Arterial Blood Gas (ABG)

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Abstract

The arterial blood gas test (ABG) is one of the most common and useful tests performed by medical professionals. The ABG checks a patient’s arterial blood to determine acidity and levels of oxygen and carbon dioxide in their blood. It is especially useful to determine whether oxygen therapy is working for a patient or to reveal important information about a patient’s metabolic state. The goal of ABG sampling to reflect the patient’s physiologic state is discussed.
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Statement of Need

Health care professionals are often required to analyze respiratory, metabolic and mixed acid-base imbalances through ABG sampling. Nurses often need to enhance and refresh their knowledge of ABG interpretation to understand treatment.

Course Purpose

To provide nursing professionals with basic knowledge of the ABG laboratory test and to be able to interpret values.
Learning Objectives

1. List common sites for taking blood for an ABG test.
2. Identify normal ranges for ABG results.
3. Recognize abnormal ABG results.

Target Audience

Advanced Practice Registered Nurses, Registered Nurses, Licensed Practical Nurses, and Associates

Course Author & Director Disclosures

Jassin M. Jouria, MD, William S. Cook, PhD, Douglas Lawrence, MA, Susan DePasquale, CGRN, MSN, FPMHNP-BC – all have no disclosures

Acknowledgement of Commercial Support

There is no commercial support for this course.

Activity Review Information

Reviewed by Susan DePasquale, CGRN, MSN, FPMHNP-BC

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Please take time to complete the self-assessment Knowledge Questions before reading the article. Opportunity to complete a self-assessment of knowledge learned will be provided at the end of the course.
1. Which one of the following is the most common puncture site for arterial blood gas tests?
   a. femoral artery
   b. radial artery
   c. brachial artery
   d. axillary artery

2. Acid is a substance that _______ a hydrogen ion.
   a. accepts
   b. rejects
   c. accumulates
   d. donates

3. This molecule in the blood binds to and transports oxygen:
   a. protein
   b. bicarbonate
   c. hemoglobin
   d. phosphate

4. A patient’s ABG test results indicate that CO₂ levels have decreased while pH has increased. This could indicate a state of which one of the following:
   a. alkalosis
   b. acidosis
   c. atelectasis
   d. fibrosis
5. A patient’s ABG report shows a pH of less than 7.35 and a plasma bicarbonate ion concentration of less than 22mmol/L. This reading may indicate which one of the following conditions:
   a. metabolic alkalosis
   b. respiratory alkalosis
   c. metabolic acidosis
   d. respiratory acidosis
Introduction

The arterial blood gas (ABG) test is performed to evaluate acid-base balance and lung function. It involves puncturing a patient’s artery and drawing blood with a thin needle. The most common puncture site is the radial artery; however, the femoral artery and the brachial artery may be used. Blood can also be drawn from an arterial catheter. Regardless of the chosen site, once the blood is drawn it is measured and analyzed for abnormalities in one of the following:  

- pH (reflection of the negative log of hydrogen content in the blood)
- PaCO\textsubscript{2} (gas and acid controlled by the lungs)
- HCO\textsubscript{3} (alkaline substance controlled by the kidneys)
- PaO\textsubscript{2} (partial pressure of oxygen in arterial blood)
- O\textsubscript{2} Sat (oxygen saturation)

ABG levels are often measured in acutely ill patients who show signs of respiratory distress.\textsuperscript{2} Other indications for ABG sampling include patients with diabetic ketoacidosis, kidney disease, heart failure, infection, and drug overdose.\textsuperscript{3} Results of the ABG test are not diagnostic and should be used in conjunction with other exams. The ABG sampling may be performed with tests such as BUN, electrolyte, and creatinine measurements to evaluate glucose and kidney function.
In addition to other medical conditions, the ABG test also helps clinicians investigate for disorders that may cause acidosis or alkalosis. The test uses a complex calculator, known as the A-a Gradient calculator to measure successful gas exchange and oxygenation. Blood gas analyzers utilized during ABG testing also measure concentrations of hemoglobin, oxyhemoglobin, carboxyhemoglobin, methemoglobin, and lactate.

To help understand how the results of the ABG test are interpreted, medical professionals must know basic physiologic principles of how the body maintains a state of homeostasis. By exploring the normal ranges, practitioners will better understand the significance of abnormal ABG results.
Normal Metabolic And Cellular Function

The human body requires a delicate balance between acid and base for normal metabolic and cellular function. This balance is achieved through buffering systems made up of both respiratory and metabolic functions. Any irregularity in one of these functions will result in imbalance.

Acid-Base

“Acid” is defined as any substance that can donate a hydrogen ion; and “base” encompasses any substance that can accept a hydrogen ion. Naturally, acid contributes to an acidic state, while base contributes to an alkaline state. Acid-base is a reflection of the pH in the body. This is the measurement of the concentration of acid or alkalinity in the body. It is directly influenced by bicarbonate ($\text{HCO}_3^-$) and carbon dioxide ($\text{CO}_2$). The pH scale ranges from 1 to 14; values of less than 7 are considered acidic, while values of greater than 7 are considered alkaline. The optimal pH level is between 7.35 and 7.45. Any deviation from this range can disrupt metabolism.

Buffers

The respiratory and renal systems along with buffer mechanisms play an important role in regulating the body’s acid-base balance. The buffer system acts as the first line of defense to counteract fluctuations in pH levels. There are four blood buffers that combine with bicarbonate and hydrogen ions to help maintain normal blood pH. These buffers include the following values and percentages listed below.
**Bicarbonate (HCO$_3$)**

This is an essential buffer system for the body and either a positive or negative fluctuation in this acid-base component will result in an imbalance. The normal ratio is twenty-parts HCO$_3$ to one-part carbonic acid. This enzyme is found in intracellular and extracellular fluids and enables the kidneys to excrete H$^+$ ions in the urine while reabsorbing bicarbonate into the blood.$^5$ In this capacity, the kidney eliminates an acid to restore pH. The normal range of HCO$_3$ is 22 to 26 mEq/L.$^8,9$

**Hemoglobin**

This molecule in the blood binds with and transports oxygen (O$_2$). The total amount of oxygen transported by the blood is known as the oxygen content and the largest quantities are carried in hemoglobin and red blood cells. This is known as the oxygen-hemoglobin saturation (SaO$_2$) and is measured as a percentage. Normal results range from 94% or greater.$^8,9$

**Phosphate**

This compound combines with substances in the body to help stabilize pH. It acts as a buffer in the intercellular fluid and in the urine in a similar manner as bicarbonate.$^8$

**Protein**

Approximately three-quarters of the chemical buffering is accomplished within intracellular proteins. Proteins are located in the blood and cells of the body and can function as either an acid or a base.$^6$
Respiratory System

The respiratory system also plays a role in the physiology of acid-base balance. The inhalation of oxygen during breathing contributes to the exchange of oxygen and carbon dioxide at the cellular level. Carbon dioxide (CO₂) reacts with water to form carbonic acid, which helps to regulate pH. If CO₂ levels decrease, pH increases, which may result in a state of alkalosis. The normal range pH serum CO₂ level is from 35 to 45 mmHg.¹⁰

Chemical-sensing cells, known as chemoreceptors, regulate the respiratory system by monitoring CO₂, oxygen (O₂) levels, and acid concentration in the blood. If levels in any one of these change, the chemoreceptors, located in the central nervous system, aorta, and carotid arteries, alert the brain. Once these triggers are activated, the brain increases the breathing rate, which helps to restore pH back to normal. This does so by excreting excess CO₂ from the blood, while increasing the rate of oxygen.¹¹ The normal range of CO₂ is 60 to 70 mmHg; any rate above this measurement acts as a depressant to the central nervous system and could ultimately result in respiratory arrest if left unchecked.¹²

Renal System

To maintain homeostasis, for every hydrogen ion secreted in the urine, a sodium ion is reabsorbed into the extracellular fluid. This action occurs in the renal tubes and allows the kidneys to regulate pH. Chloride and potassium within the renal tubules also play a role in pH balance. A decrease in chloride can cause alkalosis, and elevated potassium levels can cause acidosis. High sodium levels may also contribute toward alkalosis due to the secretion of hydrogen.¹²
Normal ABG Result Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial pressure of oxygen (PaO2)</td>
<td>75 - 100 mmHg</td>
</tr>
<tr>
<td>Partial pressure of carbon dioxide (PaCO2)</td>
<td>38 - 42 mmHg</td>
</tr>
<tr>
<td>Arterial blood pH</td>
<td>7.38 - 7.42</td>
</tr>
<tr>
<td>Oxygen saturation (SaO2)</td>
<td>94 - 100%</td>
</tr>
<tr>
<td>Bicarbonate (HCO3)</td>
<td>22 - 28 mEq/L</td>
</tr>
</tbody>
</table>

Source: U.S. National Library of Medicine

Transportation of Oxygen

Along with acid-base balance, the ABG test assesses the patient’s oxygen level and oxygen saturation (SaO2). Oxygen in the pulmonary system is represented as a partial pressure of gas (PaO2). When this oxygen enters the alveoli, its normal concentration range is 80 mmHg to 100 mmHg. These alveoli receive oxygen with every breath, and the oxygen is then diffused into the lung. When the oxygen departs the alveoli to the pulmonary capillaries, carbon dioxide is exhaled from the lungs.11

In healthy patients, the ABG test will reveal normal levels of oxygen and carbon dioxide. The oxygen saturation refers to the percentage of oxygen that binds to hemoglobin. The measurement of oxygen transported through the blood is referred to as the oxygen content of the blood. Once the oxygen reaches the tissue level through transportation by hemoglobin, it is unloaded and participates in cellular aerobic metabolism.11,12
Several conditions can affect the attraction of oxygen to hemoglobin. A “shift to the left” indicates that oxygen is bound too tight to hemoglobin. Decreased levels of carbon dioxide, alkalosis, or hypothermia could cause this to occur. A “shift to the right” means the hemoglobin is releasing too much oxygen. Increased levels of carbon dioxide, acidosis, or fever could cause this shift.\textsuperscript{13}

\textbf{Common Sites of Sample Collection}

A respiratory therapist, phlebotomist, physician, or nurse draws the arterial blood for ABG sampling. Planning for the test involves the best selection of a puncture site, which will typically include the radial, femoral, or brachial arteries. Assessment of collateral circulation to the hand and wrist must first be performed in cases of radial artery sampling. This can be accomplished by performing what is known as an Allen test.\textsuperscript{14} During this procedure, clinicians occlude both the ulnar and radial arteries. The patient then pumps the fist until the blood has drained and the hand appears pale. Pressure is then released from the ulnar artery, while the radial artery remains occluded. If the hand returns to normal, adequate circulation is present. If it fails to return to the normal color within approximately 10 seconds, another site must be used for arterial puncture.\textsuperscript{14,15}

\textit{Radial Artery}

Puncture at the radial artery site is the preferred method of obtaining a sample for blood gas analysis due to the artery’s location on the wrist. The procedure is performed as outlined below.\textsuperscript{16}

1. Palpate the patient’s radial pulse with the index and middle finger of the nondominant hand and clean the puncture site with antiseptic.
2. Insert the needle at a 45-degree angle, while palpating the radial pulse proximal to the puncture site with the non-dominant hand.

3. As the needle slowly advances into the lumen of the radial artery, the arterial blood flow begins to fill the syringe. It is not necessary to pull back the plunger, unless the patient has a weak pulse or an unvented plunger with a small needle is being utilized.

4. The needle can be removed after 2 to 3 mL of arterial blood has been obtained. After the procedure, apply occlusive pressure at the puncture site with a piece of gauze for approximately five minutes prior to applying an adhesive bandage.

*Femoral Artery*

In cases where radial artery sampling is not feasible, femoral artery sampling may be a viable alternative. However, the deeper the structure, the higher the risk is for damage to nearby nerves. The potential for infection must also be taken into account prior to performing this procedure.

The femoral artery is located midline between the symphysis pubis and the superior iliac crest, and two to four centimeters distal to the inguinal ligament. The procedure is performed as outlined below.

1. Palpate the patient’s femoral pulse with the middle and index finger on the non-dominant hand and clean the puncture site with antiseptic.

2. Insert the needle at a 60 to 90 degree angle, while palpating the femoral pulse proximal to the puncture site with the non-dominant hand.
3. As the needle slowly advances into the lumen of the femoral artery, the arterial blood flow begins to fill the syringe. It is not necessary to pull back the plunger, unless the patient has a weak pulse or an unvented plunger with a small needle is being utilized.

4. The needle can be removed after 2 to 3 mL of arterial blood has been obtained. After the procedure, apply occlusive pressure at the puncture site with a piece of gauze for approximately five minutes prior to applying an adhesive bandage.

**Brachial Artery**

The brachial artery is another option for blood gas sampling; however, because the structures are harder to identify than the other locations, it is the least preferred site. It is located between the medial epicondyle of the humerus and the bicep tendon in the antecubital fossa. It can be identified in the groove between the tricep and bicep tendons. The procedure is performed as outlined below.¹⁶

1. Palpate the patient’s brachial pulse with the index and middle finger of the non-dominant hand and clean the puncture site with antiseptic.

2. Insert the needle at a 45 to 60 degree angle, while palpating the radial pulse proximal to the puncture site with the non-dominant hand.

3. As the needle slowly advances into the lumen of the brachial artery, the arterial blood flow begins to fill the syringe. It is not necessary to pull back the plunger, unless the patient has a weak pulse or an unvented plunger with a small needle is being utilized.
4. The needle can be removed after 2 to 3 mL of arterial blood has been obtained. After the procedure, apply occlusive pressure at the puncture site with a piece of gauze for approximately five minutes prior to applying an adhesive bandage.

After the ABG test, patients should be monitored for potential complications, which may include:

- Local hematoma
- Air or thrombus embolism
- Arterial occlusion
- Infection
- Hemorrhage
- Local anesthetic reaction
- Vessel laceration

ABG testing may also be difficult in patients who are cognitively impaired or uncooperative because their pulses may be difficult to locate. Also, in cases of obesity, excess subcutaneous fat may limit access to the vascular area.

**Blood Gas Analyzer Machine**

Once the blood is drawn through one of the aforementioned methods, it is then sent to the blood gas analyzer machine for analysis. There are a variety of manufactures and the technical design has evolved since their inception in the 1950s; however, the function remains fairly straightforward. The blood gas analyzer machine aspirates the blood from the syringe and measures the pH as well as the partial pressures of carbon dioxide, nitrogen, and oxygen and bicarbonate concentration.
The basic components of the machine include three electrodes that determine pH, PcO\textsubscript{2} and Po\textsubscript{2}. Each electrode is calibrated at two reference points and measurements are taken based on these points. Once this laboratory analysis is complete, the results are forwarded to the physicians for interpretation and potential treatment options.

\textbf{ABG Measurement Interpretation}

A systematic approach is necessary to properly analyze arterial blood gas results. Using the baseline references as guidance, clinicians assess oxygenation, pH, standard bicarbonate (sHCO\textsubscript{3}), base excess, and partial pressure of carbon dioxide (PaCO\textsubscript{2}). Once the arterial blood specimen is taken, the steps outlined below will be taken to analyze the results.
**Assess Oxygenation**

Arterial oxygen tension (PaO$_2$) is the partial measurement of the partial pressure of oxygen in arterial blood. Arterial oxygen tension is composed of alveolar gas exchange, inspired oxygen concentration, and tissue oxygen consumption. During this stage of arterial gas assessment, clinicians record the inspired gas concentration and P/F ratio, which is the ratio between PaO$_2$ and the inspired oxygen concentration. Hemoglobin saturations should also be assessed during this stage.

**Assess pH**

As discussed earlier, the normal pH range is between 7.35 and 7.45. Any variation could result in a state of acidosis or alkalinity. Even small changes in pH levels can be clinically significant due to a large fluctuation in hydrogen ion concentration.

**Assess standard bicarbonate (sHCO$_3$)**

Standard bicarbonate can be used to isolate metabolic causes of acid-base disturbance. Any abnormal sHCO$_3$ reading may indicate primary or compensatory metabolic acid-base issues. During this stage of the testing, the arterial blood gas analyzer’s software calculates the values of sHCO$_3$ and base excess. A decreased level of sHCO$_3$ indicates acidosis, which is likely to be metabolic in origin, and an increased level of sHCO$_3$ metabolic alkalosis.
Assess arterial partial pressure of carbon dioxide (PaCO$_2$)

A low or high PaCO$_2$ reading may also indicate metabolic acidosis or alkalosis respectively. Next, the PaCO$_2$ should be evaluated to identify any ventilatory issue, which may be present in an acid-base disturbance.$^{5,18}$ In cases where the respiratory drive is normal, compensatory hypocarbia should be present. Irregular levels of arterial pressure of carbon dioxide could be caused by a variety of conditions, such as chronic obstructive pulmonary disease, incipient ventilator failure, or opioid analgesia.$^{18}$

Assess additional analysis

Other considerations may also be useful in determining the cause of any acid-base abnormality. Factors to consider include electrolytes, hemoglobin, glucose, and lactate concentrations.$^{18}$ Many arterial blood gas analyzers are now set up to evaluate these additional analytes.

Acid-Base Disorders

After studying the ABG test information, clinicians will be able to identify any potential acid-base disorders. During the interpretation and treatment of abnormal arterial blood values, the disorders commonly present are discussed below.

Respiratory Acidosis

Respiratory acidosis occurs when the body tries to compensate for excessive partial pressure of carbon dioxide. During respiratory acidosis, excess hydrogen in the urine is excreted in exchange for bicarbonate ions.$^{2,5}$ When respiration is impaired during respiratory acidosis, the lungs are unable to
excrete carbon dioxide effectively and the accumulation of this carbon dioxide forms an acid in the blood.\textsuperscript{2} Respiratory acidosis can be caused by any condition that causes a patient to develop a depressed respiratory status, such as chronic obstructive pulmonary disease, infection, asphyxia, central nervous system depression, and hypoventilation.\textsuperscript{5}

**Respiratory Alkalosis**

During respiratory alkalosis excessive exhalation of carbon dioxide causes a decrease in blood carbon dioxide concentration. This results in a decrease in hydrogen ions, which leads to an increase in pH. Common causes include pulmonary disease, high altitudes, hyperventilation, and stroke.\textsuperscript{2,5}

**Metabolic Acidosis**

Metabolic acidosis occurs when there is a reduction in bicarbonate, or an accumulation of fixed acid. It is marked by a pH of less than 7.35 and a plasma bicarbonate ion concentration of less than 22mmol/L. The bicarbonate level decreases, as the lactic acid accumulates, resulting in a decrease in pH and bicarbonate levels. Metabolic acidosis may be caused by the failure of the kidneys to excrete hydrogen ions, severe diarrhea, poor infusion induced by shock, and excessive production of acids caused by diabetic ketoacidosis.\textsuperscript{2,5}

**Metabolic Alkalosis**

During metabolic alkalosis, there is an increase in pH levels and bicarbonate and a decrease in fixed acid.\textsuperscript{2} It is marked by a bicarbonate ion level of greater than 26 mmols. During metabolic alkalosis, the kidneys attempt to
conserve hydrogen, which results in the respiratory system decreasing ventilations. Metabolic alkalosis can be caused by severe loss of gastric acid induced by excessive vomiting, use of steroids or diuretic drugs, and excessive intake of alkaline medications, such as antacids, potassium deficiency, and Cushing’s Syndrome. Symptoms of metabolic alkalosis include slowed breathing, tremors, irritability, and nausea.

**Summary**

Nurses may have difficulty with the interpretation of an arterial blood gas (ABG) test. The best approach to ABG interpretation is a systematic one. Primary aspects of ABG analysis involve the blood pH, whether it is normal, acidotic or alkalotic, and the pO2 level indicating whether the patient is hypoxic. It’s also necessary to understand compensatory mechanisms, such as with the rise and fall to maintain pH balance in the setting of respiratory or renal failure.

To be proficient in ABG interpretation nurses need to understand the body systems involved to maintain adequate oxygenation and acid-base balance, and to practice ABG analysis. By understanding the various aspects of ABG testing and interpretation, medical and nursing professionals are able to better treat any underlying conditions related to respiratory and metabolic (acid-base) disturbances. The systematic approach to ABG analysis can help determine the differential diagnoses, which will help to ensure the best possible outcomes for patients.

Please take time to help the NURSECE4LESS.COM course planners evaluate nursing knowledge needs met following completion of this course by completing the self-assessment Knowledge Questions after reading the article. Correct Answers, page 22.
1. Which one of the following is the most common puncture site for arterial blood gas tests?
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   b. radial artery
   c. brachial artery
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   b. rejects
   c. accumulates
   d. donates

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   a. metabolic alkalosis
   b. respiratory alkalosis
   c. metabolic acidosis
   d. respiratory acidosis

Correct Answers:

1. b
2. d
3. c
4. a
5. d
REFERENCE SECTION

The reference section of in-text citations include published works intended as helpful material for further reading. Unpublished works and personal communications are not included in this section, although may appear within the study text.


15. Barone, J.E., Madlinger, RV. Should an Allen test be performed before radial artery cannulation? *J Trauma*. 2006; 61: 468-470


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