Arterial Blood Gas Analysis and Acid-Base Balance Disorders

Arterial Blood gas analysis (ABG), is a test that measures the amount of oxygen (O2) and carbon dioxide (CO2) in the blood, as well as the acidity (pH) of the blood.

It is an essential part of diagnosing and managing a patient's oxygenation status and acid-base balance. The usefulness of this diagnostic tool is dependent on being able to correctly interpret the results.

Purpose of Arterial Blood Gas Analysis

1. Evaluates how effectively the lungs are delivering oxygen to the blood and how efficiently they are eliminating carbon dioxide from it.
2. It indicates how well the lungs and kidneys are interacting to maintain normal blood pH (acid-base balance).
3. To assess respiratory disease and other conditions that may affect the lungs, and to manage patients receiving oxygen therapy (respiratory therapy.
4. To determine the pH of the blood and the partial pressures of carbon dioxide (PaCO2) and oxygen (PaO2) within it.
5. To assess the effectiveness of gaseous exchange and ventilation, be it spontaneous or mechanical.
6. It allows patients' metabolic status to be assessed, giving an indication of how they are coping with their illness.

If the pH becomes deranged, normal cell metabolism is affected.

For you to understand Arterial Blood Gas analysis you will need to have knowledge about the acid-base balance, buffer systems and acid-base balance disorders which we shall look at briefly before we proceed.

Overview of Acid-Base Balance and Its Disorders

The pH is a measurement of the acidity or alkalinity of the blood.
The more H+ present, the lower the pH will be, the fewer H+ present, the higher the pH will be.

The pH of a solution is measured on a scale from 1 (very acidic) to 14 (very alkalotic).

A liquid with a pH of 7, such as water, is neutral (neither acidic nor alkalotic).

The normal blood pH range is 7.35 to 7.45.
In order for normal metabolism to take place, the body must maintain this narrow range at all times.

When the pH is below 7.35, the blood is said to be **acidic**.

Changes in body system functions that occur in an acidic state include:

- A decrease in the force of cardiac contractions,
- A decrease in the vascular response to catecholamines,
- A diminished response to the effects and actions of certain medications

When the pH is above 7.45, the blood is said to be **alkalotic**.

An alkalotic state interferes with tissue oxygenation and normal neurological and muscular functioning.

Significant changes in the blood pH above 7.8 or below 6.8 will interfere with cellular functioning, and if uncorrected, will lead to death.

The body self-regulate acid-base balance in order to maintain pH within the normal range through the use of delicate buffer mechanisms between the respiratory and renal systems.

The Respiratory Buffer Response

A normal by-product of cellular metabolism is carbon dioxide (CO2). CO2 is carried in the blood to the lungs, where excess CO2 combines with water (H2O) to form carbonic acid (H2CO3).

The blood pH will change according to the level of carbonic acid present

The carbonic acid present triggers the lungs to either increase or decreases the rate and depth of ventilation until the appropriate amount of CO2 has been re-established.

Activation of the lungs to compensate for an imbalance starts to occur within 1 to 3 minutes.

The Renal Buffer Response

In an effort to maintain the pH of the blood within its normal range, the kidneys excrete or retain bicarbonate (HCO3-).

As the blood pH decreases, the kidneys will compensate by retaining HCO3 - and as the pH rises, the kidneys excrete HCO3 - through the urine

Although the kidneys provide an excellent means of regulating acid-base balance, the system may take from hours to days to correct the imbalance.

When the respiratory system and renal systems are working together, they are able to keep the blood pH balanced by maintaining 1 part acid to 20 parts

Acid-Base Disorders

Respiratory Acidosis:

It is defined as a pH less than 7.35 with a PaCO2 greater than 45 mm Hg.

Acidosis is caused by an accumulation of CO2 which combines with water in the body to produce

carbonic acid, thus, lowering the pH of the blood

Causes of respiratory acidosis

Any condition that results in hypoventilation can cause respiratory acidosis. These conditions include:

- Central nervous system depression related to head injury
- Central nervous system depression related to medications such as narcotics, sedatives, or anesthesia
- Impaired respiratory muscle function related to spinal cord injury, neuromuscular diseases, or neuromuscular blocking drugs
- Pulmonary disorders such as atelectasis, pneumonia, pneumothorax, pulmonary edema, or bronchial obstruction.
- Massive pulmonary embolus.
- Hypoventilation due to pain, chest wall injury/deformity, or abdominal distension

The signs and symptoms of respiratory acidosis

Pulmonary symptoms include dyspnea, respiratory distress, and/or shallow respirations.

Nervous system manifestations include headache, restlessness, and confusion.

If CO2 levels become extremely high, drowsiness and unresponsiveness may be noted.

Cardiovascular symptoms include tachycardia and dysrhythmias.

Increasing ventilation will correct respiratory acidosis.

The method for achieving this will vary with the cause of hypoventilation.

Causes that can be treated rapidly include pain pneumothorax and CNS depression related to medications. If the cause cannot be readily resolved, the patient may require mechanical ventilation while treatment is rendered.

Although patients with hypoventilation often require supplemental oxygen, it is important to remember that oxygen alone will not correct the problem

Respiratory Alkalosis

Respiratory alkalosis is defined as a pH greater than 7.45 with a PaCO2 less than 35 mm Hg.

Causes of respiratory acidosis

Any condition that causes hyperventilation can result in respiratory alkalosis.

These conditions include:

- Psychological responses, such as anxiety or fear.
- Pain
- Increased metabolic demands, such as fever, sepsis, pregnancy, or thyrotoxicosis.
- Medications, such as respiratory stimulants.
- Central nervous system lesions

Signs and symptoms of respiratory alkalosis

Nervous system alterations include light-headedness, numbness and tingling, confusion, inability to concentrate, and blurred vision.

Cardiac symptoms include dysrhythmias and palpitations.
Additionally, the patient may experience dry mouth, diaphoresis, and tetanic spasms of the arms and legs.

Treatment of respiratory alkalosis centers on resolving the underlying problem.

Patients presenting with respiratory alkalosis have dramatically increased work of breathing and must be monitored closely for respiratory muscle fatigue.

When the respiratory muscles become exhausted, acute respiratory failure may ensue

Metabolic Acidosis

Metabolic acidosis is defined as a bicarbonate level of less than 22 mEq/L with a pH of less than 7.35.

Causes of metabolic acidosis

Metabolic acidosis is caused by either a deficit of base in the bloodstream or an excess of acids, other than CO2.

Diarrhea and intestinal fistulas may cause **decreased levels of the base.**

Causes of **increased acids** include:
- Renal failure
- Diabetic ketoacidosis
- Anaerobic metabolism
- Starvation
- Salicylate intoxication

Signs and symptoms

Nervous system manifestations include headache, confusion, and restlessness progressing to lethargy, then stupor or coma.

Cardiac dysrhythmias are common and Kussmaul respirations occur in an effort to compensate for the pH by blowing off more CO2.

Warm, flushed skin, as well as nausea and vomiting, are commonly noted.

The presence of metabolic acidosis should spur a search for hypoxic tissue somewhere in the body.

Hypoxemia can lead to anaerobic metabolism system-wide, but hypoxia of any tissue bed will produce metabolic acids as a result of anaerobic metabolism even if the PaO2 is normal.

Current research has shown that the use of sodium bicarbonate is indicated only for known bicarbonate-responsive acidosis, such as that seen with renal failure.

Routine use of sodium bicarbonate to treat metabolic acidosis results in subsequent metabolic alkalosis with hypernatremia and should be avoided.

Metabolic Alkalosis

Metabolic alkalosis is defined as a bicarbonate level greater than 26 mEq/liter with a pH greater than 7.45.

Causes of metabolic alkalosis

Either an excess of base or a loss of acid within the body can cause metabolic alkalosis.
Excess bas