**ABG *Rush***

**Reference Room**

***What is the power of Hydrogen (pH)?***

Plasma pH (N= 7.35-7.45) is an indicator of the hydrogen ion (H+ )concentration in the blood stream. The concentration of hydrogen in arterial blood is extremely important for determining acid-base balance because it tells about the acidity (acidosis) or alkalinity (alkalosis) of the blood. As the concentration of H+ goes up, the pH value goes down (<7.35) and the blood becomes more acidic (acidosis). In reverse, as the concentration of H+ goes down, the pH value goes up (>7.45) and the blood becomes more alkaline (alkalosis).

Maintaining homeostasis is a complex balancing act that depends upon every organ in the body. The homeostatic mechanisms, or internal self-regulating processes, that maintain a state of equilibrium in the body consist of buffer systems, the lungs and the kidneys.

When interpreting ABG results, always begin by deciding if the patient is within the normal ranges of acid – base balance (pH = 7.35-7.45). An abnormal condition is occurring when too many acids are being produced (pH < 7.35). The body responds by allowing more base to accumulate. There is an abnormal condition occurring when too many bases are being produced (pH > 7.45). The body responds by allowing more acids to accumulate. For whatever reason, when the normal ratio between bicarbonate (20 parts) and carbonic acid (1 part) is disrupted, pH changes.

The normal range for pH is 7.35 – 7.45.

When the body responds to changes in acid-base balance, or attempts to maintain homeostasis, it is called compensation. Plasma pH values, carbonic dioxide and bicarbonate levels give us clues about the changes and compensation for the changes but we will get to that after ***What is CO2***and ***What is HCO3-.***

***What is carbon dioxide (CO2)?***

Carbon dioxide is a gas produced in the body as a bi-product of metabolism. When dissolved in water, carbon dioxide becomes carbonic acid. An excess of carbonic acid in the body creates an acidotic state. The lungs regulate carbon dioxide gas by adjusting the rate and depth of ventilation. With too much carbon dioxide (>45mEq/L), ventilation increases to blow off excess CO2. When there is too little carbon dioxide, (<35mEq/L), ventilation slows to retain the CO2.

CO2 values obtained from arterial blood are an indicator of the carbon dioxide in the blood. If the CO2 is >45mEq/L, then the blood becomes more acidotic. In reverse, if the CO2 is <35mEq/L, then the blood will become more alkaline. The lungs can regulate the level of CO2 by increasing or decreasing the rate and depth of respirations.

The normal range is 35mEq/L to 45mEq/L of CO2.

***What is Bicarbonate (HCO3-)?***

Bicarbonate is a salt and the most important buffer in the blood regulated by the kidney. Normal HCO3- values range from >22mEq/L to < 26 mEq/L, which is the measure of the level of bicarbonate in the blood stream. The body’s major extracellular buffer system is the bicarbonate-carbonic ***acid buffer*** system. The amount of bicarbonate generated by this system, or lack thereof, is assessed when measuring arterial blood gases. The kidneys can reabsorb and excrete in urine bicarbonate ions if there is too much (>26 mEq/L) and the blood is in an alkaline state or the kidneys can regenerate and retain bicarbonate ions if there is too little (< 22mEq/L) and the blood is acidic state.

If the normal ratio between bicarbonate (20 parts) and carbonic acid (1 part) is disrupted, the pH will change.

The normal range is 22mEq/L to 26 mEq/L of ***HCO3-.***

***Respiratory Acidosis (Carbonic Acid Excess)***

Respiratory acidosis is an abnormal condition that occurs when the pH of the blood is less than 7.35 and the CO2 is greater than 45mEq/L. Respiratory acidosis is always the result of inadequate excretion of CO2 with inadequate rate and/or volume of ventilation, causing an increase in carbonic acid. The main cause of respiratory acidosis is hypoventilation (volume or depth of respiration) resulting from conditions that impair respiratory drive (toxins – sedative overdose or CNS disease) and airflow obstruction (sleep apnea, asthma, COPD, pneumonia, airway edema). The lungs will compensate by increasing the rate and depth of respirations to decrease or blow off the excess CO2. The kidney is the most powerful compensatory mechanism but is slow in its rescue efforts. Over 3 – 5 days the kidneys will significantly increase HCO3- reabsorbtion to achieve a 20 – 1, HCO3- to carbonic acid ratio for homeostasis.

Early signs and symptoms of respiratory acidosis are headache, anxiety, irritability, blurred vision and restlessness, tachycardia, and hypoxia. Without treatment, other symptoms can occur such as sleepiness, tremors, delirium and eventually coma.

Treatment is to provide adequate ventilation, deep breathing & coughing, positioning, chest physiotherapy, suctioning, oxygen as indicated, hydration, medications as indicated and to treat the cause.

***Respiratory Alkalosis (Carbonic Acid Deficit)***

Respiratory alkalosis is an abnormal condition that occurs when the pH of arterial blood is greater than 7.45 and the CO2 is less than 35mEq/L. Respiratory alkalosis is always caused by hyperventilation which results in an excessive “blowing off” of CO2. Blowing off CO2 decreases the amount of carbonic acid that can be produced thereby lowering the acidity of the blood. The most common conditions that can result in respiratory alkalosis are panic attacks and anxiety but other abnormal conditions such as pain, drug overdose, the early phase of salicylate poisoning, fever, infection, brain injury, and hypoxia can cause hyperventilation and respiratory alkalosis. Pregnancy may also cause respiratory alkalosis.

Signs & symptoms of respiratory alkalosis are dyspnea, xerostomia, dizziness, lightheadedness, numbness and tingling, inability to concentrate, heart palpitations, tachycardia, heart arrhythmias and sometimes loss of consciousness.

Treatment for respiratory alkalosis is directed at the underlying cause. Respiratory alkalosis caused by anxiety or a panic attack can be treated by having the patient breathe more slowly or into a paper bag, providing reassurance and restricting oxygen intake by with pursed-lip breathing or breathing through one nostril.

***Metabolic Acidosis (Base Bicarbonate Deficit)***

Metabolic acidosis is an abnormal condition that occurs when the pH of arterial blood is less than 7.35 and the HCO3- concentration is less than 22 mEq/L. The condition begins in the kidneys when either they cannot eliminate enough acid (diabetic ketoacidosis, starvation, the late phase of salicylate poisoning, and methanol [wood alcohol] or ethylene glycol [antifreeze] poisoning, alcohol use, heart failure, dehydration or prolonged exercise) or when they eliminate too much bicarbonate (diarrhea, vomiting, diuretic therapy, or renal failure). The lungs will attempt to compensate with deep rapid respirations to eliminate CO2 and decrease carbonic acid production and the kidneys will excrete acidic urine with more Hydrogen ions.

Signs and symptoms of metabolic acidosis are deep rapid respirations, confusion, fatigue, headache and sleepiness, lack of appetite, nausea and vomiting, and fruity breath (diabetic acidosis/ketoacidosis). Physical assessment findings include low blood pressure, cold, clammy skin, arrhythmias and shock.

Treatment for metabolic acidosis is directed at treating the underlying cause and correcting fluid and electrolyte disturbances.

***Metabolic Alkalosis (Base Bicarbonate Excess)***

Metabolic alkalosis is an abnormal condition that occurs when the pH of arterial blood is greater than 7.45 and the HCO3- concentration is greater than 26 mEq/L. The most common cause of metabolic alkalosis is diuretic therapy but nearly any condition in which the patient becomes hypokalemic may cause metabolic alkalosis. Another common cause of metabolic alkalosis is fluid volume losses from vomiting or gastric suctioning resulting in excess losses of hydrogen ions. Excessive steroid use may cause metabolic alkalosis and excessive ingestion of antacids containing sodium bicarbonate (Maalox, Milk of Magnesia, Pepto-Bismol, Rolaids, Tums, Mylanta) can also cause metabolic alkalosis. The lungs will compensate by decreasing the rate and depth of respirations resulting in a CO2 >45mEq/L, and the kidneys will excrete alkalotic urine with more HCO3- ions.

Symptoms of metabolic alkalosis are not specific. Because hypokalemia is often present with metabolic alkalosis, there may be weakness, myalgia, polyuria, and cardiac arrhythmias.

Treatment for metabolic alkalosis depends upon the underlying cause and correcting fluid and electrolyte disturbances.

***What is compensation?***

The pulmonary and the renal systems work together (compensate for each other) to keep the pH within the normal range (7.35 – 7.45). To explain, think of the lungs and the kidneys as business partners whose job is to maintain their work relationship at a 20 – 1 ratio. As you recall, a 20 – 1 ratio, bicarbonate to carbonic acid, keeps pH on task and within the normal range. When there is full compensation one of the partners (lungs or kidneys) has fully compensated for the other by maintaining the 20 – 1 ratio and therefore keeping the pH within a normal range. For example, fully compensated respiratory acidosis would look something like this, and *this* is arbitrary – do not try to figure out if the ratio is accurate since that is well beyond the scope of this reference tip!

pH 7.38CO2 50 HCO3- 30

The pH is normal but the CO2 value tells us that the patient is acidotic and that the acidosis is in some way related to the pulmonary system. More information about the patient would inform us what the problem might be, for example asthma or a sedative overdose. Fortunately, CO2’s partner HCO3- is working very hard to maintain the 20 -1 ratio and has been successful enough to keep pH within the normal range. Therefore, the patient is in respiratory acidosis and is ***fully compensating*** for the acid-base imbalance which is being caused by some abnormal respiratory condition.

On the other hand, if HCO3- had been a slacker or had not quite gotten up to speed, the pH would be less than 7.35 (acidotic) and we would say that the patient is in respiratory acidosis and is ***partially compensating*** for the acid – base imbalance. The ABG results would look something like this:

pH 7.31CO2 50 HCO3- 30

The same principle applies to a metabolic imbalance but in that case the bicarbonate informs us that a metabolic condition exists. Therefore, the CO2 would be compensating/partially compensating for HCO3-.

The chart below may be helpful in seeing the number values associated with each imbalance but the numbers are only one part of the picture. The signs and symptoms a patient reports or exhibits are essential for understanding the patient’s condition and deciding upon the medical and nursing care management.

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| **Respiratory Acidosis** | **pH** | **CO2** | **HCO3-** |  | **Metabolic Acidosis** | **pH** | **CO2** | **HCO3-** |
| Uncompensated | < 7.35 | > 45 | Normal |  | Uncompensated | < 7.35 | Normal | < 22 |
| Partially Compensated | < 7.35 | > 45 | > 26 | Partially Compensated | < 7.35 | < 35 | < 22 |
| Compensated | Normal | > 45 | > 26 | Compensated | Normal | < 35 | < 22 |
|  | | | |  |  | | | |
| **Respiratory Alkalosis** | **pH** | **CO2** | **HCO3-** |  | **Metabolic Alkalosis** | **pH** | **CO2** | **HCO3-** |
| Uncompensated | > 7.45 | < 35 | Normal |  | Uncompensated | > 7.45 | Normal | > 26 |
| Partially Compensated | > 7.45 | < 35 | < 22 | Partially Compensated | > 7.45 | > 45 | > 26 |
| Compensated | Normal | < 35 | < 22 | Compensated | Normal | > 45 | > 26 |

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| **Respiratory Acidosis** | **pH** | **CO2** | **HCO3-** |  | **Metabolic Acidosis** | **pH** | **CO2** | **HCO3-** |
| Uncompensated | -2 | -2 | 0 |  | Uncompensated | -2 | 0 | -2 |
| Partially Compensated | -2 | -2 | 2 | Partially Compensated | -2 | 2 | -2 |
| Compensated | -1 | -2 | 2 | Compensated | -1 | 2 | -2 |
|  | | | |  |  | | | |
| **Respiratory Alkalosis** | **pH** | **CO2** | **HCO3-** |  | **Metabolic Alkalosis** | **pH** | **CO2** | **HCO3-** |
| Uncompensated | 2 | 2 | 0 |  | Uncompensated | 2 | 0 | 2 |
| Partially Compensated | 2 | 2 | -2 | Partially Compensated | 2 | -2 | 2 |
| Compensated | 1 | 2 | -2 | Compensated | 1 | -2 | 2 |