Topical Review

Blood Gas Analyzers

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Acid-base and respiratory disturbances are common in sick and hospitalized veterinary patients; therefore, blood gas analyzers have become integral diagnostic and monitoring tools. This article will discuss uses of blood gas analyzers, types of samples that can be used, sample collection methods, potential sources of error, and potential alternatives to blood gas analyzers and their limitations. It will also discuss the types of analyzers that are available, logistical considerations that should be taken into account when purchasing an analyzer, and the basic principles of how these analyzers work.

Introduction

Acid-base and respiratory disturbances are common in our sick and hospitalized veterinary patients. As veterinary medicine has advanced, identifying these disturbances via blood gas analysis has become an integral part of our diagnostic workup and aid in developing treatment plans. Blood gas analyzers can directly measure pH, partial pressure of oxygen (PO_2) and carbon dioxide (PCO_2), a variety of electrolytes, and various metabolites including glucose, lactate, blood urea nitrogen (BUN), and creatinine. Blood gas analysis can be run on either arterial or venous samples. Obtaining and interpreting blood gases is crucial in critically ill patients with dynamic disease processes such as sepsis, severe trauma, respiratory disease, and organ failure. The development of point-of-care analyzers has allowed blood gas analysis to be performed on site by primary care veterinarians, no longer requiring samples to be sent out to diagnostic laboratories or referral facilities, which could delay appropriate treatment. Immediate test results (analysis typically takes 1-5 minutes) allow for rapid interpretation, affording immediate implementation of targeted treatment plans, ultimately improving patient outcomes.[1,2]

This article will discuss uses of blood gas analyzers, samples that can be used, sample collection methods, sources of error, and the utility and limitations of potential alternatives to blood gas analyzers. It will also discuss the types of analyzers that are available, logistical considerations that should be taken into account when purchasing an analyzer, and the basic principles of how these analyzers work.

Uses of a Blood Gas Analyzer

Blood gas analysis can provide information that can directly affect the diagnosis and treatment of emergent and critically ill veterinary patients. Many of the acid-base, electrolyte and respiratory disorders that can be detected by blood gas analysis are associated with variable and subtle clinical signs. This makes direct evaluation of these disorders and the compensatory responses that arise from them all the more essential, and allows for a more in-depth, global evaluation of the critically ill patient. Metabolic alterations can lead to altered cardiovascular function, changes in the neurologic status of the patient, respiratory function, and even response to various drug therapies.

Assessment of the acid-base status in a patient with hypoperfusion allows for a better understanding of the pathophysiologic processes occurring in that patient, can guide fluid resuscitation, and affords objective evaluation of the response to fluid therapy. Identifying a patient with severe acidemia can help direct the diagnostic workup, as it provides discriminating information about the various disease processes that can cause an acidosis and aid in treatment planning, including whether infusion of alkalinizing therapy such as sodium bicarbonate is warranted.

Respiratory function, specifically the patient's ability to oxygenate and ventilate, can be evaluated from a blood gas. Although pulse oximetry can be used to detect hypoxemia, arterial blood gas analysis, specifically measurement of PaO_2, remains the gold standard. Physical examination findings in patients with hypoxemia can include cyanosis, but this is not present until hypoxia is severe making it an unreliable indicator of adequate oxygenation. Respiratory rate and effort can be difficult to interpret as they are affected by many other factors such as pain, excitement, fear, and metabolic derangements, and can be masked by sedation or anesthesia. Evaluation of the oxygenation status of a patient on an arterial sample can direct oxygen supplementation in cases of hypoxemia and can be used to monitor response to therapy with subsequent blood gases. Ventilation can be assessed by the PCO_2 on both venous and arterial gases. The ventilation status of the

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Table 1
Normal Values for Blood Gases[21,30]

	Arterial	Venous
Canine		
pH	7.35-7.45	7.35-7.45
PO_2 (mm Hg)	90-100	30-42
PCO_2 (mm Hg)	35-45	40-50
HCO_3 (mmol/L)	20-24	20-24
BE (mmol/L)	−4 to +4	−4 to +4
Feline		
pH	7.34 ± 0.1	7.30 ± 0.08
PO_2 (mm Hg)	102.9 ± 15	38.6 ± 11
PCO_2 (mm Hg)	33.6 ± 7	41.8 ± 9
HCO_3 (mmol/L)	17.5 ± 3	19.4 ± 4
BE (mmol/L)	−6.4 ± 5	−5.7 ± 5

patient via PCO_2 can document the presence of hyper/hypoventilation and can be used to monitor response to therapy to address ventilation disturbances. Additionally, electrolytes and metabolites can be evaluated and supplemented as needed. Many different facets of the patient's systemic status can be evaluated and addressed via blood gas analysis.

Acid-Base Analysis

Traditional acid-base analysis identifies 4 acid-base disturbances in either the respiratory or metabolic system including metabolic acidosis or alkalosis and respiratory acidosis or alkalosis. Reference ranges for arterial and venous blood gas parameters in the dog and cat are summarized in Table 1.

The first step in evaluating a blood gas is to determine if there is acidemia or alkalemia present by looking at the pH. If the pH is less than 7.35, acidemia is present. If the pH is above 7.45, alkalemia is present. The next step is to determine what process is causing the pH change, metabolic, or respiratory. It should be noted that patients can have multiple concurrent acid-base disorders that may lead to a normal or near normal pH; therefore, even if the pH is normal, the steps described below should still be completed when analyzing any blood gas.

Metabolic acidosis is the most common acid-base disturbance in dogs and cats.[3] It is characterized by a decrease in pH, bicarbonate (HCO_3), and base excess (BE), often in conjunction with a compensatory decrease in PCO_2. This disturbance can be caused by metabolic production of an endogenous acid (lactate or ketones), impaired urinary excretion of an endogenous acid (phosphates and sulfates), addition of an exogenous acid (ethylene glycol or salicylates), or a loss of HCO_3 from the kidneys or intestinal tract.[4] Metabolic alkalosis is characterized by an increase in pH, HCO_3, and BE often in conjunction with a compensatory increase in PCO_2. This disturbance is most commonly caused by a loss of chloride via vomiting or from the kidneys secondary to furosemide administration or by long-term administration of alkali such as sodium bicarbonate.[4]

Respiratory acidosis is characterized by a decrease in pH and increase in PCO_2 often in conjunction with a compensatory increase in HCO_3 and BE. A respiratory acidosis is generally the result of respiratory failure and hypoventilation. A PCO_2 measurement greater than 45 mm Hg is termed hypercapnea, and is indicative of hypoventilation. Causes of respiratory acidosis range from diseases that inhibit the respiratory center (increased intracranial pressure and brainstem lesions), ability to ventilate (cervical spinal cord disease/compression, neuromuscular junction dysfunction, and severe muscular weakness), airway obstruction, or abnormal gas exchange with severe pulmonary parenchymal disease.[5] Respiratory alkalosis is characterized by an increase in pH and decrease in PCO_2 often in conjunction with a compensatory decrease in HCO_3 and BE. A PCO_2 measurement of less than 35 mm Hg is termed hypocapnea and is indicative of hyperventilation. Causes of respiratory alkalosis include stress, pain, hypoxemia, pulmonary disease (pulmonary thromboembolism), or centrally mediated hyperventilation.[5]

These disturbances cause a change in the pH with a subsequent expected compensatory mechanism in the opposite system. Respiratory compensation occurs quickly and is completed within a few minutes whereas metabolic compensation has a longer onset and takes 2-5 days to complete.[6] It is important to point out that there would never be overcompensation of an acid-base disorder; the change in pH would signify the primary disturbance and if the amount of compensation is beyond what is expected, a mixed disorder (with more than 1 primary disturbance occurring simultaneously) may be present. The reader is referred elsewhere for a more in-depth approach in evaluating blood gas results and expected compensatory changes.[7-9]

Types of Blood Gas Samples

Blood gas analysis can be done on venous or arterial samples. Venous samples are easiest to obtain, either from direct venipuncture or from an intravenous catheter. They can be used to evaluate metabolic and electrolyte disturbances and give information about the ventilation status of the patient, but are not as useful in evaluating the oxygenation of the patient.[8] Blood gas values from venous samples can be affected by alterations in peripheral circulation and metabolism. Measured values on a venous blood gas can be reflective of the metabolic activity of the tissues distal to the site of sample collection, and thus can vary (see Sample Collection section); therefore, when available, central venous samples are preferred over peripheral venous samples, but in patients who are well perfused, a great deal of information can be obtained from a peripheral venous blood gas.

An arterial sample is least likely to lead to inaccuracies because of poor perfusion, but requires more advanced technical skills to obtain. Arterial samples are best used when trying to evaluate the oxygenation status of the patient in addition to metabolic, electrolyte, and ventilation disturbances. When evaluating blood gas results, it is important to know which type of sample has been obtained, as venous and arterial samples have different reference ranges. For example, venous PCO_2 is normally approximately 5 mm Hg higher than arterial PCO_2, and this should be taken into consideration when evaluating results (Table 1).

Sample Collection

Samples for venous blood gas analysis can be taken from the cephalic, saphenous, and jugular veins. Because variations in local tissue bed perfusion can affect samples taken from peripheral veins, more central sample sites, such as from sampling catheters placed in jugular veins, are generally preferred as they would give a better global picture of the acid-base status of the patient.[10] A venous sample may also be collected from an intravenous catheter already in place, with those collected from central catheters placed in the jugular or the lateral saphenous or femoral veins that extend into either the cranial or caudal vena cava the least susceptible to error. For arterial samples, the dorsal pedal or femoral arteries are the most common sites for arterial blood gas sampling, although the coccygeal and auricular arteries can also be used. If repeat sampling is required then an arterial catheter should be placed.[11] The site of sample collection, whether