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Anaesthetic Case Challenges Mini Series

Session One: Monitoring anaesthesia challenges – what is that screen trying to tell you?

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Monitoring anaesthesia challenges – what is that screen trying to tell you?

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Introduction:

Anaesthesia can be defined as a reversible and **controlled** coma like state. The term "controlled" emphasises the importance of monitoring the anaesthetised patient.
Nowadays, to monitor anaesthesia, people mostly rely on multiparameters monitors, but it is important not to forget about monitoring the patient and having an idea of the whole picture.
Monitoring anaesthesia is fundamental as it allows timely and informed response to changes in the patient's status. It is important to monitor more than one body system and more than one variable per body system. For example, heart rate (cardiovascular system variable) may be increased in the case of hypotension or pain. If looking at the blood pressure (other variable for the cardiovascular system), this will be low if the heart rate has increased in response to hypotension and high in the case of response to pain.
Writing parameters and observations down on an anaesthetic record is important as – not only it is a legal document - but it will also help visualize trends and is part of the anaesthetic history for that patient.

The patient:

Although when a multiparameter monitor is present, the anaesthetist tends to rely on the machine and leaves the patient a bit more on the side, monitoring the patient itself is paramount for good anaesthesic monitoring. The presence or absence of reflexes, the quality of the pulses, the temperature of the extremities, are all parameters which are fundamental for monitoring anaesthesia, some even more important than those a machine can show.
Adequate depth of anaesthesia is essential to avoid the patient responding to surgical stimulation or the anaesthetic plane being too deep so that it become unsafe for the patient. To assess depth of anaesthesia – unless a BIS monitor is present – one must rely on reflexes and physiological parameters

Parameter	Light Anaesthesia	Adequate Anaesthesia	Deep Anaesthesia	Comments
Eye position	Central	Rotated ventrally	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 and will feel present in breeds with very developed masseters muscles, such as Staffordshire bull terriers
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	

These parameters are only indicative of an anaesthetic plane. The person monitoring anaesthesia has to take into consideration several factors such as which drugs are being used and what is happening to the patient. For instance, a patient which has received dissociative anaesthetics will be more likely to have a central eye and persistent jaw tone.
In the author's personal opinion, the eyeball position in a cat is often unreliable and cats can "jump off the table" with ventrally rotated eyes. Jaw tone seems to be more reliable than eye position in this species.
Also, during too deep isoflurane anaesthesia, because this agent is vasodilatant, the patient may become hypotensive and the heart rate may increase as a compensatory mechanism (although sometimes this response is blunted).
Another parameter which may behave differently from what is described in the table above is the heart rate during light plane of anaesthesia. In dogs more frequently than cats, when lightly anaesthetised, heart may decrease – possibly due to vagal stimulation (maybe related to the presence of the endotracheal tube).

Reflexes and jaw tone: as described in the table

Mucous membrane's colour: Should be monitored on a regular basis.

- Pink: normal (although in the author's opinion cats always look a bit paler)
- Pale: hypoperfusion, anaemia, vasoconstriction
- Red: vasodilation, local congestion
- Brick red: Haemoconcentration, hypercapnia
- Blue: cyanosis – A note should be made about cyanosis. It is necessary to have approximately 5 g/dL of de-oxygenated haemoglobin in the capillaries generates the dark blue colour appreciated clinically as cyanosis, hence an anaemic may be hypoxemic without showing any cyanosis. Studies have shown that the detection of cyanosis and its correlation to hypoxaemia is unreliable as dependent on too many factors (subject, Hct, light..) . Finally, another limiting factor is that the human eye is able to detect cyanosis when SpO_2 < 80% which is already too low.

- Yellow: icteric, oxyglobin

Capillary refill time: This is an indication of peripheral perfusion

- CRT < 2 sec = normal
- CRT extremely quick = congestion
- CRT> 2 sec= peripheral hypoperfusion

Peripheral pulses: The rate, rhythm, quality and synchronicity of peripheral pulses with heartbeats should be assessed.
A dramatic change in pulse rate should always be investigated.

Increased pulse rate	Decreased pulse rate
Drug related (atropine, ketamine, adrenaline)	Drug related (α-$_2$agonists, opioids...)
Light plane of anaesthesia	Deep plane of anaesthesia
Pain	CNS disease – increased ICP
Hyperthermia	Hypothermia
Hypotension	Vagal stimulation (light plane of anaesthesia, surgical manipulation, oculo-cardiac reflex)
Hypovolaemia	Hyperkalaemia
Hypoxaemia	Cardiac disease
Hypercapnia	
Hyperthyroidism	
Anaemia	
Pheochromocytoma	
Cardiac disease	

When assessing pulse quality, one is assessing , i.e the difference between systolic arterial pressure and diastolic arterial pressure. It is not an indication of systolic blood pressure. This means that, in theory, feeling the pulse of a patient with a diastolic of 40 mmHg and a systolic of 80 mmHg (pulse pressure 80-40=40 mmHg) will – in theory - feel the same as the pulse of a patient with a diastolic of 80 mmHg and a systolic of 120 mmHg (pulse pressure 120-80=40 mmHg). The difficulty that one encounters to eliminate said pulse by compressing it will be an indication of the systolic.
Pulses can be bouncy (hyperdynamic pulses) in hypovolaemic patients. These will feel big but 'empty' and will be easy to compress.

Respiration: This differs from ventilation (discussed further down). Respiration is monitored by looking at chest excursions or the reservoir bag. The rate, rhythm, depth and respiratory effort should be taken in consideration. Some drugs cause characteristic respiratory patterns, for instance ketamine can cause apneustic breathing (rapid breaths followed by breath-holding on inspiration).
Apnoea can be caused by anaesthetic overdose or too rapid injection of induction agents, although isoflurane anaesthetised cats breath-hold when the anaesthetic plane is light.
Panting can be seen as a response to pain, during light anaesthetic planes, during hyperthermia, hypercapnia, hypoxaemia, restrictive lung disease or even due to some drugs (opioids, mostly methadone can cause panting, although when given during general anaesthesia transient apnoea is most commonly seen)
An increased respiratory effort will always have to attract the attention of the anaesthetist. During spontaneous ventilation, an increase inspiratory effort will indicate upper airway obstruction (endotracheal tube, trachea). An increased expiratory effort will indicate lower airway obstruction (bronco-constriction).
Respiratory noises (the presence or absence of) are also important. The presence of mucous in the endotracheal tube is often referred in the reservoir bag. Auscultation of the chest 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:
Many other parameters can be useful to assess the anaesthetised patient. **Muscle tone** and **shivering** should be absent in an adequately anaesthetised patient. The presence of **salivation** or **regurgitation** could indicate a too light plane of anaesthesia.
The **surgical site** can be a source of information. This should be monitored for bleeding as the person performing the surgery will often not be able to have a clear idea of the amount of blood loss. Also, if the tissue is very pale this could indicate poor **peripheral perfusion**. The latter is also characterised by a different core-periphery temperature.
It is important to have a wide picture of everything that is happening in the operating room.
With the exception of taste, all senses should be used when monitoring an anaesthetic. Listening to the surgeon (asking for help, asking for more swabs very early after the previous batch or even suddenly going silent) can indicate a problem in the surgical site even before this is visible to the person monitoring the anaesthetic. One should also listen for leaks around the endotracheal tube, alarms and beeps from the monitor. Smelling for leaks or regurgitation for example is also part of monitoring an anaesthetic.

The monitor:

The use of a multiparameter monitor is a very useful (essential) help in monitoring anaesthesia and has allowed patients to be anaesthetised in a much safer fashion. The introduction of what is now considered to be basic monitoring has decreased mortality and morbidity rates in both humans and animals. More advanced monitoring techniques (such as cardiac output, bispectral index) are becoming more and more common as well, at least in human anaesthesia
This said, in no way one should only rely on the multiparameter monitor and forget about the patient or viceversa.

Electrocardiogram (ECG):

The ECG shows the **electrical activity** in the heart. It is not an indication that cardiac output is actually occurring. It is important to realise that the ECG shown on most multiparameter monitors is not comparable to an ECG obtained on ECG paper where measurements can be done. When looking at an ECG on a multiparameter monitor the following has to be examined:
- Is the rhythm sinus? Is there a P, a QRS and a T? Is there a P for every QRS? Is there a QRS for every P?
- Is it rhythmic?

- Is the rate adequate for that patient in that situation with those drugs on board?

Normally a 3 lead ECG is measured and as a rule of thumb, lead II with the Lellow (yellow) lead will be placed on the Left fore limb, the Red lead on the Right fore limb and the Black lead (sometimes green) on the Back limb. This positioning of the leads is not essential.

During anaesthesia an ECG will help recognise arrhythmias. To differentiate these from artefacts (due to movement or electrodiathermy for example) simultaneous pulse palpation is fundamental.

These notes will not cover all the arrhythmias that may be encountered under general anaesthesia but the most common ones.

- Sinus arrhythmia – Ideally this arrhythmia would be called respiratory sinus arrhythmia, as it is synchronous with the respiratory phases. Heart rate increases during inspiration and decreases during expiration. The change in heart rate is vagally mediated. During inhalation, the decrease in intrathoracic pressure increases venous return to the heart; this is registered by stretch receptors and causes an increase in heart rate. This arrhythmia is considered normal in dogs but if noticed in cats one should look for a cause of increased vagal tone, more often an upper airway obstruction.
- Sinus bradycardia – Depends on the fitness status of the patient and the drugs it has received. Sinus bradycardia is usually defined as a heart rate of less than 60 bpm in dogs or less than 100 bpm in cats. Of course, in very fit dogs having received medetomidine and methadone for example, a heart rate of less than 40 bpm is to be expected.
- Sinus tachycardia – Again the patient and the situation need to be taken into account. This is normally defined as a heart rate of more than 150 bpm in dogs or more than 200 in cats.
- Second degree atrio- ventricular blocks – most commonly seen after an α-2-agonist has been administered. The ECG will show one or more P waves not followed by a QRS complex.
- Ventricular premature complexes (VPCs) - In this case the ECG will show an early 'odd' beat, normally wide and bizarre, with no P wave and usually followed by a longer pause. Common causes for the appearance of VPCs are:
  - Pain
  - Hypoxia
  - Blunt cardiac trauma
  - Catecholamine release
  - Splenic manipulations
  - Drugs
  - Electrolyte imbalances (magnesium, potassium)
- Ventricular tachycardia – this is characterised by more (by definition - more than 3) VPCs in a row. Ventricular tachycardia should be treated if it appears to be polymorphic (beat-to-beat variations in the ECG morphology), if the rate is higher than 200 bpm, if they are R-on-T and/or if there are pulse deficits which affect blood pressure. To be precise, if the rhythm is ventricular but the rate is < 180 bpm, then this is defined as idioventricular rhythm.

<u>Pulse oximetry:</u>

This measures saturation of haemoglobin with oxygen (SpO_2 %). A pulse oximeter consists of two light-emitting diodes which flash beams at red and infrared frequencies (660 nm and 940 nm, respectively). There is a photo detector on the other side and a microprocessor that analyses the changes in light absorption during the arterial pulsatile flow (ignores the non-pulsatile component of the signal - which results from the tissues and venous blood). The oxygen saturation is then estimated (via an algorithm based on humans) by measuring the transmission of light through the pulsatile tissue bed.

Peri-anaesthetic mortality in cats was decreased by 40-82% when pulse oximetry was used. In humans the use of pulse oximetry combined to capnography decreased peri-operative incidents by 88-93%. Most pulse oximeters give a pulse rate and an audible beep, the pitch of which is normally related to the saturation of haemoglobin. Some are associated to a plethysmogram which is a curve reflecting the pulse.

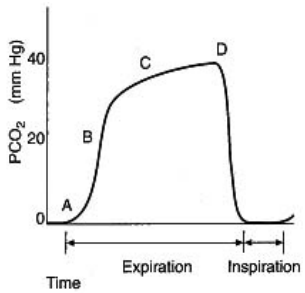
It is important to understand that pulse oximetry does not give an indication of oxygen delivery to the tissues. If there is only one red blood cell in circulation and this is saturated with oxygen, the SpO_2 % will be 100% but the oxygen content and delivery to the tissue will of course be null. In the normal anaesthetised patient, SpO_2 % should be over 97%. Unfortunately, pulse-oximetry has several limitations (see also cyanotic mucous membranes). The reading is not immediate but occurs after a delay of approximately 10-20 seconds. Also, pulse-oximeters are not very accurate at an SpO_2 % of less than 80%. Many factors interfere with pulse oximetry readings. These include pigmented mucous membranes, shivering or movement, peripheral vasoconstriction or poor peripheral perfusion, light and electromagnetic interferences, bad probe positioning, the use of IV dyes, the presence of carboxy-haemoglobin (SpO_2 % will always read 100%) or meta-haemoglobin (SpO_2 % will always tend to be 85%).

It has been demonstrated that when a curve is present the readings are reliable if the curve resembles to an arterial pulse waveform and the pulse rate given from pulse oximeter corresponds to the actual pulse rate of the patient. Studies have also shown that placing a swab between the pulse oximeter probe and the tongue can improve reading quality.
Many pulse oximeter monitors nowadays also display the **perfusion index** (PI). This is a continuous, non-invasive measure of peripheral perfusion given by the ratio of the pulsatile blood flow to the non-pulsatile blood in peripheral tissue. Normal PI in a dog is yet to be determined with certitude, current values are about 1.8 on the tongue and 0.3 on the vulva. In a study in dogs undergoing ovariohysterectomy and comparing lactate and PI, the latter failed to reflect hypoperfusion.

Capnography:
This gives an indication of ventilation. Usually end tidal CO_2 ($EtCO_2$) and inspired CO_2 ($FiCO_2$) are measured (capnometry). These are often associated to a capnogram, i.e a curve showing the change in CO_2 at the level of the measuring device. $EtCO_2$ is measured because it is closely related (5 mmHg difference in healthy lungs) to $PaCO_2$. As mentioned previously capnography (used together with pulse oximetry) decreased anaesthetic related errors in human medicine. Capnography is not only an indication of adequacy of ventilation, but it is also useful to check the correct placement of an endotracheal tube (ETT), disconnection of the breathing system, metabolism and last but not least cardiac output.
Capnography can be measured in two ways:

- Main stream capnography, where the measurement occurs through a device situated at the end of an ETT, in line with the respiratory gas stream. Although bulky (less for newer generation capnographs) and expensive, this method has the advantages of being 'real time' and of being more reliable mostly in patients with low tidal volumes.
- Side stream capnography, where the measurement of the sample occurs in a cell within the monitor. The sample is aspirated at the level of an adaptor attached at the end of the ETT (or nasal catheter) and directed to the monitor via a long plastic water vapor permeable (Nafion) sampling line through a water trap. The sample flow rate ranges within 50-250 ml/min.
  The sampled gas may also contain anesthetic gases and therefore when using this technique, scavenging of the gases sampled must be taken into consideration. Side stream capnography is less bulky and is probably more commonly used in our veterinary clinics. Problems associated with this method are a delay in giving a reading due to the "transit" time of the sample from the ETT to the monitor (where it is processed), dilution of the sample in small animals with faster respiratory rate and artifacts due to leaks, interference of the sample with water vapor or due to obstructions of the sample line.

Normal capnograph:



The expiratory phase is divided in:

- A: Exhalation of CO_2 free gas contained in dead space
- B: Expiratory upstroke – Emptying of airways, beginning of emptying of alveoli
- C: Expiratory plateau – Uneven emptying of the alveoli
- D: End tidal CO_2 ($EtCO_2$) – peak exhaled CO_2.

$EtCO_2$ is an indication of:

- Metabolism
- Cardiac output
- Ventilation

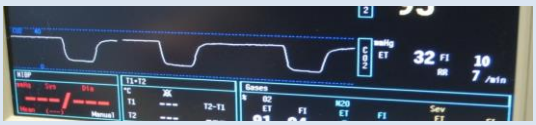
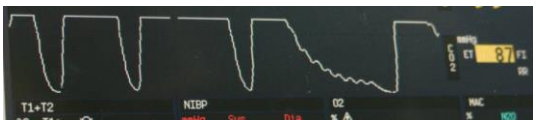
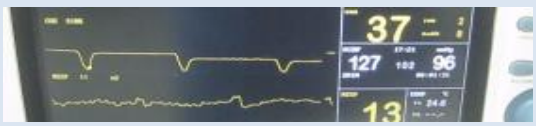
When two of these parameters are stable then an alteration in the value will be an alteration of the third parameter.

	↑ $EtCO_2$	↓ $EtCO_2$
Metabolism	Increased	Decreased
Cardiac output	Increased	Decreased
Alveolar ventilation	Decreased	Increased

Normal $EtCO_2$: 35-45 mmHg
4.6-6 kPa
5-6%

Normal $FiCO_2$: 0

Many monitors have 'reference' lines, one is normally 0 mmHg and the other one can be set to a value (50 mmHg for example). When looking at a capnogram it is useful to look at these reference lines as sometimes the $EtCO_2$ value given from the capnograph is due to artefacts or cardiac oscillations.
Other than the $EtCO_2$ value, a capnogram can give a lot on information.

Cardiac oscillations: oscillations seen in the end of the expiratory plateau and during in the descending limb. Caused by the heart beating against the lungs. Oscillations rhythmic and synchronized to the heart rate	
Rebreathing: curve not going back to 0 and increased $FiCO_2$. Generally, an $FiCO_2$ < 3 mmHg is acceptable. Mainly (but not only) caused by: – Non-rebreathing system: Inadequate fresh gas flow – Rebreathing system: Exhausted CO_2 adsorbent or sticky unidirectional valve	
Hypoventilation: $EtCO_2$ > 45 mmHg or 6 kPa or 6%. Occurs very often under general anaesthesia, mostly drug induced	
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	
Leak around the ETT – Characterized by an absence of the plateau. Caused by a too small ETT or a leaking cuff	
Decreased cardiac output, ventilation or metabolism: Under general anaesthesia, a decrease in $ETCO_2$ with stable respiratory rate is often associated with decreased cardiac output	

Blood pressure:

This is the pressure exerted by circulating blood on the walls of blood vessels. Normally if not specified it is assumed that by saying blood pressure one refers to arterial blood pressure. Systolic, diastolic and mean arterial blood pressures are usually measured. In anaesthetic practice, mean arterial blood pressure (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. Blood flow to major organs undergoes a phenomenon called “autoregulation”, which means that said organs receive a constant amount of blood when MAP is in the range of 50-150 mmHg. If MAP falls below or above this range, then the blood flow to the organ is respectively decreased or increased beyond physiological values and organ damage may occur.

MAP is depending on cardiac output and systemic vascular resistance (MAP=CO X SVP). In some circumstances, severe vasoconstriction can cause a normal/high MAP but it these cases, tissue perfusion is impaired because blood does not “reach” the tissues adequately.

In anaesthetised animals, arterials blood pressure ranges are:

Systolic (SAP): 90-130 mmHg

Diastolic (DAP): 55-90 mmHg

Mean (MAP): 60-100 mmHg

These values may vary according to the source and what drugs are used.

Blood pressure can be measured via a direct (invasive) method and indirect (non-invasive) method.

- **Non-invasive blood pressure** - These methods commonly use a cuff placed on a limb (or tail). The width of the cuff is usually said to be 40% of the limb/tail circumference. The cuff is inflated and the blood flow is occluded. The reappearance of blood flow as the cuff is deflated will give an indication of the blood pressure.

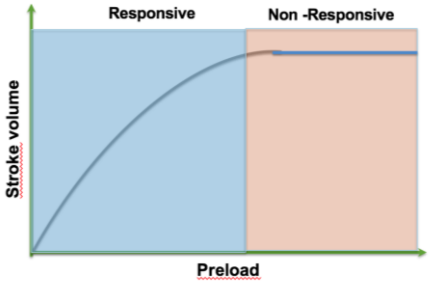
- Doppler. An ultrasound probe is placed on an artery and a cuff proximally to this probe. In this apparatus, ultrasound waves are emitted, reflected by the red blood cells which shift the frequency of this ultrasound wave and finally received by a transducer on the same probe. The transducer produces an audible sound related to the flow velocity of the red blood cells. The cuff is usually inflated with the aid of a sphygmomanometer which also shows the pressure in the cuff. As the inflating cuff occludes blood flow, the sound disappears. As the cuff is deflated, the pressure at which the sound reappears is the systolic blood pressure. In cats this pressure is thought to be closer to the MAP than the systolic. Others report this pressure to be approximately MAP+15 mmHg in this species. Advantages of the Doppler technique are that this method can be used in all size animals and its reliability is not affected by arrhythmias (as long as the user is aware of them and deflates the cuff accordingly). Also, the continuous sound of the pulse can be used to monitor pulse rate. It is relatively inexpensive. Disadvantages of the Doppler are the noise produced can be disturbing mostly in the presence of interferences and this method requires a minimal degree of skill from the user.
- Oscillometric – The cuff is usually automatically inflated and deflated at regular intervals. Returning blood flow is detected by pulsatile pressure changes in the cuff itself and reflects systolic blood pressure. Mean arterial blood pressure is measured as the pressure in which pulses detected from the cuff are maximal and diastolic as the pressure in which they disappear. Some devices also give a heart rate and if this value is correct then the blood pressure readings are trustworthy. Advantages of this method are that it is easy to use although cuff positioning is important, and it gives regular readings. Unfortunately, blood pressure measurements are affected by extremes of heart rates and arrhythmias and most apparatuses struggle to give an accurate reading in very small patients.

- Invasive blood pressure measurement – This direct method is considered the ‘gold standard technique’ of measuring blood pressure. Direct measurement of blood pressure requires the placement of a cannula in a peripheral artery. The arteries used most commonly include the dorsal metatarsal, plantar metacarpal/metatarsal, femoral, aural and coccygeal arteries. The arterial cannula is connected to a mechanical or electronic pressure transducer through a hep-saline filled non-compliant line. Nowadays electronic transducers are mostly used. These should be placed at the same level of the heart and zeroed to atmospheric pressure (as they measure gauge pressure and not absolute pressure). The transducer is connected to the monitor that will continuously show a blood pressure waveform and which will measure systolic and diastolic blood pressure and calculate mean arterial blood pressure. Advantages of this technique are its reliability (also in the presence of extremes of heart rates and arrhythmias) and continuity of measurement. The latter is particularly important in heamodynamically unstable patients. Because of the presence of an arterial cannula, if required, the sampling of arterial blood is easy to perform. Unfortunately, this technique also comes with some disadvantages such as problems related to an arterial cannula placement (haemorrhage, infection, clot formation, ischaemia) and difficulty to place said cannula in smaller patients.

Pulse pressure variation: This parameter can only be measured in patients which are mechanically ventilated and in which BP is measured invasively. In mechanically ventilated patients, positive pressure ventilation promotes cyclical changes in stroke volume, and is coupled with arterial pulse pressure changes. Stroke volume and arterial pulse pressure rise during inspiration and SV decreases during expiration. Pulse pressure variation is calculated from the difference between the maximum and minimum SAP and DAP (pulse pressure - PP) variations over a single respiratory cycle in a mechanically ventilated patient, divided by the mean of the maximum and minimum variations and expressed as a percentage.

$$PPV\ (\%) = \frac{PP_{MAX} - PP_{MIN}}{(PP_{MAX} + PP_{MIN})/2} \times 100$$

PPV can determine fluid responsiveness of a patient when MAP and CVP could not. In a study in isoflurane anaesthetised dogs, the best cut-off for PPV to distinguish between responders and non-responders was 15%. In other words, PPV can help identify where, on the Frank Starling curve, a patient is at that point in time.



PPV has some limitations, and several commonly occurring factors can alter the results. These include cardiac arrhythmias, mechanical ventilation with low tidal volumes (<8ml/kg), low lung compliance and open thorax.

Temperature

Under general anaesthesia it is common for animals to become **hypothermic**. This is caused by a multitude of factors which include depression of thermoregulation caused by anaesthetic drugs, decreased heat production, increased heat loss caused by vasodilation, evaporation, contact with cold gases, surfaces, scrubbing materials… It is therefore good practice to monitor – continuously or intermittently- the body temperature of anaesthetised patients and to avoid hypothermia with the aid of heating devices.

Although hypothermia in a dog corresponds to a core temperature of <37.8 °C, its negative effects really start at a core temperature <34°C. The negative effects of hypothermia include decreased metabolism of drugs, decreased minimum alveolar concentration (MAC) requirements, arrhythmias (non-responsive to common antiarrhythmic drugs), decreased immune cell function and increased risk of infection and of spread of metastasis, impaired coagulation processes, decreased sensibility of baroreceptors and consequent hypotension, impaired oxygen delivery to the tissues and shivering on recovery with increased oxygen consumption.

Less often, patients under general anaesthesia can develop **hyperthermia**. This can be genuine, due to vasoconstriction in hairy animals covered by drapes undergoing a prolonged anaesthetic with or without heating aids, or it can be malignant hyperthermia (or some sort of channelopathy leading to hyperthermia). Malignant hyperthermia is a genetic disease mostly triggered by exposition to inhaled anaesthetics, but recently some atypical forms have been reported. Prompt response to this form of hyperthermia is vital to increase the already little chance of survival.

Other parameters:

- **Urine output** – This is a useful indication of kidney perfusion. A urine output of 1- 1.5 ml/kg/hr is deemed normal. This will increase with increasing intravenous fluid administration. Under general anaesthesia and in the hospitalised patient receiving opioids, the influences of altered haemodynamics, sympathetic activity and humoral factors alter urine production and a urine output of > 0.7 ml/kg/hr can be accepted.
- **Central venous pressure (CVP):** This is measured via a jugular catheter placed with its tip just in front of the right atrium. CVP gives an indication of fluid load. Unfortunately it is not very accurate as it is influenced by a multitude of factors (position, vessel compliance, cardiac contractility, changes in intrathoracic pressures, surgical manipulations..). The normal range is 3-8 cmH_2O but because of its inaccuracy, it is better to look at trends rather than at single numbers.

- **Oxygen analysers:** measure inspired and expired oxygen concentrations. This can be important when other gases are used (medical air or N_2O) or in low flow anaesthesia as an FiO_2> 30% is required.
- **Anaesthetic agent measurement**: Measures the inspired and expired concentrations of the inhaled anaesthetic agent. This is based on the principle that alveolar agent (Et_{agent}) reflects its cerebral concentration. The value can be compared to MAC, but it is just an INDICATION. Anaesthetic agent measurement is also useful in detecting vaporiser problems (i.e vaporizer not locked on the back bar).
- **Spirometry**: Gives an indication of compliance of the lung, tidal volume, peak inspiratory pressure and positive end expiratory pressure applied. Depending on which curve is looked at (pressure-volume or flow-pressure loop) different issues can be identified. From a around the ETT, to broncocostriction, to airway obstruction.
- **Cardiac output (CO) monitors:** What really matters under anaesthesia is flow of blood and oxygen to the tissues. Blood pressure is the easiest way for the anaesthetist to approximate this, but better than BP would be CO. Unfortunately, the majority of the techniques for measuring CO have a limited application in veterinary practice due to their invasive approach and associated complexity and risks. The gold standard for monitoring CO in veterinary medicine is the thermodilution technique (TD). This requires the insertion of a catheter into the pulmonary artery through the jugular vein, and the application of a cold solution to calculate the CO by temperature differences between the blood within the right atrium and the pulmonary artery, making it too invasive and risky (arrhythmias, hypothermia, vessel perforation...). More recently transoesophageal echocardiography (TEE) and pulse contour analysis are making an increased appearance in referring practices and may become a commonly used anaesthetic monitoring in a decade or so. In recent studies, the trans-gastric view of the LVOT by TEE was determined to be a valid and minimally invasive alternative to clinically monitoring CO in dogs during anaesthesia. However, during hypotension, the CO obtained by TEE was less reliable but still acceptable. This TEE technique failed to prove its accuracy in previous studies. The discrepancy between results for the TEE is probably due to the difficulty associated with the different sizes of dogs. The most (successful) recent study used a method called PRAM (pressure recording analytical method) which is a new, less invasive technique allowing beat-by-beat stroke volume monitoring from the pressure signals recorded in femoral or radial arteries. Again, more studies need to be done and an accurate, non-invasive, user friendly CO monitoring device is still to be determined.

Conclusions

When monitoring a patient under general anaesthesia it is vital to have a picture of the whole situation (animal, surgery, monitor, drugs used). It is not just writing down numbers but being able to understand where they come from, why things are happening and what to do. Monitoring anaesthesia does not stop only at monitoring the animal but the entire anaesthetic machine and the surgeon.