# PERIOPERATIVE MONITORING AND SUPPORTIVE CARE

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Progression and specialization in the field of veterinary surgery has resulted in more sophisticated and often longer diagnostic and surgical procedures. Fortunately, advancements in veterinary medicine over the past decade have been coupled with advances in patient monitoring technology. A complete understanding of the instrumentation, capabilities and limitations of individual monitoring devices is essential to realize the full potential of this technology. It is important to note that patient monitoring devices should be utilized to supplement and not replace conventional "hands-on" monitoring techniques.

Optimal supportive and nursing care during the perioperative period (the interval immediately before, during and following an operation) is also essential to decrease patient morbidity and mortality. While this is particularly true for the critical postoperative patient, the healthy patient following elective surgery will also benefit from basic monitoring and supportive care that could avert catastrophe. It should be noted that patient monitoring is not exclusive to the intraoperative period, but should be maintained throughout the perioperative period and appropriate supportive care initiated when indicated. The complexity of perioperative monitoring is generally dictated by the condition of the patient and the availability and capability of support staff. However, the support staff does require a thorough understanding of specialized surgical and anesthetic procedures and potential perioperative complications. This understanding and knowledge when combined with a hands-on, systematic approach to perioperative patient care will increase the likelihood for a positive outcome.

## Arterial Blood Pressure

Arterial blood pressure (ABP) is the product of cardiac output (heart rate x stroke volume) and systemic vascular resistance. This formula reveals that although ABP is not a direct measure of cardiac output, it can provide an assessment or estimate of cardiovascular function and tissue perfusion. Together with local metabolic activity, ABP is the primary determine of cerebral, coronary, pulmonary and renal blood flow. As such, decreases in ABP can indicate significant decreases in blood flow to vital organs with potential catastrophic effects. With respect to arterial blood pressure, the following definitions apply:

1. Systolic Arterial Pressure (SAP) – Arterial pressure during left ventricular contraction (systole)
2. Diastolic Arterial Pressure (DAP) – Arterial pressure during left ventricular filling (diastole)
3. Mean Arterial Pressure (MAP) – Average pressure across an arterial wall during the cardiac cycle where MAP = (SAP-DAP) / 3 + DAP
4. Hypotension – SAP less than 80 mm/Hg or MAP less than 60 mm/Hg

5. Hypertension – SAP greater than 200 mm/Hg or MAP greater than 130 mm/Hg

Three methods are available for the measurements of arterial blood pressure in companion animal practice and include the following:

*Doppler ultrasound:* This method utilizes the application of two piezoelectric crystals over a peripheral arterial pulse. The piezoelectric crystals measure blood flow through a vessel or measure motion within the wall of an artery. The artery is occluded proximal to the crystal by inflation of a cuff placed circumferentially around the extremity. As the occluding pressure is released, blood flow returns and is detected by the piezoelectric crystals (one crystal emits into audible sound waves and the other crystal receives). The received ultrasonic waves are converted into audible sound waves and amplified. The point at which audible arterial blood flow returns corresponds with the systolic blood pressure depicted on an aneroid gauge. The pitch of the sound reflects the velocity of the flow within the vessel. Therefore, the louder sound, the higher velocity of flow.

Advantages of the ultrasonic Doppler technique include cost and relative user friendliness. The Doppler also provides an audible assessment of the pulse character, rate and rhythm. Disadvantages of the Doppler include lack of identification of the mean arterial pressure (considered the main determinant of organ perfusion). Technical errors including improper cuff placement and inappropriate cuff size can limit reliability. The optimal cuff bladder width is 40% of the circumference of the extremity and the optimal cuff length is 150% of the circumference of the limb. Recent studies in cats evaluating the Doppler ultrasound suggest that the systolic pressure may be underestimated when compared to measurements obtained from direct arterial catheter placement.

*Oscillometric:* Automated oscillometric blood pressure devices measure oscillations or vibrations within a blood pressure cuff created by the pulse wave traveling through the arterial wall. A machine attached to the blood pressure cuff rapidly inflates and then slowly deflates the cuff automatically. As the cuff deflates, the pressure of maximal oscillation amplitude is determined and represents the MAP. SAP and DAP are also determined. Primary advantages of this method of blood pressure monitoring include automatically and the determination of MAP. Disadvantages include patient motion artifact and the need for adequate patient positioning with the pressure duff at the level of the heart. Research suggests that this method of blood pressure evaluation may be less accurate in cats than in dogs. Some anesthesiologists suggest that oscillometric monitoring may not be reliable in patients under 8 kilograms.

*Direct (Arterial Catheter):* Direct arterial blood pressure measurement is considered the gold standard and the means to which the results of indirect methods are compared. Direct ABP involves the sterile catheterization of a peripheral artery (dorsal metatarsal, dorsal metacarpal or lingual). The arterial catheter is connected to a pressure transducer and monitor. Although outweighed by the more accurate and continuous information provided. Direct arterial access for intermittent blood gas sampling is also advantageous for both the clinician/technician and patient.

Monitoring blood pressure should not be limited to the intraoperative period. Invaluable information regarding a patient's preoperative status can be obtained following evaluation of the preoperative blood pressure. Monitoring intraoperative blood pressure trends can alert both the surgeon and anesthetist to potential surgical or anesthetic problems. For example, prolonged traction of the portal vein and caudal vena cava during surgical correction of a portosystemic shunt can result in inadvertent hypotension due to distributive shock. A gradual decrease in circulation blood volume associated with ongoing hemorrhage without concurrent decrease in the percentage of inhalant anesthetic can result in an increased anesthetic depth and hypotension. These scenarios help demonstrate how continued communication between the surgeon and anesthetist can identify and advert potential intraoperative complications.

Postoperative monitoring of blood pressure is essential in the postoperative critical patient. Postoperative hypotension can be indicative of surgical complications such as ongoing hemorrhage and sepsis. Anesthetic complications including inappropriate administration of perioperative drugs or inadequate volume resuscitation can also be identified.

The treatment of hypotension in the perioperative patient is directed towards identification and correction (if possible) of the etiology of the hypotension. Any critical patient should have measurement of the MAP prior to induction of anesthesia. If hypotension is identified, anesthesia should be delayed until normotension is achieved. If delay in anesthetic induction is contraindicated, the anesthetic protocol should be modified to include drugs that do not promote hypotension.

## Pulse Oximetry

Pulse oximetry provides an invaluable tool for monitoring the perioperative small animal patient in modern day veterinary practice. The practicality, usefulness and cost of effectiveness of pulse oximetry have resulted in extension of its use far beyond that of the academic setting.

Pulse oximetry utilizes the principle of varying light reflection properties of oxygenated and deoxygenated blood. When applied across skin or mucous membranes, pulse oximeters emit two wavelengths of light (red and infrared) that are transmitted across the tissue bed. The difference between light absorption during pulsation (arterial blood flow) and background absorption (venous blood, soft tissue and bone) are determined. Microprocessors within the pulse oximetry unit then convert the information into a percentage of hemoglobin saturation and a pulse rate. Some oximetry units display this information as a waveform in addition to the $SpO_{2\ \text{and}}$ pulse rate. The waveform can be invaluable in determining if the numeric values displayed are accurate. The waveform should look like a direct arterial pressure waveform (with discernable peaks and troughs) and the pulse rate should match the palpable heart rate before a $SpO_2$ reading is accepted.

Pulse oximetry provides an indirect, noninvasive estimate of the percent of arterial hemoglobin saturated with oxygen ($SpO_2$). From this value, the user can extrapolate and make inferences regarding the actual in vitro arterial hemoglobin saturation ($SaO_2$) and the patient's oxygenation status. Under normal circumstances, the $SaO_2$ is 95% or greater. With moderate desaturation, the $SaO_2$ may reach 90%. A $SaO_2$ less than 90% is indicative of severe desaturation can indicate inadequate oxygen content with resultant tissue hypoxia. As with any monitoring device, a complete understanding of the limitations of pulse oximetry is essential. Factors influencing accuracy of pulse oximetry include peripheral vasoconstriction, low pulse pressure, patient motion, skin pigmentation, edematous tissue, anemia and dyshemoglobinemias (carbon monoxide poisoning).

Although pulse oximetry is becoming standard for anesthetic monitoring, its use in monitoring the postoperative patient is often overlooked. Unfortunately, it is during the postoperative period that patients may be at increased risk for inadequate hemoglobin saturation and hypoxemia. These patients have recently been removed from high concentrations of oxygen period, these patients may remain influenced by muscle relaxants, sedatives and analgesics (particularly opioids) that can promote hypoventilation and resultant decreased SaO2. Pulmonary atelectasis secondary to prolonged surgical recumbency can also promote inadequate $SaO_2$. Postoperative thoracotomy patients may be at an increased risk for decreased $SaO_2$ secondary to pain (associated with the surgical approach and potentially chest tube) and the resultant hypoventilation. Pneumothorax must also be considered in any postoperative thoracotomy patient that has decreased $SaO_2$ unresponsive to oxygen supplementation.

## Capnography

Capnography refers to the measurement of carbon dioxide concentration in exhaled air. The primary indication for the measurement of end-tidal carbon dioxide partial pressure ($ETCO_2$) is to ESTIMATE the arterial carbon dioxide partial pressure ($PaCO_2$). Because capnography provides a continuous, noninvasive measurement of $ETCO_2$, it has been advocated as the single most important value to monitor an anesthetized patient's ventilatory status.

In general, the $ETCO_2$ is by the rate of $CO_2$ production, the rate of deliver of $CO_2$ from the tissues to the pulmonary vascular bed, the rate of $CO_2$ exchange between the blood and alveoli and the rate of $CO_2$ removal via alveolar ventilation status. Normal $ETCO_2$ values for awake, spontaneously breathing patients have been reported between 35 to 46 mm/Hg for dogs and 32 to 35 mm/Hg for cats. The generally accepted normal range of $ETCO_2$ for the anesthetized patient is 35 to 45 mm/Hg with hypoventilation occurring at >50 mm/Hg and hyperventilation occurring at <30 mm/Hg.

A capnograph is a graphic display of the changes in $ETCO_2$ during a single respiratory phase. It is generally displayed as a waveform visualized on the monitor screen. This waveform represents the continuous changes in $CO_2$ as detected by the infrared monitor placed within the patient circuit (at the end of the endotracheal tube for main stream monitors). By evaluating the waveform and understanding its implications/limitations, one can make critical judgments regarding a patient/s ventilatory status. Air within the trachea and bronchi (anatomic dead space) contains almost no $CO_2$ and is exhaled at the beginning of the expiratory phase. The $CO_2$ content of the expired air begins to rise sharply as more alveolar gas is exhaled until a plateau is reached. As inspiration begins, exhaled air is replaced by inhaled air and the $CO_2$ content drops to zero.

General anesthesia has several effects upon a patient's ventilatory status. Perhaps the most clinically important effect is the tendency towards hypoventilation that is noted with inhalant anesthetics and opioids. Inhalant anesthetics including halothane and isoflurane result in the depression of chemoreceptor sensitivity. Chemoreceptors are located in the brainstem, carotid and aortic bodies and monitor the $PaCO_2$, $PaO_2$ and hydrogen content of blood. If abnormalities are detected by these receptors, the brain's respiratory center is stimulated and the appropriate response (increase or decrease in minute ventilation) is evoked. Under general anesthesia, this response is delayed/suppressed and hypoventilation can result. Hypoventilation leads to the accumulation of carbon dioxide in the blood (hypercapnia) and resultant acidosis. This acidosis further suppresses the chemoreceptors and a "snow ball" effect may result. As noted above, opioids can also result in significant respiratory depression during the perioperative period. This hypoventilation can result despite an apparently normal respiratory pattern and rate.

"Permissive hypercapnia" is an occasional employed technique utilized with ventilator patients. This term refers to a state of controlled hypoventilation with resultant increase in ET $CO_2$ (and presumably a corresponding increase in $PaCO_2$). The elevated $ETCO_2$ /$PaCO_2$ may be beneficial in treating systemic hypotension as hypercapnia results in peripheral vasoconstriction secondary to increased sympathetic tone. Mild to moderate elevations in the partial pressure of arterial $CO_2$ can increase cerebral blood flow, which may be beneficial in cases of cerebral ischemia. Extreme caution should be utilized when the $ETCO_2$ becomes moderately to severely elevated as concurrent acidosis can result in metabolic derangement such as myocardial contractility depression and decreases oxygen carrying capacity of hemoglobin. A profound increase in intracranial pressure can occur.

In human medicine, $ETCO_2$ is presently being utilized for such clinical practices as verification of endotracheal tube replacement, assessment of conscious sedation safety, evaluation of mechanical ventilation and detection of hypoventilation during general anesthesia. Recently, the use of $ETCO_2$ in the emergency room during CPR has increased. Several human studies have correlated increased $ETCO_2$ to the return of spontaneous circulation. This is of obvious importance, as CPR need not be interrupted to determine if spontaneous circulation has been restored.