Lesson Plan: Acid Base Balance and ABG Interpretation

West Michigan Regional Medical Consortium

Topic:	Acid Base Balance and ABG Interpretation
Presenter:	Nicholas McManus, DO FAAEM
Location:	https://wmrmcc.thinkific.com/courses/acid-base
Credit Category:	Preparatory
License Level:	Paramedic
Credits:	1
Format:	1 hour lecture

Objectives: Upon completion of this CE, the participants will be able to:

Cognitive

1. Define acid-base balance and blood gas analysis.
2. Identify treatments for abnormal values based on findings.
3. Discuss perfusion and how it is affected by acidosis or alkalosis.
4. Identify respiratory acidosis/alkalosis and causes.
5. Identify metabolic acidosis/alkalosis and causes.
6. Discuss blood gas physiology.
7. Discuss assessment of perfusion.

Outline for Presentation:

1. **ACID-BASE BALANCE AND BLOOD GAS ANALYSIS**
    a. Definitions
        i. The body pH is strictly regulated within a narrow range of **7.35 and 7.45**
        ii. **Acidosis (< 7.35)** = accumulation of acids → decrease in blood pH
        iii. **Alkalosis (> 7.45)** = accumulation of a base → increase in blood pH
        iv. **Acidemia** = term used when describing a blood pH < 7.35
        v. **Alkalemia** = term used when describing a blood pH > 7.45
        vi. *It is possible to have a mixed process resulting in both an acidosis and an alkalosis*
    b. Physiology
        i. Even minor changes in pH can have devastating effects on protein stability and many biochemical processes.
        ii. Normal cellular metabolism constantly produces and excretes CO_2 into the blood.
        iii. **Buffer System**
            1. **CO_2 + H20 ←→ H_2CO_3 ←→ HCO_3^- + H^+**
            2. This process is in an equilibrium, meaning all components of the left and right sides co-exist at all times and the concentration of any component

is determined by the concentration of the components on the other side of the equation.

3. So, if there is an increase in the concentration of any component on one side, will shift the equation to the other side, leading to an increase in the concentration of all components on that side.
4. This equation is paramount in your understanding of acid base regulation in the body.
5. Continuous Carbon dioxide production by cells within the body drives the equilibrium to the right, resulting in the production of more hydrogen ions.
6. pH is a function of hydrogen ion concentration.
7. More hydrogen = higher acidity and lower pH.
8. Under normal ongoing metabolism, the blood is constantly being made more acidic.
9. The body compensates to keep blood pH at a steady state.
10. There are 2 mechanisms by which this is achieved:
    a. Lungs
        i. A decrease in central and arterial chemoreceptors leads to deeper and faster respirations and CO_2 is eliminated through expired air → less hydrogen is made → blood pH returns to normal.
        ii. This mechanism is fast, occurring in minutes to hours.
    b. Kidney
        i. Bicarbonate is reabsorbed, and Hydrogen ions are excreted in the urine.
        ii. The kidney controls blood pH by regulating the amount of hydrogen ion secretion and the amount of bicarbonate reabsorption.
        iii. This mechanism is slow, taking days to respond and compensate for changes in pH

c. Respiratory Acidosis

i. Due to retention of CO2 secondary to hypoventilation.

ii. Causes
1. Primary lung disorders decreasing perfusion at the alveoli
2. Respiratory depression from medications, neuromuscular or neurodegenerative diseases as well as with aggressive breath holding.

iii. Symptoms
1. Depressed mental status from CO_2 narcosis.

iv. Metabolic Compensation
1. Occurs at the kidney, which conserves more filtered bicarbonate

2. By adding new bicarbonate into circulation and by excreting more hydrogen ions.
3. Other smaller chemical buffer systems also assist taking up hydrogen ions, to take it out of circulation.

v. Treatment
1. Treat the underlying cause
2. NIPPV to help drive off CO_2

d. Respiratory Alkalosis

i. Due to a loss of CO_2 due to hyperventilation.

ii. Causes
1. Fever
2. Anxiety
3. Hyperventilation
4. High altitude with lower partial pressure of oxygen concentrations
5. As a respiratory compensation for a metabolic acidosis, such as aspirin poisoning

iii. Symptoms
1. Tachypnea, dizziness, confusion and seizures - *due to vasoconstriction from raised pH.*

iv. Metabolic compensation includes a
1. Decrease in bicarbonate reabsorption
2. Less hydrogen wasting at the kidneys
3. Release of hydrogen ions from other smaller chemical buffer systems.

v. Treatment
1. Slow the ventilatory rate.
2. If the patient is hyperventilating, reassuring the patient and letting the patient breath into a paper bag may help.
3. If the patient is on a ventilator, the breath rate can be turned down resulting in less CO_2 loss at the lungs.

e. Metabolic Acidosis

i. Due to a reduction in the plasma bicarbonate levels.

ii. Causes
1. Secondary to diarrhea
2. Due to consumption of other metabolic processes such as DKA with ketoacid formation, lactic acidosis from seizure or exercise.

iii. Symptoms
1. Kussmaul's respirations - deep, slow and irregular respirations
2. Tachypnea

iv. Respiratory Compensation
1. Tachypnea – an attempt to increase the respiratory rate and blow off more CO_2

v. Metabolic Compensation
   1. Kidneys excrete more hydrogen ions and conserving more bicarbonate.

vi. Treatment
   1. Treat the underlying cause
   2. Sodium Bicarbonate may be given if the pH falls below **6.9**

f. Metabolic Alkalosis

i. Caused by an increase in Plasma bicarbonate WITHOUT change in CO_2

ii. Causes
   1. Vomiting with loss of HCl
   2. Diarrhea with loss of colonic secretions
   3. Certain medications.

iii. Symptoms
   1. Weakness
   2. Neuralgias
   3. Altered mental status
   4. Seizures.

iv. Respiratory Compensation
   1. Decrease in the respiratory rate to retain more CO_2

v. Metabolic Compensation
   1. Kidneys conserve more hydrogen ions and excrete more bicarbonate

vi. Treatment
   1. Treat the underlying cause
   2. Potassium is likely to be low in patients with vomiting and diarrhea and should be replaced
   3. Hydrochloric acid can potentially be given for severe alkalosis, and possibly with dialysis where a low bicarbonate dialysate is used

g. Blood Gas Physiology

i. Alveoli
   1. As air is inspired into the lung and down the trachea, bronchi and bronchioles, it eventually ends up at the Alveoli where the gas exchange occurs.
   2. pAO_2 is about **100 mmHg**
   3. $pACO_2$ is about **40 mmHg**

ii. Pulmonary Artery
   1. The pulmonary arteries carry deoxygenated blood from the heart to the pulmonary capillary beds where gas exchange occurs.
   2. pAO_2 is about **40 mmHg**
   3. $pACO_2$ is about **46 mmHg**
   4. The higher partial pressure of carbon dioxide in the pulmonary artery in comparison to the lower partial pressure of carbon dioxide in the

alveolus, favors movement of CO_2 down its concentration gradient and into the alveoli

5. Oxygen will also move from an area of higher concentration to an area of lower concentration, and this favors the movement of oxygen from the Alveolus and into the pulmonary capillaries.

iii. Pulmonary Vein

1. pAO_2 is about **100 mmHg**
2. $pACO_2$ is about **40 mmHg**
3. The pulmonary vein then pumps blood back to the heart, and it is then subsequently pumped via systemic arteries to target tissue.

iv. Target Tissue

1. pAO_2 is < **40 mmHg**
2. $pACO_2$ is > **46 mmHg**
3. Again, oxygen will move down its concentration gradient from an area of higher concentration to an area of lower concentration, and oxygen will move into the tissue
4. CO_2 will move down its concentration gradient from an area of higher concentration in the tissue, to an area of lower concentration in the capillary bed.

h. ABG Interpretation

i. **ABG Components**

1. **pH** - tells us if there is an acidotic or an alkalotic process going on.
2. **pCO_2** - tells us if the issue is the fault of the respiratory system.
3. **pO_2** - tells us if the patient has adequate oxygenation.
4. **HCO_3^-** - tells us if there pH imbalance is a metabolic issue.
5. **SpO_2** - another assessment of oxygenation, but much more prone to erroneous readings.
6. **Base Excess** - another way of measuring the metabolic component as it contributes to pH homeostasis.
   a. Normal Range: + 2 to – 2
   b. +2 means there is a lot of base present, favoring an alkalotic process, or compensation in the direction of an alkalotic process.
   c. – 2, means there is the lack of base within the blood that is available to participate in the buffer system.

ii. Buffer System Review

1. **$CO_2 + H20 \leftrightarrow H_2CO_3 \leftrightarrow HCO_3^- + H^+$**
2. 2 mechanisms by which this is achieved:
   a. Lungs
      i. A decrease in central and arterial chemoreceptors leads to deeper and faster respirations and CO_2 is eliminated

through expired air → less hydrogen is made → blood pH returns to normal.

ii. This mechanism is fast, occurring in minutes to hours.

b. Kidney

i. Bicarbonate is reabsorbed, and Hydrogen ions are excreted in the urine.

ii. The kidney controls blood pH by regulating the amount of hydrogen ion secretion and the amount of bicarbonate reabsorption.

iii. This mechanism is slow, taking days to respond and compensate for changes in pH

iii. ABG Interpretation Steps:

1. **Step 1**: Give it a last name
   a. The pH will give you this
   b. Is it acidosis or an alkalosis. Is the pH up or down.
2. **Step 2**: Give it a first name
   a. Which part of the buffer system is broken and who can we blame for the abnormal pH.
   b. Important: Use the HCO_3 or CO_2 off of the Basic Metabolic Panel (venous specimen) not the actual ABG for this part.
      i. CO2 combines with water to give carbonic acid, which quickly dehydrates to bicarbonate and hydrogen ions. So, a measurement of bicarbonate is also a measurement of total body CO2. Do not confuse this with the partial pressure of dissolves Carbon dioxide gas that is measured on the ABG. Don't overthink this part. For now, just know that the pCO2, or partial pressure of carbon dioxide indicates respiratory involvement, and an elevation favors acidic Hydrogen ion formation where the CO2 on the venous drawn basic metabolic panel is the bicarbonate measurement, indicates metabolic involvement, and an elevation favors a basic environment with more bicarbonate.
   c. Always start by looking at the pCO2 FIRST.
      i. Is the pCO2 abnormal, and does it fit with the pH?
         1. If YES, the PRIMARY issue is the fault of the respiratory system
            a. Respiratory Acidosis = low pH and a high pCO2
            b. Respiratory Alkalosis = high pH is high and the low pCO2

2. If NO, THE PRIMARY issue is the fault of the metabolic system
    a. Look at the bicarbonate
    b. Metabolic alkalosis = high pH with a high HCO_3^-
    c. Metabolic Acidosis = low pH and a low HCO_3^-
3. *ROME: Respiratory Opposite and Metabolic Equal*

3. **Step 3**: determine if compensation is present.
    a. Once you determine if the primary problem is respiratory or metabolic, look at the other value (the pCO_2 or HCO_3) that is not part of the primary problem.
    b. Is it within normal limits, or is it abnormal?
    c. If it is abnormal, does it move in the opposite direction that you would expect for the pH?
    d. If so, there is compensation by that system.
4. **Step 4**: ensure that the paO_2 and SpO_2 is adequate and not abnormal.
    a. Deoxy-hemoglobin dissociation curve.
        i. *Shift to the left*
            1. You won't see a drop in the pulse oximetry reading until the oxygen concentration in the blood is extremely low.
            2. Causes: High pH, alkalosis, hypothermia
        ii. Shift to the right
            1. Higher concentration of O_2 in the blood at the time the pulse Oximeter reading starts to fall.
            2. Causes: low pH and hyperthermia.
    b. RBC Physiology
        i. Hemoglobin
            1. 4 subunits (2 alpha and 2 beta)
            2. Each subunit contains a Heme group
            3. An oxygen or carbon dioxide molecule can bind to each of these heme compounds
        ii. **Met-hemoglobin**
            1. Contains Fe_3^+ → cannot bind O_2
            2. *Causes: nitrates found in foods, or medications such as lidocaine, sulfonamides, dapsone, benzocaine, pyridium and nitrates can cause a higher concentration of methemoglobin.*

3. *Causes a change in the Hgb protein → causes the normal heme groups to have a much higher affinity for oxygen → cannot release bound* O_2
4. SpO_2 will tend to read in the mid 80's as this is measuring the amount of oxygen being transported around in the blood.
5. Though, the patient can look profoundly cyanotic. This is because the oxygen that is present in the blood, is not able to be released from the red blood cells at target tissues, so the patient gets cyanotic despite a modest decrease in SpO2.
6. Treatment:
    a. Methylene blue

iii. Carbon Monoxide

1. CO molecules can also bind to the heme sites on the hemoglobin protein.
2. This forms a much more stable complex with the heme group than oxygen does
3. SpO_2 will still read normal as all heme sites still occupied
4. Treatment:
    a. High flow O_2 in hopes to outnumber the CO molecules and regain their sites on the RBCs

c. Assessment of perfusion

i. Hypoxemia:
1. determined by PaO_2
2. Low oxygen concentration measures in a blood sample.

ii. Hypoxia
1. determined by SpO_2
2. Low concentration of delivered oxygen to tissue.

iii. We can use these two readings to determine if perfusion is adequate.

iv. PaO2 = FiO_2 X 5.5
1. *I typically just use 5, as it will get you close enough and easier to calculate in my head.*
2. FiO2 is the concentration of oxygen in the air we breathe.

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3. Normal room air is made up of 21% oxygen. So if we multiply 21 x 5, we get 105. So, a normal PaO2 in someone breathing room air is about 105 mmHg.
4. Determining FiO_2
   a. Room air 21
   b. Nasal Cannula
      i. 1 L = 24
      ii. 2 L = 28
      iii. 3 L = 32
      iv. 4 L = 36
      v. 5 L = 40
      vi. 6 L = 44
   c. Face Mask
      i. 6 L = 35
      ii. 7 L = 41
      iii. 8 L = 47
      iv. 9 L = 53
      v. 10 L = 59
   d. Non-Rebreather
      i. Add 10% for every Liter of flow
   e. Venti mask
      i. FiO2 is dependent on the adapter piece and the flow rate.

Outline for Presentation:

1. Introductions and Overview of Course
2. Definitions
3. Buffer System
4. Respiratory Acidosis/Alkalosis
5. Metabolic Acidosis/Alkalosis
6. Blood Gas Physiology
7. ABG Interpretation steps
8. Assessment of perfusion
9. Summary
10. Quiz

Student Evaluation Method: Quiz to be completed at end of course with an 80% or better for course completion.

Evaluation of Presentation: Continuing Education Program Sponsor Evaluation Form will be filled out by all participants.