

Importance of Acid-Base Balance in The Human Body

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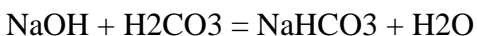
Abstract:

This article provides a comprehensive overview of the critical importance of acid-base balance in the human body, emphasizing its role in maintaining homeostasis and normal physiological function. The paper begins by explaining the principle of isohydria, wherein the hydrogen ion concentration in biological fluids is regulated within a narrow range. The stability of blood pH is essential for the proper functioning of enzymes and metabolic pathways, with a physiological norm around 7.35–7.45. Buffer systems such as the bicarbonate, phosphate, and protein buffers serve as the first line of defense against pH fluctuations caused by metabolic and respiratory activities. The article then examines the mechanisms underlying acidosis and alkalosis, both of which can manifest in compensated or uncompensated forms and are categorized as either respiratory or metabolic in origin. Non-gaseous (metabolic) acidosis is identified as one of the most severe disturbances, often resulting from conditions such as diabetes, prolonged physical exertion, or organ dysfunction. Conversely, respiratory acidosis is typically associated with impaired gas exchange in pulmonary diseases or CNS depression. The article also discusses less common forms of alkalosis, often resulting from vomiting, bicarbonate overload, or hyperventilation. Diagnostic considerations, classification of acid-base disorders, and therapeutic strategies—ranging from oxygen therapy and electrolyte management to pharmacological interventions—are addressed in detail. Through clinical and biochemical perspectives, the study underscores the importance of timely identification and management of acid-base disturbances in preventing systemic complications and promoting patient recovery.

Keywords: Acid-Base Balance, Ph Value, Buffer Systems, Isohydria, Acidosis, Alkalosis, Respiratory Acidosis, Metabolic Acidosis, Metabolic Alkalosis, Respiratory Alkalosis, Bicarbonate Buffer, Ph Status in the Body

Introduction

The pH of acidic and basic solutions tends to change over time. This is mainly due to absorption of various gases from the air or dissolution of container-wall materials into the solution [1]. For example, atmospheric CO₂ dissolves to form carbonic acid, which reacts with sodium hydroxide as follows:



The concentration of hydrogen ions in the human body does not change. This property of biological fluids is called isohydria. For example, the pH of human blood is 7.36. Maintaining this indicator depends on a number of physicochemical and physiological mechanisms, the most important of which is the combined action of the body's buffer systems [2]. Buffer systems (buffers) are systems that have the property of maintaining the concentration of hydrogen ions without significantly changing either when an acid or alkali is added or when diluted. They are divided into 3 main groups according to their composition:

1. Systems consisting of a mixture of a weak acid and its salt:



2. Systems consisting of a mixture of a weak base and its salt:



3. Systems consisting of a mixture of salts of polybasic acids[3]:



Other buffer solutions:

1. H₂CO₃ + NaHCO₃ - bicarbonate buffer
2. HCOOH + HCOONa - formate buffer
3. PtCOOH + PtCOONa - protein buffer
4. HHb + KHb - hemoglobin buffer
5. HHbO₂+NaHbO₂- oxohemoglobin buffer.

The importance of buffer systems in medicine: When the body's ability to maintain the concentration of H⁺ ions within certain limits decreases, the acid-base balance is disturbed, and as a result, acidosis or alkalosis is observed in biosystems [4]. All disorders of acid-base homeostasis are divided into acidosis and alkalosis depending on the change in the concentration of hydrogen ions. Acidosis is a violation of the acid-base balance, in which an absolute or relative excess of acids appears in the blood and the concentration of hydrogen ions increases [5]. Alkalosis is characterized by a change in the ratio of acids and bases, in which an increase in the absolute or relative amount of bases and a decrease in the concentration of hydrogen ions are observed. According to the degree of compensation, all acidoses and alkaloses are divided into compensated and uncompensated [6]. Compensated acidosis and alkalosis are conditions in which the absolute amounts of H₂CO₃ and NaHCO₃ change, but the H₂CO₃/NaHCO₃ ratio remains within the normal range (approximately 1:20). While maintaining this ratio, the blood pH does not change significantly, that is, it remains in the range of 7.35-7.45. Accordingly, uncompensated acidosis and alkalosis are conditions in which not only the total amount, but also the ratio of the components of the bicarbonate buffer changes, as a result of which the pH goes beyond the normal range. Acidosis and alkalosis are divided into gaseous (respiratory, respiratory) and gasless according to the mechanisms of development [7].

Classification of acid-base disorders:

1. Gaseous (respiratory) acidosis.
2. Gaseous acidosis:
 - a) metabolic;
 - b) excretory;
 - c) exogenous;
 - d) combined forms (combination of various gasless acidoses).
3. Mixed acidosis (gas + gasless)
4. Gaseous (respiratory) alkalosis.
5. Gasless alkalosis:
 - a) excretory
 - b) exogenous.
6. Mixed forms of acidosis and alkalosis (respiratory alkalosis compensated by metabolic acidosis; gasless alkalosis compensated by respiratory acidosis).

Methods

Non-gas acidosis: is the most severe and common form of acid-base disturbance, which can be encountered in the practice of doctors of all specialties. The causes of non-gas acidosis are diverse [8]. It is observed with an excess of hydrogen ions in the body or the loss of bicarbonate from the extracellular fluid. Of any origin, the most rapid and severe is hypoxia. Excessive formation of non-oxidized metabolic products (lactic, pyruvic acids, acetone bodies, etc.) is observed in diabetes mellitus, starvation, heavy physical exertion, diffuse inflammation, and severe liver damage. Lactic acidosis can occur in patients with leukemia, lymphoma, lymphogranulomatosis, and other malignant tumors [9]. Drugs that inhibit mitochondrial function can also lead to life-threatening lactic acidosis. These include biguanides used to treat diabetes and antiviral nucleoside analogues used to treat HIV infection.

Gas acidosis: is a common form of acid-base imbalance in the organism. An increase in carbon dioxide in the blood is the main mechanism for shifting the balance in the direction of an increase in hydrogen ions. In this regard, the most common causes of respiratory acidosis are:

- 1) all types of diseases of the respiratory system, accompanied by impaired gas exchange between the alveoli and blood or external air (chronic obstructive pulmonary disease, pulmonary edema, pneumonia, bronchial asthma, emphysema, interstitial fibrosis, pulmonary sarcoidosis, collagenosis, hemo- and pneumothorax, etc.) [10];
- 2) inhibition of the respiratory center with an overdose of morphine-like drugs, barbiturates, brain injuries, inflammation, edema, etc.;
- 3) disorders of the respiratory tract (aspiration of foreign bodies, asthmatic conditions, etc.);
- 4) acute circulatory disorders, in which the blood flow slows down so much that the resulting carbon dioxide does not have time to pass from the blood to the lungs;
- 5) breathing air or gas mixtures with high concentrations of carbon dioxide [11];
- 6) paralysis and paresis of the respiratory muscles caused by various causes (poliomyelitis, neuropathy, myasthenia, treatment with muscle relaxants, etc.).

Results and Discussion

Gasless alkalosis is a less common form of pathology than acidosis, but not an uncommon one. The main mechanism of imbalance in gasless alkalosis is the loss of non-volatile acids from the body or the excessive intake of bases. In this regard, the reasons leading to the development of gasless alkalosis are very few [12]. This is the intake of large amounts of alkaline substances (most often sodium bicarbonate during heartburn, alkaline mineral waters). Gasless alkalosis also occurs with frequent and uncomfortable vomiting, for example, with toxicosis of pregnant women, constipation, food toxicosis, with the loss of a large amount of gastric juice; with gastric fistula, with repeated multiple removal of gastric juice [13]. Often, repeated vomiting in children occurs with pyloric stenosis, severe whooping cough. The cause of metabolic alkalosis may be due to decreased excretion and increased reabsorption of HCO_3^- in primary or secondary hyperaldosteronism.

Gaseous (respiratory or respiratory) alkalosis - The causes of gaseous alkalosis are various effects that increase the volume of pulmonary ventilation and promote the removal of carbon dioxide from the blood. This is observed when breathing air in hypobaric conditions at high altitudes [14]. In this case, shortness of breath and the accompanying hypocapnia contribute to a decrease in the amount of carbon dioxide in the atmosphere and excitation of the respiratory center due to oxygen starvation. Respiratory alkalosis also develops with shortness of breath that occurs with brain damage (trauma, encephalitis, stroke, edema, etc.), hyperthermia, and excessive intake of salicylates. Respiratory alkalosis is caused by psychogenic hyperventilation (hysteria, anxiety, severe pain syndrome), sepsis caused by gram-negative bacteria, the effect of progesterone on the respiratory center during pregnancy, the accumulation of ammonia in acute liver failure, and changes in the ratio of glutamic acid and -ketoglutarate in brain tissue, particularly in the respiratory center [15].

Treatment of Acidosis (Increased Acidity of the Blood) Acidosis occurs when the pH level is below 7.35. It develops due to metabolic or respiratory causes.

Metabolic alkalosis Causes: Acidosis due to vomiting, hypokalemia, diuretics. Treatments: Sodium chloride and potassium chloride infusion: To reduce the alkalinity of the blood. Stop or adjust diuretics: Reduce or replace the drugs that caused the alkalinity. Correct hypovolemia: Restore the body's necessary fluids through infusion.

Respiratory alkalosis Causes: Hyperventilation (rapid breathing), stress, lack of oxygen at high altitudes [16]. Treatments: Breathing control: Slowing the breathing rate or normalizing it with special devices. Increasing CO_2 levels: Special methods are used to increase the amount of carbon dioxide in the blood.

Conclusion

Maintaining acid-base balance is vital for the physiological integrity of the human body. Even minor deviations in blood pH can significantly affect enzymatic reactions, metabolic stability, and overall cellular function. The integrated action of buffer systems, respiratory regulation, and renal compensation work collectively to ensure acid-base homeostasis. However, when these mechanisms fail, acidosis or alkalosis may occur, potentially leading to serious health consequences. Metabolic acidosis, often arising from conditions like diabetes or hypoxia, and respiratory acidosis due to lung pathologies are the most commonly encountered disorders. Alkalosis, though less frequent, can result from vomiting or hyperventilation and requires equally careful management. Understanding the classification, causes, and clinical features of these disturbances allows for timely diagnosis and effective treatment. The clinical application of interventions such as bicarbonate therapy, respiratory support, and fluid-electrolyte management illustrates the multidisciplinary approach necessary for restoring homeostasis. In conclusion, acid-base regulation is not only a fundamental concept in medical science but also a cornerstone of patient care, underscoring the necessity of continuous monitoring and targeted intervention strategies in clinical settings.

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