Monitoring can be performed by techniques which do or do not involve invasion of the body cavity. Non-invasive methods, which include clinical observation, are simpler and more easily applied. Careful monitoring is essential for safe anaesthesia, cardiovascular and respiratory functions, to ensure the physiological well-being of the patient. Monitoring equipment such as Apalerts, Dopplers and Pulse Oximeters each play a role in patient monitoring.
Blood pressure measurement during anaesthesia is a useful tool to ensure that cardiovascular function is sufficient to meet the demands of vital organs for oxygen and other nutrients. This allows the anaesthetist to recognise situations in which those needs are not being met.

Advantages of using a Doppler
Arterial blood pressure is an indirect measure of the overall function of the cardiovascular system. Therefore it is a very practical and reliable method when used in veterinary patients to assess their cardiovascular function, especially if used in combination with other monitoring parameters (e.g. heart rate, cardiac rhythm, mucous membrane colour and capillary refill time).

Monitoring trends in blood pressure can provide useful information about anaesthetic depth. As a general rule, blood pressure decreases progressively with increasing depth of anaesthesia, while surgical stimulation in a lightly anaesthetised patient often results in an abrupt elevation in blood pressure.

How does it work?
To measure arterial blood pressure, you need to have a means of:
1. Detecting blood flow (amplification sound box)
2. Temporarily occluding blood flow (inflatable cuff)
3. Measuring the pressure at which blood flows first return when the occlusion is released (ultrasonic probe).

The probe (which acts as a transmitter and receiver for ultrasonic signals) is positioned over a superficial artery of a distal limb or the tail. Ultrasonic waves emitted by the transmitter are reflected back to the receiver at a different frequency, due to the movement of red blood cells flowing within the artery and the pulsations of the vessel wall. The resulting "doppler shift" produces a "whooshing" noise which varies in frequency. An inflatable cuff is positioned proximal to the probe and systolic blood pressure can be measured by inflating the cuff until flow ceases, then recording the pressure in the cuff at which flow first returns to the limb as the cuff is slowly deflated. This pressure reading is taken from the sphyg.

Features of flow detector include:
1. Ease of application
2. Portability
3. Accuracy in measuring systolic blood pressure
4. Suitable for use on animals of almost any size

User tips for use of Doppler:
- Ensure Doppler is not on metal surface
- Do not remove probe leads from the Doppler in between use
- Prep skin site with alcohol
- Apply gel on sensor prior to placing on animal with volume switched turned down
- Try moving probe and skin together - not just probe over skin
- For tiny animals such as birds or rats the probe can be attached directly to chest area

Hint: Placement of cotton wool between tape and back of probe may help contact.

How can it be used in a veterinary practice?
The probe is usually placed over the metacarpal or metatarsal arteries on the plantar surface of the limb in small animals, although the dorsal pedal or coccygeal (tail) arteries can also be used. It is helpful to clip and clean the site thoroughly with alcohol prior to placing the probe. Ultrasonic gel or KY jelly is applied to the concave side of the probe and the probe firmly taped into place. Cuff width and position are very important. The optimal cuff width is 40% of the circumference of the limb. Overly narrow cuffs (or ones applied too loosely) produce falsely elevated readings, while cuffs which are too wide generate inappropriate low measurements. The cuff should be positioned so that the inflatable bladder sits over the artery i.e. the bladder should be positioned on the medial aspect of the limb or the ventral aspect of the tail.

Blood pressure is measured by attaching a hand-bulb to one limb of the cuff and a simple manometer to the other. The Doppler is switched on to ensure that a loud signal can be heard. The cuff is then inflated with the hand-bulb until the signal ceases. Systolic blood pressure is considered to be that pressure at which the signal first returns as the cuff is slowly deflated. Blood pressure should be recorded at 5 minute intervals, although in compromised patients it may be preferable to measure more regularly.

Normal systolic blood pressure in conscious cats and dogs range from 110 to 160mmHg (at least 90-110mmHg is needed to ensure adequate delivery of blood and oxygen to vital organs). Hypotension is therefore defined as a systolic blood pressure less than 90mm-Hg - any drop in blood pressure below this should be brought to the attention of the veterinarian immediately.

Treatment of Hypotension
You may need to do one or all of the following:
- If anaesthetised, lighten the plan of anaesthesia
- Administer intravenous fluids
- Give positive inotropic drugs (these will increase the contractility of the heart i.e. increase the strength of the heart beat).

REFERENCES:
NZVA Conference 2001
'Monitoring the Anaesthetised Patient - Advanced Monitoring Techniques'
Roz Machon, Massey University
Judy Chapman, Waikato Polytech

The Doppler Flow Meter and its use in vet clinics
Pulse Oximeter and its use in vet clinics

The use of pulse oximeters is becoming more popular in veterinary medicine.

What is a pulse oximeter?
It is a machine that measures how much of the haemoglobin in the arterial blood supply is carrying oxygen.

How does it work?
Pulse oximetry is based on two physical principles:
1. Oxyhaemoglobin (haemoglobin - carrying oxygen or Hb-O₂) and deoxyhaemoglobin (haemoglobin not carrying oxygen or Hb) absorb light differently.
2. Arterial blood flow can be detected as a pulse wave.

The pulse oximeter probe emits two different wave-lengths of light (one red and one infrared), which are shone through a tissue capillary bed and detected by a receiver on the other side of the probe. Oxyhaemoglobin absorbs infrared light well but does not absorb a significant amount of red light. Deoxyhaemoglobin is the opposite, absorbing red light well and only a little infrared light.

Light transmission through tissues and venous blood remains constant, while that of oxygenated arterial blood is variable with each pulse wave. The pulse oximeter measures the difference in absorption between the static arterial blood and pulsatile arterial components. Hence the term ‘pulse’ oximeter.

After measuring the absorption of the two different wavelengths of light and subtracting the static component of absorption, the pulse oximeter then computes the ratio between these values and relates this ratio to the arterial oxygen saturation.

Normal Values
It is common practice to maintain arterial Hb-O₂-saturation above 95%. When the saturation drops below 90% there is a marked, severe drop in oxygen tension.

Tissue oxygenation/cell respiration
The most important mechanism for the transport of oxygen from the lung to the tissues is the reversible binding of oxygen with haemoglobin. Deoxygenated Hb in blood binds with oxygen in the lungs. Hb-O₂ then travels around the body to the capillary beds within the tissues. O₂ then diffuses into the tissues to be used in cell respiration. Deoxygenated Hb then travels back to the lungs to collect more O₂.

Hypoxemia could be caused by:
1. Low oxygen content of air being breathed in
2. Hypoventilation
3. Lung disease

Body stores of oxygen are very small. Hence any changes in oxygenation occur rapidly.

The detection of hypoxemia (low blood oxygen) can be noted by cyanosis of the patient. Cyanosis varies with the individual and is influenced by a number of patient and environmental factors. Therefore it may not be noted until the hypoxia is severe, resulting in organ damage or even patient death.

The pulse oximeter provides a simple, non-invasive and continuous means of estimating arterial oxygen saturation.

Uses of the Pulse Oximeter in Veterinary Practice
It can be used in the anaesthetised or awake animal and can be used for intermittent or continual monitoring.

1. Monitoring oxygenation
During the anaesthetic period
Changes in O₂-saturation may be due to any of the following:
- Correct endotracheal placement (if O₂-saturation rises after placement, correct placement is likely)
- Breathing system leaks and disconnections (may not be immediately apparent when O₂ is supplemented above room air concentrations)
- Failure of O₂ delivery (O₂ tank empty)
- Hypoxic gas mixture (for those who use nitrous oxide)
- Hypoventilation (not reliable when used on a patient receiving O₂-supplementation)
- Ventilator malfunction or incorrect settings
- Endotracheal tube obstruction
- Bronchospasm
- Pneumothorax
- Pulmonary embolism
- Malignant Hyperthermia

Postanaesthetic monitoring
In immediate post-anaesthetic period to assess the need for continued oxygen support following extubation (a trial of breathing room air while monitoring will serve as a test).

During cardiopulmonary arrest
During oxygen supplementation
Monitoring saturation during oxygen supplementation allows one to titrate the amount of oxygen delivered to the patient.
The Pulse Oximeter and its use in vet clinics

2. Monitoring blood pressure and circulation
If a strong signal can be obtained distally on a limb (i.e. toe web) then the systolic blood pressure can be determined by placing an inflatable blood pressure cuff proximal to the probe, inflating the cuff until the signal disappears and then slowly deflating the cuff until the signal reappears. This is a rough indicator of systolic blood pressure. (The most accurate estimate of systolic blood pressure by this method is to average the readings obtained when the signal disappears (during inflation) and subsequently reappears (during deflation).

3. Vascular volume
A reduction in signal strength or intermittent performance may signal the development of hypovolemia during surgery, although this is more reliable when mechanical ventilation is used (the positive pressure ventilation magnifies the hypovolemia).

4. Monitoring pulse rate
Monitors will provide a continuous pulse rate.

5. Monitoring peripheral blood flow
The arterial pulse signal from a pulse oximeter can be used as a rough indicator of peripheral blood flow. In a vasodilated hypotensive patient that has a good pulse signal strength, peripheral perfusion is likely adequate. If the pulse signal is low and the patient is hypotensive, peripheral perfusion may be inadequate.

Sources of possible error when using the Pulse Oximeter

1. Motion artifact (shivering, awake and moving)
2. Fluctuating ambient light that is interpreted as a pulsatile signal
3. Poor signal quality due to hypotension (e.g. shock), venous congestion, hypothermia, vasoconstriction (e.g. Vasoconstrictive drugs), electrical noise.
4. Other types of haemoglobin: Carboxyhaemoglobin (produced by carbon monoxide poisoning, smoke inhalation) reads as saturated Hb and will give an erroneously high saturation reading. Methaemoglobin (produced by nitrobenzene, benzocaine, prilocaine and dapsone intoxications), by virtue of its absorption characteristics will drive the reported saturation toward a value of 85%. In a desaturated patient this value may be erroneously high, in a well-saturated patient, erroneously slow.
5. Skin pigmentation may produce inaccuracy in readings e.g. Chow chows, black labradors.
6. Too larger probe being used will cause some light output not to pass through the tissues and give falsely high values.
7. The pulse oximeter doesn’t seem to be greatly affected by anemia (unless haematocrit of less than 10%) or jaundice.
8. Nail polish causes an underestimate of saturation measured with a finger probe (not usually a problem in veterinary patients).

Sites of attachment
- Tongue (the most accurate area)
- Lip
- Ear
- Toe web
- Nasal septum
- Prepuce
- Vulva
- Rectal mucosa

An SpO₂ of >94% is desirable in anaesthetised patients. While marked desaturation is uncommon in normal, healthy patients receiving 100% oxygen, compromised patients, or those maintained with injectable agents often have difficulty oxygenating blood properly. Readings of less than 90% in the presence of a strong pulse signal are indicative of significant desaturation and hypoxia, and may result from either respiratory or cardiovascular dysfunction. The veterinarian should be notified immediately and the patient evaluated carefully. In addition, the anaesthetic machine and circuit should be checked for possible problems such as an empty oxygen tank, dangerously low oxygen flow rates, the delivery of an inappropriate nitrous oxide: oxygen ratio, or the disconnection of the patient from the circuit. Patient support includes the immediate provision of supplemental oxygen if the animal is not already receiving 100% oxygen, intubation if necessary, and ventilatory support in the form of intermittent positive ventilation. Blood pressure should be measured and hypotension corrected if present.

It is important to note that the pulse oximeter is not a measure of ventilation (ventilation is the product of respiratory rate and tidal volume). Respiratory rates can be misleading if used as the sole measure of ventilation. Tidal volume is often markedly reduced in the anaesthetised animal). Normally SpO₂ values are common in patients with marked hypoventilation, especially when the animal is receiving 100% oxygen. The pulse oximeter will also not detect hypercapnia (a build-up of carbon dioxide in the blood).

Hence the use of a pulse oximeter in a veterinary practice can greatly improve the standard of care offered to patients. It allows abnormalities in the cardiovascular and ventilatory systems to be detected and rectified early, minimising organ damage or avoiding possible death.

REFERENCES
‘Anaesthetic Monitoring’ Shoof International NZVA Conference, 2001 - Articles attached
‘How to use Pulse Oximetry’ Jane Quandt TNAVC 2000 proceedings
Using an Apalert respiration monitor is an effective way of assessing and maintaining anaesthetic depth. As well as apnoea warning, the Apalert can signal the occurrence of slow or shallow breathing giving early notice of impending problems. It can also draw your attention to other situations such as hypothermia, exhausted gas supply and blockages or leakages in the gas anaesthesia equipment.

Features of the Apalert respiration monitor include:
- Audible apnoea alarm
- Sensitivity adjusts to patients down to 1kg
- Audible and visual breath indicators
- Apnoea period trigger alarm adjustable from 10 to 60 seconds
- Digital display indicates time between breaths
- Handsfree alarm rest
- Volume of audible signal is adjustable
- Alarms automatically increase in volume if ignored
- Rechargeable internal battery

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'tWhat is your pulse oximeter telling you?' Glenn Pettifer TNAVCS 2001 proceedings
‘Pulse oximetry in the ICU’ Lesley King, Small Animal Critical Care
‘Monitoring the Anaesthetised Patient; Advanced Monitoring Techniques’ Roz Machon, Massey University Judy Chapman, Waikato Polytech.
Respiration Monitoring

Sensitivity Setting
This procedure takes a short amount of time at the beginning of each anaesthetic to ensure the Apalert is adjusted to the particular patient. Therefore if the patient's respiratory tidal volume decreases significantly during surgery the monitor can detect this and sound the alarm. Experience will be the guide to setting the sensitivity control. To begin select from the following table:
The sensor element is a thermal transducer triggered by the temperature change between inspired (cool) and expired (warm) gas. Greater sensitivity is required when:
i) the ambient temperature is higher
ii) the patient is hypothermic
If the Apalert does not respond to breaths at the recommended setting, increase sensitivity one unit at a time until breaths are registered.
If breaths are registered at the suggested setting, reduce setting one unit at a time until the Apalert no longer responds, then increase the sensitivity one unit.

Operation
• Connect sensor to patient airway using ET/sensor adaptor
• Turn Apalert on and select duration between breath time with the control switch. The display will begin counting seconds.
• Select and adjust sensitivity
• Adjust volume if required
• Each breath should produce a short audible beep and a single flash of the green L.E.D. after which the digital time display with automatically rest to zero.
• If there is no breath within the preset time, the apnoea alarm commences. A breath will reset the alarm or it may be reset manually.

Alarm
The alarm indicates breath has not been detected within preset sensitivity or time and the status of the patient should be evaluated. Check the patients vital signs. Consider why the alarm may have activated:
• Respiratory depression due to anaesthetic overdose.
• Physiological apnoea, for example following hyperventilation.
• Fault with anaesthetic equipment preventing patient breathing.
• Sensor disconnected from patient or adaptor.
• Leakage from around the E.T. tube.
• Patient hypothermia.

During longer procedures increases in sensitivity will be needed. Reasons include patients temperature falling, temperature of gas in circuit increasing, respiratory pattern changing to deeper breaths less often and patient settling to lower metabolic rate.

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★ Table is recommended as a guide only