ACID BASE BALANCE

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Introduction

❖ **The major physiological function of the body is maintenance of homeostasis. The biological and chemical processes that are constantly occurring in our bodies depend on having a consistent environment in which to work.**

❖ **Homeostasis is the body's system for maintaining that consistency. An important and integral goal of homeostasis is acid-base regulation.**

The chemical reactions within our bodies only function within a narrow pH range. Diseases can effect this range causing a multitude of problems. It is vital that emergency responders understand the mechanisms we use to maintain this balance.

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❖ **Maintenance of acid-base homeostasis is a vital function of the living organism. Deviations of systemic acidity in either direction can impose adverse consequences and when severe can threaten life itself.**

❖ **Effective management of acid-base disturbances, commonly a challenging task, rests with accurate diagnosis, sound understanding of the underlying pathophysiology and impact on organ function, and familiarity with treatment and attendant complications .**

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ACID-BASE

- Maintenance of the internal environment in a state of dynamic equilibrium requires that the acid base balance be maintained within the optimal physiologic range (pH7.35-7.45).
- Any deviation from this range can seriously disrupts enzymatic catalysis of intracellular chemical reaction and vital electrochemical process critical to nerve conduction synaptic transmission and muscle contraction.

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PHYSIOLOGY

- The body is composed of several systems; each composed of organs made of different types of tissue that are, in turn, composed of individual cells.

Each cell needs energy and has its own internal mechanisms for meeting those needs. As cells use nutrients to produce energy, they produce byproducts. Two of these byproducts effecting acid-base balance are carbon dioxide (CO_2) and hydrogen (H^+).

- The key to regulating pH is in regulating hydrogen ion concentration. The levels of hydrogen in the body make a tremendous impact on the ability to maintain homeostasis. Maintenance of these levels is what regulation of acid-base balance is all about.

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WHAT IS ACID-BASE BALANCE

- **Acid-base balance is defined by the concentration of hydrogen ions.**

- **In order to achieve homeostasis, there must be a balance between the intake or production of hydrogen ions and the net removal of hydrogen ions from the body.**

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DEFINITION OF TERM

❖Define the PH.

- The PH of solution is a measure of its hydrogen ion concentration.
- Specifically PH reflects the negative logarithm of the hydrogen ion - log $[H^+]$.
- 7 is neutral

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THE PH AND H CONCENTRATION ARE INVERSELY RELATED:

- As the H+ ion concentration increased, the PH decreased.
- As the H+ ion concentration decreased, the PH increased.
- A Low pH indicates the solution is more acidic.
- A high pH indicates the solution is more alkaline.

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An Acid

- Is a substance that can donate or contribute H ions.
- Molecules containing hydrogen atoms that can release hydrogen ions in solutions are referred to as an acid.
- An example of an acid is hydrochloric acid (HCL)
- Any substance releasing H^+
- H+ concentration increases (pH decreases)

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A Base

- Is a substance that can **accept** or **combine** with **H** ions to **remove** these ions from a solution.
- A base is an ion that can **accept** a hydrogen ion.
- An example of a base is the bicarbonate ion.**(HCO3)**
- Any substance **accepting H^+**
- **H+ concentration decreases (pH increases)**

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How is Acid-Base balance measured

- Hydrogen ion concentration is expressed on a logarithm scale using pH units (part/percentage hydrogen).
- 7.0 being neutral
- Body systems carefully control pH of the body within the range (7.35-7.45)

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pH

- A low pH corresponds to a high hydrogen ion concentration
- The term "Acidosis" refers to the addition of excess hydrogen ions and the body has a pH that falls below 7.35
- A high pH corresponds to a low hydrogen concentration
- The term "Alkalosis" refers to excess removal of hydrogen ions from the body and has a pH that rises above 7.45

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WHY IS ACID-BASE BALANCE IMPORTANT?

- Metabolism requires numerous enzymes
- Enzymes are proteins
- pH affects protein structure
- Protein structure affects function
- Deviations from normal pH can inactivate enzymes and shit down metabolic pathways

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ACID-BASE BALANCE

- **BLOOD pH**
  - **Blood and tissue pH 7.35 – 7.45**
  - **Enzymes function well within this range**
  - **Enzymes function poorly (or not at all) when significantly outside this range**
  - **This range must be maintained**
  - **Acid-Base balance**

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HOW THE BODY DEFENDS AGAINST FLUCTUATIONS IN PH

Three Systems in the body:

1. **Buffers in the blood**
2. **Respiration through the lungs**
3. **Excretion by the kidneys**

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BUFFER SYSTEMS

- **BUFFERS** Any mechanism of resistant significant changes in pH Accomplished by converting:
- Strong acid → Weak acid
- Strong base → Weak base
- Buffer systems prevent major changes in the pH of body fluids by removing or releasing H, they can act quickly to prevent excessive changes in H concentration.
- H ions are buffered by both intracellular and extracellular, the major extracellular is the bicarbonate (HCO_3)-carbonic acid (H_2CO_3) buffer system.

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- **Normal (ABG): 20 part of HCO_3 : 1 part of H_2CO_3, if this ratio is altered, the pH will change.**

- **Carbonic dioxide (CO_2) is a potential acid, when dissolve in water, its comes Carbonic acid H_2CO_3**
- **$CO_2 + H_2O = H_2CO_3$, if $CO_2\uparrow$, $H_2CO_3\uparrow$**

- **Intracellular include the organic and inorganic phosphates and plasma proteins, red blood cell and Hemoglobin.**

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BUFFERS

❖physiological buffer

- System stabilizing pH by controlling body's output of acids, bases or CO_2
  - ➢Urinary system
    - Buffers greatest quantity
    - Requires hours or days to exert effect
  - ➢Respiratory system
    - Smaller effect
    - Exerts effect within minutes

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❖Chemical buffer system

- Combination of weak acid and weak base
- Binds to H^+ as H^+ concentration rises
- Releases H^+ as H^+ concentration falls
- Can restore normal pH almost immediately
- **Three major chemical buffer systems**
  - Bicarbonate system
  - Phosphate system
  - Protein system

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1. Buffers in the Blood

- **Blood: through buffering by plasma proteins and haemoglobin**
- **Buffers are substances that neutralize acids or bases**
- **Bicarbonate which is a base and carbonic acid in the body fluids protect the body against changes in acidity. These buffer systems serve as a first line of defense against changes in the acid-base balance**

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2. Respiration through the lungs

- **Respiratory System controls the pH by the rate and depth of respiration to increase or decrease the release of CO_2.**
- **If the buffer system isn't able to maintain pH in its normal range, the respiratory system will adjust the frequency and depth of respiration to compensate. In an acidic environment (a low pH and an excess of H+), hyperventilation will "blow off" excess CO2, in effect returning pH to normal.**

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- In an alkalotic environment (a high pH and a H+ deficit), decreasing the depth and frequency of ventilation will cause the body to keep CO2, thus increasing H+. The respiratory system is amazingly effective in regulating pH.
- Carbon Dioxide which is formed during cellular metabolism forms carbonic acid in the blood decreasing the pH
- When the pH drops respiration rate increases this hyperventilation increases the amount of CO2 exhaled thereby lowering the carbonic acid concentration and restoring homeostasis

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RESPIRATORY CONTROL OF PH

- $CO_2 + H_20 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$
- Addition of CO_2 increases H^+ concentration
- Removal of CO_2 decreases H^+ concentration
- Can neutralize 2-3 x more acid as chemical buffers

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RESPIRATORY SYSTEM

- When the H+ ion increase this cause chemoreceptors to stimulate the respiratory center of the medulla to increase the rate and depth of respiration.
- In this manner, increases or decreases in acidity set in motion an feedback loop which causes self-correcting behavior. The respiratory system begins to have an effect on pH within a matter of minutes.

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3. by the Kidneys Excretion

- The kidneys play the primary role in maintaining long term control of Acid-Base balance
- The kidney does this by selecting which ions to retain and which to excrete
- The kidneys adjust the body's Acid-Base balance.
- The kidneys regulate the bicarbonate level in the ECF, they can regenerate bicarbonate ions as well as reabsorb them from the renal tubular cell.

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RENAL SYSTEM

- The normal daily diet includes certain amount of acids. Unlike Carbonic dioxide (Co2), Phosphoric and sulfuric acid are nonvolatile and can not be eliminated by the lungs. Because accumulation of these acid in the blood would lower its pH (making more acidic) and inhibit cell function, they must be excreted in the urine. These excess acids are bound to chemical buffers such as phosphate ions and ammonia (NH3).

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RENAL CONTROL OF pH

- Can neutralize more acid or base than both respiratory system and chemical buffers

- Renal tubules secrete H^+
  - H^+ excreted in urine
  - Exchanged for sodium ion
  - Only possible when H^+ concentration inside tubule cells is greater than H^+ concentration in kidney filtrate

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Renal System

- The final line of defense against acid-base imbalance is the renal system. The kidneys are able to selectively change the amount of H+ secreted into urine and therefor passed from the body.

- If the pH of the solution being filtered in the nephron is acidic, the kidneys increase the amount of H+ secreted into the urine, thereby decreasing the acidity and increasing pH in the blood/body.

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If the pH in the kidneys is alkalotic, the nephrons in the tubules

- will decrease the amount of H+ secreted, thereby increasing the acidity and lowering pH in the blood/body. While the kidneys are best able to compensate for large variations in pH, their effect is not seen for hours or even days.
  - Can eliminate large amounts of acid
  - Can also excrete base
  - Can conserve and produce bicarbonate ions
  - Most effective regulator of pH
  - If kidneys fail, pH balance fails

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The Body and pH

- Homeostasis of pH is tightly controlled
- Blood = 7.35 – 7.45
- < 6.8 or > 8.0 death occurs
- Acidosis (acidemia) below 7.35
- Alkalosis (alkalemia) above 7.45
- Acids are H^+ donors.
- Bases are H^+ acceptors, or give up OH^- in solution.

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Small changes in pH can produce major disturbances

- **Most enzymes function only with narrow pH ranges**
- **Acid-base balance can also affect electrolytes (Na^+, K^+, Cl^-)**
- **Can also affect hormones**

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Rates of correction

- Buffers function almost instantly
- Respiratory mechanisms take several minutes to hours
- Renal mechanisms may take several hours to days
- Normal metabolism produces H^+ (acidity)
- Three Homeostatic mechanisms:
- Buffer systems - instantaneous; temporary
- Exhalation of CO_2 - operates within minutes; cannot completely correct serious imbalances
- Kidney excretion - can completely correct any imbalance (eventually)