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Interpretation of Blood Gas and Acid-Base Data

Julia H. Riley, BVSc, MS*

Before discussing clinical cases we would like to present a brief recent history of developments in the area of acid-base and blood gas analysis so some appreciation of the efforts of those who have worked to simplify measurement techniques and clarify clinical evaluation procedures may be justly given. We would also like to illustrate with the aid of two clinical cases the importance of proper interpretation of acid-base and blood gas data.

In 1908 Henderson applied physico-chemical principles to estimation of the hydrogen ion concentration in physiologic fluids. He stated that

\[ [H] = K \cdot \frac{[\text{acid}]}{[\text{base}]} \]

In this equation he laid down the foundation for the relationship between an excess of acid or base in the blood and an increase or decrease in the hydrogen ion concentration.

Hasselbalch modified the original equation by converting it to logarithmic terms.

\[ \text{pH} = \text{pK} + \log \frac{[\text{acid}]}{[\text{base}]} \]

Hasselbalch was the first to measure blood pH in 1910.¹

The principles and measurement of acid-base and blood gas phenomena have been nurtured and refined over the past fifty years.

The first measurements of acid-base and blood gas parameters were performed on clinical patients in the early 1950's. This significant step contributed to the survival of numerous patients whose treatment (life) had previously depended on mere guesswork on the part of the clinician.

Fortuitously for veterinarians and dogs, in particular, most of the research in the area of acid-base balance and blood gas analysis has revolved around the canine species. Prediction equations for this species are applied to humans.

When dealing with pathological disturbances we often tend to forget two very basic facts of life for terrestrial species. The first is that multicellular species are faced with the minute-by-minute defense of their acid-base balance against acid loads of metabolism. The second is that normal osmolality must be maintained in a dessicating environment. We see homeostasis of acid-base balance and osmolality as two of an animal's three most urgent needs: the third being availability of oxygen.

The cause of death in all animals is due to failure of the regulatory mechanisms in one or more of the above systems. For example, in diabetes mellitus, death ensues because of the acidosis and hyperosmolality that are the result of insulin deficiency. Furthermore, in the treatment of this disease, the activity of insulin is severely compromised by the acidosis.

Acid-base and blood gas values are normally confined within narrow, stable limits. Mechanisms controlling these values are finely tuned. As compared to blood glucose, which in a dog may vary between 50 mg/dl and 200 mg/dl without much of a deleterious effect on the animal, even a twofold change in \([\text{HCO}_3^-]\) is extremely serious.

Case 1

The following values were taken half an hour before death and prior to the administration of bicarbonate to a dog undergoing surgery for correction of patent ductus arteriosus.

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Iowa State Veterinarian
The first step in evaluation of data is to decide if the data is real or if some error has lead to misfitting data. Check can be made of blood gas data using the following formula:

\[ [H^+] = 24 \times \frac{pCO_2}{[HCO_3^-]} \]

\[ [H^+] = \frac{24 \times 815}{26.5} \]

74.47* = 73.8 nmoles/1

We find 74.47 approximately equals 73.8 nmoles/1 and so no gross errors have been made in sampling or measurement.

The next steps in evaluation should be an orderly inspection of the values.

pH — A pH of 7.128 is a severe acidosis but does not reveal the cause of the acidosis. A pH value is of no use to the clinician in formulating treatment because it does not show whether the condition is metabolic or respiratory, whether there is any compensation, nor does it help in identification of whether the condition is acute or chronic.

pO₂ — A low value is reflected for O₂ dissolved in the plasma so we may conclude that the animal is hypoxic. The degree of hypoxia is not a mere reflection of this absolute value. Rather, it depends on the body temperature, pH, 2,3 DPG concentration, and the position of the oxygen dissociation curve. Low body temperatures reduce dissociation between O₂ and Hb; high body temperatures act conversely. A low pH (acidosis) causes problems because the degree of saturation of Hb is decreased; high pH causes Hb to be saturated at a much lower partial pressure of oxygen — a problem can be caused at the tissues because the gradient for O₂ is not steep enough to allow O₂ to leave the blood for the tissues. Consequently, the tissues have to be abnormally low in O₂ before there is any delivery of O₂ from the blood. Due to the low pH in this instance and the low pO₂, the degree of saturation was 81.2%. As this condition progresses hypoxia will lead to anaerobic metabolism and a late metabolic acidosis will be superimposed on the primary respiratory acidosis.

The conditions mentioned above are responsible for shifting the oxygen dissociation curve to the left or right of its normal position. They are detected when a \( P_{50} \) value is calculated.

pCO₂ — Severe hypercarbia is present. The severity of the hypercarbia makes it a primary condition. Circumstances are such that voluntary lowering of the ventilation to the extent seen here would produce fatal hypoxia and CO₂ narcosis. A prediction equation allows us to verify this premise.

\[ \Delta [H^+] = 0.8 \Delta pCO_2 \]

34.47 = 0.8 × 41.5

34.47 = 33.2

[HCO₃⁻] — The bicarbonate concentration lies slightly above the normal range. The reason for the increase is due to a shift of the carbonic acid equilibrium to the right. Such a shift normally occurs to the extent of 3-4 mEq/1 with respiratory acidosis due to CO₂ + H₂O → H⁺ + HCO₃⁻.

TCO₂ — The total CO₂ will mostly lead the [HCO₃⁻] by a small amount, as under nearly all circumstances the CO₂ is derived from the [HCO₃⁻]. (Total CO₂ includes all forms of CO₂ in the blood.)

BE — This value shows the amount of titratable acidity present in the blood. Because it was an experimentally derived value, it is directly applied to correction of a metabolic disturbance therapeutically. In this case the disturbance is entirely respiratory and would not respond to correction by NaHCO₃ therapy.

Hb — Severe anemia is present.

Osmolality — The dog is hyperosmolar but the reason for its hyperosmolality was not determined because of lack of data. The serum Na⁺, glucose, and BUN all must be known before pathogenesis can be determined. Treatment for the acid-base disorder would be worked out on the basis of dealing with a concurrent hyperosmolality disorder.

*95% confidence.
Cl⁻—A hypochloremia² is present. Since the bicarbonate is normal, an unmeasured anion could account for the measured value. (Body fluids are kept close to neutral pH so when a loss of an anion such as chloride occurs there must be a corresponding increase in another anion.) On the other hand an unmeasured osmole could also account for the low chloride.

Pathologists' Diagnosis—Acute uncompensated respiratory acidosis with concurrent hypochloremia, hyperosmolality, and anemia.

Therapy—The dog was given bicarbonate.

Result of Treatment—Ventricular fibrillation occurred after therapy and the dog died.

Reason for Treatment Failure—The dog's problem was not one of metabolic acidosis but was one of severe respiratory acidosis. The rapid infusion of bicarbonate led to a fatal cardiac arrhythmia.⁶

Correct Treatment—The treatment this animal should have received was hyperventilation to blow off the CO₂ and raise the oxygen, followed by a transfusion and supplemental laboratory data to determine the causes of hypochloridemia and hyperosmolality.

Case 2

Blood gas samples were taken from a dog that had undergone concurrent surgery for a diaphragmatic hernia and caesarian section. Samples were taken at the termination of anesthesia. The surgeon suspected the dog was not recovering due to blood loss and ordered 500 ml of blood to be given.

Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.867</td>
</tr>
<tr>
<td>pO₂</td>
<td>528.3</td>
</tr>
<tr>
<td>pCO₂</td>
<td>29.9</td>
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<tr>
<td>[HCO₃⁻]</td>
<td>5.2</td>
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<tr>
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<tr>
<td>BE</td>
<td>-29.4</td>
</tr>
<tr>
<td>Hb</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Evaluation

A check of the data shows there has been no serious sampling or measurement errors.

\[ [H^+] = \frac{24 \times pCO₂}{HCO₃⁻} \]

135.85 ≈ 158

pH—Severe acidosis is present. The limits of life are defined by pH 7.00 and pH 7.7.¹⁹

pO₂—Positive pressure ventilation during surgery has caused this hyperoxia.

pCO₂—Ventilation with 100% oxygen is responsible for the washout effect on pCO₂ and resultant hypocarbia. A decreased pCO₂ is seen when compensation for a metabolic acidosis is present but this was not the case here: the animal's ventilation was controlled by the anesthesiologist. We must conclude that the respiratory alkalosis was iatrogenic.

[HCO₃⁻]—A very severe deficit exists indicating a severe metabolic acidosis is present.

BE—A deficit in fixed base or an excess of hydrogen ions to the tune of 29.4 mmole/1 of bicarbonate space is present.

Pathologist's Diagnosis—Hyperoxia, severe metabolic acidosis, respiratory alkalosis, anemia.

Treatment—The dog was given 500 ml of blood post-surgically.

Result of Treatment—The dog was removed from the assisted ventilation and died 15 minutes postsurgically.

Reason for Treatment Failure—This dog had no reason to want to breathe; its pCO₂ was below normal range; its pO₂ was well above normal arterial oxygen. Infusion of blood would add to the metabolic acidosis already present and may have overloaded the circulatory system which was already depressed due to the effect of acidosis on the myocardium.⁸,¹¹

Conclusion

The correct functioning of cellular metabolism depends on the acid-base balance of the animal. Partition and distribution of drugs used is dependent on the acid-base balance of the animal. The cases illustrated above show the result of misinterpretation of acid-base data. Neither of the cases is presented as typical for that particular set of circumstances—it is not possible to guess at the acid-base values an animal may have present.
The VCII Women's 3-player intramural volleyball team placed first in class A competition during winter quarter.

The VMII men's basketball team finished the recent intramural season with a record of 7-1.