PRODIGY ANESTHESIA

ARTERIAL BLOOD GAS INTERPRETATION

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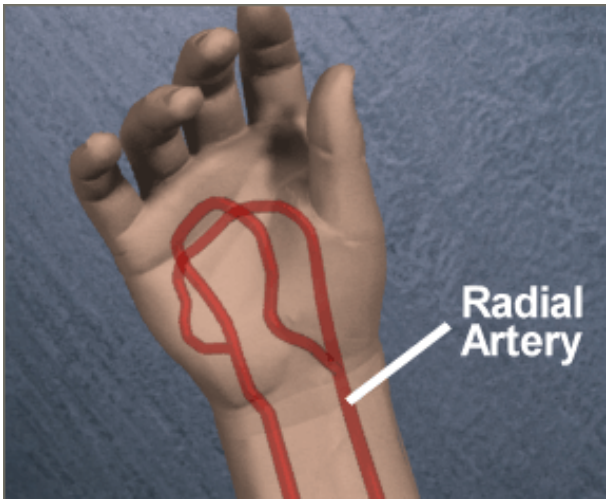

ABG stands for arterial blood gas. It is a blood sample drawn usually from the radial artery, as shown in the picture to the left. It is also occasionally drawn from the brachial or femoral artery. After the blood sample is drawn, it is sent to the lab where it is analyzed by a machine. The machine detects the levels of several gases and chemicals in the blood. The most important elements that it detects are the pH level, the oxygen content, the carbon dioxide content and the bicarbonate content. An analysis of these values can inform you of how well a patient is exchanging gases in his lungs and how well his body is maintaining a normal pH.

PaO2: 100
pH: 7.4
PaCO2: 40
HCO3: 24

The PaO2 represents the oxygen content of the blood. The 'P' stands for partial pressure, which is simply the pressure of oxygen gas in the blood compared to all the other gases present. The O2, of course, is the chemical notation for oxygen and the 'a' represents arterial blood.

The normal range for the PaO2 is 80-100 mmHg (millimeters of mercury). If the PaO2 is less than 80, then you already know that the patient is not getting

enough oxygen into his bloodstream. If the PaO2 is higher than 100 then the patient is getting a large amount of oxygen (this may happen if the patient is receiving high concentrations of oxygen from a mask or ventilator). Both a low PaO2 and a high PaO2 can be dangerous, but obviously, a low PaO2 causes immediate problems that must be fixed quickly.

PaO2: 100
pH: 7.4
PaCO2: 40
HCO3: 24

The pH indicates whether the blood is acidic or alkaline. The normal pH range is 7.35 to 7.45. If the pH is less than 7.35, then the blood is acidic and the patient is said to be acidotic, or in a state of acidosis. If the pH is greater than 7.45, then the blood is alkaline and the patient is said to be alkalotic, or in a state of alkalosis.

PaO2: 100
pH: 7.4
PaCO2: 40
HCO3: 24

Believe it or not, the carbon dioxide level is a better indicator of how well you are breathing than the oxygen level is. If you are breathing too slow, or not breathing at all, your body is not able to get rid of the CO2 quickly enough and it builds up in your bloodstream. This makes your PaCO2 level become elevated. If you are breathing too fast (hyperventilating), your body exhales too much CO2 and your PaCO2 level decreases. PaCO2 obviously reveals a great deal about a patient's respiratory status. As a matter of fact, when you see 'PaCO2' think of the word 'respiratory'. It's going to come in handy later.

If the patient is acidotic (pH less than 7.35) and the PaCO2 is greater than 45, the patient is in respiratory acidosis. If the patient is alkalotic (pH greater than 7.45) and the PaCO2 is less than 35 the patient is in respiratory alkalosis. Respiratory acidosis just means that the patient is acidotic because he isn't breathing well, thus he is retaining CO2.

Respiratory alkalosis means that the patient is hyperventilating and breathing out too much CO2. A simple tip to remember is that CO2 is virtually the same thing as acid. As a matter of fact, it becomes converted to carbonic acid in your bloodstream. If your PaCO2 level increases then the level of acid in your blood increases and the pH drops. If the PaCO2 level decreases then the acid level in the blood decreases and the pH rises.

PaO2: 100
pH: 7.4
PaCO2: 40
HCO3: 24

It is important to remember that HCO3 is virtually the same thing as base, much like CO2 is like acid. If the level of HCO3 decreases then the level of base in your blood decreases, then the blood is alkaline and the patient is said to be alkalotic or in a state of alkalosis. The normal HCO3 level is 22 to 26.

PaO2: 100
pH: 7.28
PaCO2: 51
HCO3: 25

Step One: Look at the PaO2. Is it normal, low, or elevated? This will tell you whether or not the patient is getting enough oxygen. In this case, it is 100. The normal range is 80-100, so this is a normal value. What if the PaO2 was 60? This would tell us that the patient was hypoxic, meaning that his oxygen level was too low. What if the PaO2 was 250? This would tell us that the patient was hyperoxygenated. He most likely would be receiving oxygen by mask or some other source and we would need to cut his oxygen level down.

Step Two: Look at the pH. Is it low, high or normal? It is lower than 7.35, isn't it? So is the patient acidotic or alkalotic? If you guess acidotic, you're right. So now we know that the patient is well oxygenated, but he has an acidosis of

some sort. The next trick is to determine whether it is due to respiratory causes (PaCO2) or metabolic causes (HCO3).

Step Three: Look at the PaCO2. The normal level is 35 to 45. This is easy to remember because it is the same as the last two digits of a normal pH (7.35-7.45). Is this level high, low or normal? A PaCO2 of 51 is obviously high.

REMEMBER: In a patient who is acidotic, a high PaCO2 is the DEFINITION of RESPIRATORY ACIDOSIS.

Step Four: Look at the HCO3. The normal bicarbonate level is 22-26. Is this one high, low or normal? A bicarbonate of 25 is normal so this does not tell us what kind of acidosis we have.

So, just by our definition, we already knew that we were dealing with RESPIRATORY ACIDOSIS when we reached Step Three.

Step Five: Look back at the pH. This may sound confusing right now, but you will understand later when we deal with normal pH levels, altered PaCO2 and HCO3 levels, and a type of ABG called a COMPENSATED ABG. For now, just remember that even though the pH is normal, you may be able to tell that there was or is an underlying problem and the body has already compensated for it.

Let's begin looking at some ABG's.

Example 1

PaO2: 90
pH: 7.52
PaCO2: 43
HCO3: 30

Step One tells you to look at the PaO2. This one is 90, which is between 80-100, so it is normal.

Step Two tells you to look at the pH. The pH is higher than the 7.35-7.45 range. This means that the patient is alkalotic.

Step Three tells you to look at the PaCO2. It is 43 which is in the normal range of 35-45. So, we know that the alkalosis is not respiratory in origin.

Step Four tells you to look at the HCO3. It is 30. The normal HCO3 range is 22-26, so this is elevated. This means that there is a metabolic problem.

Now, we know that the patient is in a state of metabolic alkalosis.

Example 2

PaO2: 94
pH: 7.61
PaCO2: 27
HCO3: 26

Step One: Look at the PaO2. It is 94, which is normal.

Step Two: Look at the pH. It is 7.61 and this is way too high. The patient is in a state of alkalosis. Now we need to figure out whether it is metabolic or respiratory.

Step Three: Look at the PaCO2. It is 27, and this is obviously too low. So far, we know that the patient is in alkalosis and has a low PaCO2. If CO2 is the same thing as acid, and he does not have enough of it, then this is the reason why his pH is too high. Remember that the PaCO2 represents respiratory, so you already know without continuing that this is respiratory alkalosis. This is common in patients who are hyperventilating (breathing too fast). We'll look at the next two steps just to double-check.

Step Four: Look at the bicarbonate. The HCO3 is 26. This is normal, so we are reassured that the PaCO2 abnormality is the cause of the alkalosis.

Step Five: Look back at the pH. (This won't mean anything to you, yet, but remember that later on we will HAVE to include this step in order to diagnose more complicated ABG's.

Example 3

PaO2: 85
pH: 7.21
PaCO2: 39
HCO3: 15

Step One: Look at the PaO2. It is 85, which is normal.

Step Two: Look at the pH. It is 7.21, which is acidotic.

Step Three: Look at the PaCO2. It is 39, which is normal.

Step Four: Look at the HCO3. It is 15, which is low. This tells you that the patient is in metabolic acidosis because the bicarbonate level is too low.

Step Five: Not applicable yet.

Example 4

PaO2: 70
pH: 7.35
PaCO2: 55
HCO3: 30

Step One: Look at the PaO2. It is 70, which is low. The patient is hypoxic.

Step Two: Look at the pH. It is 7.35, which is normal. Does that mean that nothing is wrong with the ABG? Let's look at the rest of the values and see if they are normal.

Step Three: Look at the PaCO2. It is 55, which is elevated. This means that there is something wrong with the patient's respiratory status.

Step Four: Look at the HCO3. It is 30, which is also elevated. That means that there is something wrong with the patient's metabolic status as well!

Step Five: Look back at the pH. This becomes important now, and you have to ask yourself, Is the pH on the acidotic or alkalotic side of 7.40? In other words, if 7.40 is a neutral pH, is the pH of the ABG above 7.40 or is it below 7.40? It is 7.35 which is on the acidotic side. What happened? Well, the pH was abnormal to begin with and the patient COMPENSATED for the abnormality. Eventually, a patient who has a metabolic pH abnormality will change his breathing to bring the pH back to normal. If he had a respiratory pH abnormality his metabolic system would change the level of HCO3 to bring the pH back to normal. Here's an example: if someone had too much bicarbonate in their bloodstream, their pH would be elevated (alkalotic). In order to balance this altered pH, the brain tells the lungs to breathe slower so that more CO2 is retained in the body. This increased CO2 acts to lower the body's pH back to normal. The same thing can happen if the pH is too low (acidotic). The brain will tell the body to breathe faster to get rid of CO2 and raise the pH back to normal.

Remember that CO2 is acid and HCO3 is base and that they can increase or decrease over time to achieve a balanced pH.

The pH is on the acidotic side of 7.40 so this tells you that the patient was originally alkalotic. This seems confusing, but now you know that step five has a real purpose. The next section will go into greater detail about compensation and show you a simple trick for naming the disorder.

ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	7.36	pH:	7.41
PaCO2:	50	PaCO2:	52
HCO3:	30	HCO3:	31

ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	7.36	pH:	7.44
PaCO2:	29	PaCO2:	27
HCO3:	18	HCO3:	16

Take a close look at the pH of each of these ABG's. You may notice that they are all normal. Now, take a look at the PaCO2 and the HCO3 of each of these ABG's. They're all abnormal! Even though the pH is normal, these are not normal ABG's. They are called COMPENSATED ABG's.

This means that there was once an abnormality, but the body compensated for it. When the body experiences a change in the level of CO2 in the body, it will release more HCO3 to balance it and when the HCO3 level changes, it will cause the lungs to breathe faster or slower to change the amount of CO2 in the blood. Eventually, the body will change the PaCO2 or HCO3 enough to bring the pH back to normal. This is when it is called a COMPENSATED ABG. Although it seems complicated, the next series of lessons will teach a simple method for naming these ABG's.

ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	**7.36**	**pH:**	**7.41**
PaCO2:	50	PaCO2:	52
HCO3:	30	HCO3:	31

ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	**7.36**	**pH:**	**7.44**
PaCO2:	29	PaCO2:	27
HCO3:	18	HCO3:	16

Step 1: Look at the pH. Obviously, the pH is normal in all four of these examples. There is, however, a simple difference that will be the key to naming each ABG. Ask yourself if the pH is on the alkalotic or acidotic side of normal. That is, is the pH above 7.40 or below 7.40? If the pH is higher than 7.40, then we will say that the condition was originally an alkalosis and is now a COMPENSATED ALKALOSIS. If the pH is less than 7.40, then the condition was originally an acidosis and is now a COMPENSATED ACIDOSIS.

Step 2: Now, place an arrow beside the pH to indicate whether it is above 7.40 or below 7.40.

ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	↓**7.36**	**pH:**	↑**7.41**
PaCO2:	50	PaCO2:	52
HCO3:	30	HCO3:	31

ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	↓**7.36**	**pH:**	↑**7.44**
PaCO2:	29	PaCO2:	27
HCO3:	18	HCO3:	16

Step 3: Now ask yourself if the PaCO2 is lower or higher than normal. If it is lower than normal, then place an arrow pointing down beside it. If it is higher than normal, then place an arrow pointing up beside it.

ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	↓7.36	pH:	↑7.41
PaCO2:	↑**50**	**PaCO2:**	↑**52**
HCO3:	30	HCO3:	31

ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	↓7.36	pH:	↑7.44
PaCO2:	↓**29**	**PaCO2:**	↓**27**
HCO3:	18	HCO3:	16

Step 4: Ask yourself the same question about the HCO3. Is it higher or lower than normal? If it is higher than normal, then place an arrow beside it

pointing up. If it is lower than normal, then place an arrow beside it pointing down.

ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	↓7.36	pH:	↑7.41
PaCO2:	↑50	PaCO2:	↑52
HCO3:	↑**30**	**HCO3:**	↑**31**

ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	↓7.36	pH:	↑7.44
PaCO2:	↓29	PaCO2:	↓27
HCO3:	↓**18**	**HCO3:**	↓**16**

Step 5: Now, look at the arrows beside the values in each ABG. Do you notice something about them? In some of the ABG's, the arrows are all pointing in the same direction, and in the other ABG's, there is an arrow that is pointing in the opposite direction. IF ALL THREE ARROWS POINT IN THE SAME DIRECTION, THE ABNORMALITY IS METABOLIC IN ORIGIN.

Step 6: Now, simply put the name together according to the steps you've just learned.

All of the ABG's are COMPENSATED ABG's since their pH is normal, but the PaCO2 and HCO3 are both abnormal.

The ABG's with a pH less than 7.40 are ACIDOTIC.

The ABG's with a pH greater than 7.40 are ALKALOTIC.

The ABG's that have arrows all pointing in the same direction have a METABOLIC abnormality.

The ABG's that have arrows pointing in different directions have a RESPIRATORY abnormality.

Comp. Respiratory Acidosis		**Comp. Metabolic Alkalosis**	
ABG #1		**ABG #2**	
PaO2:	75	PaO2:	89
pH:	↓7.36	pH:	↑7.41
PaCO2:	↑50	PaCO2:	↑52
HCO3:	↑30	HCO3:	↑31

Comp. Metabolic Acidosis		**Comp. Respiratory Alkalosis**	
ABG #3		**ABG #4**	
PaO2:	90	PaO2:	93
pH:	↓7.36	pH:	↑7.44
PaCO2:	↓29	PaCO2:	↓27
HCO3:	↓18	HCO3:	↓16

PRACTICE PROBLEMS

1. J.K. is a 71 year old male with a history of a myocardial infarction and subsequent CABG two years ago. He was admitted to the emergency department this evening with SOB as his chief complaint. He is prescribed digoxin, lasix, potassium, and coumadin, but hasn't taken any of his medicines since he ran out a week ago. He is severely dyspneic. On auscultation, you hear crackles throughout his lungs as well as an S3 gallop. You suspect that he is having an exacerbation of CHF. His ABG's are shown below. How would you interpret them?

PaO2: 68
pH: 7.21
PaCO2: 52
HCO3: 23

2. H.M. is a thirty year old male who has been admitted for depression and attempted suicide. He is awake, alert, and oriented, but appears withdrawn. He admits to taking 12-15 acetaminophen tablets about three hours ago. He denies any pain or shortness of breath. You have started two large-bore IV's and are about to insert a nasogastric tube. His ABG results have just returned. How would you interpret them?

PaO2: 93
pH: 7.42
PaCO2: 37
HCO3: 24

3. T.L. is a 34-year old female who complains of abdominal cramping, severe vomiting and diarrhea for four days. She denies seeing any bright red blood or coffee-ground material in her vomitus. She has a fever of 102.1 and her heart rate is 108. An IV has been started and the physician plans to admit her overnight for rehydration. She states that her husband had similar symptoms over a week ago.You have received her ABG results. How would you interpret them?

PaO2: 98
pH: 7.56
PaCO2: 40
HCO3: 32

4. O.C. is a 62 year-old male with emphysema. He has smoked cigarettes for over 40 years. He was admitted to ICU for severe SOB. While obtaining an admission history he comments that he is always short of breath, but that it became much worse about six hours ago. On his chart are the ABGs that were drawn on room air in the emergency department. How would you interpret them?

PaO2: 82
pH: 7.36
PaCO2: 56
HCO3: 29

5. J.H. is a 49 year-old female who collapsed at home after a brief period of confusion. She was intubated by paramedics on the scene and rushed to the hospital. A CT scan was obtained and it revealed a cerebral aneurysm. J.H. has just been placed on a ventilator with an FiO2 of 50%, tidal volume of 650ml, and a rate of 24. Her ABG's are shown below. How would you interpret them?

PaO2: 85
pH: 7.50
PaCO2: 21
HCO3: 25

6. N.K. is a thirty year-old male diagnosed with pancreatitis. His chief complaint on arrival was severe abdominal pain and vomiting. He has a nasogastric tube to intermittent suction. You notice that over the past two days previous nurses have documented gastric output that totalled over 2 liters. The results of his morning ABG's are shown below. How would you interpret them?

PaO2: 100
pH: 7.61
PaCO2: 42
HCO3: 35

7. G.B. is a 42 year-old executive who complains of intermittent nausea and abdominal pain for the past two months. He has recently noticed that his stools have appeared tarry and black. He states that he is under a great deal of stress at work. He has no other medical history. He takes no prescription medications, but has been taking between twenty and forty antacid tablets a day in an attempt to relieve his symptoms. His ABG results are shown below. How would you interpret them?

PaO2: 95
pH: 7.44
PaCO2: 62
HCO3: 32

8. R.E. is a 72 year-old female who was diagnosed with pneumonia and admitted to the hospital a week ago. She has had a persistent high-grade fever. Her temperature now is 103.2. Her heart rate is 99 and her respirations are 28. The physician ordered ABG's and the results are shown below. How would you interpret them?

PaO2: 92
pH: 7.43
PaCO2: 28
HCO3: 13

9. F.D. is a 58 year-old male who suddenly collapsed at home. He was found to be in ventricular fibrillation when the paramedics arrived. He was successfully defibrillated and intubated on the scene. En route to the emergency department, he went into ventricular fibrillation again. This time, however, defibrillation attempts were unsuccessful. At one point during the code, after arriving at the hospital, a pulse was obtained and ABG's were immediately drawn. The results are shown below. How would you interpret them?

PaO2: 60
pH: 7.04
PaCO2: 62
HCO3: 23

10. D.K. is a 34 year-old chronic renal failure patient awaiting transplant. He was admitted to the hospital with right lower lobe pneumonia, malaise and severe anemia. His ABG results are shown below. How would you interpret them?

PaO2:	89
pH:	7.22
PaCO2:	38
HCO3:	18

ANSWERS

1. Hypoxic respiratory acidosis. J.K. has a PaO2 less than 80, which indicates he is hypoxic. Also, he has a pH less than 7.35, a PaCO2 greater than 45, and a normal HCO3, which all indicate respiratory acidosis. Congestive heart failure limits the ability of the lungs to effectively exchange gases. This leads to a decrease in the PaO2 and an increase in the PaCO2.

2. Normal. All of H.M.'s ABG values are normal. By itself, acetaminophen is not associated with changes in the pH, but respiratory acidosis and hypoxia may occur in cases severe enough to cause respiratory depression or coma.

3. Metabolic alkalosis. T.L.'s ABG values exhibit a pH higher than 7.45, a normal PaCO2, and an HCO3 higher than 26, which is indicative of metabolic alkalosis. This corresponds well with her symptoms of prolonged vomiting and diarrhea. Vomiting and diarrhea are associated with a loss of electrolytes leading to alkalosis.

4. Compensated respiratory acidosis. O.C. suffers from a chronic obstructive respiratory disorder that reduces the ability of the lungs to exchange gases effectively. Because of this, the PaCO2 is elevated and the PaO2 approaches the level of hypoxia. Because the condition progresses over a great length of time, the body has time to compensate and return the pH back to normal by elevating the HCO3 level.

5. Respiratory alkalosis. J.H. is diagnosed with respiratory alkalosis as evidenced by the pH greater than 7.45, a PaCO2 less than 35, and a normal HCO3. In this instance, the alkalosis may have been induced intentionally. J.H. suffered a cerebral aneurysm. Since an elevated carbon dioxide level can exacerbate cerebral swelling, mandating a higher respiratory rate on the ventilator can help eliminate carbon dioxide and decrease the potential for further damage. It should be noted, however, that the PaO2, although not technically considered hypoxic, is dangerously low. In this case, the ventilator may need to be adjusted accordingly.

6. Metabolic alkalosis. N.K.'s ABG indicates metabolic alkalosis as evidenced by the pH higher than 7.45, normal $PaCO_2$, and elevated HCO_3. The alkalosis is probably due to the massive loss of electrolytes from vomiting and nasogastric related to the pancreatitis.

7. Compensated metabolic alkalosis. G.B.'s ABG indicates compensated metabolic alkalosis as evidenced by the pH between 7.40 and 7.45, a $PaCO_2$ greater than 45, and an HCO_3 greater than 26. This is probably due to the fact that G.B. has been taking large amounts of an alkaline substance to relieve symptoms of an ulcer. To counteract the effect of the antacids on his pH, G.B.'s body has responded by increasing the $PaCO_2$ level.

8. Compensated respiratory alkalosis. R.E.'s ABG tells you that a compensated respiratory alkalosis is present. Although pneumonia is a condition that is sometimes associated with acidosis due to its effects on the respiratory system, the alkalosis is probably present due to R.E.'s prolonged fever.

9. Hypoxic respiratory acidosis. F.D.'s ABG results indicate a severe hypoxic respiratory acidosis. This is the effect expected of cardiopulmonary arrest. When respirations cease, $PaCO_2$, which is normally eliminated through respiration, builds up in the body, causing acidosis.

10. Metabolic acidosis. D.K.'s ABG results exhibit metabolic acidosis as evidenced by a pH less than 7.35, a normal $PaCO_2$, and an HCO_3 less than 22. Metabolic acidosis is a frequent complication of chronic renal failure.