Anesthetic Maintenance and Monitoring

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Introduction to monitoring
The most important monitor for a patient under anesthesia is a dedicated person who is evaluating anesthetic depth, and monitoring cardiovascular and respiratory function. Monitoring equipment can be useful, especially in compromised patients, but should not take the place of a trained anesthetist. The most commonly used monitoring tools include an electrocardiography, capnography, pulse oximetry, and arterial blood pressure.

The American College of Veterinary Anesthesia and Analgesia monitoring guidelines have been published and refer to the following for anesthetized patients: Circulation, oxygenation, ventilation, temperature, neuromuscular blockade (when utilized), record keeping, the recovery period, and personnel.

Anesthetic Depth
Anesthetic depth can be determined through evaluation of various indicators, including, but not limited to, swallowing, maintenance of reflexes (palpebral and corneal reflexes), movement, response to surgical stimulation, lacrimation and salivation, muscle tone, and eyeball position. Evaluation of these factors in conjunction with heart rate, blood pressure, and respiratory rate should be performed when determining adjustments to vaporizers and constant rate infusions in patients under anesthesia.

Heart rate monitoring

Doppler
A Doppler blood flow detector utilizes an ultrasonic probe to emit an ultrasound frequency that bounces off red blood cells and the signal is then received by the ultrasonic probe. The signal is converted to a sound, which is audible as a “whooshing” sound. The Doppler probe is most often placed over a median palmar or plantar artery. The audible signal is utilized to determine heart rate.

Electrocardiography
An electrocardiograph (ECG) monitors the electrical activity of the heart. An ECG will determine a HR based on the electrical activity, but this rate is often inaccurate. ECGs are ideal monitoring tools for evaluating electrical disturbances (arrhythmias). It is important to remember that the ECG does not assess the mechanical function of the heart – it is possible to have a normal ECG on your screen and have a patient without a heartbeat!

ECGs provide continuous assessment of heart rhythm and infer a heart rate by measuring deviations of the waveform away from the baseline. The heart rate given by your ECG monitor should never be relied upon as the only method of determining heart rate.

A 3-lead ECG system is most commonly used in anesthetized patients with the white lead placed on the right forelimb, the black lead placed on the left forelimb, and the red lead placed on the left hindlimb. With each beat of the heart, 3 different waves forms are generated – P waves, QRS complexes, and T waves.

The P wave is the first and represents contraction of the atria. The QRS complex represents contraction of the ventricles. Finally, the T wave occurs and indicates repolarization of the ventricles.

The first step in evaluation of the ECG consists of determining the heart rate. The second step is to evaluate the rhythm – is it regular or irregular? Finally, a normal ECG should show a p wave for every QRS and a QRS for every p.
Troubleshooting your ECG should start with first making sure that your patient has a pulse. Then, determine if all leads are currently attached to your patient, make sure the contacts of the leads with your patient are wet (using gel or alcohol). Interference by motion or cautery are also common reasons for ECGs to give abnormal waveform tracings.

**Blood pressure monitoring**

There are two methods of monitoring arterial blood pressure (ABP): invasive or non-invasive.

*Invasive blood pressure monitoring*

Invasive blood pressure monitoring requires the placement of a catheter into an artery. Most commonly, a catheter is placed in a dorsal pedal artery in small animal patients. The placement of an arterial catheter requires patience and skill and should be performed when it is of great importance that accurate blood pressure monitoring occur in an anesthetized patient. Non-invasive blood pressure monitoring is the most common method for ABP monitoring in small animal patients. Non-invasive pressure is measured using a Doppler, sphygmomanometer, and a cuff or by using an oscillometric blood pressure monitor.

*Non-Invasive blood pressure monitoring*

*Doppler, sphygmomanometer, cuff*

After a Doppler blood flow detector is placed, a blood pressure cuff is then placed proximal to the Doppler probe. The width of the blood pressure cuff should be 40 to 60% of the circumference of the limb. The cuff is then attached to a sphygmomanometer. Air is added to the cuff by the sphygmomanometer, which occludes the audible Doppler signal. The air is slowly removed from the cuff via the sphygmomanometer and the Doppler signal is again heard. The point the Doppler signal is audible corresponds to the systolic arterial blood pressure.

*Oscillometric*

An oscillometric blood pressure monitor utilizes a similar technique as the Doppler. The oscillometric monitor is connected to the blood pressure cuff placed on the limb as above utilizing special tubing. The monitor adds air to the cuff until it cannot detect the arterial pulsations in the limb. The air is then slowly removed from the cuff until the artery starts to pulse. The monitor detects the pulsations and calculates systolic, diastolic, and mean ABPs.

Both non-invasive ABP monitoring techniques are likely to underestimate blood pressure. This is most likely in small patients, such as small breed dogs and cats. Motion artifact can interfere with ABP measurements. The cuff or Doppler can slip on the limb and interfere with measurements.

**Respiratory system monitoring/Oxygenation**

*Capnography*

A capnograph measures the amount of carbon dioxide in the air that is breathed in and out by the patient. It is non-invasive, the information is continuous, and occurs in near-real time (depending on the equipment, there may be a small lag time). While capnography does not measure blood CO2 directly, it is well-correlated to blood CO2 in most small animal patients. Normal values in anesthetized patients for end-tidal CO2 (EtCO2) are 40 to 50 mmHg. These values correlated to blood CO2 values of 45 to 55 mmHg.

Capnographs utilize a sensor and computerized monitor. With some capnographs, the sensor is connected between the endotracheal tube and the breathing circuit (mainstream capnography). Other capnographs utilize an adaptor placed between the endotracheal tube and breathing circuit, and use sidestream sampling to remove air from the circuit which is then analyzed by a monitor. There is a small lag time with side stream capnography.

Capnography can be used to detect problems in anesthetized patients, such as: esophageal intubation, tracheal extubation, apnea, exhausted CO2 absorbant, hypoventilation, hyperventilation, and rebreathing of CO2.

*Pulse oximetry*

A pulse oximeter estimates oxygen saturation of hemoglobin. Red and infrared light passes through tissue and is transmitted to a photocell. The two different type of light are absorbed differently by oxyhemoglobin and reduced hemoglobin. The flow of red cells with each beat of the heart is detected as the red cells flow through vessels and the pulse oximeter utilizes this information to also display a heart rate.
A pulse oximeter is non-invasive, the information is continuous and in real time. Pulse oximeters are also cost-effective. Oxygen desaturation can occur at any time in an anesthetized patient, and pulse oximeters are useful in patients that are hypoxemic or have diffusion impairments.

The pulse oximeter utilizes absorption of light as an indicator of oxygen saturation of hemoglobin. As such, pigmented tissue can be a source of error for pulse oximeters. Pulse oximeters do not function well in times of poor perfusion; often the pulse ox is unable to give a reading. The monitor also becomes less accurate in low oxygen states and can be affected by patients with severe anemia. In small veterinary patients, the pulse oximeter clip can apply pressure to tissues that results in compression and decreased blood flow.

A normal oxygen saturation should be above 90%, and ideally greater than 95%.

**Recovery**

Post-operative deaths account for 47% of deaths in dogs and 61% of deaths in cats. Monitoring should be continued into the recovery period.

**References**