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A CONCISE REVIEW ON HOMEOSTASIS OF ACID BASE EQUILIBRIUM AND ITS DERANGEMENT

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ABSTRACT

The aim of this review article is to show importance of ions and ph of various metabolism occurring inside the complex human body. It informs the role of ions in maintaining homeostasis and their concentration. The importance of water as a universal solvent and its role as a vital nutrient is also highlighted. There exists an osmotic equilibrium in the body which is necessary for life. This is achieved by desirable levels of water and solutes present inside the body. These ionic solutes also determine ph of the body. Depending on the cause, that is, whether metabolic or respiratory, major changes in ph can cause the body environment to become alkaline or acidic. To combat the change, the body activates compensatory mechanism to bring ph back to normal. These compensatory changes can be respiratory for metabolic disorders and renal for respiratory disorders. The recent coronavirus pandemic, according to new researches is said to has been causing kidney failure and hence causes metabolic acidosis. This calls for the need to combat such common disorders with proper diagnosis and further treatments.

KEYWORDS: Acid- base balance, buffers, acidosis, alkalosis, pH.

INTRODUCTION

Ions, the stable configuration of an element which makes it either positively or negatively charged are present in very small amount in human body. These are also called electrolytes in human body. We also have nonionic components such as proteins and glucose. Together these contribute significantly to Homeostasis. Homeostasis refers to maintenance of constant internal environment of human body regardless of external surroundings changes. [1]. The aim of this review is to highlight the role of substance in maintaining acid base balance of body, to bring out the diseases and disorders in their imbalance and natural human mechanism to overcome these.

Water

Almost all atoms need a solvent to form ions from which they can either gain or lose electron to become anion and cation respectively. In living beings this solvent is water. This water dissolves substance and produces their iconic form. This occurs not only in human body but the world around us. Therefore, water is rightly referred to as universal solvent. Water is a physiological nutrient forms an essential component of diet. When there is decrease of water even by 1% can cause weakness and fatigue which hampers the ability of person to carry out their activities.

Water Homeostasis

In an average 70kg man, the total body water(TBW) is 60%of his bodyweight that is 42L. [2]

In women it is 50% of their body weight. This arises due to fact that women have more adipose tissue than men. [3] Water intake and excrete is regulated by human body to achieve the desired level. The recommended water intake ia about 1.5L per day. [4] When the body has sufficient water the person is said to be hydrated and when are water levels the below normal he is considered dehydrated. Dehydration causes hypertonicity in body fluid and progress to acid base imbalance the further details of this is dealt later in the paper. The 60%of total body water is further divided into the following compartments given as a chart below.

Table 1: Distribution of body water.

<table>
<tr><td rowspan="2">Total body water
60%
42L</td><td>EXTRACELLULAR
20%
14L</td><td colspan="2">Plasma 11L</td></tr>
<tr><td></td><td>Extravascular fluid
3L</td><td>Transcellular fluid
Interstitial fluid</td></tr>
<tr><td></td><td colspan="3">INTRACELLULAR
40%/28L</td></tr>
</table>

Osmosis

Osmosis is a phenomenon of transfer of water molecule from a region of low solute concentration to a region of high solute. Osmosis plays a major role in maintaining the osmolality as well as volume of body fluid compartments. Osmotic difference between extracellular and intra cellular fluid is around 280-295 mOsmol/L. Osmotic equilibrium between these compartment is maintained by movement of ions in these components. These movements are facilitated by pumps and channels spread across the cellular membrane.

Table 2: Normal range of major ionic solutes.[5]

SOLUTES	ECF		ICF
	PLASMA	INTERSTIAL FLUID	
Cations(mEq/L)			
Na^+	142	140	14
K^+	4.2	4	140
Ca^{2+}	1.3	1.2	0
Mg^{2+}	0.8	0.7	20
Anions(mEq/L)			
Cl^-	106	108	4
HCO_3^-	24	28	10
PO_4^{2-}	2	2	11
Proteins	1.2	2	4

Based on tonicity or osmolarity and volume of fluid injected or lost in the body fluid the compartments undergo following changes in volume as well as osmolarity.

1. Isotonic The isotonic solution is the one which has same osmolarity as that of other body fluid. When a person is injected with isotonic solution he undergoes isotonic volume expansion. When he loses large amount of body fluid as in accident, when there is huge amount of blood loss it causes isotonic volume contraction [6]
2. Hypotonic A hypotonic solution is the one which has less solute particles than the solvent that is it has lesser osmolarity than the cell. The cell when placed in this solution having lesser osmolarity tends to absorb water through osmosis causing increase inter cellular volume with same extra cellular volume. This can be markedly seen in red cells hypotonic saline such as a solution whose concentration is less than 0.9%Nacl. The red cells absorb water so much that they tend to rupture causing hemolysis.
3. Hypertonic: This conditions arise when there is increase in osmolarity of surrounding fluid. This causes the cell to loose water due to osmosis and the cell shrinks. This condition arises when patients suffers from dehydration or hypernatremia or hyperkalemia.

This equilibrium of osmolarity and volume forms basis for normal metabolic activities of cell and maintains cell integrity necessary to carry out normal functions of life.

Following changes are seen when important ionic gradient is disrupted

(1) Hyponatremia-which includes acute and chronic stages of hyponatremia. Based on clinical history patients are further classified as

1. Hypovolemic hyponatremia associated with decrease in overall volume of body fluid compartments along with sodium.
2. Hypervolemic hyponatremia
3. Euvolumic Hyponatremia

2) Hypernatremia is also classified into hyper hypo and euvolumic hypernatremia.[7]

pH of Body Fluid

The pH of all body fluid is around 7.3 to 7.5. The pH of blood is 7.4. This pH of blood is maintained by buffers. A buffer solution is the one which resist a change in their pH. Buffers are formed by mixing a weak acid with strong base or weak base with strong acid. The buffering capacity of a solution is calculated by using Henderson-Hasselebalch equation.

Derivation of Henderson-Hasselbalch equation: -

Consider a solution of weak acid;

$HA(aq)+H_2O \leftrightarrow H_3O^- + A^-$

$K_a=[H_3O^-][H^+]/[HA]$

$H_3O^- = K_a [HA]/A^-$

Taking negative logarithm on both sides and rearranging the equation we get,

$pH=pka+\log10([A^-]/[HA])$

or, $pH=pka+\log10(\text{conjugate base/acid})$.[8]

The main buffers in human body include

- Protein buffer
- Hemoglobin buffer
- Phosphate buffer
- Ammonia buffer
- Bicarbonate buffer.[9,10]

In acid base disorders we mainly look at the parameters of carbon dioxide, bicarbonate ions and carbonic acid. Therefore, the major significant change in acidity and

basicity of the body is due to impairment of bicarbonate buffer.

Role Of Bicarbonate Buffer

The amount of carbon dioxide and water play a major role in acid base physiology. The carbon dioxide and H+ are combined to form carbonic acid by the action of enzyme carbonic acid anhydrase. This enzyme, carbonic anhydrase is found in red blood cells. This reaction is reversed in lungs where hydrated form of carbon dioxide is converted to carbon dioxide to be expelled out.

$H_2CO_3 \longleftrightarrow HCO_3^- + H^+$

Disorders Of Acid Base Balance-Pathophysiology

When the pH of blood is above 7.45 it is referred as alkalemia and when pH is below 7.35 it is referred as acidemia Metabolic disorder which arises due to metabolic error such as diabetic ketoacidosis or even conditions like starvation, dehydration, etc. Respiratory disorder which can occur in mountain sickness and other related respiratory disorder such as obstructive lung disease such as emphysema and restrictive lung diseases such as chronic bronchitis. These disorders cause acid base imbalance. There is compensatory mechanism performed by the human body in order to achieve the desired homeostatic pH. These include renal and respiratory compensatory mechanisms. But these compensations rarely bring back the pH to 7.4.

Metabolic disorders

It can cause increases in pH called as metabolic alkalosis and decrease in pH called metabolic acidosis. For these disorders levels of bicarbonate ions plays a major role in causing change in pH. The normal level of bicarbonate is 22mEq/L. The compensatory mechanism for these disorders is respiratory mechanism.

Metabolic acidosis

The pH decreases as bicarbonate levels fall. This may happen due increase excretion of bicarbonate ion due to vomiting diarrhea and dehydration. The fall in pH is sensed by peripheral chemoreceptors which are carotid and aortic body which causes changes in respiration. The body produces hyperventilation such that the carbon dioxide is release at high rate and in turn decreases level of carbonic acid. This causes increase in pH back to homeostatic level. Hence the in metabolic acidosis there is compensatory respiratory alkalosis.

Metabolic alkalosis

In this disorder there is increase in bicarbonate level which causes increase in pH of blood. This can occur due to vomiting, diarrhea, diuretics and alkali load.[11] This disorder is compensated when the human body undergoes hypoventilation which causes increases level of carbon dioxide in blood. Thus more of carbon dioxide is used to produce carbonic acid by the action of carbonic anhydrase in RBC or red blood cells. Hence increasing the pH back to normal. This is compensatory respiratory acidosis for the disorder. It is also treated by hypochloremia and hypokalemia.

Respiratory Disorders

Respiratory disorder can arise due to changes in respiration that is hypoventilation which cause decrease amount of gas exchange and hyperventilation which increases gas exchange. The main parameter checked here is levels of pCO2 which is reflected in the blood as carbonic acid. These disorders are mainly compensated by metabolic and renal mechanism.

Respiratory acidosis

In this disorder hypoventilation is causes decreased gas exchange which in turn increases level of carbon dioxide in blood. The carbon dioxide is converted to carbonic acid in blood by carbonic anhydrase. This condition is seen in obstructive lung disease such as COPD, cystic fibrosis and emphysema or in muscular disorder such as myasthenia gravis.[12]

The increase carbon dioxide in arterial blood is directly reflected in cerebrospinal fluid. Therefore, rise in pH is sensed by central chemoreceptors in brain. In acute phase it can cause hyperventilation. In chronic state the choroid plexus in brain is stimulated which in turn starts secreting bicarbonate in cerebrospinal fluid. This shuts off the central chemoreceptors. But the compensatory mechanism is actually the renal mechanism. It retains bicarbonate and increases pH.

Respiratory alkalosis

This disorder occurs due to hyperventilation which decreased amount of carbon dioxide in blood. In this disorder the compensatory renal acidosis occur which causes more excretion of bicarbonate and hence decrease pH. It is seen in acute and chronic high altitude sickness. At high altitude the when given enough time the body is able to adjust to the new low pO_2 in a process known as acclimatization. The peripheral chemoreceptors are activated and they are mainly responsible for increased ventilation rate to about five folds. [13]

Clinical Significance

These disorders are seen in daily medical practice. Therefore, proper history taking and good lab testing are key to diagnosis of this condition. The disorder diagnosed should be corrected for the root cause then provide supportive treatment for the prognosis of the disease.

Limitations of the Study

This review done is a concise explanation of acid base balance and its abnormalities. A greater in depth study and analysis with newer scientific information can be done in future

Conflict of Interest

The author declares that there is no conflict of interest and no financial help was taken from the institution or any other funding department.

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