Physical Assessment

Monitoring the critically ill patient begins with the physical assessment. This does not require any special equipment; we make use of our senses. Looking, listening, feeling, and smelling can garner a variety of information concerning the patient’s condition. A complete physical examination is performed; it will be necessary to develop some system of examining a patient so as not to miss potential problems. The veterinary technician is encouraged to become comfortable with performing a physical examination. It will enable you to be able to detect trends or changes in your patient’s condition.

Simply by looking at the patient we can determine if there is respiratory difficulty; we can determine the level of consciousness, pupillary light responses and note the patient’s posture (neurological assessment). We can look at mucous membrane color and capillary refill time, indicators of peripheral perfusion. We can determine if there is any blood loss or wounds.

We can auscultate the chest for abnormal breath and heart sounds. Crackles and wheezes indicate a small airway or alveoli problem. Diminished or absent breath sounds indicate pleural filling defects (pneumothorax, hemothorax, diaphragmatic hernia). Loud stertorous sounds indicate upper airway problems. Auscultation of the heart may reveal murmurs or arrhythmias. Diminished heart sounds suggest pericardial tamponade.

Palpation of pulses is a way of assessing stroke volume, heart rate and rhythm. Cool extremities may indicate decreased peripheral perfusion. Checking skin turgor and gum moisture can assess hydration status. Organomegaly can be determined by abdominal palpation.

Smelling the animal’s breath can pick up uremia and ketoacidosis.

The patient’s history and physical findings provide the foundation for which further critical care decisions are made. Additional diagnostic, therapeutics and monitoring decisions will be based on repeated physical examinations.
Cardiovascular

Assessing Heart Rate and Electrical Activity

Heart rate is a nonspecific parameter. It is usually measured by auscultation of the heart and palpation of an artery, automatically taken from an ECG or arterial pulse pressure wave. The normal heart rate for a dog and cat is 100 - 140 and 110 - 140 beats per minute, respectively. There are several reasons for tachycardia (hypovolemia, hypotension, hypoxemia, excitement, fever, drugs, and pain) and bradycardia (drugs, hyperkalemia, severe hypothermia, and increased vagal tone). If arrhythmias are auscultated then an ECG is indicated. The ECG reflects electrical activity; it does not measure mechanical activity. An arrhythmia is defined as an irregular heart rhythm. The heart rate defines the rhythm as a tachyarrhythmia or a bradyarrhythmia. Wide bizarre QRS complexes may be ventricular premature contractions (VPCs), right ventricular hypertrophy or right bundle branch block (BBB). VPCs are often not preceded by a P wave (the other two are). VPCs and right BBB are associated with wide QRS waveforms. Small normal appearing QRS complexes may be due to pericardial effusion. Abnormally tall-tented T waves may be due to hyperkalemia. S-T segment slurring or depression may be due to myocardial hypoxia.

Assessing the Determinants of Stroke Volume

Stroke volume is the amount of blood pumped out of the heart with each beat and there are three primary determinants of stoke volume. Stroke volume is increased as the walls of the ventricles are stretched during diastole (preload); as the strength of contraction (contractility) increases; and as the forces that opposes blood flow from the heart (afterload) decreases. The filling pressures of both ventricles serves as a gage to filling volume. Estimates of filling pressure can be made by measuring central venous pressure (CVP for the right heart) and pulmonary artery wedge pressure (PAWP for the left heart). PAWP is not commonly measured in practice, it requires the placement of a special catheter in the pulmonary artery. Contractility is difficult to determine, some indicators include visualization by ultrasonography, strength of heart sounds, and palpation of the precordium and pulse quality.

Central Venous Pressure (CVP)

Central venous pressure is the amount of pressure reflected from the intrathoracic anterior vena cava to a column of water in a plastic manometer or a pressure transducer and oscilloscope. Changes in pressure in the thorax produce fluctuations in the water manometer or wave forms on the oscilloscope. Central venous pressure is a measure of the hearts ability to pump fluids returned to it and is also an estimate of the relationship of blood volume to blood volume capacity. CVP should be measured when heart failure is suspected or as an aid in determining the end-point to aggressive fluid therapy. We generally assume that a reasonable preload has been achieved when the CVP approaches 10 Cm H₂O (7.5 mm Hg). If cardiac output, pulse quality, blood
pressure and or perfusion parameters (CRT, mucous membrane color, urine output, and appendage temperature) are acceptable we can assume that effective blood volume restoration has been accomplished. If not, we can assume that the heart is unable to handle the venous return.

The Numbers

The normal range is 0 - 10 Cm H\textsubscript{2}O (0 - 7.5 mm Hg). A CVP less than 0 may be due to vasodilation (increased volume capacitance) or hypovolemia. A CVP in the normal range but in the face of signs consistent with vasoconstriction may still be due to hypovolemia. A CVP greater than 10 Cm H\textsubscript{2}O (13.6 mm Hg) may be due to right heart failure (inability to function as a pump), fluid over-load, vasoconstriction (decreased volume capacitance), pericardial effusion and positive pressure ventilation.

The Measurement

A catheter is placed in the anterior vena cava via the jugular vein for measurement of the CVP. To assure proper placement of the catheter, a small fluctuation in the fluid meniscus within the manometer synchronous with the heart beat or chest excursions should be seen. Large fluctuations in the fluid meniscus synchronous with the heart beat suggest placement of the catheter in the right ventricle. A water manometer is placed in the fluid line via a three-way stopcock. The stopcock is turned off toward the patient to fill the manometer from the fluid source. The manometer is filled approximately three-quarters full. When the manometer is filled the stopcock is turned off toward the IV fluids, this opens the pathway to the patient and the fluid level drops in the manometer. When the fluid stops dropping, note the reading (taken between ventilatory excursions). To determine the zero reference point a horizontal line is drawn between the manometer and the top of the manubrium. The point where the horizontal line intersects the manometer is the zero reference point. The difference between the initial reading and the zero reference point is the CVP measurement. For example the initial reading is 15 Cm H\textsubscript{2}O, the zero point is 10 Cm H\textsubscript{2}O the CVP is 5 Cm H\textsubscript{2}O.

CVP can be measured with a transducer attached to a jugular catheter and placed at the level of the right atrium. The blood water interface transmits a pressure to the transducer that in turn converts the signal to a measurement that is displayed on an oscilloscope. The measurements are usually in mm Hg and can be converted using the conversion factor 1 mm Hg = 1.36 Cm H\textsubscript{2}O.

Regardless of the technique utilized, measurements are ideally taken with the patient in the same recumbent position, and the same person takes the measurement. The goal is to be consistent in taking the readings and to monitor the trends.

Arterial Blood Pressure

Arterial blood pressure is measured by indirect and direct methods. Arterial blood pressure is the product of cardiac output, vascular capacity and blood volume. The
three determinants work together in concert to maintain blood pressure. Should one of the three become sub-normal the other two should compensate.

**Indirect (Noninvasive) Measurements**

Doppler Method

The doppler detects flow of blood through an artery and converts this to an audible signal. When an occlusive cuff is applied to a limb and inflated, flow is occluded. The cuff pressure is slowly decreased while looking at a sphygmomanometer. With the first sound of flow the pressure reading from the sphygmomanometer is noted, this approximates systolic pressure.

Oscillometric Method

Several blood pressure units utilize the oscillometric technique. A cuff is applied to a limb and automatically inflated; the cuff detects oscillations in the underlying artery. As the cuff is gradually deflated oscillations are detected. The first detected pulsation is the systolic pressure, the point at which the maximum pulsation is detected is the mean blood pressure, and the point were oscillations disappear is the diastolic pressure.

Factors Affecting Indirect Pressure Measurements

Cuff width should be approximately 40% the circumference of the limb. A cuff that is too wide will yield an erroneously low reading, likewise, a cuff which is to narrow will yield an erroneously high reading. One of the biggest factors, which affect indirect blood pressure measurements, is cuff placement. If the cuff is too tight you will get an erroneously low reading, and if the cuff is placed too loose you will get an erroneously high reading. Other factors affecting measurements include low blood pressure or flow states; small vessels / vessel constriction; and motion (oscillometric methods).

**Direct (Invasive) Measurements**

Of the techniques available for measuring blood pressure direct or invasive techniques are the most accurate. This technique yields a continuous measurement of mean blood pressure or systolic, diastolic and mean blood pressure. After a clip and surgical prep, a catheter is placed percutaneously or via cutdown in the dorsal pedal or femoral artery and attached to a monitoring device. Monitoring devices include the water manometer (much like the CVP), aneroid manometer, and transducer.

Factors Affecting Direct Pressure Measurements

It’s important that the transducer be zeroed to the level of the right atrium. If the transducer is lowered below the level of the heart a erroneously high pressure reading will be obtained owing to the increased hydrostatic pressure placed on the transducer, likewise, an erroneously low reading will be obtained if the transducer is raised above
the level of the heart. Excessive tubing length may dampen the measurements. Thin wall tubing will also result in dampened waveforms; it is best to use high-pressure tubing, which is non-compliant.

The Numbers

Normal systolic, diastolic, and mean blood pressure are approximately 100-160, 60-100, 80-120 mm Hg respectively. Systolic and mean pressures below 80 mm Hg and 60 mm Hg respectively warrant therapy. Causes of hypotension include: hypovolemia, peripheral vasodilation, and decreased cardiac output. Hypertension may be caused by chronic renal failure and an adrenal tumor - pheochromocytoma.

Respiratory

Assessing Oxygenation and Ventilation

Arterial PH & Blood Gases

Arterial PH and blood gases give us a clue as to what is going on at the cellular level. The typical blood gas profile includes: PH, PaO₂, (oxygenation) PaCO₂ (ventilation), HCO₃⁻ or base balance (metabolic).

Collection, Storage and Analysis

Collection of a blood sample for blood gas analysis entails percutaneous puncture of an artery such as the dorsal pedal or femoral artery. The sample is collected in a heparinized coated syringe being careful not to introduce air or applying excessive negative pressure, both of which can affect your PaO₂ measurement. Once the sample is collected the artery is held off for a few minutes. Air bubbles are expelled from the syringe and the syringe is corked and placed in a ice water bath. Blood gas samples may stay in a ice water bath for several hours before metabolism alters the PH or blood gas values.

Blood gas measurements are performed on a pH and blood gas analyzer, this is an expensive and labor-intensive piece of equipment to maintain, however, there are several point-of-care inexpensive portable PH and blood gas analyzers have been developed. They are financially and technically feasible for use in private practice. An alternative to owning an analyzer is to take the blood sample to the nearest human hospital; perhaps arrangements can be made wherein they will run the sample for a minimal fee.

The Numbers

The pH combined with bicarbonate or base balance tells us about the metabolic status of the patient. Normal pH is 7.35 - 7.45, a pH less than 7.35 is termed acidemia and a pH greater than 7.45 is termed alkalemic. A patient has a metabolic acidosis if the bicarbonate is less than 18 mmol/L or base deficit is more negative than -4. Alkalosis is
identified by bicarbonate greater than 27 mmol/L and base excess greater than +4.

\( \text{PaO}_2 \) measures the patient’s ability to oxygenate the blood. The normal range is 80-100 mmHg (when breathing room air). When the inspired oxygen concentration is greater than room air (21%), the expected \( \text{PaO}_2 \) will be at least five times the inspired oxygen concentration. For example, a patient breathing 40% oxygen, the expected \( \text{PaO}_2 \) is 200 mm Hg. If you take that same patient breathing the same inspired oxygen concentration and the \( \text{PaO}_2 \) is 100 mm Hg you can say that the patient has a pulmonary problem. A \( \text{PaO}_2 \) less than 60 mmHg is considered hypoxemic and therapy should be started at this point. Some causes for hypoxemia include hypoventilation, ventilation perfusion-mismatch, right to left shunt and diffusion impairment, low inspired oxygen.

\( \text{PaCO}_2 \) measures the patient's ability to ventilate. The normal \( \text{PaCO}_2 \) is 40 mm Hg with a range of 35-45 mm Hg. A \( \text{PaCO}_2 \) less than 35 mm Hg (hypocapnia) is indicative of hyperventilation (excessive elimination of \( \text{CO}_2 \)). A \( \text{PaCO}_2 \) less than 20 mm Hg may lead to decreased cerebral blood flow leading to cerebral hypoxia. A \( \text{PaCO}_2 \) greater than 45 mm Hg (hypercapnia) is indicative of hypoventilation (decreased elimination of \( \text{CO}_2 \)). A \( \text{PaCO}_2 \) greater than 60 mm Hg may be associated with hypoxemia if the patient is breathing room air. When a \( \text{PaCO}_2 \) reaches this level, ventilator therapy may be required. Hypercapnia may be caused by CNS disorders, pleural filling disorders, abdominal or thoracic restrictive disorders and pulmonary parenchymal disease.

\textit{Pulse Oximetry}

Pulse oximetry provides noninvasive and continuous information about the percent oxygen bound to hemoglobin. In essence, oxygen saturation is the ratio of oxy-hemoglobin to deoxy-hemoglobin and oxy-hemoglobin. \texttt{ASpO2}” is commonly used when referring to oxygen saturation readings obtained with a pulse oximeter.

\textbf{Technology}

Pulse oximeters emit red and infrared light that is passed through a body tissue toward a receiving photo detector. A pulsating arterial supply is needed for the pulse oximeter to function properly. Oxygen alters light absorption by the hemoglobin molecule. The degree of change in the light transmission is measured as oxygen saturation.

\textbf{Measurements & Factors Affecting Results}

Pulse oximeters may be attached to the ear, tongue, lip, tail, prepuce and rectum. It is necessary to have good pulsatilie flow at the sight.

Factors affecting measurements include low perfusion states; motion (pulse oximeter can not discern pulsatile flow vs motion); optical interference (ambient light, optical shunt, and edema).
The Numbers

SpO$_2$ and PaO$_2$ are related by the oxy-hemoglobin dissociation curve, one value can be derived from the other as long as the curve is normal. While both pulse oximeter and arterial blood gases (PaO$_2$ specifically) measure the lungs ability to deliver oxygen to the blood the numbers obtained are quite different. Caution should be exercised when interpreting SpO$_2$ values with animals breathing 100% oxygen. Animals with a PaO$_2$ of 500 or 100 would still show a SpO$_2$ from 98 - 99%, which is hardly a significant difference.

*End Tidal CO$_2$*

Capnography is the measurement of ET CO$_2$; this allows the continuous monitoring of exhaled carbon dioxide by analyzing samples obtained directly from the airway. Carbon dioxide readily diffuses across the capillary membrane and quickly equilibrates with alveolar gas. As these gases are exhaled, the CO$_2$ at the end of the breath, or the ET CO$_2$ closely approximates arterial CO$_2$. Normal ET CO$_2$ is approximately 1 - 4 mm Hg less than the PaCO$_2$. Factors affecting measurements include gas leaks, sensor obstruction, and taking readings during the early part of exhalation.

**Laboratory Assessment**

**Hematocrit and Total Solids**

Hematocrit (Hct) and total solids (TS) can be used to gauge fluid therapy estimate hemoglobin concentration and, to a certain degree, assess blood loss. The two tests should be interpreted together to minimize errors in interpretation. Increase in both Hct and TS indicate dehydration, decrease in both Hct and TS is suggestive of recent blood loss or clear fluid administration. Increase in TS and normal Hct may indicate anemia with dehydration. Both normal Hct and TS may be normal in peracute blood loss. TS may decrease with reduced albumin levels; albumin is a contributor to oncotic pressure.

**Blood Glucose**

Glucose provides an energy source for cells. Hypoglycemia should be considered in patients that are at risk for sepsis; or are hypothermic, seizing, or exhibiting altered mentation. Marked hyperglycemia can be associated with coma.

**Electrolytes**

Electrolytes play a major role in the maintenance of inter-compartmental water balance and cell function. Baseline electrolytes should be obtained and monitoring continued as therapy progresses. Fluid therapy can alter various serum electrolyte concentrations, and may require adjustment of the electrolyte composition in the fluids being administered. Commonly measured electrolytes include serum potassium, sodium,
chloride, magnesium and ionized Calcium.

**Colloid Oncotic Pressure**

Colloid oncotic pressure (COP) can be measured and used to guide fluid therapy. COP is a force created by large plasma proteins that do not move freely across capillaries. The presence of colloids in the vascular space has the effect of pulling water from the interstitium into the vascular space. The goal is to maintain a COP greater than 15 mm Hg.

**Lactate**

When perfusion decreases and oxygen delivery is reduced the body shifts from aerobic to anaerobic metabolism resulting in lactate formation. Elevated blood lactate (lactate > 2 mmol/L) has been proposed as an indicator of inadequate tissue oxygenation. Although elevated blood lactate levels often signify generalized tissue hypoxia, a normal value does not rule out regional lactate production.

**Summary**

To provide effective monitoring and nursing care one must be familiar with normal values. In addition, the veterinary technician must know the differential rule outs for abnormal monitored values; how the monitoring equipment functions; and how to troubleshoot equipment problems. Information from monitored parameters should be integrated with each other in order to develop an overall picture of the patient's condition.