Why should we monitor our anesthetized patients? Anesthesia may compromise the patient’s homeostasis at any time during the anesthetic period and in a myriad of ways, all of which are not predictable. Also, anesthetic emergencies tend to be rapid in onset and devastating in nature. Monitoring provides us with information that can be used to predict the onset of a crisis and help the anesthetist to maximize patient safety and minimize adverse effects of anesthesia on the organ systems. Monitoring improves our odds of having an uneventful anesthetic period and recovery.

Because anesthesia can cause Central Nervous System, cardiovascular and respiratory depression, it makes sense that we would want to monitor all of these systems in some way. The American Society of Anesthesiologists (ASA) Standards for Basic Anesthesia Monitoring call for qualified anesthesia personnel to be present in the room throughout the conduct of all general anesthetics, regional anesthetics, standing anesthetics, and monitored anesthesia care. Further, during all anesthetics, the patient’s oxygenation, ventilation, circulation and temperature should be continually evaluated. To this end they require oxygenation to be monitored by inspired gas analysis and blood oxygenation (pulse oximetry, blood gases). Ventilation monitored by clinical signs and capnography (expired gas analysis). Circulation should be monitored by ECG, heart rate, blood pressure, palpation of pulse and/or Doppler ultrasonic flow detector. Temperature is another parameter that they require to be monitored.

In the veterinary patient, the priorities for monitoring begin with depth of anesthesia in a “hands on” fashion. “Hands on” means a dedicated person monitoring important parameters through continuous data collection and interpretation. These parameters include heart rate, heart rhythm, blood pressure, oxygenation (O2 saturation), ventilation (pO2, pCO2) and temperature.

The American College of Veterinary Anesthesiologists has similar recommendations to the ASA. ACVA includes a recommendation for a continuous written record to be maintained from the pre-medication period through the recovery period. This record should contain detailed patient information to include owner’s last name, patient’s name, clinic identification number, age, species, breed and color description. An account of the drugs and dosages and time of administration to the patient should be documented. Dosages should be given in mgs not mls. A running record of vital signs should be kept. Minimally this should include heart rate, respiration rate and systolic blood pressure. Additionally, diastolic and mean arterial pressure, CO2 concentration and temperature should be monitored and recorded if these parameters are available to the anesthetist.

Over the years there has been a migration to the use of continuous monitors. Their advantages are numerous. The most obvious advantage is that they allow for the monitoring anesthetist better access to information as they can be used to detect acute changes, make rapid interpretation of data and effect a response quickly and immediately. It also allows for good monitoring in the event of limited manpower in the clinic. In small animal anesthesia the most cost effective continuous monitor would, in my estimation, be the Doppler. However, it is unpredictable at times in the equine patient. Therefore, I would recommend a simple ECG as the primary piece of equipment needed.
After temperature, pulse and respiration measurements that you can do by “hand”, the first parameter to measure would be blood pressure. The blood pressure of an awake animal is similar to that of humans; normal being around 120/80. Under anesthesia you want to maintain, minimally in the equine patient, a systolic pressure (SAP) of 100 mmHg, diastolic (DAP) of 50 mmHg and a mean (MAP) of 70 mmHg. Blood pressure can be measured using either a direct or indirect method. The direct method requires the insertion of a catheter into the artery of the patient and attaching to it an anaeroid manometer or blood pressure transducer. Direct blood pressure monitoring is continuous. This requires practice as arterial catheter placement can be challenging. This method also requires that the anesthetist maintain a patent catheter. The indirect measurement of blood pressure can be achieved with the use of a Doppler flow detector or an oscillometric cuff monitor. As mentioned before, the Doppler is not as useful in the equine patient as in small animals. If you choose the indirect method it is recommended that you check the blood pressure every 5 minutes.

Patient oxygenation is another parameter that should be monitored. This can be accomplished with the use of a pulse oximeter. Pulse oximetry is an estimate of arterial oxygen status determined by the measurement of the degree of oxygen being carried by hemoglobin. It is reported as a percent. The pulse oximeter also measures heart rate. It is a continuous measurement and most oximeters have an audible heart rate detector and alarm. The accuracy of the pulse oximeter can be influenced by positioning and vasodilation or vasoconstriction. In general, an SpO2 reading of 90% indicates a PaO2 = 60 mmHg and an SpO2 of 99% indicates an SpO2 > 100 mmHg. Pulse oximetry is a beneficial measurement in the face of pulmonary disease, airway disease or in situations where desaturation is an expected event. The pulse oximeter is NOT a respiratory or ventilation monitor.

Ventilation, in my estimation, is one of the most important measurements to monitor. To assess ventilation, you must monitor pO2 and pCO2 levels. Carbon dioxide is a byproduct of metabolism that is removed from the body through the respiratory system. If the patient has a normal metabolism, the measured levels of CO2 are a direct indicator of the efficacy of his/her ventilation status. Carbon dioxide can, at high levels, be anesthetic to the patient. It can also stimulate a stress response that includes epinephrine release, arrhythmias and tachycardia. Prolonged elevation of CO2 levels can cause damage to the nephrons. This damage does not become clinical until 65% of the total nephrons are destroyed. A poorly ventilated patient could have CO2 caused nephron damage that contributes to renal disease and failure at a later time; perhaps as long as years later. A patient on 100% O2 should have a pO2 measurement of 400-500 mm Hg.

The two ways in which to monitor ventilation are blood gas analysis and capnography. Blood gas analysis is the “gold standard” for measuring the exact amount of carbon dioxide and oxygen in the arterial blood of a patient. It can be used for accurate assessment of adequacy of both ventilation and oxygenation. A heparinized blood sample is collected anaerobically from an artery and introduced into a blood gas analyzer that measures pH, PaO2, and PaCO2 with electrodes and calculates bicarbonate and base excess/deficit. Metabolic acidosis indicates inadequate tissue perfusion and oxygen delivery. Metabolic acid means increased acid production or decreased acid excretion. Respiratory acidosis indicates inadequate ventilation. Some blood gas analyzers (Irma or I-Stat) will measure lactate. Lactate levels, which have been correlated to prognosis, indicate adequacy of tissue perfusion.
Capnography measures the end-tidal CO₂ (ETCO₂) by taking a sample of exhaled gas from the endotracheal tube in intubated patients. Although sampling works best in intubated patients; a sample can be obtained from an awake, un-intubated animal using a tight fitting face mask. By sampling gas at the end of the expiratory phase, the sample will be alveolar gas or end-tidal gas rather than dead space or non-perfused gas. ETCO₂ is a fairly accurate estimation of arterial carbon dioxide. Capnography can be a good estimation of PaCO₂ and adequacy of ventilation in endotracheally intubated patients but can be difficult and inaccurate in awake patients. It is also inaccurate in patients with significant ventilation-perfusion (V-Q) mismatch. The equipment necessary for capnography is expensive but has an added parameter that is very helpful to the anesthetist. The capnograph also measures inspired and expired (end tidal) inhalant levels.

It is important to monitor the cardiovascular system as well as the respiratory system. Heart rate is the most obvious parameter associated with this system. Heart rate can be monitored by palpation of a peripheral pulse, use of a stethoscope or ECG, a pulse oximeter, or Doppler blood pressure monitor. Pulse pressure is the difference between systolic and diastolic pressures. If the heart rate you obtain is different from the rate you determine by auscultation then there is a pulse deficit and an ECG should be performed to rule out an arrhythmia. Mucous membrane color is another indicator of patient condition. Gum color as opposed to tongue color should be evaluated. Pink is an indication of good perfusion and oxygenation; pale, gray or white are usually caused by vasoconstriction, significant hypotension or cardiac arrest. Bright red is present in the face of endotoxic or septic shock whereas bright pink is indicative of hypercarbia. Capillary refill time should be about 1 second but will be prolonged by low blood pressure and/or cardiac output as well as vasoconstriction.

Body temperature should be monitored in all anesthetized patients, however due to the size of the adult equine patient and the large surface area of mucous membranes exposed to the air during abdominal surgeries, it is very hard to maintain a normal body temperature in these patients. In foals less than 500lbs., body temperature is more easily maintained. Hypothermia can be an indication of poor cardiac output and poor tissue perfusion. Harmful effects of extended periods of hypothermia can include cardiac dysrhythmias, bradycardia, platelet dysfunction and coagulopathies, altered mental status, impaired renal function, decreased drug metabolism and reduced MAC. Poor wound healing and increased chance of postoperative infections are serious adverse side effects of hypothermia. Hypothermia is considered a temperature of < 97F and hyperthermia > 102.5F. Hypothermia can be treated with circulating warm water blankets, Bair Hugger forced air heating blankets, blankets, and/or fluid warmers. Obviously the warm water blankets must be used over the top of the patient as opposed to under it. Wrapping bubble wrap around the patient’s legs has been proven to help slow body heat loss. Foals can be kept warm quite well with the use of forced air blowers.

The goal of patient monitoring is early detection of an adverse response to anesthesia.” Is the patient tolerating the procedure” is an important question. Patient monitoring aids the anesthetist in being proactive in the response and treatment of adverse effects of the anesthetic period. The anesthetist should use monitoring to determine when and how to minimize the intensity and duration of stressors his/her patients face. No patient should be worse off for having undergone anesthesia.

References available upon request.