The goal of monitoring is to ensure perfusion of tissues with oxygenated blood. To accomplish this goal three general areas are monitored: (1) Perfusion, (2) Oxygenation, and (3) Ventilation. In addition to monitoring the previous parameters a specific individual should be responsible for administering, monitoring and keeping the anesthetic record. An anesthetic record should be kept not only as a legal document but to further the ability of the anesthetist in identifying trends that may compromise the patient. A sample record is included on the last page. By diligently monitoring the cardiac patient adverse events will be identified early enough in the anesthetic period that poor outcomes can be prevented.

Monitoring techniques may be divided into two classes: (1) Subjective and (2) Objective. Subjective monitoring consists of using your hands, eyes and ears to assess the patient. Objective monitoring uses electronic devices to provide quantitative data for the anesthetist to interpret.

**Perfusion**

Perfusion may be monitored subjectively by assessment of capillary refill time (CRT). Normal capillary refill time is approximately two-seconds. Pulse pressure may be assessed by palpating the dorsal pedal (metatarsal artery, carpal or lingual arteries of an anesthetized patient. When a patient is anesthetized the lingual artery is the most accessible. The pulse pressure is the difference between the systolic and diastolic blood pressure. For example if the systolic pressure equals 120 mmHg and the diastolic blood pressure equals 80 mmHg the pulse pressure would be 40 mmHg (120 – 80 = 40) Pulse pressure should be strong and regular. Irregular pulse quality or an irregular rhythm may indicate the presence of an arrhythmia or variable cardiac contractility.

Measurement of mean arterial pressure (MAP) is utilized to estimate cardiac output (CO) and perfusion of peripheral tissues. Mean arterial pressure may be measured using a 20-gauge over the needle catheter placed in the dorsal metatarsal artery connected to a transducer and oscilloscope (monitor). More commonly mean arterial pressure is measured using the Doppler technique or the oscillometric technique. The Doppler method uses a piezoelectric transducer to produce ultrasound waves. The transducer is placed over an artery and a blood pressure cuff attached to a sphygmomanometer is placed between the transducer and heart. Inflation of the
A cuff occludes arterial blood flow. Blood pressure may be determined by slowly releasing cuff pressure. Return of arterial blood flow is determined by listening. When sound is heard the pressure indicated on the sphygmomanometer is between mean arterial pressure and systolic arterial pressure. In smaller patients (cats) the pressure is closer to mean arterial pressure. In larger patients the pressure is closer to systolic pressures. Mean arterial blood pressure is a weighted average. The heart spends more time in diastole than in systole. Mean arterial pressure equals systole + diastole + diastole/3. The calculation of mean arterial pressure is weighted toward diastole. Mean arterial pressure should always be greater than 60mmHg.

Cat with Doppler

The oscillometric method determines mean arterial pressure by using a cuff that is controlled by a microprocessor. A bladder within the cuff is inflated to supra-systolic pressures that completely occlude arterial blood flow. The pressure is slowly decreased until oscillations are detected. Systolic pressure is calculated when oscillations are first detected. Mean arterial pressure is calculated when oscillations are at the highest number or maximal in number. Diastolic pressures are calculated just prior to the point when the cuff is so loose that the bladder within detects no oscillations. The width of the cuff can affect accuracy of data collected by the oscillometric method. The cuff width should be 30–50% of the circumference of the limb it is placed upon. The oscillometric method works best in larger animals.
Oxygenation

Oxygenation may be determined subjectively by observing mucus membrane color for cyanosis. It is important to remember that five grams of hemoglobin must be unsaturated before the cyanosis is observed. Observation of mucus membranes for cyanosis is a not a reliable method of determining oxygenation because it occurs at percent hemoglobin saturations that are extremely low. Objectively oxygenation can be determined by performing an arterial blood gas or use of a pulse oximeter. A pulse oximeter determines percent saturation by utilizing infra-red and red light generated by a light emitting diode. Hemoglobin saturated with oxygen and unsaturated hemoglobin absorbs light at different frequencies which allows the percent hemoglobin saturation to be determined.

Pulse oximeter placed on a tongue

The oxygen-hemoglobin dissociation curve describes the relationship between percent saturation and the partial pressure of oxygen within the blood.

A percent saturation of 90 equals a partial pressure of 60 mmHg of oxygen within the blood. A patient with less than 60 mmHg of oxygen is considered hypoxic.
Oxygen-hemoglobin dissociation curve

When utilizing a pulse oximeter to continuously estimate the percent hemoglobin saturation the anesthetist should be aware that errors in the reading may occur if methemoglobin or carboxyhemoglobin species are present. Therefore in cases of smoke inhalation, carbon monoxide inhalation or acetaminophen toxicity the pulse oximeter will provide erroneous data.

Ventilation

Ventilation may be monitored subjectively by observation of the breathing bag or watching thoracic wall movement. An esophageal stethoscope or precordial stethoscope may be utilized to listen to breath sound. Objectively ventilation may be monitored by determining the partial pressure of carbon dioxide in blood via an arterial or venous blood gas. Additionally a capnograph can provide the amount of carbon dioxide in exhaled gases.

A capnograph provides a “breath by breath” determination of the amount of end-tidal carbon dioxide is in each breath. This allows the anesthetist to estimate the arterial carbon monoxide partial pressure in the blood. End-tidal carbon monoxide is usually 5 mmHg lower than the arterial partial pressure. See diagram below:
Carbon dioxide production.

Clinically the capnograph is useful to verify tracheal intubation. It allows the anesthetist to detect rebreathing of carbon monoxide that may occur when inspiratory or expiratory one-way valves are stuck in the open position. It will also detect rebreathing of carbon monoxide if the sodasorb (carbon dioxide absorber) is exhausted or if dead-space in the breathing circuit is too large.
Anesthesia record