



Interpreting ABGs: The Basics

2.0 Contact Hours

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Acknowledgments

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Purpose

The purpose of this course is to provide the learner with basic information on how to interpret arterial blood gas results.

The course will also provide a brief review of the anatomy and physiology of the respiratory and renal system as it applies to arterial blood gas interpretation.

Understanding the underlying pathophysiology associated with a patient's condition and how it relates to an acid-base imbalance will also be discussed.

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Learning Objectives

After successful completion of this course, you will be able to:

1. Identify which systems help maintain an acid-base balance in the body.
2. Identify one of the first signs of an acid-base imbalance.
3. Identify components of an arterial blood gas (ABG) and list normal ranges for each component.
4. Describe how to evaluate ABG results.
5. Identify and define abnormal ABG results.
6. Define compensation.
7. Identify different conditions that can cause an acid-base imbalance.

Introduction

Identifying potential changes in patient status is an important responsibility for all healthcare professionals working in a clinical setting. Nurses and other caregivers that perform routine patient assessments should be proficient at evaluating their patients for signs and symptoms of respiratory compromise. Since patients that are exhibiting signs of respiratory compromise will likely undergo arterial blood gas (ABG) analysis, it is important to have the ability to analyze the results of the blood gas and apply that knowledge to create an appropriate plan of care.

When one thinks of ABG analysis, oxygenation may come to mind first. However, the more complicated and in some ways more important part of ABG analysis is pH regulation.

ABG analysis will indicate if a patient's injury or disease process is impairing oxygenation or affecting the body's acid-base balance.

Normal pH Regulation: Overview

When you first study clinical acid-base disturbances, you may be frustrated as this concept is a difficult one to grasp. However, practice and experience will ease the frustration. The objective of this course is to make acid-base interpretation a simple series of steps that you can follow with confidence, to logically decipher the type of acid–base disturbance presented.

pH regulation is an example of a regulatory system that our bodies maintain so effectively that we don't often give the process much thought. As we go about our daily activities, the elimination and neutralization of acids that are produced during cellular metabolism are being eliminated by our kidneys and lungs. With the help of chemical buffers, the acid-base balance within our bodies is usually regulated within a narrow range (7.35 to 7.45). When that balance can't be maintained, our body reacts by a process known as compensation. If the body is unable to compensate, the result can be death (Lian, 2010; Sood, Paul, & Puri, 2010).

Normal pH Regulation: Maintaining a Balance

In some ways, pH regulation is similar to breathing; unless there is evidence of a problem, we don't think about the processes required to sustain a healthy metabolism. As healthcare professionals, we are attuned to the life-saving principles of the ABC's (airway, breathing and circulation). On a cellular level, these same principles are interventions that are performed to maintain an acid-base balance that is compatible with life. The respiratory system, in addition to the renal system, provides the body with the ability to help regulate the acid-base balance that is vital for aerobic metabolism.

Alterations in normal breathing and kidney function can dramatically affect the ability of the body to regulate the balance between normal metabolism and impaired metabolism (Martini, Nath, & Bartholomew, 2012).

There are a number of tests that can help to identify acid-base status. One extremely useful blood test is the arterial blood gas (ABG) analysis. Components of an ABG include:

- pH (potential of hydrogen ions)
- PaCO₂ (partial pressure of arterial carbon dioxide)
- HCO₃ (bicarbonate)
- PaO₂ (partial pressure of arterial oxygen)
- BE (base excess)

Depending on the source of the imbalance, subtle changes in breathing may be the first sign that an imbalance exists.

Did You Know

The pH is a measurement of hydrogen (H⁺) concentration. The pH and H⁺ ion concentration is inversely related; if the H⁺ concentration is high, the pH will be low.

Normal pH Regulation: Recognizing a Problem

One of the first signs of an acid-base problem is often a change in normal breathing patterns. Once we recognize that a patient has an alteration in effective breathing, interventions and diagnostic testing, such as ABG analysis may be performed to identify the source of the imbalance. Interpreting the information obtained from an ABG result, combined with the patient's history and our knowledge of normal pathophysiology (as it applies to acid-base balance) will help us to plan how to resolve the problem (Lippincott, 2012).

A & P Related to Acid Base Imbalance: The Lungs

The following information about respiratory and renal anatomy and physiology as it relates to acid base balance will help to provide healthcare professionals with a brief review of the body's mechanism for acid-base regulation.

During the process of exhalation, the lungs excrete carbon dioxide and water from the body. When CO₂ and H₂O combine, they make up carbonic acid. Since the normal cellular activities of the body are always producing carbon dioxide, the lungs can usually adjust the amount of carbon dioxide that is contained in extra cellular fluid through the process of respiration. The depth and rate of respiration can also be influential in regulating the body's acid-base balance through adjustments by chemoreceptor that respond to the acid-base and oxygen level in the blood as well (Martini, Nath, & Bartholomew, 2012).

When examining an acid-base imbalance, remember that the CO₂ value represents the respiratory system. A high level of carbon dioxide might indicate that the lungs are not eliminating carbon dioxide effectively. Another consideration to remember about CO₂ is that the lungs can usually rapidly eliminate CO₂ from the body through the process of rapid deep respiration (also known as the patient is "blowing off CO₂") or retain CO₂ by shallow and slow respiration.

Remember that CO₂ is associated with the lungs.

A & P Related to Acid Base Imbalance: The Kidneys

The body uses chemical reactions to carry out functions such as digestion and tissue repair. These chemical reactions generate acids. Some acid in the blood is acceptable, but excess acid (acidosis) can disrupt many bodily functions. Healthy kidneys help maintain the body's acid-base balance by excreting acids into the urine and returning bicarbonate (alkaline or base substance) to the circulation. This "reclaimed" bicarbonate neutralizes much of the acid that is created when food is broken down in the body (NKUDIC, 2010). Since normal metabolism produces acid, the kidneys are continuously at work to maintain homeostasis by excreting metabolic acid. This is accomplished by several mechanisms involving bicarbonate and hydrogen ions.

Although healthy kidneys remove waste from the blood, the kidneys preserve protein. After the cells use the protein, the remaining waste product is returned to the blood as urea, a compound that contains nitrogen. Healthy kidneys remove urea from the blood by excreting it in the urine. Impaired kidneys may fail to separate protein from waste products, resulting in proteinuria.

Creatinine is a waste product in the blood created by the normal breakdown of muscle cells during activity. Healthy kidneys remove creatinine from the blood by eliminating it in urine. When the kidneys are not working well, creatinine builds up in the blood. Creatinine levels in the blood can vary, and each laboratory has its own normal range, usually 0.6 to 1.2 mg/dL.

The kidneys excrete all types of acid manufactured by the body (metabolic acid) except carbonic acid which is produced by the lungs.

A&P Related to Acid Base Imbalance: Putting the Information Together

You can determine the type of acidosis or alkalosis by evaluating the carbon dioxide and bicarbonate values. These two components work to balance the pH. The respiratory component involves the elimination (or retention) of carbonic acid via carbon dioxide (CO₂). The metabolic component involves the kidneys which produce bicarbonate (HCO₃). The kidneys can also help control the pH by eliminating hydrogen (H⁺) ions. The respiratory system can respond within minutes to an increase in acid but the response is weak. The kidneys have a much more powerful response but are slow to respond; usually taking approximately 48 hours to make any change (Lian, 2010).

Another way to think of this is that CO₂ reacts with H₂O, either by associating or dissociating. This impacts the H⁺ ion concentration in the body, which in turn causes the pH to change. Dynamic equilibrium occurs, as the body attempts to keep CO₂ within normal range.



If the body's H⁺ ion level increases, the H⁺ then binds with HCO₃⁻, to create CO₂ that can be eliminated by the lungs. If the CO₂ level increases, then the body will combine CO₂ with H₂O, to create free H⁺ to be excreted by the kidneys.

Test Yourself

The respiratory system helps regulate the acid-base balance through elimination or retention of:

- A. HCO₃
- B. CO₂ – Correct!
- C. H⁺

Buffer Systems

Buffers are types of chemicals that aid in controlling the pH of body fluids. To maintain a stable body pH, a system of buffers exists within the body to create a stable ionic concentration. This will maintain the body's pH within an ideal range.

The chemical composition of the blood is extremely important for human cells. If the pH of the blood and external fluid is too low (too many hydrogen $[H^+]$ ions), an excess of H^+ ions will enter cells. Conversely, if the pH of the blood and external fluid is too high, an excess of bicarbonate (HCO_3) ions will enter cells. An altered pH will disrupt cellular activity and metabolic processes. In order to maintain the proper chemical composition inside cells, the chemical composition of the fluids outside the cells must be kept relatively constant. This constancy is known as homeostasis.

Patient Assessment

Performing a health assessment provides a foundation for all patient care and involves the use of analytical thinking to help identify key factors that can contribute to patient outcomes. Recognizing alterations in normal functioning comes with an understanding of basic human physiology and clinical experience.

As clinicians, once we have identified that a patient has an alteration in normal functioning, it is important to approach the problem by using a goal directed strategy that employs critical thinking and reasoning (Smith-Temple & Johnson Young, 2010). A systematic approach to identify symptoms such as abnormal breathing patterns or impaired renal function are examples of problems that can be linked to even more significant alterations in health.

Consider ineffective breathing; healthcare professionals have learned that a systematic approach to identifying the cause of the problem is important. Diagnostic testing such as a chest X-ray can help to identify the source of the problem and specific interventions such as oxygen therapy might help treat the problem. Sometimes further investigation is required to identify the source of a problem, and in the case of ineffective breathing, an arterial blood gas analysis may be ordered.

Want to learn more about nursing assessments? See RN.com's Assessment Series.

Acid-Base Disturbances

An acceptable acid-base balance must maintain pH within a narrow range (7.35-7.45). The lungs and the kidneys work together to maintain acid-base balance. However if one or the other systems is not working properly, acid-base disturbances occur.

An imbalance in pH can result from:

- Respiratory acidosis
- Metabolic acidosis
- Respiratory alkalosis
- Metabolic alkalosis

The information contained in an ABG result will indicate the type of imbalance and whether or not the individual's body is responding to the imbalance by "compensating" for the problem.

As you begin to examine ABG results, you will recognize that when ABGs are abnormal, there will be a deficit or excess of one (or more) of the components.

Analysis of ABGs: Overview

Developing an understanding of ABG results will help caregivers to respond appropriately to their patient's physiologic needs. If you wish to learn how to interpret arterial blood gas results you will need to use a systematic approach that involves memorizing a few key numbers and concepts. These include:

Normal pH: 7.35 to 7.45. The absolute value of a normal pH is 7.4

Normal CO₂ (carbon Dioxide level/PaCO₂): 35-45 mmHg

Normal HCO₃ (bicarbonate level): 22-26 mEq

Normal PaO₂ (oxygenation level): 80-100 mmHg

Later on in the course you will also learn about matching the CO₂ or the HCO₃ with the pH and determining the significance of the CO₂ or the HCO₃ going the opposite direction of the pH.

Memorizing Key Components

In order to interpret ABGs accurately, you must memorize a few key numbers using a systematic approach. Always begin by evaluating the pH.

Analysis of ABGs: Steps 1 & 2

Step One: The pH

The first step to interpret ABGs is to determine if the patient has a normal pH. The pH will provide you your first most valuable piece of information: does the patient have acidosis or alkalosis.

Recall that a normal pH value is 7.35 to 7.45. Now memorize the following facts:

- ***When the patient's pH is less than 7.35, the patient has some type of acidosis.***
- ***When the patient's pH is above 7.45, the patient has some type of alkalosis.***

Some essential information is still missing though. You can't address the imbalance because you don't know what type of acidosis or alkalosis the patient is experiencing.

Step Two: Evaluating CO₂

The second step to interpret an ABG result is to look at the carbon dioxide level.

The normal carbon dioxide level for most patients is 35 to 45 mmHg. Note the similarity between normal carbon dioxide levels (35-45 mm Hg) and normal pH (7.35-7.45). This may help to trigger your memory.

Also note that when you evaluate carbon dioxide values, you are effectively looking at lung function. You will need to memorize that:

- A carbon dioxide level **greater** than 45 mmHg indicates acidosis (there is too much CO₂ being retained).
- A carbon dioxide (CO₂) value **less** than 35 mmHg indicates alkalosis (there is not enough CO₂).

Analysis of ABGs: Quick Review

Quick review so far:

- A normal pH is 7.35-7.45. A pH less than 7.35 means some type of acidosis, a pH greater than 7.45 means some type of alkalosis.
- A normal CO₂ is 35-45 mmHg. A CO₂ value less than 35 mmHg indicates a low level of CO₂ and indicates a respiratory alkalosis. A level greater than 45 mmHg means too much CO₂ and a respiratory acidosis.

Test Yourself:

Your patient has a pH of 7.24. Follow step one (look at the pH).

- The patient has a pH less than 7.35 and therefore has some kind of acidosis.

This patient also has a CO₂ of 55 mmHg. Follow step two (look at the CO₂).

- The CO₂ level is greater than 45 mmHg. This level is too high and indicates a lot of CO₂. A high level of CO₂ indicates acidosis.

From the information you have learned so far, this patient has:

Respiratory acidosis – Correct!

Respiratory alkalosis

Metabolic acidosis

Analysis of ABGs: Steps 3 & 4

Step Three: Evaluating HCO₃

Now it's time to examine the bicarbonate component of ABG analysis.

The third step to interpret an ABG result is to examine the bicarbonate level. **A normal bicarbonate (HCO₃) level is 22-26 mEq.**

You will need to memorize that:

An HCO₃ level less than 22 mEq indicates there is not enough HCO₃. A low level of bicarbonate means acidosis.

An HCO₃ value higher than 26 mEq indicates a high level of bicarbonate, too much HCO₃. This means alkalosis (Lian, 2010).

Step Four: Matching pH, HCO₃ and CO₂ Using ROME

After the previous examples, you may have started to notice that whenever the pH is **high** and the HCO₃ is **high**, the patient has metabolic alkalosis.

In other words, when the direction of movement of the pH **matches** the direction of movement of the HCO₃ (the direction of movement [up or down] is the **same**), the disorder is **metabolic** in nature.

Conversely, when the direction of movement of the pH is **opposite** to the direction of movement of CO₂, the disorder will be **respiratory** in nature.

Analysis of ABGs: Example 1

For example:

Your patient's ABG results are as follows:

pH: 7.50

CO₂: 44 mmHg

HCO₃: 30 mEq

Step 1: Look at the pH. The pH is too high. This indicates some type of alkalosis.

Step 2: Look at CO₂. This value is within normal limits.

Step 3: Look at HCO₃ and note that it is too high (too alkaline).

Step 4: Since both the pH and the HCO₃ *match* in the direction of their movement (both are elevated), this is *metabolic* condition. Since both pH and the HCO₃ are high, this indicates an *alkalosis*. This disturbance is thus a metabolic alkalosis.

Analysis of ABGs: Using Acronyms

Using Acronyms

Some people use the acronym "R.O.M.E." to assist them in memorizing this concept/relationship:

R =Respiratory

O =Opposite

M =Metabolic

E =Equal

Where: **R=O** and **M=E**

Analysis of ABGs: What does this Mean

The CO₂ is the **respiratory (R)** component of the ABG. If CO₂ moves in the **opposite (O)** direction to the pH (i.e: pH falls and CO₂ increases), then the disorder is **respiratory** in nature. If pH falls and CO₂ increases, there is a respiratory acidosis. If pH rises and CO₂ decreases, there is a respiratory alkalosis.

Remember: R=O (Respiratory = Opposite direction of movement)

Conversely, the HCO₃ is the **metabolic (M)** component of the ABG. If the HCO₃ moves in the **same/equal (E)** direction to the movement of the pH (ie: pH falls and HCO₃ falls), then the disorder is metabolic in nature. If the pH is low and the HCO₃ is low there is a metabolic acidosis. If the pH is high and the HCO₃ is elevated, there is a metabolic alkalosis.

Remember: M=E (Metabolic = Equal/same direction of movement)

Look at the examples again and use the acronym to confirm the result. Remember ROME to help you determine what ABG results mean.

Analysis Table One

A table can also be useful to remember the concept of ROME:

State	pH	CO ₂	HCO ₃
Respiratory Acidosis	↓	↑	N
Metabolic Acidosis	↓	N	↓
Respiratory Alkalosis	↑	↓	N
Metabolic Alkalosis	↑	N	↑

Analysis of ABGs: Example 2

Here is another example:

Your patient's ABG results are as follows:

pH: 7.30

CO₂: 50 mmHg

HCO₃: 22 mEq

Look at the pH. The pH is too low. This indicates some type of acidosis. The CO₂ is high. The pH and the CO₂ are opposite one another, this is **respiratory acidosis**. After the previous examples, you may have started to notice that whenever the pH is high and the HCO₃ is high, the patient has **metabolic alkalosis**.

Analysis of ABGs: Step 5

Step 5: Is the Oxygen Saturation Out of Range?

A normal PaO₂ is 80 – 100 millimeters (mm) of mercury (Hg).

As healthcare professionals, we are very familiar with oxygen therapy. In general, when a patient's oxygen level is low, we anticipate the healthcare provider will order oxygen therapy. One exception to correcting low levels of oxygenation involves patients with COPD (chronic obstructive pulmonary disease). Recall that the COPD patient's respiratory drive does not trigger from the amount of CO₂ but rather low O₂ levels. If the amount of oxygen is increased the respiratory drive decreases and the patient will not breathe. In addition, research indicates that high levels of oxygen can be detrimental as well (Martini et al., 2012).

Applying information on oxygen:

The PaO₂ is 74. This level is ____ and indicates _____ (low, hypoxia)

The PaO₂ is 130. This level is ____ and indicates _____ (high, too much O₂ or hyperoxia)

The PaO₂ is 96. This level is ____ and indicates _____ (normal, normal O₂)

You have almost mastered the art of interpreting ABGs! Before moving on to learn how to determine if the body is trying to correct a pH imbalance (compensation), review the following quick tips and practice interpreting a few basic ABG results.

Analysis of ABGs: Quick Tips 1-3

Quick Tips

Step 1: Always look at the pH first to determine if a patient is acidotic or alkalotic:

pH: A normal pH is 7.35 – 7.45.

If the pH is less than 7.35, the patient is acidotic.

If the pH is greater than 7.45, the patient is alkalotic

Step 2: Evaluate CO₂:

A normal CO₂ is 35 – 45 mmHg.

If the CO₂ is less than 35 mmHg then it is below normal.

If the CO₂ is greater than 45 mmHg then the CO₂ is above normal.

Step 3: Evaluate HCO₃:

A normal HCO₃ is 22 – 26 mEq

If the HCO₃ is less than 22 mEq then it is below normal.

If the HCO₃ is greater than 26 mEq then it is above normal.

Analysis of ABGs: Quick Tips 4-5

Quick Tips

Step 4: Matching pH, HCO₃ and CO₂

Use the acronym ROME or the analysis table to determine the cause of the disturbance:

If the disturbance is **respiratory** in nature, the movement of **CO₂** will be in the **opposite** direction to the movement of the pH (R=Respiratory and O=Opposite direction).

If the disturbance is **metabolic** in nature, the movement of **HCO₃** will be in the **same** direction to the movement of the pH (M=Metabolic and E=Equal or same direction).

Step 5: Examine O₂:

A normal PaO₂ is 80 – 100mm Hg.

If the PaO₂ is less than 80 mmHg then it is below normal. The PaO₂ is too low.

If the PaO₂ is greater than 100 mmHg then it is above normal. The PaO₂ is too high.

Analysis of ABGs: Practice Scenario 1

Practice Scenario One

Your newly admitted 79-year-old pneumonia patient is unable to tolerate lying flat even though she has been lying down with two pillows behind her back. You elevate the head of her bed to high Fowlers and notice that she has a weak productive sounding cough with tenacious green tinged sputum. You also notice that her resting respiratory rate has increased from 20 per minute to 32 per minute and is slightly shallow. Her oxygen saturation (O₂ sat) was 94% and it's now 85%. You have checked the O₂ sat probe and it is positioned correctly on her finger. You auscultate her lungs and hear some coarse sounds (rhonchi) and diminished air movement in both bases.

As part of your assessment you also take another set of vital signs. Her heart rate was 98 beats per minute (bpm) and now it is 112bpm. Her blood pressure (BP) was 110/88 and now it's 122/90. Because of these results, now you are concerned about hypoxia and possible respiratory compromise. You report this information to the healthcare provider.

The healthcare provider has ordered an ABG and oxygen at 2L per minute via nasal cannula (nc) after the ABG has been drawn. She asks you to call her with the ABG results. Immediately after the respiratory technician has drawn the ABG, you apply oxygen at 2L per nc. A chart review of her history indicates she does not have a history of any pulmonary disease.

Analysis of ABGs: Practice 1 Q&A

Practice Scenario One

The ABG results come back. Your patient's ABG results are:

pH: 7.29

CO₂: 49 mmHg

HCO₃: 27 mEq

PaO₂: 78 mmHg

Step one: look at the pH. Is the pH high or low?

The patient's pH is 7.29. This is lower than normal; therefore your patient has some type of acidosis. Is the acidosis related to a breathing problem (respiratory acidosis) versus a body/kidney problem (metabolic acidosis)? Proceed to the next step to determine what type of acidosis the patient has.

Step two: Look at the CO₂. Is the CO₂ high or low?

The patient's CO₂ is high. The pH is low and the CO₂ is high. This appears to be respiratory acidosis. Proceed to step three to check the HCO₃.

Step three: look at the HCO₃. Is the HCO₃ high or low?

The HCO₃ is very close to normal; it's not low and is one point above normal. This patient appears to have respiratory acidosis. Proceed to step four to match the pH, HCO₃ and CO₂.

Step four: Match the pH, CO₂ and HCO₃

Match the pH, HCO₃ and CO₂: Using the acronym R.O.M.E or the analysis table, we also know that when the movement of pH is opposite to the movement of CO₂ (R=Respiratory and O= Opposite), the disorder is respiratory in nature.

From step one, we determined that this imbalance is an acidosis. From step 4 we confirm that the disorder is respiratory. We thus have a respiratory acidosis.

Step five: look at the O₂. Is the O₂ high or low?

Look at the PO₂. The patient's oxygen level is low. She needs more oxygen.

Analysis of ABGs: Interpreting Case 1 Results

In scenario one, you determined that your patient was exhibiting signs and symptoms of difficulty breathing. She is elderly (79 years old) and has undoubtedly lost lung elasticity and pulmonary function due to the aging process. She has no history of pulmonary problems such as COPD; however, she has been diagnosed with pneumonia. Her ABG results confirm that she is not breathing effectively; she has *respiratory acidosis and hypoxia*.

As a healthcare professional, you are aware that there are certain interventions that the healthcare provider can order to help the patient breathe more easily. There are also nursing interventions that you can apply that do not usually require an order (depending on the patient's condition).

Nursing interventions may include:

- Elevating the head of the bed.
- Offering ice chips or frequent small amounts of fluids (if not contraindicated).
- Providing oral care, frequent positioning and deep breathing/coughing exercises, incentive spirometry and other interventions related to enhancing oxygenation (Lippincott, 2012).

Analysis of ABGs: Practice Scenario 2

Scenario Two

A sixty year old male was just found unresponsive in the men's bathroom in the lobby of the medical facility where you work. He was last seen about five minutes earlier waiting for his wife to have lab work drawn. CPR is now in progress. He is quickly transferred to the emergency department (ED) where he is defibrillated, intubated and placed on a mechanical ventilator. Lab work and a chest x-ray confirming endotracheal (ET) tube placement has been obtained. Now that the patient is somewhat stabilized with a heart rate of 88 and a blood pressure of 120/77, the ED physician has requested an ABG. The ventilator is delivering 100% oxygen via the ET tube.

Analysis of ABGs: Practice 2 Q&A

Scenario Two

The blood gas results are as follows:

pH: 7.25

CO₂: 50 mmHg

HCO₃: 26 mEq

PaO₂: 150 mmHg

Step 1: pH is 7.25. Is the pH normal?

No- this pH indicates acidosis.

Step 2: CO₂ is 50 mmHg. Is the CO₂ normal?

No – it is high, this must be respiratory acidosis.

Step 3: HCO₃ is 26 mEq. Is the HCO₃ normal?

Yes- It is within normal limits; therefore this is NOT a metabolic disorder.

Step 4: Match the pH, HCO₃ and CO₂.

Using the acronym R.O.M.E. or the analysis table we can confirm that this is a respiratory disorder, since the movement of the pH is opposite to the movement of CO₂ (R=O). The movement of the pH was down, but the movement of the CO₂ was up.

Step 5: PaO₂ is 150 mmHg. Is the PaO₂ normal?

No - it's too high and needs correction.

Analysis of ABGs: Interpreting Case 2 Results

This patient has respiratory acidosis. You have likely already determined why he has acidosis: apnea during his period of being unresponsive caused a buildup of CO₂. His oxygen level is now too high and should be decreased.

Another key piece of information will help you to determine if his body is trying to correct the acidosis: Compensation.

Compensation: What is Compensation?

Compensation is a difficult concept to understand and requires a great deal of patience and practice. Do NOT get frustrated. Once you are able to master the concept of compensation, acid-base imbalances will cease to be a daunting concept and you may actually enjoy the process of looking for clues to determine the sequence of events occurring in the body!

What is Compensation?

When the body recognizes that the pH is not normal, it will try to compensate or correct the pH. Compensation is an attempt by the body to maintain homeostasis.

If the pH is imbalanced due to a breathing or respiratory problem, the kidneys attempt to balance the pH.

If it is a renal imbalance, the respiratory system will attempt to compensate.

To determine if an acidosis or alkalosis is being compensated, always look at the opposite system. If the disorder is respiratory in nature, look to the kidneys (HCO_3) for compensation. If the disorder is metabolic in nature, look to the lungs (CO_2) for compensation (Lian, 2010).

Compensation: Opposite System

Compensation always comes from the opposite system.

In some cases, the body will not be able to completely restore the pH back to normal (complete compensation) and the imbalance is only partially corrected. This is called ***partial compensation***.

When the buffering systems of the body are successful in restoring a pH within normal limits, the ***compensation is said to be complete***.

The process for correcting (compensating) the imbalance can involve the lungs (respiratory system) and/or the kidneys (renal system).

The lungs control the amount of carbon dioxide through the rate and depth of respiration:

- Rapid and deep respiration works to increase (eliminate) or “blow off” the amount of CO_2 .
- Slow and shallow respiration decreases the amount of CO_2 that is eliminated.

Depending on the patient’s status, they may or may not be able to compensate. In patients that are not breathing effectively the body will not have the ability to eliminate CO_2 very quickly. As mentioned early in the course, if the lungs are not impaired, they have the ability to compensate much more rapidly than the kidneys.

The renal system contributes to the regulation of the body’s normal pH by the elimination or retention of hydrogen ions (H^+) via the carbonic acid system (H_2HCO_3). The renal system helps to maintain a balanced pH by generating carbonic acid or not generating it (the effects regulate the pH). The process is slower in comparison to the respiratory system.

You will be able to identify if compensation is occurring after you determine which type of acid-base imbalance your patient is experiencing but it can be a little tricky!

Did You Know

Compensation Methods

Respiratory acidosis: Kidneys attempt to compensate by increasing the rate of H^+ secretion and bicarbonate reabsorption.

Metabolic acidosis: Lungs attempt compensation by blowing off excess CO_2 through hyperventilation.

Respiratory alkalosis: Kidneys attempt compensation by decrease H^+ secretion, chloride retention, decreased HCO_3 reabsorption, and excreting fewer acid salts.

Metabolic alkalosis: Lungs attempt to compensate by retention of CO_2 , through hypoventilation.

Compensation: Respiratory/Metabolic Disturbances

To determine compensation, we will add an additional step; Step 6:

To determine whether or not compensation is occurring in the body, we look at the opposite system:

- **Respiratory disturbances:**

If there is a respiratory disorder (acidosis or alkalosis), we look at the HCO_3 (the opposite system) to determine if compensation is occurring.

If the HCO_3 is within normal limits, we can deduce that no compensation is occurring.

If the HCO_3 is elevated or lowered, we can deduce that compensation is occurring.

If the pH is restored to within normal limits, the compensation is complete. If the pH is not restored within normal limits, the compensation is incomplete.

Compensation: Respiratory/Metabolic Disturbances

- **Metabolic disturbances:**

If there is a metabolic disorder (acidosis or alkalosis), we look at the CO_2 (the opposite system) to determine if compensation is occurring.

- If the CO_2 is within normal limits, we can deduce that no compensation is occurring.

- If the CO_2 is elevated or lowered, we can deduce that compensation is occurring.

- If the pH is restored to within normal limits, the compensation is complete. If the pH is not restored within normal limits, the compensation is incomplete.

Step 5: Look at the oxygen level.

Step 6: The next question is: Is this fully or partially compensated?

The next question we need to address is whether or not this compensatory effort is a partial or a full compensation. To answer this question, look at the pH. If the pH is within normal limits, then the compensation is complete. If the pH is not restored back to normal limits, the compensation is incomplete (partial).

Analysis Table

When the compensation factors are added to the analysis table, the picture becomes clearer. If the pH is normal in the table, then it is completely compensated.

State	pH	CO ₂	HCO ₃
Respiratory Acidosis	↓	↑	N
Metabolic Acidosis	↓	N	↓
Respiratory Alkalosis	↑	↓	N
Metabolic Alkalosis	↑	N	↑
Compensated Respiratory Acidosis	N or ↓	↑	↑
Compensated Metabolic Acidosis	N or ↓	↓	↓
Compensated Respiratory Alkalosis	N or ↑	↓	↓
Compensated Metabolic Alkalosis	N or ↑	↑	↑

Analysis of ABGs: Practice Scenario 3

A twenty-year-old male with type I diabetes came into urgent care, complaining of nausea and vomiting. His respirations are 26, heart rate is 130, and blood pressure is 130/80. His oxygen saturation is 94% on room air. His blood glucose level was 345 mg/dL. The physician has also ordered an ABG.

The blood gas results are as follows:

pH: 7.42

CO₂: 33 mmHg

HCO₃: 18 mEq

PaO₂: 75 mmHg

Step 1: pH is 7.36. Is the pH normal?

Yes; but it is on the acidotic side of the absolute normal of 7.4.

Step 2: CO₂ is 33 mmHg. Is the CO₂ normal?

No – it is low, which is same direction as the pH, indicating a compensation.

Step 3: HCO₃ is 18 mEq. Is the HCO₃ normal?

No- it is low, which is the same direction as the pH, indicating a metabolic problem.

Step 4: Match the pH, HCO₃ and CO₂.

Using the acronym R.O.M.E. or the analysis table we can confirm that this is a metabolic disorder, since the movement of the pH is same to the movement of CO₂ (M=E). The movement of the pH was down, and the movement of the HCO₃ was down. The movement of the CO₂ is also down, showing that a compensation is occurring.

Step 5: PaO₂ is 75 mmHg. Is the PaO₂ normal?

No - it's too low and needs correction.

Step 6: Is this partially or fully compensated? The pH is back within normal range, which shows full compensation.

No - it's too low and needs correction.

Analysis of ABGs

Interpreting Case Three Results

This patient has metabolic acidosis with full compensation. Although there is compensation, if the patient's nausea, vomiting, and blood glucose levels are not maintained, the body will not be able to maintain the acid-base correction.

Compensation: Base Excess

A Word about Base Excess

Near the beginning of the course, base excess is listed as one of the components of an arterial blood gas. Memorizing these values is not essential to interpreting ABGs; however, understanding the significance of base excess levels helps to identify if and how the body may be compensating for the imbalance.

Base excess represents the difference between acid and base levels in arterial blood. The normal range is between +2 and -2.

Base excess levels less than -2 indicate metabolic acidosis or metabolic compensation for respiratory alkalosis.

Base excess levels above +2 indicate metabolic alkalosis or metabolic compensation for respiratory acidosis (Sood et al., 2010).

Mixed Acid-Base Balances

Most patients will have only one type of acid-base imbalance. In some cases if an imbalance persists, the patient may have two primary types of imbalance. This is known as a mixed acid-base imbalance and can result from renal and respiratory dysfunction (Sood et al., 2010).

Test Yourself

Compensation occurs when the body tries to restore pH balance by using which two systems?

- A. Respiratory and cardiac
- B. Renal and musculoskeletal
- C. Respiratory and renal – Correct!

Causes of Imbalances: Respiratory Acidosis

Respiratory acidosis (low pH and high CO₂) can result from hypoventilation related to a number of conditions including:

- **Pneumonia (Byrd, 2014a)**
- **Restrictive lung disease such as fibrosis, sarcoidosis**
- **Neuromuscular problems such as multiple sclerosis or Guillain-Barre syndrome**
- **Obstructive lung disease such as emphysema, chronic bronchitis**
- **Pneumothorax**
- **Injury/trauma to the chest wall**
- **Airway obstruction**
- **Pulmonary edema**
- **Respiratory distress**

Causes of Imbalances: Respiratory Acidosis

Early symptoms of respiratory acidosis may present as tachypnea, tachycardia and diaphoresis. As the acidosis progresses other symptoms emerge that include:

- **Dysrhythmias**
- **Bradypnea**
- **Hypotension**
- **Altered level of consciousness**
- **Somnolence (Byrd, 2014a)**

Causes of Imbalances: Respiratory Alkalosis

Conditions that Cause Respiratory Alkalosis

Respiratory alkalosis (high pH and low CO₂) can result from hyperventilation related to a number of conditions including:

- Pulmonary embolism
- Excessive mechanical ventilation (blows off too much CO₂)
- Anxiety, panic disorders
- Pneumothorax
- Liver failure
- Fever, infections
- Hyperthyroidism

- Pain
- Trauma

(Byrd, 2014b)

Symptoms of Respiratory Alkalosis

Symptoms of respiratory alkalosis may present as anxiety, tachypnea, tachycardia and diaphoresis. Other symptoms can emerge that include:

- Paresthesia of the extremities and around the mouth
- Syncope
- Vertigo
- Seizures
- Coma

(Byrd, 2014b)

Causes of Imbalances: Metabolic Acidosis

Conditions that Cause Metabolic Acidosis

Metabolic acidosis (low pH and low HCO_3) can result from an increase in acid related to a number of conditions including:

- Ketoacidosis from diabetes or starvation
- Lactic acidosis related to tissue hypoxia
- Renal failure
- Bicarbonate loss from diarrhea, pancreatic fistula
- Salicylate overdose
- Rapid infusion of normal saline related to increased chloride load

(Thomas, 2013a)

Symptoms of Metabolic Acidosis

Symptoms of metabolic acidosis include:

- Weakness
- Altered level of consciousness
- Headache
- Tachypnea that progresses to Kussmaul's
- Dyspnea
- Chest pain
- Abdominal discomfort, decreased appetite, nausea and vomiting

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- Dysrhythmias
- Hypotension
- Coma

(Thomas, 2013a)

Causes of Imbalances: Metabolic Alkalosis

Conditions that Cause Metabolic Alkalosis

Metabolic alkalosis (high pH, high HCO_3) can result from a number of conditions related to a loss of acid that include:

- Potassium-wasting diuretic medications
- Steroid therapy
- Severe vomiting or nasogastric suctioning
- Liver disease
- Hypokalemia

(Thomas, 2013b)

Symptoms of metabolic alkalosis include:

- Altered level of consciousness
- Weakness
- Nausea, vomiting, diarrhea
- Paresthesia of the extremities and around the mouth
- Myalgia
- Bradypnea
- Arrhythmia
- Seizures
- Coma

(Thomas, 2013b)

Test Yourself

Diabetic ketoacidosis is a common cause of:

- A. Metabolic alkalosis
- B. Metabolic acidosis – Correct!
- C. Respiratory acidosis

Correcting Imbalances

Treatment for acid-base disturbances focuses on correcting the underlying cause of the imbalance.

Correcting Respiratory Acidosis

Since respiratory acidosis is caused by the inadequate elimination of CO₂ from the lungs, the treatment goal for respiratory acidosis is to improve ventilation. Expect to administer drugs such as bronchodilators to improve breathing and, in severe cases, to use mechanical ventilation. If the patient is not ventilated, the administration of supplemental oxygen will help to improve oxygen saturation. It is also important to maintain good pulmonary hygiene to keep lung function optimal. Suctioning of the airways may be necessary to achieve this goal (Byrd, 2014a).

Correcting Respiratory Alkalosis

Respiratory alkalosis occurs when too much CO₂ is blown off. Usually, the only treatment goal for respiratory alkalosis is to slow the breathing rate. If anxiety is the cause, encourage the patient to slow his or her breathing. Some patients may need an anxiolytic. If pain is causing rapid, shallow breathing, provide pain relief. Breathing into a paper bag allows a patient to re-breathe CO₂, raising the level of CO₂ in the blood (Byrd, 2014b).

Correcting Metabolic Acidosis

Treatment for metabolic acidosis focuses on correcting the underlying cause. The acidosis can also be treated directly. If it's mild, administering I.V. fluid may correct the problem. If acidosis is severe, you may administer intravenous sodium bicarbonate, as prescribed (Thomas, 2013a).

Correcting Metabolic Alkalosis

Treatment for metabolic alkalosis also focuses on treating the underlying cause. Frequently, an electrolyte imbalance causes this disorder, so treatment consists of replacing fluid, sodium and potassium (Thomas, 2013b).

Conclusion

In this course, you learned:

Identifying potential changes in patient status is an important responsibility for all healthcare professionals working in a clinical setting.

Nurses and other caregivers that perform routine patient assessments should be proficient at evaluating their patients for signs and symptoms of an acid-base imbalance.

Practicing the steps described in this course will assist you in identifying the acid-base imbalance, so that corrective measures can be implemented to restore pH to normal levels.

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Note: All dosages given are for adults unless otherwise stated. The information on medications contained in this course is not meant to be prescriptive or all-encompassing. You are encouraged to consult with physicians and pharmacists about all medication issues for your patients.

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