Take these 6 easy steps to ABG analysis

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THE ARTERIAL BLOOD GAS (ABG) is a lab test that measures the acid-base balance (pH) and oxygenation of an arterial blood sample, usually obtained by direct arterial puncture. You can learn valuable information about your patient by analyzing the ABG results. For example, subtle changes in the pH may signal hemodynamic decompensation, while improvements in oxygen saturation may be related to improved perfusion.

Like many other lab tests, the ABG is a tool to help you provide better care for your patients. Let's take a closer look.

Measure for measure

The blood pH is a measurement of the acid content of the blood, specifically, the partial-pressure of hydrogen ions in the blood. Too many hydrogen ions in the blood lower the partial pressure and decrease the pH, causing acidosis. Conversely, too few hydrogen ions increase the partial pressure and the pH level rises, causing the patient to become alkalotic. Because the human body is sensitive to changes in pH, the normal range is narrow; more on that later.

The ABG can measure two factors that affect the pH: the partial-pressure of carbon dioxide ($PaCO_2$) and bicarbonate (HCO_3) levels. $PaCO_2$ measures carbon dioxide (CO_2) in the blood; it's affected by CO_2 removal in the lung. (CO_2 is produced by body tissues as a byproduct of metabolism.) Respiratory disorders like emphysema will affect the lungs' ability to remove CO_2. $PaCO_2$ is the respiratory component of the ABG.

The HCO_3 measures the bicarbonate content of the blood, and it's affected by renal production of bicarbonate. If the body produces more acid than the kidneys can buffer with bicarbonate, the patient will develop acidosis. If, on the other hand, too much bicarbonate is produced, alkalosis develops. HCO_3 is the metabolic component of the ABG.

The ABG also assesses oxygenation, as I mentioned earlier. The partial-pressure of oxygen (PaO_2) measures the amount of oxygen dissolved in the blood. After oxygen dissolves in the blood, it attaches to hemoglobin. The number of hemoglobin binding sites that have oxygen attached to them is called the oxygen saturation (SaO_2). An SaO_2 of 95% means that 95% of the available hemoglobin binding sites have oxygen attached. The SaO_2 is dependent on the PaO_2. Oxygen has to first dissolve in the blood before it can bind to hemoglobin. Body temperature, blood pH, and $PaCO_2$ levels can affect how easily oxygen attaches to hemoglobin and will, therefore, affect the SaO_2.

Allen, is that you?

Allen's test is used to confirm redundant circulation. To perform it, occlude the radial and ulnar arteries by applying firm pressure to the inner and outer aspects of the wrist. Maintain the pressure until the hand turns pale; then release the pressure on the ulnar artery. The hand should "pink up." If the hand remains pale, insufficient redundant circulation is present and damage to the radial artery could result in ischemia of the hand. Another site should be considered to draw an ABG sample.

Choosing the target

ABG samples must be drawn from an artery that's close to the skin and has adequate redundant circulation. The radial artery is generally the preferred site because it's readily accessible and its redundant circulation comes from the ulnar artery. (See *Allen, is that you?* for more on testing for redundant circulation.) Care should be taken when drawing a blood sample from the wrist of a patient with carpal tunnel syndrome; the condition may make him more susceptible to the risk of injury of the underlying nerves.

If, for whatever reason, the radial artery can't be used to draw the blood sample, the femoral artery is the second choice. It, too, is readily accessible and has redundant circulation. The downside is that this site is more prone to infection.

The choice of last resort is the brachial artery. This vessel often lacks redundant circulation, and damage to the brachial artery can result in ischemia of the forearm and hand.

Drawing class

Drawing an ABG sample is similar to drawing a venous blood sample. Put on clean gloves and then prep the site using an alcohol or povidone-iodine wipe. Because the artery often isn't visible, you'll have to palpate it. Once you locate it, you make the puncture.

Syringes used for arterial samples are different from those used for venous samples. An arterial syringe usually has a small-bore needle attached (22-gauge or smaller), and the syringe contains heparin to prevent clotting. Once the artery is punctured, blood will start flowing into the syringe. Pressure in the arterial system usually provides a brisk, sometimes pulsatile, flow. Be careful not to introduce air bubbles into the sample because they'll alter oxygen readings.

The sampling syringe is marked to show when the required amount of blood is drawn (usually 1 to 1.5 ml). Once the correct amount of blood is drawn, the needle should be withdrawn rapidly and pressure applied immediately. If bleeding occurs at the puncture site, it may be quite brisk and could cause a hematoma or, rarely, primary compartment syndrome. Maintain pressure on the puncture site for a minimum of 5 minutes, even longer if the patient has an elevated prothrombin time/activated partial thromboplastin time (PT/aPTT) or if he's taking anticoagulants. Apply a pressure dressing to prevent oozing or rebleeding.

When you document the procedure, be sure to include the arterial puncture site, results of the Allen's test, any difficulties encountered during the procedure, application of pressure, what type of dressing was used, and the patient's response.

Now that I've given you a refresher on the procedure, let's delve into how the ABG results are analyzed to give you important data about your patient.

Your 6-step program

An ABG result is best analyzed by dividing it into the two major components I discussed at the beginning of this article: acid-base balance and oxygenation. This process can be described by the following steps.

1. *Analyze the pH.* Although 7.4 is the optimal blood pH, the body will tolerate a pH from 7.35 to 7.45. If the pH is lower than 7.35, the patient is acidotic; if it's higher than 7.45, he's alkalotic. If the pH is in the normal range, look to see which side of 7.4 it lies on. If the pH is 7.37, it's said to be normal lying on the acidotic side. This indicates that the patient may

Normal values for ABGs

cheat sheet

pH	7.35-7.45
$Paco_2$	35-45 mm Hg
Pao_2	80-100 mm Hg
HCO_3	22-26 mEq/L
Sao_2	95-100%

Note: These are normal values at sea level.

Glossary of terms used in ABG analysis

pH	Acid content of the blood
$Paco_2$	Carbon dioxide content of the blood
Pao_2	Oxygen content of the blood
HCO_3	Bicarbonate content of the blood
Sao_2	Percentage of hemoglobin saturated with oxygen
Hypoxia	Inadequate oxygenation of the tissue
Hypoxemia	Low oxygen content in the blood
Hypercarbia	High carbon dioxide content
Acidemia	Too much acid in the blood
Alkalemia	Too many buffers in the blood
Compensation	Ability of the body to stabilize acid-base imbalances

be acidotic, but his kidneys are compensating to make the pH closer to normal.

2. *Analyze the PaCO_2.* Remember, CO_2 is produced in the tissues of the body and eliminated in the lungs. Changes in the PaCO_2 level reflect lung function. Normal PaCO_2 levels range from 35 to 45 mm Hg. A PaCO_2 level below 35 mm Hg can be caused by hyperventilation—basically blowing off CO_2—which will make the patient alkalotic. When the PaCO_2 level raises above 45 mm Hg and the patient retains CO_2, he's said to be acidotic.

3. *Analyze the HCO_3.* Bicarbonate is produced by the kidneys and represents the metabolic component of the blood gas. Normal levels are from 22 to 26 mEq/L. An HCO_3 level below 22 mEq/L indicates acidosis, and a level above 26 mEq/L indicates alkalosis.

4. *Match either the PaCO_2 or the HCO_3 with the pH.* If the pH is low and the PaCO_2 is high, the patient has respiratory acidosis. The patient has respiratory alkalosis if the pH is high and the PaCO_2 is low. If the pH and HCO_3 are high but the PaCO_2 is normal, the patient has metabolic alkalosis. The patient has metabolic acidosis if the pH and HCO_3 are low and the PaCO_2 is normal.

5. *Determine whether the PaCO_2 or the HCO_3 go in the opposite direction of the pH.* If so, then the patient has compensation. Compensation is the ability of one system to attempt to balance the pH when the other system is causing an imbalance. For example, when the respiratory system (CO_2) becomes acidotic, the metabolic system (HCO_3) will become alkalotic to attempt to bring the pH back to normal. The respiratory system can compensate within seconds, but it may take hours for the metabolic system to fully compensate.

6. *Analyze the PaO_2 and SaO_2 for hypoxemia.* If the PaO_2 is less than 80, or the SaO_2 is less than 95%, the patient has hypoxemia. A patient on supplemental oxygen has a PaO_2 of more than than 100.

These examples will help

Let's look at three examples of ABG results and what they tell you about your patient's condition. Here's the first example:

- pH, 7.28
- PaCO_2, 56
- PaO_2, 70
- HCO_3, 25
- SaO_2, 89%

So, what do these numbers tell you about the patient? The pH is less than 7.35, indicating acidosis. The PaCO_2 is higher than 45, indicating acidosis. The PaCO_2 matches the pH, making it a respiratory acidosis. The HCO_3 is normal, indicating there's no compensation. The PaO_2 and SaO_2 are low, indicating hypoxemia.

The full diagnosis for a patient with these ABG results is uncompensated respiratory acidosis with hypoxemia. This patient may be suffering from pneumonia, chronic obstructive pulmonary disease (COPD), or some other primary respiratory disorder. Treatment will consist of administering oxygen to improve his oxygenation and decrease his PaCO_2 by improving his ventilation. That's an encyclopedia of knowledge to get out of a small amount of blood!

Let's look at another example:

- pH, 7.5
- PaCO_2, 36
- PaO_2, 92
- HCO_3, 27
- SaO_2, 97%

The pH is above 7.45, indicating alkalosis. The PaCO_2 is normal, with no compensation. The HCO_3 is above 26, which is alkalotic; it matches the pH, indicating metabolic alkalosis. The PaO_2 and SaO_2 are normal.

The full diagnosis indicated by this ABG analysis is uncompensated metabolic alkalosis. The patient is losing acid from the body, probably from vomiting or loss from a nasogastric (NG) tube. Treatment should be aimed at limiting gastrointestinal (GI) loss and giving I.V. fluids to replace volume and restore pH balance.

Having fun yet? Let's do one more.

- pH, 7.37
- PaCO_2, 66
- PaO_2, 70
- HCO_3, 37
- SaO_2, 93%

Although the pH is normal, it's less than 7.4. So it's on the acidotic side. The PaCO_2 is above 45, which is acidotic; it matches the pH, indicating respiratory acidosis. The HCO_3 is above 26, which is alkalotic; it goes in the opposite direction, indicating compensation. Because the pH is adjusted back into the normal range, it's called full compensation. Both the PaO_2 and the SaO_2 are low, indicating hypoxemia.

The full diagnosis for the patient with this ABG analysis is fully compensated respiratory acidosis with hypoxemia. Compensation from the kidneys takes several hours, indicating that this problem is probably chronic. Treatment will likely include oxygen administration. The $PaCO_2$ will remain uncorrected if the problem is in fact chronic, such as in COPD. Trying to correct $PaCO_2$ isn't advised because the patient will simply resume retaining CO_2 once treatment stops.

Now let's get into more detail about the types of acidosis and alkalosis and how they're treated.

Acidosis vs. alkalosis

Respiratory acidosis is caused by the lungs' inability to effectively remove the CO_2 produced by metabolism. It's most often caused by a pulmonary disorder, like COPD, asthma, pneumonia, or pulmonary edema. To remove the excess CO_2, the patient will have to move more air through his lungs. This can be accomplished by using bronchodilators to open up the airways, or by using a bilevel positive airway pressure (BiPAP) machine to increase tidal volume. The metabolic system compensates for respiratory acidosis by producing more HCO_3. This process is slow, and full compensation by the kidneys indicates a chronic condition.

As I said earlier, *respiratory alkalosis* is caused by blowing off CO_2, usually by hyperventilation. You should encourage the patient to slow his breathing. In some cases, it's helpful to have the patient breathe into a paper bag; this allows the rebreathing of CO_2. If a patient on a BiPAP machine or a ventilator develops respiratory alkalosis, his respiratory rate or tidal volume is probably set too high and needs to be adjusted. In respiratory alkalosis, the metabolic system compensates by lowering the HCO_3.

Metabolic acidosis can be brought on by a variety of conditions, ranging from kidney failure, poisoning (especially with antifreeze or aspirin overdose), diarrhea, or shock to diabetic ketoacidosis. Treatment of the underlying condition should come first. If that doesn't fully resolve the acidosis, then administration of sodium bicarbonate may be appropriate. The pulmonary system compensates for metabolic acidosis by increasing the respiratory rate, thus increasing CO_2 removal.

Metabolic alkalosis can be the result of loss of acid from the stomach through vomiting or excess NG suction. If vomiting can be controlled or NG suction slowed down, alkalosis may resolve spontaneously. If not, I.V. fluids are typically given for volume replacement and correction of the imbalance. The pulmonary system compensates for metabolic acidosis by decreasing the respiratory rate and retaining CO_2.

A 6-step program for ABG analysis

cheat sheet

1. Analyze the pH.
2. Analyze the $PaCO_2$.
3. Analyze the HCO_3.
4. Match either the $PaCO_2$ or the HCO_3 with the pH.
5. Does either the $PaCO_2$ or the HCO_3 go in the opposite direction of the pH?
6. Analyze the PaO_2 and SaO_2.

Pass it on

If no compensation is found in the ABG analysis, the problem is likely to be acute; the patient's acid-base imbalance may cause respiratory, cardiac, or GI dysfunction. Treatment goals include managing the underlying disorder to correct the pH.

If, on the other hand, compensation is indicated by the test results, the disorder may be chronic and the acid-base imbalance may persist despite treatment. Instruct the patient on how to manage the underlying disorder so the imbalance doesn't become worse. ■

Learn more about it

Martin L. *All You Really Need to Know to Interpret Arterial Blood Gases*, 2nd edition. Philadelphia, Pa. Lippincott Williams & Wilkins, 1999.

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