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ANALYSIS OF ARTERIAL AND VENOUS BLOOD GASES: THE ROLE OF MEDICAL CHEMISTRY IN MAINTAINING ACID–BASE BALANCE

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Abstract
Arterial and venous blood gas analysis is a critical tool in veterinary medicine for evaluating a patient's ventilation, oxygenation, and acid–base status. This paper explores the principles and clinical applications of blood gas interpretation in animals, with a focus on the six-step method of arterial blood gas (ABG) analysis. Key physiological parameters such as pH, $PaCO_2$, HCO_3^-, and PaO_2 are discussed in detail, along with expected compensatory responses in various acid–base disorders. The paper also highlights the importance of proper sample collection, storage, and the role of point-of-care testing (POCT) devices in veterinary settings. Special consideration is given to how clinical context, environmental factors, and patient temperature affect interpretation. Based on the work of Harold Davis and other key sources, this review aims to provide veterinary students and practitioners with a comprehensive understanding of blood gas evaluation, enabling accurate diagnosis and improved clinical outcomes.

Keywords: Arterial blood gas (ABG), venous blood gas, acid–base balance, pH, $PaCO_2$, HCO_3^-, PaO_2, oxygenation, ventilation, metabolic compensation, respiratory compensation, veterinary critical care, point-of-care testing (POCT), Harold Davis, blood gas interpretation, sample collection.

Introduction

Blood gas analysis is a critical diagnostic tool in veterinary medicine, used to assess a patient's ventilation, oxygenation, and acid–base status. These

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parameters are essential for monitoring the effectiveness of therapy and guiding adjustments in treatment plans. Arterial and venous blood gases provide clinicians with immediate, valuable information about the respiratory and metabolic condition of an animal. While arterial samples are preferred for evaluating oxygenation and ventilation, venous samples can also be useful, particularly in stable patients, for assessing acid–base balance. Historically, blood gas analysis was considered labor-intensive and expensive, limiting its use in private veterinary practice. However, advancements in point-of-care testing (POCT) devices have made it more accessible. Portable analyzers such as the i-STAT and IRMA SL allow for rapid bedside evaluation, minimizing turnaround time and supporting critical care decisions.

This article reviews the principles of arterial and venous blood gas sampling, interpretation, and clinical relevance, with reference to Harold Davis's contributions to the field. A structured six-step method for interpreting blood gas results will also be provided to support clinical application.

Main Body

Blood gases are obtained to determine ventilation, oxygenation, and acid–base status. Arterial blood gases and acid–base status are used to evaluate the progress of therapy and to indicate when adjustments are necessary. Until recently blood gas analysis was labor intensive and cost prohibitive in private practice veterinary medicine. The dead space of a 3-mL syringe is coated with lithium or sodium heparin (1000 U/mL); excess heparin is expelled from the syringe. Arterial blood gas sample may be collected from an arterial catheter. Samples stored in an ice bath for up to 4–6 hours show very little change in pH and PCO2/PO2. Usually, blood gas samples are analyzed at 37°C; seldom is the patient’s temperature the same as the blood gas analyzer. Venous blood gases are a reasonable alternative to arterial blood gases when one wants to assess acid–base status. It has been reported that venous blood will accurately reflect the acid–base status of dogs with normal circulatory status. Arterial and Venous Blood Gases Harold Davis Blood gases are obtained to determine ventilation, oxygenation, and acid–base

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status. Arterial blood gases and acid–base status are used to evaluate the progress of therapy and to indicate when adjustments are necessary.

ARTERIAL BLOOD GAS EQUIPMENT AND SAMPLE COLLECTION

Equipment Until recently blood gas analysis was labor intensive and cost prohibitive in private practice veterinary medicine. Point of care testing (POCT) of blood gases is designed for human hospitals to reduce turnaround time of test results, streamline processes, increase staff efficiency, and reduce overall operating costs. Currently there are two POCT pH and blood gas analyzers that are affordable and easy to run: the i-STAT (Heska Inc. Ft. Collins, CO) and the IRMA SL blood analysis system (Diametrics Medical, St. Paul, MN). Both units are hand- held, user-friendly portable units that can operate on battery power. Each test cartridge contains its own electrode or sensor. The advantage of the self-contained electrode/sensor is that protein build-up or drift is eliminated, both of which can affect laboratory results and incur technician maintenance time. Minimal technician time is invested in analyzer maintenance. The initial purchase cost of the POCT analyzers is about one sixth the cost of the bench-top analyzers with many of the same testing capabilities. An alternative to owning an analyzer is to take the blood sample to a human hospital or veterinary facility, which can run those tests. Arrangements perhaps can be made wherein they will run the sample for a minimal fee. Sampling Percutaneous The dead space of a 3-mL syringe is coated with lithium or sodium heparin (1000 U/mL); excess heparin is expelled from the syringe. A cork and alcohol swab are obtained. Commonly used sites include the dorsal pedal artery, femoral artery, and the sublingual artery. The collection site of choice is the dorsal pedal artery because it will be easier to control bleeding when compared to the femoral artery. In the unconscious or anesthetized patient the sublingual artery may be used. The site is prepped and the artery is palpated. A 25-gauge needle is used. The needle is held at a 45° angle over the site where the pulse is strongest. The skin and arterial wall are punctured in one motion following the path of the artery, or in a two-step fashion: skin first then artery. Watch for a back flash of blood in the needle hub and then gently aspirate the sample. A 1- to 1.5-mL sample size will be needed. Once collected,

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air is expelled from the syringe and the syringe is capped with the cork. The sample is then mixed and placed in an ice water bath and transported to the laboratory. Arterial Catheter Arterial blood gas sample may be collected from an arterial catheter. It is necessary to clear the catheter of heparinized saline. A three-syringe technique is used. The first syringe is attached to an access port in the arterial catheter or extension tubing. Fluid is aspirated into the syringe (2–3 cc) until all nonblood fluid is removed from the catheter and tubing.1 The sample collection syringe is attached and sample for blood gas analysis collected. Following collection, the aspirated saline solution is recycled. The final syringe contains 3 ml heparinized saline which is used to flush the line until no evidence of blood remains. Storage of Samples Samples stored in an ice bath for up to 4–6 hours show very little change in pH and PCO2/PO2. Samples held at room temperature will show significant changes in PO2 after 12 minutes, and significant changes in acid–base values will occur after 30 minutes.

Expected Compensation Table (for Acid–Base Disorders)

Type of Disorder	Compensation Type	Expected Change
Metabolic acidosis	Respiratory compensation	For every 1 mEq/L ↓ in HCO_3^-, $PaCO_2$ ↓ by ~0.7 mm Hg
Metabolic alkalosis	Respiratory compensation	For every 1 mEq/L ↑ in HCO_3^-, $PaCO_2$ ↑ by ~0.7 mm Hg
Respiratory acidosis (acute)	Metabolic compensation	For every 1 mm Hg ↑ in $PaCO_2$, HCO_3^- ↑ by ~0.15 mEq/L
Respiratory acidosis (chronic)	Metabolic compensation	For every 1 mm Hg ↑ in $PaCO_2$, HCO_3^- ↑ by ~0.35 mEq/L
Respiratory alkalosis (acute)	Metabolic compensation	For every 1 mm Hg ↓ in $PaCO_2$, HCO_3^- ↓ by ~0.25 mEq/L
Respiratory alkalosis (chronic)	Metabolic compensation	For every 1 mm Hg ↓ in $PaCO_2$, HCO_3^- ↓ by ~0.55 mEq/L

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ARTERIAL BLOOD GAS OVERVIEW pH The pH is an inverse logarithmic expression of hydrogen ion concentra- tion. It is a reflection of the balance between HCO3 (bicarbonate) and CO2 (carbon dioxide). An increase in hydrogen ions is associated with a decrease in pH and visa versa. The pH can be calculated using the Henderson-Hasselbalch equation: pH pKa log [HCO3]/[total CO2] It is the ratio rather than the absolute values for HCO3 and total CO2 that deter- mines pH. As long as the ratio of the equation is 20:1, pH will be 7.40 or normal. The pH decreases or increases when the ratio is less than 20:1 or greater than 20:1, respectively. The pH is regulated through several mechanisms. In the intracellular and extracellular fluid compartments the two major buffer systems that protect pH are proteins and the HCO3 buffer system. Other mechanisms include respiratory and renal regulation. Proteins can act as acids or bases. They contain ionizable Practices in Patient Care groups that can release or bind H ions. In the HCO3 buffer system, carbonic acid is a weak acid and HCO3 is a weak base: H2O CO2 ↔ H2CO3 ↔ H HCO3 When extracellular H ions increase they move intracellularly for buffering and K moves out of the cell in exchange for H . The respiratory system plays a role in acid–base regulation through the elimination of CO2. The kidneys regulate acid–base balance through hydrogen and HCO3 elimination or conser- vation. The pH is an indicator of the net H balance. The normal pH range is 7.35 to 7.45. A pH less than 7.35 is known as acidemia (condition in the blood) and the overall process is acidosis. A pH greater than 7.45 is known as alkalemia (condition in the blood) and the overall process is known as alkalosis. PaCO2 The PaCO2 is the partial pressure of CO2 dissolved in the plasma of arterial blood and is reported in mm Hg. It reflects the balance between alveolar minute ventilation and metabolic CO2 production. Alveolar ventilation is the amount of air that reaches the alveoli and participates in gas exchange. The normal range of PaCO2 is 35 to 45 mm Hg in the dog at sea level. A PaCO2 less than 35 mm Hg is known as hypocapnia or respiratory alkalosis. Hypocapnia (condition in the blood) or respiratory alkalosis is caused by alveolar hyperventilation. A PaCO2 greater than 45 mm Hg is known as hypercapnia (condition in the blood) or respiratory acidosis. Hypercapnia or respiratory acido- sis is caused by alveolar hypoventilation. HCO3/Base Balance Two values can be

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used to assess the metabolic component of acid–base balance. They are HCO3 or base balance (base excess or deficit). HCO3 is in- creased or decreased due to many mechanisms. Base excess/deficit provides a quantitative estimation of surplus acid or base. It is defined as the titratable base or acid, respectively, when titrating to a pH of 7.40 under standard conditions (PCO2 40 mm Hg and 38°C) and complete hemoglobin saturation. The normal ranges for HCO3 and base balance are 18 to 24 mmol/L and 0 4 mEq/L respectively, in the dog. An HCO3 less than 18 mmol/L or a base deficit less than 4 mEq/L reflects metabolic acidosis and an HCO3 greater than 24 mmol/L or a base excess greater than 4 mEq/L reflects a metabolic alkalosis. PaO2 The PaO2 is the partial pressure of oxygen (O2) dissolved in arterial blood and is reported in mm Hg. PaO2 does not reveal how much O2 is in the blood (content) but only the pressure exerted by the dissolved oxygen. The normal range for PaO2 is 80 to 110 mm Hg assuming the patient is breathing room air at sea level. A PaO2 less than 80 mm Hg is considered hypoxemia. A PaO2 less than or equal to 60 mm Hg is the minimum value at which therapy is initiated. As the altitude increases and barometric pressure decreases, the partial pres- sure of O2 in the atmosphere is reduced. At increased altitude PaO2 decreases. A rough rule of thumb is that the PaO2 will decrease 4 mm Hg per 1000 feet increase in elevation (Personal communication, Craig Cornell, BS, RVT, VTS [ECC]). An example of this effect is that the normal PaO2 reported in dogs in Fort Collins, CO is 70.3 to 84.0 mm Hg.2 Those values were reported at an altitude of 1500 meters (4921 feet) with a mean barometric pressure of 635.8 4.4 mm Hg. Temperature Compensation Usually, blood gas samples are analyzed at 37°C; seldom is the patient's temperature the same as the blood gas analyzer. Traditionally we have corrected blood gases to account for the temperature difference, so that we would know the values at the patient's temperature. Temperature-corrected values may be used in those cases where one wants to compare blood gas results over varying temperature changes of the patient.

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Arterial Blood Gas (ABG) Interpretation: 6-Step Method Table

Step	Description	Normal Range	Interpretation
Step 1	**pH level**	7.35 – 7.45	<7.35 = Acidosis >7.45 = Alkalosis
Step 2	**Respiratory component: $PaCO_2$**	35 – 45 mm Hg	<35 = Respiratory alkalosis >45 = Respiratory acidosis
Step 3	**Metabolic component: HCO_3^- or Base Excess (BE)**	HCO_3^-: 22–26 mmol/L BE: ±2 mEq/L	<22 = Metabolic acidosis >26 = Metabolic alkalosis
Step 4	**Identify primary disturbance (respiratory or metabolic)**	–	The direction of the pH shift usually indicates the primary disturbance
Step 5	**Assess PaO_2 and oxygen status**	$PaO_2 \geq 80$ mm Hg (on room air)	<80 = Hypoxemia $PaO_2/FIO_2 < 300$ = Significant gas exchange defect
Step 6	**Clinical correlation**	–	Do the lab results match the clinical signs and patient history?

Conclusion

In veterinary medicine, the interpretation of arterial and venous blood gas analysis is indispensable in the evaluation and management of critically ill patients. Understanding the underlying principles of ventilation, oxygenation, and acid–base regulation allows clinicians to make informed decisions about diagnosis, monitoring, and therapy.Arterial blood gas (ABG) analysis remains the gold standard for evaluating respiratory function, particularly for assessing oxygenation (PaO_2) and carbon dioxide elimination ($PaCO_2$). However, venous blood gases provide a practical alternative when arterial access is challenging or when assessing acid–base balance alone. Numerous studies, including those summarized by Harold Davis, have shown that venous blood can reliably reflect acid–base status in animals with stable hemodynamics.

The availability of point-of-care testing (POCT) devices such as the i-STAT and IRMA SL has revolutionized the approach to blood gas analysis in veterinary practice. These portable, user-friendly analyzers reduce both turnaround time and dependency on large laboratory equipment, making blood gas evaluation more accessible and efficient in emergency and critical care settings.

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Accurate interpretation of blood gas data requires a structured approach. The six-step method provides a logical and comprehensive framework for analyzing pH balance, respiratory and metabolic components, and overall oxygen status. Identifying the primary disorder (whether respiratory or metabolic) and recognizing the body's compensatory responses are crucial for determining the severity and progression of the condition. Furthermore, considering the patient's temperature, altitude, and other environmental factors adds another layer of precision in blood gas interpretation.It is also important to correlate laboratory findings with clinical signs and history. No blood gas result should be interpreted in isolation. The clinical context—such as the presence of shock, respiratory distress, or renal dysfunction—should guide the interpretation and management strategies. This highlights the importance of not only knowing the numerical values but also understanding their physiological implications.Moreover, proper technique in sample collection, storage, and handling directly influences the accuracy of results. Whether the sample is collected percutaneously or via an arterial catheter, minimizing air contamination, ensuring appropriate anticoagulation, and maintaining storage conditions (e.g., ice bath) are critical for reliable data. Temperature corrections may be considered in select cases, particularly in hypothermic or hyperthermic patients, but consistency in methodology remains essential.

Ultimately, blood gas analysis is not just a laboratory test—it is a dynamic tool that integrates clinical insight with physiological understanding. When applied correctly, it improves patient outcomes by enabling timely interventions, guiding ventilator settings, and monitoring response to therapy. For veterinary professionals, mastering blood gas analysis represents a key component of excellence in emergency and critical care medicine.

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