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Federation of European Companion Animal Veterinary Associations

4: THE IMPORTANCE OF MONITORING

GOOD MONITORING SAVES LIVES

- General anaesthesia depresses all vital functions, monitoring detects early signs of a potentially harmful change so that remedial action may be taken immediately.
- The depressant effect of anaesthesia on respiration and the circulation/perfusion is significant and may be life threatening. Anaesthetic-induced respiratory depression may lead to hypercapnia and hypoxia, while circulatory depression can affect cardiac function leading to hypotension and poor tissue perfusion.
- Continuous direct monitoring is required to ensure the animal's safety and wellbeing during anaesthesia and the recovery period until it is able to maintain its own normal function. This is normally until a cat or dog can, at least, sit up and maintain its own airway i.e. can cough and swallow with clear signs of consciousness.
- The goal is to ensure adequate homeostasis during anaesthesia. The patient's own homeostatic mechanisms may be affected by medications and surgery which can cause both central nervous system (CNS) depression. For instance, coughing and swallowing to maintain the airway is suppressed, the response to rising arterial CO_2 tension is reduced and the response to blood loss and hypotension is decreased.
- Measurements should be made frequently and regularly in order that trends are visible and any problem is noticed immediately so it can be rectified before becoming serious.
- Monitoring must be performed by a staff member dedicated exclusively to anaesthesia; expecting monitoring to be only one of many tasks being performed simultaneously means that early signs of a problem will be missed.
- Essential information about the underlying physiological function can be deduced from simple measurements that can be made easily (e.g. eye position, jaw tone, palpation of the pulse and observation of breathing patterns via chest wall movement).
- The implications of all the readings taken must be understood and interpreted in order to implement any required treatment. A person who can recognise abnormal readings and respond with appropriate treatment is far more important than electronic equipment being used without understanding of the displayed information.
- Write it down! This enables changes over a period of time to be seen – it is difficult simply to remember. Anaesthetic records are very useful and are legal documents. It is also helpful to review previous anaesthetic records if the same patient is anaesthetised subsequently for consultation of drug doses and any anaesthetic complications.
- In addition to maintaining normal vital function, monitoring ensures that the depth of anaesthesia is appropriate for the procedure in progress.

ABC: Airway - Breathing - Circulation forms the basis of monitoring vital function

The AIRWAY must be kept patent, it is less important how it is kept clear. An endotracheal tube (ET tube) is generally regarded as the most reliable means but ET tubes tube can become blocked – so still needs to be monitored. Supraglottic airway devices can also be considered.

Looking at ease of respiration and the matching of chest and rebreathing bag movement are simple, visual ways to assess the airway. A normal capnograph trace (see below) is the most reliable. If the airway is obstructed, it must be cleared immediately by whatever means is appropriate.

Whilst it is advisable to intubate patients undergoing surgery, especially when intravenous anaesthetic agents are used, some very short procedures being performed on healthy animals with low aspiration risk could potentially be performed without intubation. Monitoring the airway continuously is also vital in these patients and equipment for intubation should always be available.

BREATHING must be sufficient to ensure uptake of enough oxygen to meet the metabolic demand and ensure sufficient removal of carbon dioxide. The simplest approach is to evaluate the quality of respiration and number of breaths per minute (respiratory rate).

Respiratory rate under anaesthesia is similar to that in the resting, conscious animal, although a slight decrease in rate and depth of breathing can be expected. It is therefore useful to know the normal values for each patient, information which can be obtained in the pre-anaesthetic examination.

An abnormally high or low respiration rate is likely to affect gas exchange and needs to be rectified. As well as affecting gas exchange, a change in rate also indicates a potential problem and should prompt investigation of the cause. For instance, tachypnoea may indicate hypoxia, hypercapnia, an inadequate depth of anaesthesia or that more analgesia is required. Bradypnoea (low respiratory rate) is most likely to occur when anaesthesia is too deep and suggests the anaesthetic delivery should be reduced. General anaesthetics and opioids can cause respiratory depression, reducing rate and tidal volume.

Respiration is easy to support. If the animal is intubated and connected to a breathing circuit, assisted/mechanical ventilation is easily supplied to a dog or cat. If ventilation is inadequate, the lungs should be ventilated to maintain gas exchange, generally with a reduced concentration of inhalant anaesthetic. Ventilation should be provided carefully to avoid pressure or volume induced barotrauma.

Capnography is the best monitor of respiration. It measures the concentration of CO_2 in the inspired and expired gases. The display shows a trace (capnogram) of carbon dioxide concentration against time and numerous abnormalities (of both patient and equipment) can be diagnosed. Most importantly for anaesthesia, CO_2 retention is shown by an increase above normal (35-45 mmHg) in the end expired gas ($ETCO_2$).

Pulse oximetry indicates the oxygen haemoglobin saturation (SpO_2) of the arterial blood, and thus whether the animal is adequately oxygenated. It is not a direct respiratory monitor, as oxygenation reflects the inspired oxygen percentage more than respiration.

If the animal is breathing room air (~20% oxygen) it will breathe normally to maintain a normal haemoglobin saturation of around 96%. It is acceptable to assume that in this case, respiration will be sufficient to remove CO_2 and maintain normocapnia. However, if the animal is breathing 100% oxygen, often the case during anaesthesia, only a few breaths per minute are required to maintain a normal SpO_2. In this case, respiration may well be inadequate, with very high CO_2 levels only detected by a capnograph, the pulse oximeter will continue to read a normal 96% SpO_2. This demonstrates the benefit of using both a pulse oximeter and capnography together.

A pulse oximeter is particularly valuable when an anaesthetised animal is breathing air rather than 100% oxygen, particularly during the recovery period. SpO_2 should be maintained above 90% - the pulse oximeter will indicate whether this is the case and therefore indicate when oxygen supplementation must be given.

The **CIRCULATION** must enable sufficient tissue perfusion for oxygen supply and waste removal. The first approach to monitoring is to evaluate the quality of the peripheral pulses and the pulse rate per minute. These should also remain similar to the normal values for a resting animal, a slight decrease in rate can be expected. However, this may be highly dependent on drug effects as well. It is again therefore important to know the normal values for the animal concerned (a mellow Great Dane will certainly have a different rate than an anxious Yorkie!)

Abnormally high or low heart rates usually indicate a potential problem and should prompt investigation. Tachycardia (fast heart rate) may indicate an inadequate depth of anaesthesia, drug-induced sympathetic stimulation or that more analgesia is required. It may also indicate hypovolaemia, hypoxia or hypercapnia. Bradycardia (low heart rate) may be a specific drug effect (eg. alpha-2 adrenoceptor agonists) but is most likely to occur in anaesthesia that is too deep and suggests the anaesthetic delivery should be reduced. Vagal stimulation may occur during some procedures, particularly involving the eye, and causes bradycardia.

Pulse quality is also a valuable monitor. Simply being able to detect a peripheral pulse indicates that the peripheral circulation is intact and therefore perfusion of vital central organs is likely to be adequate. A thready pulse that is hard to detect suggests that perfusion is inadequate which may be due to hypovolaemia or too deep a plane of anaesthesia.

Pulse oximetry provides some information about the circulation as it is dependent on detecting an arterial pulse. A poor signal may indicate a weak pulse and poor perfusion

Arterial blood pressure is the most accessible circulatory monitor and low blood pressure generally indicates reduced perfusion. Hypotension is commonly caused by vasodilation, blood loss, decreased venous return and poor myocardial contractility. High blood pressure without increased blood flow arises with vasoconstriction, since blood pressure is the product of cardiac output and systemic vascular resistance (BP = CO x SVR).

Most anaesthetic drugs decrease arterial tone, so it is acceptable to use BP measurement as a surrogate measure of tissue perfusion. However, alpha-2 adrenoceptor agonists cause vasoconstriction leading to transient, high blood pressure with low flow followed by reflex bradycardia. Blood pressure should not be used alone to monitor the circulation during anaesthesia. Pulse quality, mucous membrane colour, pulse oximeter and capnograph readings can all be used to help interpret the BP reading.

Arterial blood pressure can be measured either directly, from a catheter placed in an artery, or more commonly in small animals, indirectly by measuring the pressure in a cuff which is temporarily inflated around a limb or tail to compress the artery. The pressure recorded at the point when blood flow returns during cuff deflation is approximately systolic. Blood flow is usually detected using a Doppler probe on a distal artery. Alternatively the oscillometric method can be used which depends on the pressure changes in the cuff itself relating to the blood flow characteristics.

Electronic monitors are widely available which automatically inflate and deflate the cuff and calculate systolic, mean and diastolic pressure at pre-defined time intervals. These monitors are convenient to use but require judicious interpretation as they may still give a reading when they are unable to detect a pulse reliably, particularly in the face of poor circulation – when they are most needed.

The capnograph is a useful indirect monitor of circulation. Under normal circumstances, the arterial and the alveolar CO_2 percentage should be almost equal. If the circulation fails, less blood is pumped from the tissues to the lungs so there is less CO_2 to cross into the alveoli and $ETCO_2$ decreases. A decrease in $ETCO_2$ without an accompanying increase in respiration indicates failing circulation which is observed with unsuccessful cardiopulmonary resuscitation.

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The **ECG** supplies information about only the electrical activity of the heart – it is not a monitor of the circulation or cardiac mechanical activity. It is, however, the only means of diagnosing the nature of a dysrhythmia causing an irregular heart beat and is a useful aid to anaesthesia where an increased risk of dysrhythmia is anticipated. The ECG also provides an easy means of counting the heart rate and assessing the response to treatment of a dysrhythmia. The significance of dysrhythmias is assessed from their frequency, type and impact on the cardiovascular system (e.g. circulation and blood pressure).

The **DEPTH OF ANAESTHESIA** (reflecting CNS depression) must be monitored to ensure that anaesthesia is sufficient for the procedure in progress and not deeper than necessary because deep anaesthesia can be life threatening. Decreases in respiratory rate and drive, a decrease in heart rate and the extent of muscle relaxation are commonly used to assess the depth of anaesthesia. Eye position is more directly related to the anaesthetic effects on the brain and in most dogs and cats, with most anaesthetics (ketamine is a major exception), a downward rotated eye is a sign of anaesthesia appropriate for most common surgical procedures. Evaluating the depth of anesthesia takes all the monitored information together. For example, eye position, appropriate muscle relaxation (jaw tone), lack of response to noxious stimulation and acceptable values for cardiac and respiratory function in a normotensive dog or cat generally indicates proper anesthetic depth. Monitors of brain activity (electroencephalogram and bispectral index) are used for people but are rarely used in veterinary practice.

BODY TEMPERATURE usually decreases during anaesthesia and may become dangerously low without intervention. It is easier and more effective to maintain body temperature than to rewarm a cold animal, therefore prevention is the best treatment for hypothermia. The only way to track the degree of hypothermia is to measure the body temperature. This is easily and effectively done using a temperature probe placed in the oesophagus or the rectum. Probes on a cable attached to a digital display are best as they can be left in place throughout the procedure.

Hypothermia is the most common cause of delayed recovery in small animals. Although hypothermia is far more common during anaesthesia, hyperthermia may occasionally occur and is potentially immediately life threatening so is also important to detect and treat this quickly.

FLUID BALANCE is managed by the anaesthetist, so any fluids lost and all those administered as replacement or to provide normal requirements (usually 2-10 mL/kg/h) must be monitored.

Fluid input can be measured by simple drop count. Standard giving sets usually produce 20 drops per ml but this should be checked on the packet. Mini/paediatric IV drip sets are usually 60 drops per ml. Electronic drop counters and flow controllers make drop counting easier and fluid administration safer, particularly in small patients. Ideally, fluid can be administered accurately at a preset rate using a syringe driver or fluid pump. These are more reliable in ensuring the correct infusion rate. In all cases the site of administration through an IV catheter should be examined regularly to ensure the catheter has not been displaced with consequent perivascular fluid administration.

Fluid output should be assessed in all but the shortest procedures; significant blood loss must always be tracked (>10% of the circulating blood volume). Normal urine output is a sign that the kidneys are receiving adequate perfusion and is the most useful longer term monitor used to adjust fluid administration. Assessing fluid output is simply a question of measuring the volume of any fluid collected. Estimation of blood loss into swabs and drapes depends on prior measurement of the volume of water in a soaked swab and counting the swabs as they are used. Urine production (normal 0.5-2 ml/kg/hr) is most easily measured by attaching a collection bag to a urinary catheter. The volume of urine lost onto drapes and pads should be assessed in a similar manner as blood in swabs.

FECAVA BASIC PRACTICES IN VETERINARY ANAESTHESIA AND ANALGESIA

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WHAT DOES THE EQUIPMENT TELL ME?

Pulse oximeter: Oxygen haemoglobin saturation (SpO_2): how much oxygen is in the red blood cells. Also an estimation of the peripheral pulse quality and perfusion.

Normal ≥ 96%; acceptable during anesthesia >90%; lower values indicate hypoxaemia.

Capnograph: Amount of carbon dioxide in the inspired and expired gases. End tidal carbon dioxide ($ETCO_2$) is the highest reading before inspiration begins and is (almost) the same as arterial CO_2 tension.

Normal $ETCO_2$ tension: ~35-45 mmHg (can be 45-50mmHg under anesthesia)

Blood pressure (BP): The pressure in the arteries of the circulating blood at each stage of the cardiac cycle.

BP =Cardiac output (CO) x total peripheral resistance (PR).

BP is high when CO (perfusion) is high but also if PR is high.

Normal mean arterial BP: 70-90 mmHg

ECG: Represents the electrical activity of the heart. Not a measure of its pumping activity.

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