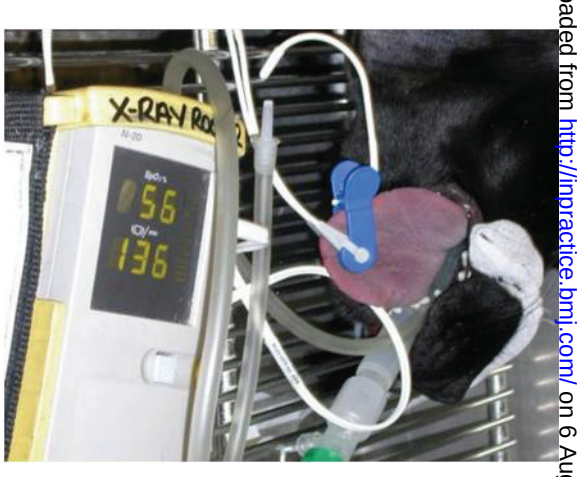


Fig 4: Cyanotic (blue) mucous membranes in a dog with a haemoglobin oxygen saturation of 56 per cent and a pulse rate of 136 beats per minute

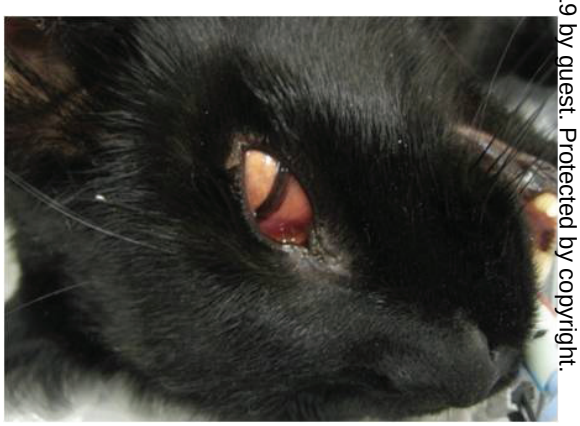


Fig 5: Icteric (yellow) mucous membranes in a cat that received oxyglobin to counter the icterus

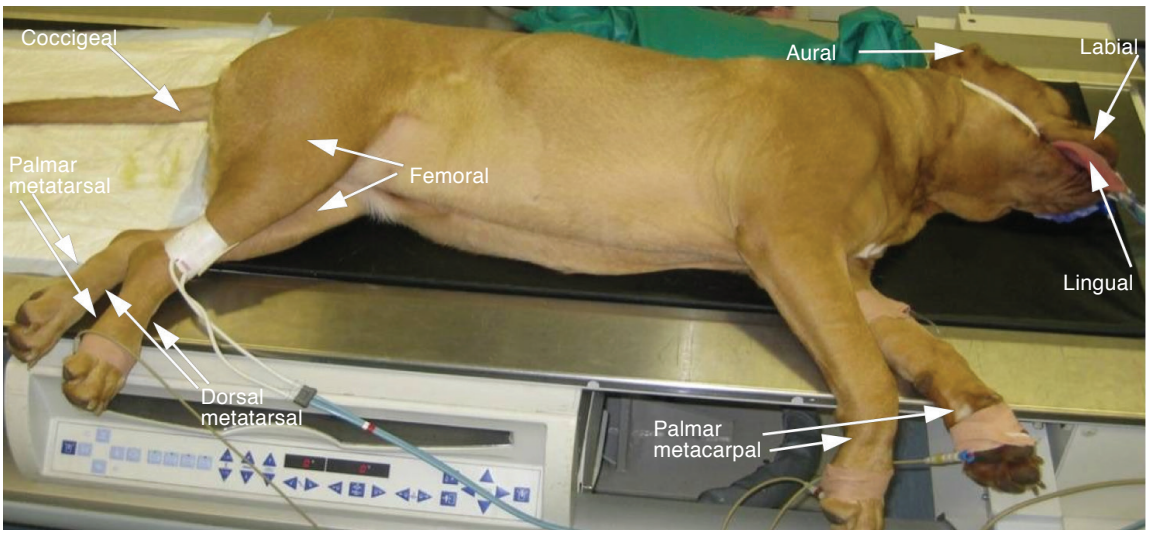


Fig 6: Different peripheral pulses that can be monitored and are easily palpable in a dog

investigated. The most common causes of changes in pulse rate are summarised in Tables 2 and 3.

Assessment of pulse quality involves evaluating pulse pressure (PP), that is the difference between the systolic arterial pressure (SAP) and the diastolic arterial pressure (DAP); it is not an indication of blood pressure. The pulse of a patient with an SAP of 80 mmHg and a DAP of 40 mmHg (PP = 80 – 40 = 40 mmHg) will, in theory, feel the same as the pulse of a patient with an SAP of 120 mmHg and a DAP of 80 mmHg (PP = 120 – 80 = 40 mmHg). The difficulty that is encountered when trying to suppress the pulse by compressing it will be an indication of the SAP (Fig 7).

Pulses can be bouncy (hyperdynamic) in hypovolaemic patients and feel big but 'empty' and will be easy to compress.

Respiration

Respiration is monitored by looking at chest excursions or the reservoir bag. The rate, rhythm, depth and respiratory effort should be taken into consideration. Some drugs cause characteristic respiratory patterns; for example, ketamine can cause apneustic breathing (rapid breaths followed by breath holding on inspiration).

Apnoea can be caused by an overdose of anaesthetic or due to the rapid injection of anaesthetic induction agents or analgesics, although cats anaesthetised with isoflurane can hold their breath when the anaesthetic plane is light.

Panting can occur during light anaesthetic planes or hyperthermia, as a response to pain, due to hypercapnia, hypoxaemia or restrictive lung disease, or even due to some drugs such as methadone – often when used alone (although when given during general anaesthesia, transient apnoea is most commonly seen).

Table 3: Causes of a decreased pulse rate

Cause of decreased pulse rate	How to rule this out?
Drug related (α2-agonists, opioids)	Check when the drugs were last given
Deep anaesthetic plane	Isoflurane does not really decrease the heart rate. Blood pressure should be decreased as well
CNS disease - increased intracranial pressure	Arterial blood pressure should be increased as well
Hyperthermia	Check temperature
Vagal stimulation (light anaesthetic plane, surgical manipulations)	Check what the surgeon is doing (manipulation of the gut, pressure on the globe), check the depth of anaesthesia
Hyperkalaemia	The ECG should show other signs (flattened P wave). Check history for causes of hyperkalaemia. Check serum potassium
Cardiac disease	More common in some specific breeds (ie, West Highland white terrier, miniature schnauzer) in which bradycardia may not be responsive to atropine (sick sinus syndrome, third degree atrioventricular block)

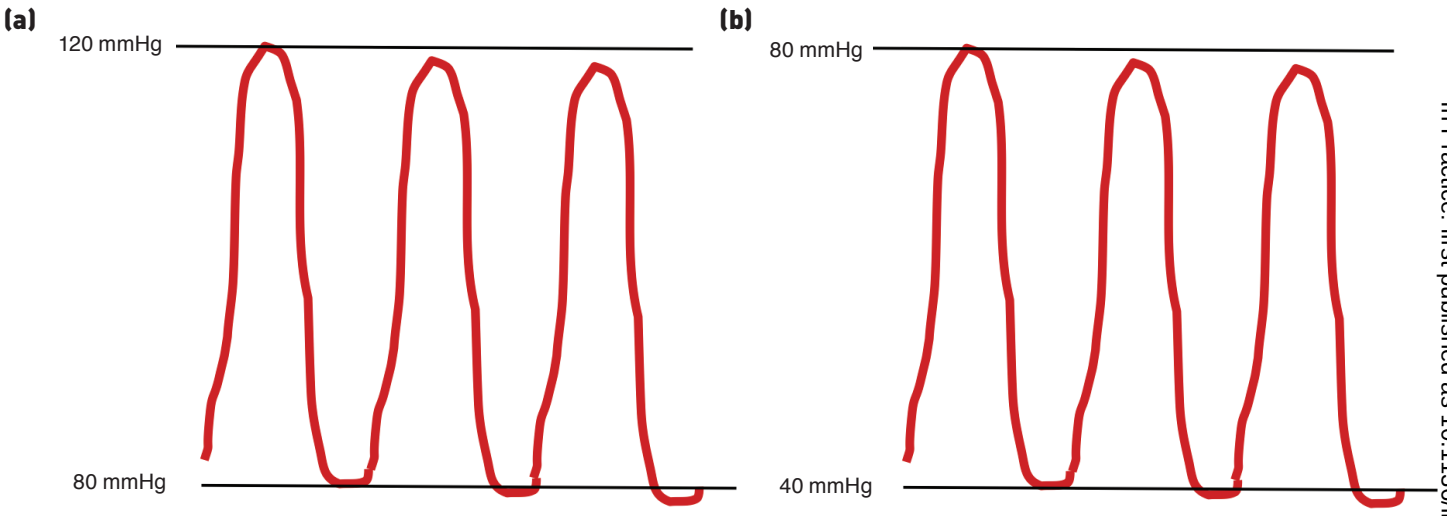


Fig 7: Two pulses that will feel the same as they have the same pulse pressure (40 mmHg) but pulse (a) will be harder to compress than (b) as it has a higher systolic pressure. Ease of compression gives an indication of systolic pressure

During spontaneous ventilation, an increased inspiratory effort will generally indicate an upper airway obstruction (eg, in the ETT or trachea). An increased expiratory effort will generally indicate a lower airway obstruction (bronchoconstriction).

The presence or absence of respiratory noises is also important. The presence of mucous in the ETT often manifests as noise in the reservoir bag. Chest auscultation can reveal the presence of pneumothorax (absence of respiratory noises), pleural effusion (muffled respiratory noises and heart sounds), pulmonary oedema (crackles), and so on.

Other parameters

In an adequately anaesthetised patient, muscle tone and shivering should be absent. The presence of salivation or regurgitation could indicate a plane of anaesthesia that is too light.

The surgical site should be monitored for bleeding, as the surgeon does not necessarily have a clear idea of the amount of blood loss. In addition, if tissues are very pale, this could indicate poor peripheral perfusion. The latter is also characterised by a different core-periphery temperature.

The person monitoring the anaesthetic should listen to the surgeon; for example, are they asking for help, asking for more swabs very early after the previous batch or even suddenly going silent, as this could indicate a problem at the surgical site even before it is visible at the monitoring site. Leaks of inhalant anaesthetic around the ETT (which can sometimes also be smelled in the room), alarms and beeps from the monitor should also be listened out for.

Monitoring the monitor

A multiparameter monitor is a very useful tool for monitoring a patient during anaesthesia. The introduction of what is now considered to be basic monitoring has reduced mortality and morbidity rates in both people and in animals. Keenan and others (1991) demonstrated a reduction in the incidence of cardiac arrest in anaesthetised paediatric human patients when multiparameter monitors were introduced. That said, in no way should one rely solely on the multiparameter monitor and forget about the patient or lose the overall picture.

Electrocardiogram

The electrocardiogram (ECG) shows the electrical activity of the heart; it is not an indication of cardiac output. When looking at an ECG on a multiparameter monitor (Fig 8), the following should be determined:

- Is the rhythm sinus? (Is there a P wave, a QRS complex and a T wave?)
- Is there a P wave for every QRS complex? Is there a QRS complex for every P wave?
- Is it rhythmic?
- Is the rate adequate for that patient in that situation?

Normally, a three-lead ECG is used and, as a rule of thumb, lead II is selected, with the yellow lead placed on the left forelimb, the red lead on the right forelimb and the black

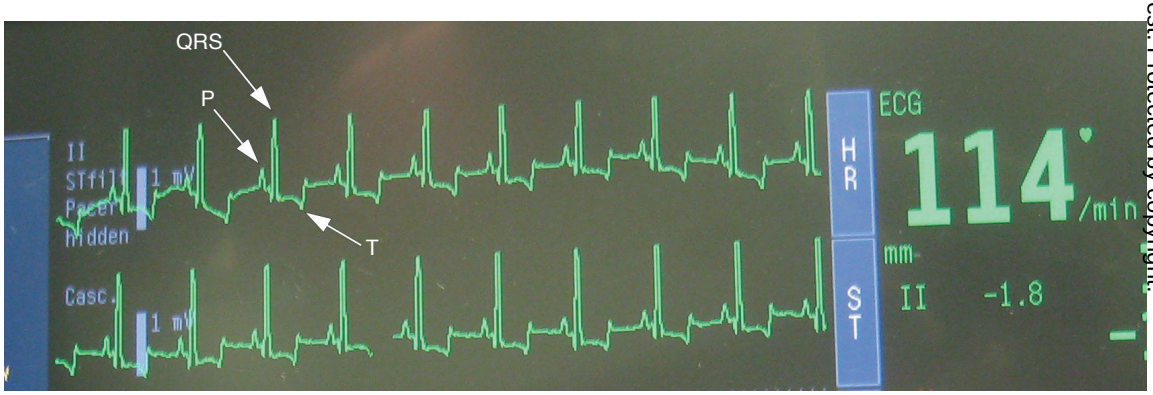


Fig 8: Normal electrocardiogram, showing P and T waves and the QRS complex

lead (sometimes green) on the back limb. This positioning of the leads is not essential, as long as they are placed in a triangle-like position around the heart. For instance, if two limbs are inaccessible, a lead can be placed on the ear or in the mouth of the patient.

During anaesthesia, an ECG will help to recognise arrhythmias. To differentiate these from artefacts (due to, for example, movement, muscle tremors or electrodiathermy), simultaneous pulse palpation is important. If this is not possible, then observing the plethysmograph may help. The most common arrhythmias seen under general anaesthesia are:

- Sinus arrhythmia. This is where the heart rate increases during inspiration and decreases during expiration (Fig 9). This arrhythmia is vagally mediated and is considered normal in dogs, but if noticed in cats, an increase in vagal tone, such as an upper airway obstruction, should be looked out for;
- Sinus bradycardia. Depending on the fitness of the patient and the drugs that have been administered, this can be defined as a heart rate of less than 60 beats per minute (bpm) in dogs or less than 100 bpm in cats. However, in fit dogs that have received medetomidine and methadone, for example, a heart rate of less than 40 bpm is to be expected. In such cases, blood pressure should be measured and, if low, the bradycardia should be addressed;
- Sinus tachycardia. This can be defined as a heart rate of more than 150 bpm in dogs or more than 200 bpm in cats. Again, the patient and the situation both need to be taken into account;
- Second-degree atrioventricular blocks. These are commonly seen after an α2-agonist has been administered. The ECG will show one or more P waves that are not followed by a QRS complex (Fig 10);
- Ventricular premature complexes (VPCs) (Fig 11). In such cases, the ECG will show an early 'odd' beat, which is normally wide and bizarre, with no P wave, followed (usually) by a longer 'compensatory' pause. Common causes for the appearance of VPCs are:
  - Pain
  - Hypoxia
  - Blunt cardiac trauma
  - Catecholamine release
  - Splenic manipulations or disease
  - Gastrointestinal disease
  - Drugs
  - Electrolyte imbalances (eg, magnesium or potassium);
  - Heart disease
  - Ventricular tachycardia. This is characterised by more than three VPCs in a row on the ECG (Fig 12) and should be treated if it appears to be polymorphic (ie, if there are beat-to-beat variations in the ECG morphology), if the rate is higher than 200 bpm, if they are R-on-T (ie, the R wave of the ectopic beat [VPC] and the T wave of the previous beat are very close together/overlapping) and/or if there are pulse deficits that affect the blood pressure.

Pulse oximetry

Pulse oximetry measures the saturation of haemoglobin with oxygen (SpO_2). Most pulse oximeters give a pulse rate and an audible beep, the pitch of which is normally related to the oxygen saturation. Some are associated with a plethysmogram, which is a curve reflecting the pulse. It is important to understand that pulse oximetry does not give an indication of oxygen delivery to the tissues: if there is only one red blood cell in circulation and this is saturated with oxygen, the SpO_2 will be 100 per cent but the oxygen content and delivery to the tissue will be nil. In normal anaesthetised patients, the SpO_2 should be over 97 per cent.

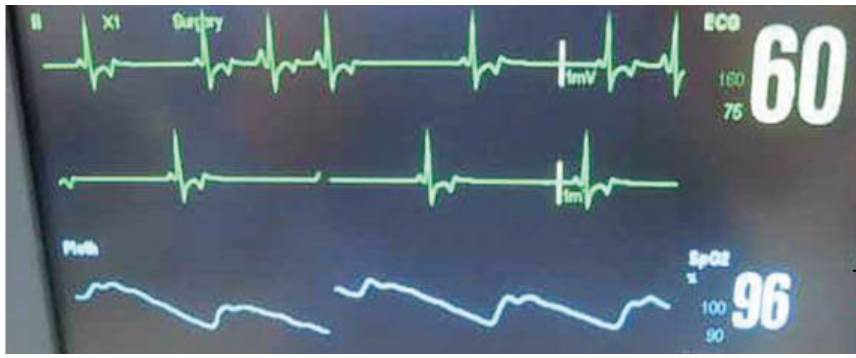


Fig 9: Electrocardiogram showing sinus arrhythmia

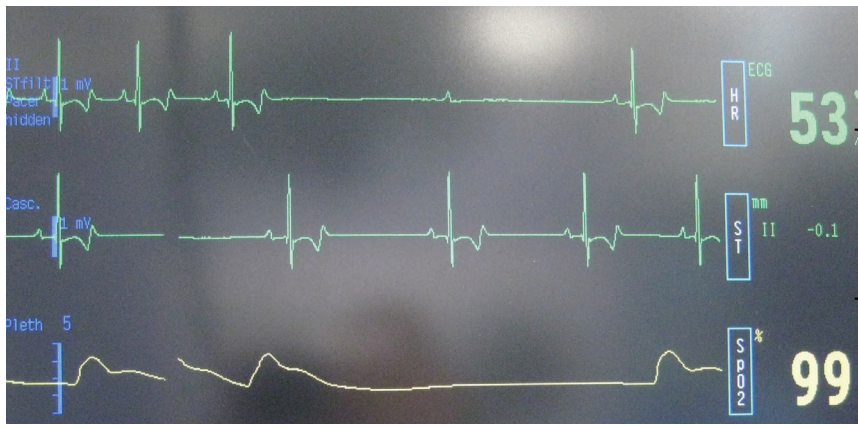


Fig 10: Electrocardiogram showing second-degree atrioventricular block, which is indicated by P waves not being followed by a QRS complex

Unfortunately, pulse oximetry has several limitations. Readings are not immediate but occur after a delay of

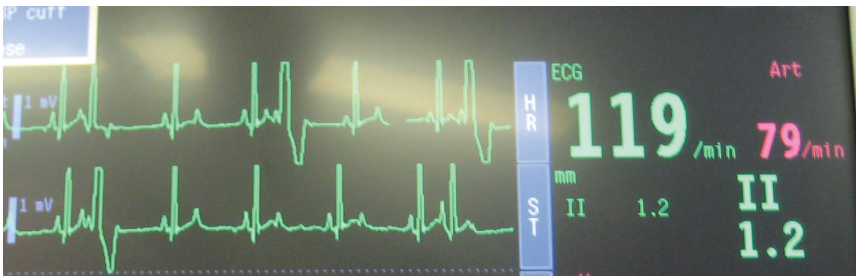


Fig 11: Electrocardiogram showing ventricular premature complexes

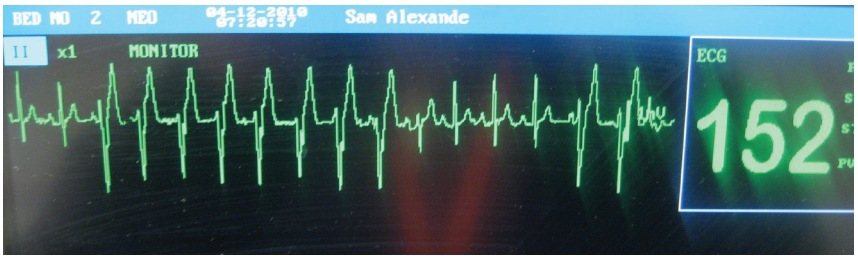


Fig 12: Electrocardiogram with more than three ventricular premature complexes in a row; this is an indication of ventricular tachycardia

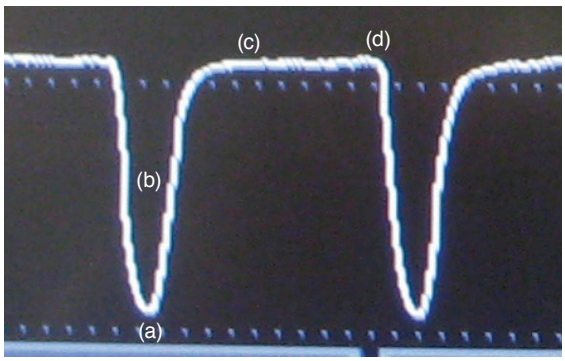


Fig 13: Normal capnogram. (a) Exhalation of CO_2-free gas contained in dead space. (b) Expiratory upstroke (emptying of the airways, beginning of emptying of the alveoli). (c) Expiratory plateau (uneven emptying of the alveoli). (d) End tidal CO_2 – peak exhaled CO_2

approximately 10 to 20 seconds, they are not very accurate at an SpO_2 of below 80 per cent (Moens 1994) and they can be altered by pigmented mucous membranes, shivering or movement, peripheral vasoconstriction or poor peripheral perfusion, light and electromagnetic interferences, bad probe positioning, the use of intravenous dyes and the presence of abnormal haemoglobins. If the plethysmogram – when present – resembles that of an arterial pulse waveform and the pulse rate given from pulse oximeter corresponds to the actual pulse rate, then the SpO_2 reading is more likely to be accurate. Brodbelt and others (2007) showed that pulse and pulse oximetry monitoring were associated with reduced perianaesthetic mortality in cats.

Fig 14: Doppler (Parks Medical) arterial blood pressure measurement in a cat, showing cuff size 2 on the distal crus

Table 4: Normal $EtCO_2$ and $FiCO_2$ values

Unit	$EtCO_2$	$FiCO_2$
mmHg	35 to 45	0
KPa	4.6 to 6	0
Per cent	5 to 6	0

Table 5: Meaning of changes in $EtCO_2$ when other parameters are stable

	Increase in $EtCO_2$	Decrease in $EtCO_2$
Metabolism	Increased	Decreased
Cardiac output	Increased	Decreased
Alveolar ventilation	Decreased	Increased

Capnography

Capnography gives an indication of the patient's ventilation. Usually, end tidal carbon dioxide ($EtCO_2$) and inspired carbon dioxide ($FiCO_2$) are measured (capnometry) (Table 4) and are often displayed as a capnogram; that is, a curve showing the change in CO_2 at the level of the measuring device. A normal capnogram (Fig 13) consists of an expiratory and an inspiratory phase.

Capnography not only indicates the adequacy of ventilation, but is also a good way to check the correct placement of an ETT, disconnection of the breathing system, metabolism and, last but not least, cardiac output.

$EtCO_2$ is closely related to arterial CO_2 (partial pressure of CO_2 [$PaCO_2$]) (5 mmHg difference in healthy lungs) and can be measured in two ways:

- By mainstream capnography, in which the measurement occurs through a device situated at the end of the ETT, in line with the respiratory gas stream. Although bulky (less so for newer-generation capnographs) and expensive, this method has the advantages of being 'real time' and more reliable than previous methods, particularly in patients with low tidal volumes;
- By sidestream capnography, in which the measurement of the sample occurs in a cell within the monitor. The sample is aspirated at the level of an adaptor attached to the end of the ETT (or nasal catheter) and directed to the monitor via a long, plastic, water vapour-permeable (Nafion) sampling line and a water trap. The sample flow rate ranges from 50 to 250 ml/min.

As the sampled gas also contains anaesthetic gases, the waste gas should be scavenged. However, problems associated with this method are the delay in giving a reading due to the 'transit' time and dilution of the sample in small animals that have a faster respiratory rate. Artefacts can also occur due to leaks, interference of the sample by water vapour or obstructions in the sample line.

$EtCO_2$ is an indication of:

- Metabolism
- Cardiac output
- Ventilation.

When two of these parameters are fixed, a change in $EtCO_2$ will be due to an alteration in the remaining parameter (Table 5).

Many monitors have two 'reference' lines: one is normally 0 mmHg and the other one can be set to a value (eg, 50 mmHg). When looking at a capnogram, it is useful to look at these reference lines because sometimes the $EtCO_2$ value given by the capnograph is erroneous due to artefacts.

Other information that can be obtained from a capnogram is given in Table 6.

Arterial blood pressure

Arterial blood pressure is the pressure exerted by circulating blood on the walls of blood vessels: SAP, DAP and mean arterial pressure (MAP) can be measured. In anaesthetic practice, the MAP is the most important value as it indicates the amount of blood in the arterial system at any time point and is closely correlated to organ/tissue perfusion. It can be calculated using the equation:

$$MAP = [(SAP-DAP)/3]+ DAP$$

Blood flow to the major organs is autoregulated to some degree. These organs receive a constant amount of blood when the MAP is approximately 50 to 150 mmHg, but if the MAP is below or above this range, the blood flow to an organ is decreased or increased, respectively, beyond physiological values and organ damage may occur. The DAP should remain over 40 mmHg to guarantee coronary perfusion.

The MAP depends on cardiac output and systemic vascular resistance. Severe vasoconstriction can cause a normal or high MAP but, in these cases, tissue perfusion is impaired because blood does not 'reach' the tissues adequately.

Table 7 gives the arterial blood pressure ranges for anaesthetised small animals. Blood pressure can be measured directly (invasive blood pressure [IBP]) or indirectly (non-invasive blood pressure [NIBP]).

Non-invasive techniques

NIBP measurements may not provide absolutely accurate blood pressure readings but can indicate trends, which are very important during anaesthesia. A non-invasive method commonly uses a cuff placed on a limb or the tail, with the width of the cuff being approximately 40 per cent of the limb/tail circumference. As the cuff is inflated, the blood flow through it is occluded. The reappearance of blood flow as the cuff is deflated will give an indication of the blood pressure.

Doppler

Advantages of the Doppler technique (Fig 14) are that it can be used in animals of any size and its reliability is not affected by arrhythmias (as long as the user is aware of them and deflates the cuff accordingly). In addition, the continuous sound of the pulse can be used to monitor the pulse rate. However, in anaesthetised cats, Doppler measurements have been shown to be unreliable (da Cunha and others 2014), provide readings that are closer to the MAP than the SAP (Caulkett and others 1998), or underestimate the SAP by 14 mmHg (Haberman and others 2006).

Disadvantages of the Doppler technique are that, if headphones are not used, the noise produced can be disturbing, mostly in the presence of interference.

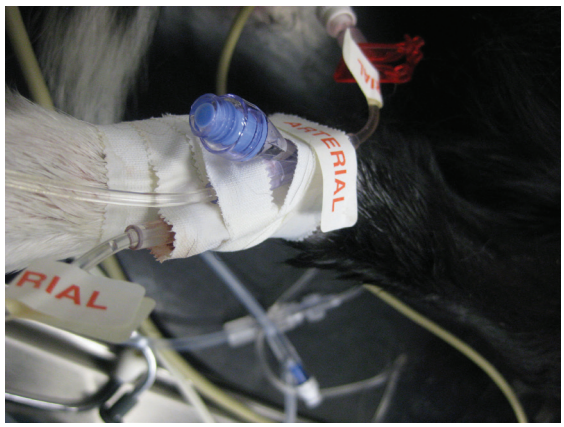


Fig 15: Arterial cannula placed for the direct measurement of blood pressure

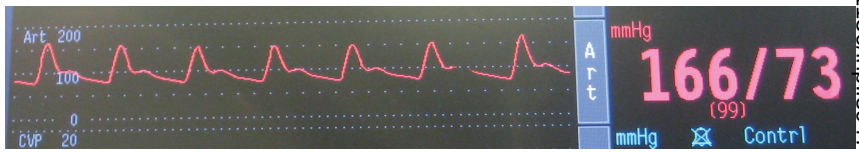


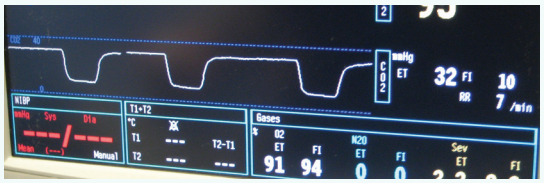
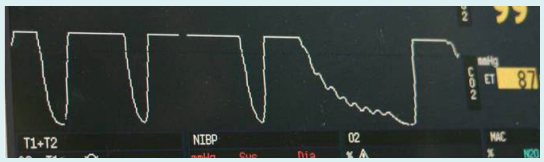
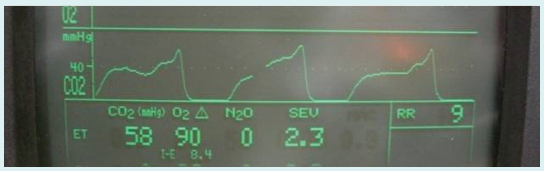
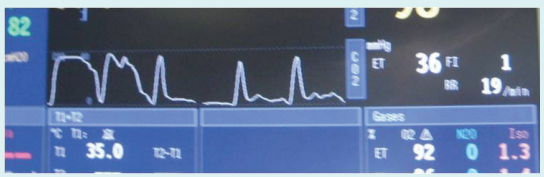
Fig 16: Invasive blood pressure reading via an arterial line. The systolic, diastolic and mean arterial blood pressures are 166 mmHg, 73 mmHg and 99 mmHg, respectively

Oscillometry

Advantages of oscillometry are that it is easy to use and gives regular readings. When devices also give a pulse rate, if this value is correct then the blood pressure readings are more trustworthy.

Blood pressure measurements are affected by extremes in heart rate and arrhythmias, and most apparatuses struggle to give an accurate reading in very small patients. To overcome these difficulties, a high-definition oscillometric technique has been developed. This method shows limited agreement with measurements

Table 6: Different capnograms, causes and actions to take

Alteration	Capnogram	What to do
Cardiac oscillations: oscillations seen in the end of the expiratory plateau and in the descending limb. Caused by the heart beating against the lungs. Oscillations are rhythmic and synchronised to the heart rate		No action required. Look at the reference lines to estimate $EtCO_2$ and $FiCO_2$ as the monitor may read them on the oscillations
Rebreathing: curve not going back to 0 and an increased $FiCO_2$. Generally a $FiCO_2$ of less than 3 mmHg is tolerated		Look for the cause of rebreathing. Most commonly this will be due to: ■ Non-rebreathing system: inadequate fresh gas flow ■ Rebreathing system: exhausted CO_2 adsorbent or sticky unidirectional valves
Hypoventilation: $EtCO_2$ is greater than 45 mmHg (or 6 kPa or 6 per cent). This occurs very often under general anaesthesia, mostly drug induced		Perform manual or mechanical positive pressure ventilation
Airway obstruction: shark fin capnogram. Caused by an obstruction in the expiratory limb of the breathing system, a foreign body in the upper airway (including mucous in the ETT), a kink in the ETT or bronchospasm		Look for kinks in the expiratory limb of the breathing system, suction the ETT (particularly if you can hear a rattle in the reservoir bag as well) If bronchospasm is a possibility, administer bronchodilators
Leak around the ETT: characterised by an absence of the plateau. Caused by a too small ETT or a leaking cuff		Cuff the ETT
Continuously decreasing $EtCO_2$: Decreased cardiac output or, less likely, metabolism. Increased ventilation		Under general anaesthesia, a decrease in $EtCO_2$ with stable respiratory rate is often associated with decreased cardiac output. If you cannot recognise a cause for a decreased cardiac output (eg, the surgeon compressing the aorta) prepare for imminent cardiac arrest

obtained by invasive methods in anaesthetised dogs (Seliškar and others 2013) and awake cats (Martel and others 2013), or when using the Doppler technique in anaesthetised cats (Petric and others 2010); however, it is being increasingly used in small animal clinics.

Invasive technique

The IBP method is considered to be the gold standard and requires placement of a cannula in a peripheral artery (Fig 15). Advantages of this technique are its reliability (also in the presence of extreme heart rates and arrhythmias) and continuity of measurement (this is particularly important in haemodynamically unstable patients) (Fig 16). Unfortunately, this technique also comes with some disadvantages, such as problems related to arterial cannula placement (eg, haemorrhage, infection, clot formation and ischaemia) and difficulty in placing the cannula in smaller patients.

Table 7: Arterial blood pressure ranges for anaesthetised small animals

	Blood pressure (mmHg)
Systolic	90 to 150
Diastolic	50 to 90
Mean	60 to 100

Temperature

Under general anaesthesia it is common for a patient to become hypothermic. It is therefore good practice to monitor – continuously or intermittently – the animal's body temperature and to use heating devices. The temperature is usually measured rectally with an electric thermometer. Multiparameter monitors have an electrical thermometer probe that can be inserted into the lower oesophagus or the rectum.

Although hypothermia in a dog corresponds to a core temperature of below 37.8°C, its negative effects really start at a core temperature of below 34°C. Negative effects include reduced metabolism of drugs, reduced anaesthetic requirements, arrhythmias, reduced immune cell function and increased risk of infection and

of metastatic spread, impaired coagulation processes, reduced sensitivity of baroreceptors and consequent hypotension, impaired oxygen delivery to the tissues, and shivering on recovery with increased oxygen consumption.

Patients under general anaesthesia can also develop hyperthermia but this is less common than hypothermia. It can be genuine or it can be malignant hyperthermia (or some sort of channelopathy leading to hyperthermia). Malignant hyperthermia is a genetic disease mostly triggered by exposure to inhaled anaesthetics. A prompt response to this form of hyperthermia is vital to increase the patient's already small chance of survival.

Urine output

Urine output gives an indication of kidney perfusion and a reading of 1 to 1.5 ml/kg/hour is normal. This should increase with increasing intravenous fluid administration. Because of a greater antidiuretic hormone secretion under general anaesthesia and in hospitalised patients receiving opioids, a urine output of above 0.7 ml/kg/hour is acceptable.

Conclusion

When monitoring a patient under general anaesthesia, it is vital to have a picture of the whole situation. It is not just a case of writing down numbers: it is important to be able to understand where the numbers come from, why things are happening and what to do. An understanding of the way monitors work will help distinguish between 'real' and spurious readings.

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Quiz: Practical guide to monitoring anaesthetised small animal patients

1. A cat has been anaesthetised and its lungs are ventilated at a rate of 15 breaths per minute with the aid of a ventilator. What is the most likely cause for the decreasing $EtCO_2$ values seen on the monitor to the right?
   a. Leak around the endotracheal tube
   b. Increased respiratory rate
   c. Decreased respiratory rate
   d. Decreased cardiac output

Answer: The correct answer is (d) because when the metabolism and respiratory rates are constant, a decreasing $ETCO_2$ indicates a reduction in cardiac output (see Table 6).

It is not (a) because there is a plateau, it is not (b) as the respiratory rate is stable and it is not (c) because, in this case, $ETCO_2$ should increase and, again, the respiratory rate is constant.