Blood pressure is the most informational parameter you can have in an anesthetized patient. Knowing how blood pressure works and how to monitor it is important in the veterinary patient because it gives us a rapid means in which to assess cardiac function. The goal is to provide adequate quantities of oxygenated blood to the peripheral tissues and to prevent tissue and organ damage due to inadequate perfusion. Many different factors play a role in blood pressure, and once you know the reasoning behind abnormal blood pressure values you can understand how to treat them appropriately.

Blood pressure is the driving force for blood flow through the capillaries that supply oxygen to organs and tissue beds of the body. The two main factors that contribute to blood pressure are cardiac output and systemic vascular resistance. Cardiac output is the amount of blood being pumped by the heart over time. Systemic vascular resistance is the amount of resistance to blood flow through the vessels. Blood pressure is cardiac output times systemic vascular resistance (BP = CO X SVR). The sympathetic nervous system maintains blood pressure by increasing cardiac contractility and increasing heart rate.

Blood pressure is measured in millimeters of mercury (mmHg), and recorded as systolic, mean, and diastolic arterial pressure. Systolic arterial pressure (SAP) is generated when the left ventricle is fully contracted. Diastolic arterial pressure (DAP) is measured when the ventricle relaxes. Mean arterial pressure (MAP) is an equation that measures the average blood flow through the vessels. MAP = [DAP + (SAP - DAP)]/3

There are two main methods in which we can monitor blood pressure: direct and indirect. Direct blood pressure is monitored through an arterial catheter attached to a pressurized fluid line, transducer, and monitor with direct monitoring capabilities. This method of monitoring is considered the gold standard because it gives accurate, instant blood pressure readings. The disadvantages are that the monitors can be fairly expensive and it takes a higher level of technical skill to place the catheter. There is also the risk of infection or blood loss at the placement site. Indirect blood pressure readings are taken with either a Doppler or an oscillometric monitor. Doppler monitoring takes place with a crystal that is placed over an artery and an audible swish sound can be heard. A cuff is placed above the crystal and attached to a sphygmomanometer. The cuff is then inflated until no sound is heard, slowly deflated, and then systolic pressure is read the point when sound returns. The units are relatively inexpensive, portable, rechargeable, and work on any size patient. Oscillometric pressures are taken with a blood pressure cuff attached to the patient and read out by a monitor. These units read systolic, mean, and diastolic arterial pressure. They require little technical skill to use, but can be unreliable in small or hypotensive patients.

Blood pressures in the anesthetized cat and dog may vary depending on the status of the patient and what they are having done. Overall though SAP should be between 100-160mmHg, MAP should be 80-100mmHg, and DAP should be 60-100mmHg. Any pressure below this is considered hypotension and action should be taken to prevent damaging consequences. Any pressure above the listed numbers is considered hypertension and action to correct this should also be taken.

Hypotensive states can lead to decreased hepatic metabolism of drugs, prolonged anesthetic recovery, hypoxemia, CNS complications, cardiac and respiratory arrest. There are three main mechanisms that cause hypotension. The first is decreased cardiac output due to myocardial depression, arrhythmias, or decreased venous return. The second is reduced systemic vascular resistance usually from anesthetic drugs, SIRS, or sepsis. The third is hypovolemia from vasodilation, hemorrhage, fluid deficits, or third space shifting of fluids.
Prolonged hypertension effects multiple organ systems. It can lead to poor tissue perfusion, arrhythmias, and reduced cardiac contractility. It can also cause renal damage leading to loss of nephrons, proteins, and coagulation factors. Hypertension can cause ocular swelling, hemorrhage, retinal detachment and blindness. It may cause an increase in intracranial pressure (ICP), brain ischemia, herniation and even death. Hypertension can be caused by pain, anesthetic drugs, hypercarbia, and some disease processes.

Many anesthetic drugs can lead to changes in blood pressure. Gas inhalants (ISO/SEVO) cause direct myocardial depression, vasodilation, and decreased cardiac output all leading to hypotension. Acepromazine, an alpha 1 blocker, causes vasodilation decreasing systemic vascular resistance resulting in hypotension. Propofol also has similar effects causing a direct decrease in MAP. Opioids such as morphine, hydromorphone, fentanyl, and even butorphanol cause bradycardia decreasing cardiac output which in turn can cause hypotension. Dexmedetomidine, an alpha 2 agonist causes vasoconstriction and an increase in blood pressure. Ketamine is a positive inotrope leading to an increase in heart rate increasing cardiac output and MAP. Anticholinergics (atropine/glycopyrrolate) cause a sinus tachycardia also increasing MAP.

Many surgical procedures have a direct effect on blood pressure as well. Inadequate analgesia can lead to hypertension from pain. Excessive surgical blood loss results in decreased volume and cardiac output causing hypotension. Procedures such as splenectomies, amputations, and large tumor removals often reduce blood volume. Animals presenting with sepsis, shock, and GDV are already in a hypotensive state and steps should be taken to correct blood pressure immediately.

Different patient factors play a role in an anesthetized animal’s blood pressure. Pediatric patients rely on heart rate to maintain cardiac output. A low heart rate in these patients may lead to low blood pressures. Extremely excited or scared animals may have an increase in blood pressure due to catecholamine release. Animals with hypovolemia, hypoproteinemia, and hypoalbuminemia can be expected to have low blood pressure during their anesthetic episode until the problem is corrected. Hyperthermia increases cardiac output and therefore increase MAP. Hypothermia causes bradycardia leading to a decrease in cardiac output which may result in hypotension. Large or obese patients may be hypotensive when placed on their back. Additional pressure on a caudal vena cava decreases venous return lowering cardiac output and blood pressure.

Certain disease process can cause changes in blood pressure that may be enhanced by anesthesia. Patients with renal disease may be hypertensive due to sodium retention. Maintaining adequate perfusion to the kidneys is important to avoid further loss of nephrons. Cardiac disease can have varying effects on blood pressure depending on the type. The goal with any patient having cardiac implications is to try and minimalize the workload on the heart and keep myocardial oxygen consumption minimal. Neurological patients may have an increase in ICP. The goal is to keep blood pressure at a normal low level and end tidal carbon dioxide (ETCO2) on the low side to prevent further increases in ICP, hypertension, and to avoid brain ischemia.

Endocrine disorders can also have an effect on an anesthetized patient blood pressure. Hyperadrenalcorticism or Cushing’s disease can leave anesthesia patients in a hypertensive state due to cortisol’s enhancement of epinephrine’s vasoconstricting effects. Hypoadrenalcorticism or Addison’s disease puts patients in a potential hypotensive state due to the effects of the disease. They can be bradycardic, dehydrated, and hypovolemic which all cause a decrease in cardiac output and blood pressure. Animals that are hypothyroid may become hypotensive from their disease. A decrease in metabolism also leads to a decrease in heart rate cardiac output, and metabolism of drugs. These patients may also be obese causing a decrease in venous return while on their backs. Hyperthyroidism effects are the opposite. Patients may be hypertensive due to an increase in cardiac output from increased heart rate and an increased metabolism of anesthetic drugs. With these disease processes the key is to not have your anesthetic episode enhance the symptoms of the disease. In animals with preexisting tachycardia, avoid drugs that increase heart rate and workload on the heart. In patients with a preexisting hypotension, maintain blood pressure with plenty of volume and limit agents that vasodilate.
There are a wide range of treatment options for patients who become hypotensive during anesthesia. The best way to fix low blood pressure is to treat the cause. Many animals become hypotensive from vasodilation due to gas anesthesia or anesthetic drugs such as Acepromazine. The best solution for these patients is to decrease gas inhalant and increase crystalloid fluid volume. If this does not work a positive pressure inotrope may be needed. Dopamine or dobutamine are good choices and can be ran at 2-10mcg/kg/min as a constant rate infusion (CRI) to increase vasoconstriction and cardiac contractility. Often hypotension can be the result of bradycardia. In these situations an anticholinergic can be given if an alpha 2 has not already been given. If hypotension is due to hypovolemia from fluid loss (vomiting/diarrhea) boluses of crystalloids at 10ml/kg can be given all the way up to 90ml/kg for shock doses. If hypotension is due to hypovolemia from third space shifting hypertonic saline can be used to pull fluid back into the vascular from the interstitial. When patients are hypotensive because of hypoproteinemia or hypoalbuminemia the best solution is to give colloid such as Hetastarch at 2-5ml/kg as a bolus or CRI. Albumin may also be given but can be fairly hard to come by and relatively expensive. When hypotension is the result of hemorrhage the best solution is to stop the bleeding. This is not always immediately possible so crystalloids at a rate of 2-3ml for every ml of blood lost can be given, Hetastarch at a rate of 2ml/kg can be given, or the best option is to start a blood transfusion. If hypotension is occurring because of a decrease in output from tachyarrhythmias a 1-3mg/kg dose of lidocaine can be given.

Hypertension is less common in the veterinary patient, but once again the best way to correct is to treat the cause. When hypertension is due to pain more analgesics should be given. If the patient has an increase blood pressure due to inadequate anesthetic depth, increase gas inhalation. Often hypertension can be seen due to alpha 2 agonists such as dexmedetomidine. The best option for these patients is to reverse the drug or wait until it effects wears off (usually within 30min). When hypertension is the result of an increase in ICP or hypercarbia the best way to decrease it is to increase IPPV and lower ETCO2. Most patients with disease processes that cause hypertension should be under control before their anesthetic episode, if this is not possible drug therapy may be necessary such as a beta blocker or a calcium channel blocker.

In summary, monitoring blood pressure in veterinary anesthesia is essential for proper patient care. Blood pressure is made up of cardiac output and systemic vascular resistance. Knowing which part of the equation is causing a change in blood pressure will let you know how to treat. There are multiple ways to take measurements and knowing your patient and your clinics needs will be the best way to decide on which one to use. Understanding how anesthetic drugs work will also be helpful in preventing pressure complications in the anesthetized patient. Many disease processes can effect blood pressure, when possible these disease should be well controlled before anesthesia, otherwise drug therapy intervention may be necessary.

References:

1. Veterinary Anesthesia and Analgesia, McKelvey & Hollingshead pg.79-88.