Acid Base and Blood Gas Analysis

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Blood gas analysis is frequently carried out in emergency and critical care patients. From a venous or arterial blood sample we can gain information about the patient’s oxygenation status, ventilation and acid base. These tests are becoming more popular as hand held point of care units are available on the veterinary market.

Acid base is a part of homeostasis that manages the balance between acids and bases which depict our pH. In simple terms acidity or alkalinity is the number of C02 or H+ ions that are present in the blood. A high number leads to an acidaemia and a low number leads to an alkalaemia. The body produces C02 and H+ ions all the time as a result of metabolism of fats, carbohydrates, proteins and phospholipids. C02 is excreted via the lungs and H+ is excreted via the kidneys. Both C02 and H+ are acids (C02 binds with water to make carbonic acid), therefore an increase in either of these will lead to a decrease in pH.

Maintenance of pH within a strict range is essential for cells and enzymes to function. Outside of this tight range enzymes and proteins become denatured. The body's pH is usually kept between 7.35 and 7.45 by a system of buffers. These buffers bind with hydrogen ions and prevent the pH from changing. Bicarbonate, haemoglobin and plasma proteins are common buffers. The buffer system is represented by this equation showing its constant interaction:

\[ H_2O + CO_2 \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \]

If something changes on one side of the equation then it must change on the opposite direction on the other side of the equation to maintain this equilibrium.

Indications

Blood gas analysis can be useful in the early identification of some diagnoses, for monitoring response to therapy and prompting specific treatment.

Arterial samples can be very useful in assessing a patient’s oxygenation and ventilation status. This technique does require more skill that a venous sample and it may be difficult to get a sample in a patient in respiratory distress. The sample is usually take from the dorsal-pedal artery but can be taken from the femoral artery, tail artery or lingual artery in anaesthetised patients.
Normal Ranges

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Dog</th>
<th>Cat</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.35 – 7.46</td>
<td>7.31 – 7.46</td>
</tr>
<tr>
<td>PC02 (mmHg)</td>
<td>31 – 43</td>
<td>25 – 37</td>
</tr>
<tr>
<td>HC03- (mEq/L)</td>
<td>18 – 26</td>
<td>14 – 22</td>
</tr>
<tr>
<td>Base Excess (BE)</td>
<td>+2 - -2</td>
<td>+2 - -2</td>
</tr>
</tbody>
</table>

Step By step Approach to Acid Base Analysis

First assess the pH

- Is it normal?
  - Is it high? >7.45 Alkalaemia
  - Is it low? <7.35 Acidaemia

Second assess the CO2

- Is it normal?
  - Is it high? >43D 37C Respiratory Acidosis
  - Is it low? <31D 25C Respiratory alkalosis
There are 4 types of disturbance that can be seen…

Respiratory Acidosis

This is the second most common disturbance that we see. It is characterised by:

- pH decreases
- PC02 increases

Common causes include:

- Hypoventilation
  - URT obstruction
  - Respiratory disease, depression, fatigue
  - CNS disease, C4-5 lesion
  - Drugs
  - Inadequate mechanical ventilation

Treatment relies upon managing the underlying problem.

Respiratory Alkalosis

This is the least common disturbance seen and it is characterised by:

- pH increases
- PC02 decreases

Common causes include:
• Hyperventilation
  o Hypoxaemia – severe
  o Hyperthermia
  o Pain, fear, stress
  o Exercise
  o Excessive mechanical ventilation

Metabolic Acidosis
This is the most common disturbance seen and it is characterised by:

• pH decreases
• HC03- decreases
• BE negative

Common causes can include:

• Increased acid production
  o DKA, lactic acidosis, uraemic acidosis, toxins – EG,

• Increased alkaline loss
  o Diarrhoea, renal disease, drugs

Treatment for this disturbance requires management of the underlying disease but in severe cases where the ph <7.1 the sodium bicarbonate administration may be considered.

Metabolic alkalosis
This is the third most common disturbance which is characterised by:

• pH increases
• HC03- increases
• BE Positive

Common causes include:

• Vomiting (loss of chloride rich fluid)
• Diuretic therapy
• Cushings
• Refeeding syndrome
Compensation

As discussed earlier the body has a buffering system that tries to maintain a normal pH despite disturbances with acid base. With metabolic disturbances the respiratory system tries to compensate by altering ventilation. This can occur very rapidly over a matter of minutes. With a respiratory disturbance the kidneys try to compensate by altering the amount of acid excreted. This occurs much more gradually over a matter of days.

Mixed disorders

You can get a patient with 2 acid base disorders at the same time such as:

- A patient in septic shock with aspiration pneumonia
  - Respiratory alkalosis – increase in ventilation to maximise oxygenation
  - Metabolic acidosis – lactic acidosis

The disorder that came first will be indicated by the pH

So which disturbance is present in the following examples:

<table>
<thead>
<tr>
<th>Patient</th>
<th>pH</th>
<th>PC02</th>
<th>HC03</th>
<th>BE</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOAS Bulldog</td>
<td>7.063</td>
<td>106.7</td>
<td>28.4</td>
<td>-4</td>
<td>Respiratory Acidosis</td>
</tr>
<tr>
<td>Vomiting terrier</td>
<td>7.490</td>
<td>37.0</td>
<td>34.8</td>
<td>10.2</td>
<td>Metabolic Alkalosis</td>
</tr>
<tr>
<td>Cardiac arrest Bichon</td>
<td>6.920</td>
<td>66.5</td>
<td>12.6</td>
<td>-21.3</td>
<td>Respiratory and Metabolic Acidosis</td>
</tr>
<tr>
<td>EG toxicity DSH</td>
<td>7.14</td>
<td>21.1</td>
<td>7.0</td>
<td>-19.9</td>
<td>Metabolic acidosis and respiratory alkalosis</td>
</tr>
</tbody>
</table>

Answers…
Arterial Blood Gas Analysis

This is the most definitive method for assessing lung function – oxygenation and ventilation. By taking an arterial sample we can measure the patient’s Pa02 and PaC02. Pa02 is the partial pressure of oxygen in the artery. The majority of oxygen is carried in the blood as oxyhaemoglobin. Once we have our values we can then use some simple equations to assess how well the patient is oxygenating.

Normal Pa02 on room air is 80 – 105mHg. Less than 80 mmHg is hypoxaemia and less than 60mmHg is sever hypoxaemia.

We can convert the oxygen inspired into a number. This is the Fi02 (fractional inspired oxygen) Room air is 21 % so we say it has an Fi02 of 0.21. Pa02 is 5 x Fi02. Therefore if our patient is being administered 100% and the sample is taken then we can expect the Pa02 to be up to 500mmHg.

Causes for hypoxaemia include:

1. Reduced Fi02
2. VQ mismatch (the most common)
3. Shunting
4. Diffusion impairment

PaC02 and hypercapnia

The rate of elimination of C02 directly influences arterial partial pressure. The production of C02 is most closely related to venous partial pressure. With normal ventilation we should maintain a normal C02 level of roughly 30 – 45 mmHg. More than 55mmHg is hypercapnia and less than 20mmHg is hypocapnia.

Common causes of hypercapnia and hypoventilation include:

- CNS disease
- C4-5 lesion
- Chest wall injury
- Fatigue
- Airway obstruction
- Pickwickian syndrome!!!

Common causes of hypocapnia and hyperventilation include:

- Hypoxaemia – severe
- Hyperthermia
- Pain, fear, stress
Exercise
Excessive mechanical ventilation

Equations to assess oxygenation and ventilation

Alveolar – arterial gradient (A-a gradient)

This is the measure of the difference in oxygen concentration between the alveoli and the artery. It is used to diagnose the source of hypoxaemia. This equation can help us to determine whether there is any problems with how the lungs transfer oxygen to the blood and how severe these problems may be. This equation should be used for blood gas results taken when the patient is on room air. You cannot use this sum if the patient is receiving oxygen therapy at the time of sampling.

\[
150 - (1.2 \times pC02) = PA02
\]

\[
PA02 - Pa02 = A-a \text{ gradient}
\]

Pa02:Fi02 Ratio (on 02)

This equation should be used instead of the A-a gradient if the sample was taken whilst the patient was receiving oxygen. You simply divide the Pa02 by the Fi02. For example a patient receiving 50 % 02 would have an Fi02 of 0.5

<table>
<thead>
<tr>
<th>Range</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;400</td>
<td>Normal</td>
</tr>
<tr>
<td>200 – 300</td>
<td>Lung injury</td>
</tr>
<tr>
<td>&lt;200</td>
<td>ARDS</td>
</tr>
</tbody>
</table>

Have a go at assessing the following blood gas samples:

Collie
Multifocal CNS disease
On a ventilator with 100% 02
Pa02: Fi02 = 273
Acute lung Injury
Respiratory centre depression and non-cardiogenic pulmonary oedema
Greyhound
? Toxin ingestion – develops respiratory distress
Room air
Pa02: FiO2 = 166
ARDS/ALI
A-a Gradient = 82 Severe

DSH
PPDH
Under anaesthesia – 100% O2
Pa02: FiO2 = 501
Normal 😊

Springer Sp
Nephrectomy
Under anaesthesia – 50% O2
Pa02: FiO2 = 368
Almost normal – mild decrease

Cocker sp
Lower motor neuron disease
Ascending paralysis
Room air
Pa02: FiO2 = 285 ALI
A-a = 50 severe