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REVIEW ARTICLE

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The imbalance of body electrolytes in HIV patients using highly active antiretroviral therapy

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ABSTRACT

Highly active antiretroviral therapy (HAART) has transformed the treatment of human immunodeficiency virus (HIV) infection, greatly extending the lives of those affected. While HAART has been shown to be effective in reducing viral replication and enhancing immune function, long-term usage has raised concerns regarding potential side effects on electrolyte balance in the body. This article provides a comprehensive review of existing literature and research findings related to electrolyte imbalance in HIV patients on HAART. The review delves into the complex link between HIV infection, HAART medications, and the disruption of essential electrolytes such as sodium, potassium, calcium, and magnesium. The review focuses on the numerous methods through which HAART medications might cause electrolyte imbalances, including renal impairment, pharmacological interactions, and metabolic abnormalities. It also examines the clinical ramifications of these imbalances, such as the development of electrolyte-related problems such as cardiac arrhythmias, renal dysfunction, and neurologic diseases, which can have a substantial influence on HIV patients' overall health and quality of life. Finally, this review emphasizes the significance of continued electrolyte monitoring and management in HIV patients receiving HAART, with the goal of striking a balance between the benefits of viral suppression and the possible hazards associated with electrolyte abnormalities. To maintain the optimal care and well-being of HIV-infected persons on HAART therapy, healthcare practitioners must remain diligent in evaluating electrolyte status and rapidly treating imbalances. Future research directions in this subject are also proposed in order to better understand the processes and long-term repercussions of electrolyte imbalances in this patient population.

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Introduction

Human immunodeficiency virus (HIV) preys on the immune system, eroding people's resistance to infections and malignancies that healthy immune systems can tackle. The CD4 cell count is commonly used to measure immune function [1]. As a result of the virus's destruction and degradation of immune cells, immunological function steadily deteriorates.

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In humans, HIV is a retrovirus that primarily affects immune system cells such as CD4+ T cells, macrophages, and dendritic cells. It both directly and indirectly destroys CD4+ T cells [2,3].

The introduction of highly active antiretroviral therapy (HAART) was a watershed moment in the treatment of HIV infection. By efficiently suppressing viral replication and restoring immunological function, HAART has transformed the prognosis and quality of life for people living with HIV [4,5]. While the benefits of HAART are apparent, its use has created serious clinical concerns, one of which is the impact on the electrolyte balance of HIV patients.

Electrolytes are minerals that are crucial for supporting numerous physiological processes such as nerve conduction, muscular contraction, and fluid equilibrium [6]. Any disruption in the delicate balance of these electrolytes can have serious consequences for general health [7–9]. This issue is especially important in the context of HIV patients using HAART, as these drugs can complicate electrolyte homeostasis maintenance [10,11].

This review explores the complex link between highly active antiretroviral medication and electrolyte disturbance in HIV patients. It investigates the processes through which HAART may affect electrolyte levels, as well as the therapeutic implications of these imbalances. In addition, we will investigate potential risk factors and therapy techniques to reduce the negative impact of electrolyte abnormalities in this patient population.

Understanding the dynamics of electrolyte imbalances in HIV patients on HAART is critical for healthcare practitioners because it can influence treatment decisions, patient outcomes, and the overall well-being of HIV patients. Addressing these problems becomes increasingly important as we negotiate the complicated landscape of HIV management to ensure the comprehensive treatment and long-term health of persons infected with this virus.

HIV/Acquired Immunodeficiency Syndrome (AIDS) Epidemiology

The HIV infection and AIDS pandemic have been a major global public health concern [12]. The World Health Organization estimates that as of 2021, HIV/AIDS has claimed the lives of over 40.1 million people worldwide, and there are currently about 38.4 million individuals living with the virus [13,14]. About 770,000 people died from HIV/AIDS in 2018 [15], including 680,000 fatalities in 2020 [16]. According to the 2015 Global Burden of Disease study, 3.3 million people worldwide were infected with HIV annually at its peak in 1997. *From 2010 to 2020, the prevalence of HIV decreased by 23%, with drops in eastern and southern Africa driving the progression* [17,18]. HIV statistics are summarized and represented in Table 1.

HIV/AIDS Pathophysiology

HIV is frequently passed from mother to child through unprotected sexual contact, blood transfusions, and the use of hypodermic needles. As soon as the virus penetrates the body, it undergoes a phase of fast viral replication, which causes an overabundance of viruses to circulate in the peripheral

Table 1. Global aids epidemic overview, 2020 (UNAIDS, 2021).

Number of people living with HIV	Total	37.7 million	[30.2 million–45.1 million]
	Adult	36.0 million	[28.9 million–43.2 million]
	Women (15 + years)	19.3 million	[15.5 million–23.1 million]
	Children (<5years)	1.7 million	[1.2 million–2.2 million]
People newly infected with HIV in 2020	Total	1.5 million	[1.0 million–2.0 million]
	Adult	1.3 million	[910,000–1.8 million]
	Women (15 + years)	660,000	[450,000–920,000]
	Children (<5years)	150,000	[100,000–240,000]
AIDS-related death in 2020	Total	680,000	[480,000–1.0 million]
	Adult	580,000	[400,000–850,000]
	Women (15 + years)	240,000	[170,000–360,000]
	Children (<5years)	99,000	[68,000–160,000]

Note: For regional definitions and country-specific estimates, please visit aidsinfo.unaids.org.

circulation. Several million particles of HIV per milliliter of blood may be present during the first infection [19]. An initial stage of influenza-like disease is followed by a latent, asymptomatic stage. The HIV host develops into AIDS once the CD4 lymphocyte level drops to less than 200 cells/ml of blood [20], a syndrome that is characterized by a lack of cell-mediated immunity and an increased risk of developing opportunistic infections and some types of malignancies as a result. Once the virus has entered the body, it undergoes a phase of high viral replication, which causes an overabundance of the virus in the peripheral circulation. A noticeable decrease in the quantity of circulating CD4+ T lymphocytes occurs in conjunction with this response. Almost universally, this acute viremia is accompanied by the activation of CD8+ T cells, which destroy HIV-infected cells, and later by the generation of antibodies, or seroconversion. It is believed that the CD8+ T cell response plays a crucial role in regulating viral levels, which spike and then begin to fall as CD4+ T cell counts increase. Although it does not completely eradicate the virus, a strong CD8+ T cell activity has been associated with a less rapid progression of the disease and a better prognosis [20]. Even while immunodeficiency symptoms, which are a hallmark of AIDS, do not manifest until years after an individual becomes infected, the majority of CD4+ T cell loss happens in the initial few weeks of infection, particularly in the intestinal wall, which houses the bulk of the body's lymphocytes [21]. The predominant expression of the C-C chemokine receptor type 5 (CCR5) co-receptor on mucosal CD4+ T cells, as opposed to a much smaller percentage on CD4+ T cells in the bloodstream, explains why mucosal CD4+ T cells are preferentially lost [21]. As a result of ongoing HIV replication, the chronic phase of the disease is characterized by persistent widespread immunological activation [22]. Since these dying cells remain dormant, productive HIV infection is not permitted. Only 5% of the stimulated CD4 T-cells in these tissues were capable of fully replicating the virus before they were destroyed by apoptosis [22]. Reverse transcription is slowed, which encourages the buildup of cytosolic DNA and leads to an abortive HIV infection. Gamma-interferon-inducible protein 16 (IFI16) detects the viral DNA [22]. Slowing down reverse transcription promotes the accumulation of cytosolic DNA and causes an HIV infection to fail. The viral DNA is recognized by gamma-IFI16 [23]. These results change our understanding of CD4 T-cell degeneration during HIV infection. The host reaction to viral DNA generated during abortive infection, rather than the virus, is what ultimately causes CD4 T-cell death [18] (see Fig. 1).

HAART

HAART is a general term for a group of treatment regimens that typically include three or more antiretroviral medications and are intended to lower plasma virus levels in HIV-1-infected patients below the threshold of detection [4]. HAART is a specially formulated mixture of many drug classes that a doctor recommends based on the patient's viral load (the amount of virus in the blood), the specific virus strain, the CD4+ cell count, and additional criteria (such as disease symptoms) [4,5]. Since its introduction, HAART has transformed a deadly disease into a chronic condition that is controlled.

The classes of HAART

There are six principal HAART drug types that focus on various viral lifecycle stages [24].Nucleoside reverse transcriptase inhibitors: they must first be phosphorylated intracellularly by host enzymes in order to stop viral replication. Lamivudine, Tenofovir, and Abacavir are among examples.

Non-nucleoside reverse transcriptase inhibitors: they attach to the HIV reverse transcriptase, causing a stereochemical alteration that prevents nucleoside binding and DNA polymerase inhibition. Nevirapine and Delavirdine are among the examples.

Protease inhibitors (PIs): they block the gag/pol polyprotein's proteolysis in HIV-infected cells by competitive inhibition. These substances cause immature, noncontagious virions. Examples include Indinavir and Atazanavir.

Integrase strand transfer inhibitors: integrase inhibitors bind viral integrase to stop viral DNA from integrating into the chromosome of the host cell. Dolutegravir is an example.

Fusion inhibitors: they bind to the gp41 glycoprotein on the envelope and stop viral fusion with CD4T cells. Enfuvirtide is an example.

CCR5 Antagonists (chemokine receptor antagonists): By blocking contact between the CD4 cells and the gp120 portion of the viral coat glycoprotein, they selectively and irreversibly restrict entry into CD4 T-cells. Maraviroc is an example.

Mechanism of action of HAART and the benefits of HAART

Antiretroviral medications do not actually kill HIV; instead, they obstruct various phases of the virus's

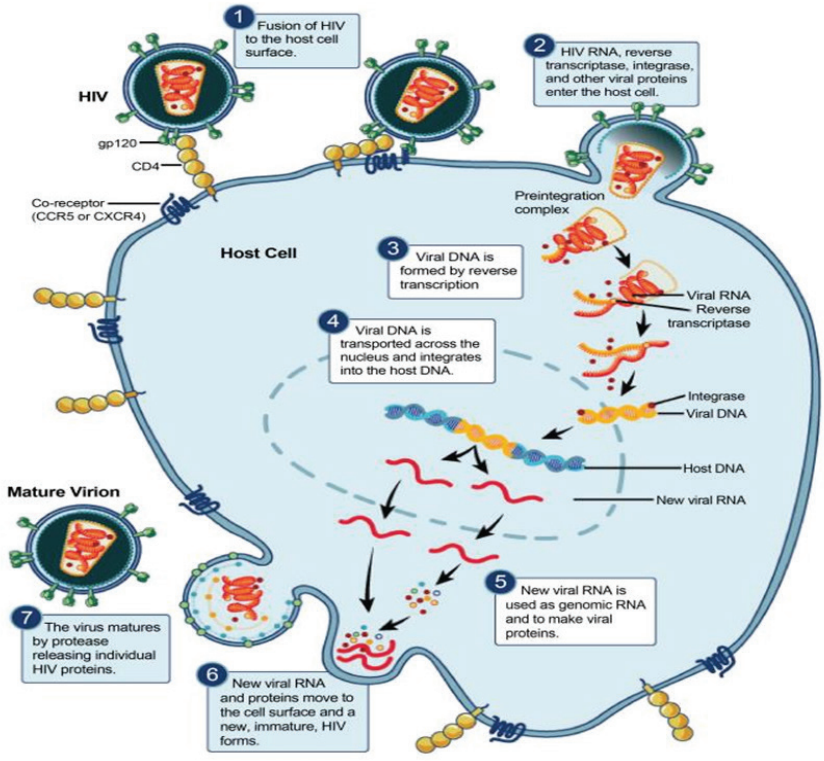

Figure 1. HIV pathophysiology: an illustration of the HIV replication cycle involving a host cell in the human body was created by the National Institute of Allergy and Infectious Diseases. It shows an HIV virion attaching to the host cell wall, releasing its contents into the host cell's matrix, viral RNA being transformed into viral DNA, which combines with the host cell DNA, and new viral RNA migrating to the host cell. https://www.wikidoc.org/index.php/File:HIV_pathophysiology01.jpeg

life cycle, including attachment to cells and the production of new copies of the virus to infect further cells. The mixture of medications functions as a sort of biological "tag team," inhibiting a variety of HIV strains that may exist in a single population. The other medications usually work to suppress a particular virus if the first one does not. There are fewer circulating viruses in the circulatory system and fewer chances for the virus in question to undergo mutation into a drug-resistant form when the viral population is kept completely suppressed (undetectable)

The advantage of HAART is that it slows and hinders the progression of stage 3 HIV, or AIDS, hinders transmission, lessens the severity of complications, and increases survival rates. It also reduces viral loads, increases CD4 cells, and improves immune system function [25]. With early ART, an HIV patient might anticipate having a normal or nearly normal life expectancy [26]. Maintaining a negligible viral load makes the possibility of transmitting HIV through intercourse to another person completely impossible [27], which invariably reduces morbidity and mortality, prevents drug resistance, and improves immune function. HAART's main objective is to lessen the spread of HIV-1 to other individuals [27].

After the viral capsid penetrates the host cell, reverse transcriptase releases the single-stranded viral RNA from the attached viral proteins and copies it into complementary DNA (cDNA) strands, as seen in Figure 2. The reverse transcription process is error-prone, resulting in a high rate of changes that contribute to both treatment resistance and the virus's capacity to avoid the body's immune system. Viral DNA-dependent DNA polymerase generates a sense strand from the antisense cDNA, and the two complementary strands combine to produce a double-stranded viral DNA that is delivered to the cell nucleus. Viral integrase then integrates the double-stranded viral DNA into the host cell's genome. For many years, the incorporated viral DNA can be dormant. Viral replication occurs when the integrated DNA provirus is transcribed into mRNA, which is then spliced into smaller pieces and carried

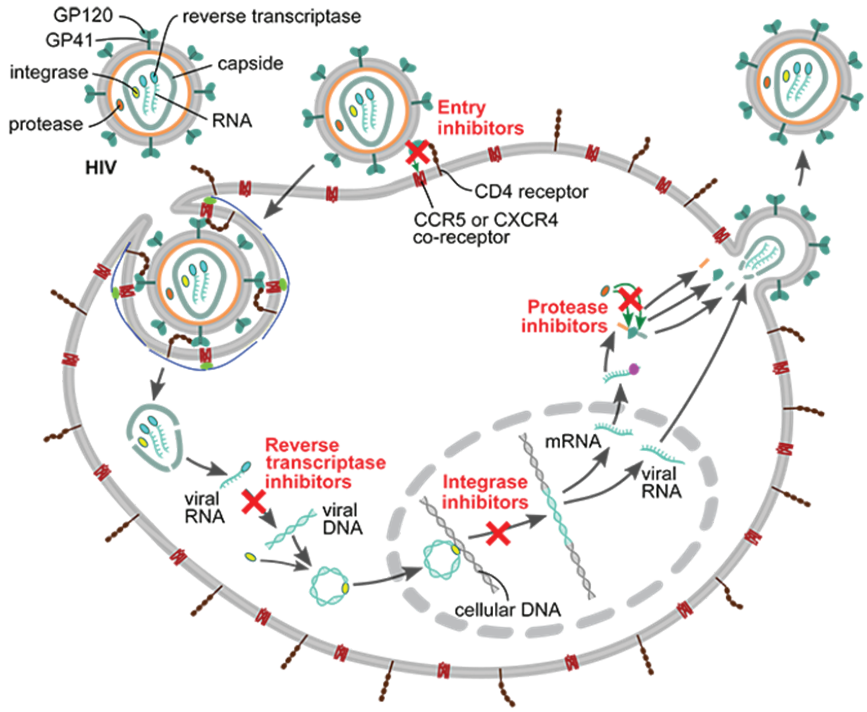

Figure 2. Replication cycle of HIV in a host cell and four classes of anti-HIV drug targets. Modified from a figure by Thomas Splettstoesser (www.scistyle.com) posted on Wikimedia Commons.

into the cytoplasm, where it is translated into regulatory proteins (Tat, Rev, Gag, and Env) that result in viral RNA packaging into new virus particles. Antiretroviral medications target viral protease (Wikipedia: Management of HIV/AIDS). Only fully developed virus particles can infect another cell.

Effect of HAART on organs of the body

Liver

5%–10% of HIV-positive individuals have severe hepatotoxicity during the first year of starting HAART, and the risk persists in future years [28].

Gastrointestinal tracts

Gastrointestinal side effects, such as bloating, nausea, and diarrhea, are frequent. These side effects may be temporary, or they may last the duration of HARRT medication [29].

Brain

Cerebral small vessel disease, which is a sign of altered cerebral vascular health, has been found in patients on ART, particularly in those taking PIs [30].

Kidney

Tenofovir, the nucleotide reverse transcriptase inhibitor, and the PI, indinavir, are the antiretroviral medications most firmly linked to direct nephrotoxicity [31]. However, other medications have been implicated less frequently. The kidney injury, which might be acute or chronic in these patients, usually results in serum electrolyte imbalance, leading to hyperkalemia, hyponatremia, or normal sodium. There have been numerous reports of reduced Na+1, K+1, and Cl serum electrolytes in HIV-positive individuals [32]. Antiretroviral therapy, medications for concurrent illnesses (superimposed to the brain, GI tract, or suprarenal glands), kidney damage brought on by HIV infection, volume loss, and changes in electrolytic metabolism can all contribute to kidney damage. Bone and cardiovascular problems develop as a result of electrolyte imbalances and changes in the metabolism of minerals in HIV/AIDS patients [33]. After performing multivariate research on serum electrolytes in HIV-seropositive subjects, according to logistic regression, a CD4+ T cell count below 200 was linked to hyponatremia, and viral loads that could be detected were linked to hypermagnesemia, hypokalemia, and hypocalcemia [34].

Electrolytes

Electrolytes are a fundamental class of chemical compounds that play a pivotal role in the functioning

of living organisms, as well as in various industrial and technological applications. These electrically charged ions, often found dissolved in fluids such as blood, sweat, and even the electrolyte solution in batteries, are the unsung heroes of our biological and chemical world. Electrolytes are responsible for a wide array of vital physiological processes, ranging from the transmission of nerve signals and the maintenance of fluid balance to the operation of countless chemical reactions within our cells [35]. Their significance extends far beyond our bodies, as they also underpin various technological advancements, such as energy storage systems and electrochemical processes.

This section comprises the captivating world of electrolytes, exploring their nature, functions, sources, and implications across different domains of science and technology. By understanding the intricate roles electrolytes play in our lives, we can appreciate their profound impact on our health, well-being, and the modern world as a whole.

The nature of electrolytes

At their core, electrolytes are compounds that can conduct electricity when dissolved in a solvent, such as water. They are typically composed of ions, which are atoms or molecules that carry an electric charge due to an imbalance in the number of protons and electrons [36]. The most common electrolytes in biological systems include positively charged cations, such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), as well as negatively charged anions such as chloride (Cl^-), bicarbonate (HCO_3^-), and phosphate (PO_4^{3-}).

The ability of electrolytes to conduct electricity arises from their ability to move freely within a solution. When dissolved, these ions become mobile, allowing them to carry electrical charges and facilitate the flow of current [36]. This property is particularly essential in biological systems, where electrical impulses are the basis for various physiological functions, such as muscle contraction, nerve signaling, and heart rhythm regulation [37].

The role of electrolytes in biological systems

Electrolytes are indispensable for maintaining the delicate balance of fluids and ions within our bodies. This balance, often referred to as electrolyte homeostasis, is crucial for overall health and proper physiological function. Deviations from the normal levels of electrolytes can have profound consequences, leading to conditions such as dehydration, muscle cramps, and even life-threatening cardiac arrhythmias [37].

In the context of human biology, some notable roles of electrolytes include:

Nerve function: Sodium and potassium ions are paramount in generating and transmitting nerve impulses. The exchange of these ions across nerve cell membranes is responsible for signal propagation, enabling communication throughout the nervous system.

Muscle contraction: Calcium ions are vital for initiating muscle contractions. The release of calcium from specialized storage structures within muscle cells triggers the contractile machinery, allowing muscles to contract and generate force.

Fluid balance: Electrolytes such as sodium and potassium help regulate the body's water balance. They control the movement of water across cell membranes, affecting cell hydration and overall fluid balance in the body.

pH regulation: Bicarbonate ions (HCO3-) play a role in regulating the body's pH level. They act as buffers, helping to maintain the blood's acidity–alkalinity balance, which is critical for enzymatic reactions and other biochemical processes.

Heart function: Calcium and potassium ions are essential for the rhythmic contractions of the heart. Any disruptions in these electrolyte levels can lead to arrhythmias and potentially life-threatening irregularities in heartbeats.

Digestion: Chloride ions are involved in the production of stomach acid, which aids in the digestion of food.

Blood clotting: Calcium ions are necessary for the blood clotting cascade, ensuring that bleeding is controlled after an injury.

These examples underscore the significance of electrolytes in maintaining the health and functionality of the human body. The precise regulation of these ions is a testament to the intricacy of biological systems, where even slight deviations from the norm can have profound consequences.

Sources of electrolytes

To maintain the balance of electrolytes in the body, it is essential to obtain these ions through dietary sources. Common dietary sources of electrolytes include:

Sodium: Found in table salt (sodium chloride), processed foods, and natural sources such as celery and beets.

Potassium: Abundant in fruits (especially bananas, oranges, and avocados), vegetables, beans, and nuts.

Calcium: Present in dairy products (milk, yogurt, and cheese), leafy greens (kale and spinach), and fortified foods.

Magnesium: Found in nuts, seeds, whole grains, leafy greens, and legumes.

Chloride: Typically consumed in the form of sodium chloride (table salt) and is prevalent in many processed foods.

A balanced diet that includes these sources helps ensure an adequate intake of electrolytes. In addition, hydration through water and electrolyte-rich beverages, especially during physical activity or hot weather, is crucial to maintain the body's electrolyte equilibrium [38].

Electrolytes beyond biology

While electrolytes are indispensable to biological systems, their importance extends into the realm of chemistry, physics, and technology. Electrolysis, for instance, is a chemical process that utilizes electrolytes to split water into hydrogen and oxygen gases. This process has wide-ranging applications, including hydrogen production for fuel cells and the electroplating of metals. In the field of energy storage, batteries, and supercapacitors rely on electrolytes to store and release electrical energy efficiently. Moreover, electrolyte solutions are used in industries such as metallurgy, electroplating, and wastewater treatment [37,38].

Regulation of some electrolytes in the kidneys

The reabsorption of Na+ along all nephron segments plays a role in maintaining the homeostasis of NaCl. However, the transport of K+ via the aldosterone sensitive distal nephron (ASDN) is particularly crucial. The connecting tubule, collecting duct, and component of the Distal convoluted tubule (DCT) are all a part of the ASDN. The DCT is heterogeneous, consisting of a distal component, the DCT2, where electrogenic Na+ and K+ transport coexists with electroneutral NaCl transport. The proximal portion, the DCT1, reabsorbs NaCl predominantly (see Fig.) [39,40].

The main apical Na+ entry channel in DCT1 cells is the NCC [thiazide-sensitive Na-Cl cotransporter (NCC)]. DCT cells appear to have a significant, albeit indirect, role in K+ secretion because they regulate the transport of NaCl through the connecting tubules, upon which the epithelial sodium channel regulates the reabsorption of electrogenic Na+ and where K+ is released. Aldosterone and angiotensin II are activated by dietary sodium restriction, which affects the NCC and helps to maintain arterial pressure and extracellular fluid ECF volume. [39]. NCC, however, also reacts to variations in dietary K+ consumption. NCC activity is decreased by a high KCl diet, and decreased KCl consumption boosts NCC

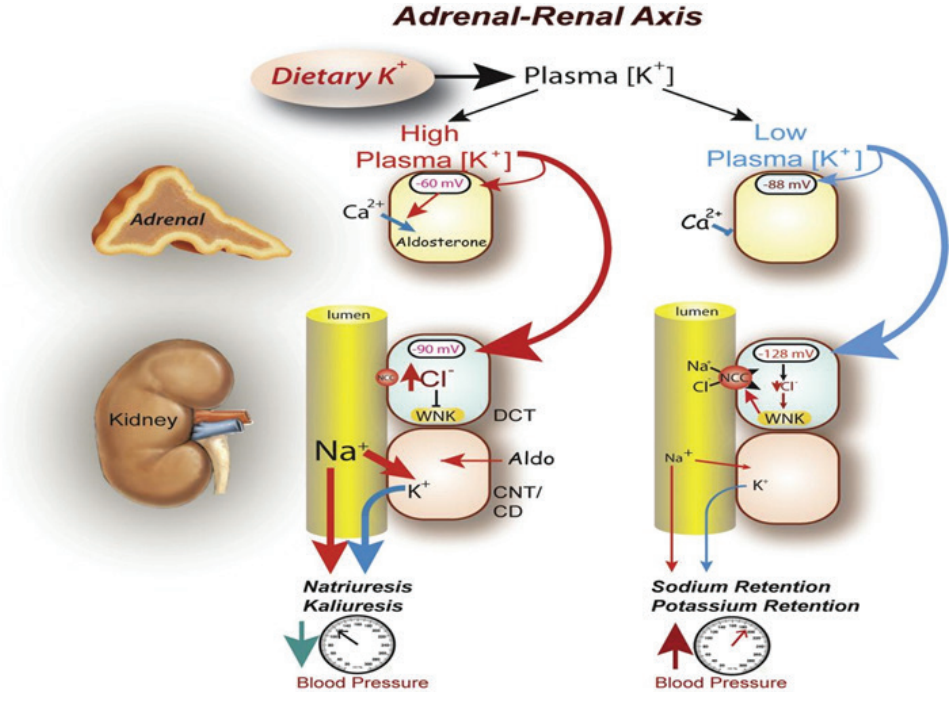

Figure 3. Adrenal-Renal Axis regulation of electrolytes [40].

activity [39]. As a result of these actions, Na+ supply to the secretory segments of K+ is altered, assisting in systemic K+ homeostasis. Although those with no lysine kinases (WNKs-Serine-threonine kinases) are crucial for preserving the equilibrium of K+ in the body, they are mainly chloride-sensitive kinases in cell structures and in vitro, which, when intracellular chloride is low, activate NCC [41].

Illustration demonstrating how plasma [K+] affects cells from the renal DCT and adrenal zona glomerulosa. Changes in membrane voltage that are comparable in direction produce opposing effects that either activate or inhibit cellular activity. Angiotensin II might act similarly in this situation to excite both cell types.

Electrolytes imbalance

An irregularity in the level of electrolytes in the body is known as electrolyte imbalance, also known as water-electrolyte imbalance. Electrolytes are essential to the body's ability to sustain homeostasis. They assist in controlling a variety of functions, including fluid balance, oxygen supply, acid-base balance, and heart and neurological function. Many disease processes involve electrolyte abnormalities, which are crucial for patient care in medicine [42].

Depending on the involved electrolyte, the causes, severity, treatments, and results of these abnormalities can vary substantially. The most severe electrolyte imbalances involve abnormal sodium, potassium, or calcium levels. The most prevalent kind of electrolyte imbalance is hyponatremia, or insufficient sodium [43]. Despite alterations in the body, the kidneys try to maintain stable blood electrolyte concentrations [44]. To balance sodium levels, the kidneys can also produce diluted urine [44].

Causes of electrolyte imbalance

Sweating, fever, or fluid loss as a result of chronic vomiting or diarrhea can all contribute to an electrolyte imbalance [45,46].

Not getting enough food or liquids.

Chronic respiratory conditions such as emphysema.

Abnormally alkaline blood pH (also known as metabolic alkalosis).

Steroids, diuretics, and laxatives are examples of medications

Symptoms electrolyte imbalance

Electrolyte abnormalities commonly manifest as: Regular heartbeat, exhaustion, fatigue, vomiting, nausea, diarrhea, headaches, abdominal discomfort, muscle cramping, disorientation, weakness of the muscles, irritability, tingling, and numbness are common electrolyte problem symptoms [47].

Electrolyte imbalance in HIV/AIDS patients

There is an astonishing diversity of electrolytes and acid-base abnormalities that individuals with HIV infection might develop. Hyponatremia and hypokalemia can occur for a variety of reasons and are more frequently fatal [48]. Similar to electrolyte disturbances, acid-base abnormalities can be caused by drugs, AIDS-related illnesses, or even the HIV infection itself and exacerbate the clinical phase of AIDS [49]. Hyponatremia and hypokalemia are the markers of severity of HIV disease but not an independent risk factor for mortality. HIV patients with low serum sodium or potassium at baseline might benefit from a close follow-up to improve outcomes.

Clinical implication of low/high level of electrolytes in HIV/AIDS patients

Sodium

Sodium is a crucial electrolyte that aids in the transmission of electrical signals throughout the body, enabling the brain and muscles to function and fire [50]. Hypernatremia is an elevated sodium level in the blood. A blood sodium concentration greater than 145 mmol/l is referred to as hypernatremia [51]. Symptoms of hypernatremia include thirst, confusion, twitching, or spasms, which are among the most significant symptoms that come from brain cell shrinking. Attacks of seizures and a state of coma may happen with extreme elevations. Causes of hypernatreniam include excessive water output from the kidneys as a result of diabetes insipidus, which is characterized by either insufficient pituitary gland secretion of the hormone vasopressin or by the defective renal response to vasopressin [52]. *Low sodium levels in the blood are known as hyponatremia*. Severe hyponatremia is characterized as having a sodium level below 120 mEq/l (135 mmol/l), according to the definition [53]. Mild symptoms consist of a diminished capacity for thought, headaches, nausea, and unsteadiness; confusion, convulsions, and coma are among the severe symptoms [52].

Potassium

Since potassium is largely contained inside of body cells, the potassium concentration in blood can vary from 3.5 to 5 mEq/l [54]. The term "hyperkalemia" refers to an increased potassium

(K+) level in the blood. Potassium level above 5.5 mmol/l is considered hyperkalemia [55]. Symptoms of hyperkalemia include palpitations, numbness, aching, weak, or aching muscles. In addition, hyperkalemia may lead to an irregular heartbeat, which may lead to cardiac arrest and eventual death [56]. Causes of hyperkalemia include rhabdomyolysis, hypoaldosteronism, kidney failure, and medications such as non-steroidal anti-inflammatory drugs (NSAIDs), angiotensin-converting enzyme (ACE) inhibitors, and spironolactone [57].

A low potassium (K+) concentration in an individual's bloodstream is referred to as hypokalemia [54]. Symptoms include fatigue, trembling in your legs, weakness, constipation, and elevation of blood pressure. Causes include diuretic abuse among athletes [58], people with eating disorders [59].

Calcium

Calcium is mostly utilized in the formation of bones. With the help of the parathyroid hormone, the parathyroid gland controls the electrolyte balance by detecting variations in calcium concentration.

A high level of calcium (Ca^{2+}) in the blood is known as hypercalcaemia. Levels above 2.6 mmol/l are considered to be hypercalcemia, with the normal range being between 2.1 and 2.6 mmol/l [60]. Symptoms include bone pain, confusion, depression, weakness, kidney stones, back pain, discomfort in the abdomen, or an irregular heart rhythm, including cardiac arrest [61]. *The limbus sign, or calcium deposits, can be seen in the eyes* [62]. Causes include cancer, deficiencies in vitamin D, high bone turnover, and kidney failure [63].

Low serum calcium levels are referred to as hypocalcemia. Levels below 2.1 mmol/l are considered hypocalcemia. Symptoms include heart arrest, disorientation, convulsions, muscle spasms, or numbness [61]. Causes are hypoparathyroidism and vitamin D deficiency [61]. *Other factors that contribute to the condition include kidney failure, pancreatitis, an overdose of calcium channel blockers, tumor lysis syndrome, rhabdomyolysis, and drugs such as bisphosphonates [44]*.

Diagnosis of electrolyte imbalance in HIV/AIDS patients

Renal function test is crucial in the diagnosis of electrolyte imbalance. Due to severe dehydration, hypernatremia (too much salt) can result in skin that is less elastic. A pinch test can be done to determine whether dehydration is affecting the patient [64].

The doctor may also test the reflexes of the patient because reflexes can be impacted by both elevated and reduced amounts of some electrolytes. It may also be helpful to check for any abnormal heartbeats or rhythms using an electrocardiogram. These alterations are brought on by electrolyte issues

Treatment and management of electrolyte imbalance in HIV/AIDS patients

Consuming water or prescription electrolyte solution can assist in restoring the patient's electrolyte balance if they have been vomiting, diarrheal, or sweating a lot. If the patient only has a slight imbalance and no other serious symptoms, oral rehydration beverages can be sufficient. Without a doctor's prescription, consuming large amounts of electrolytes can result in another imbalance and other health problems; thus, it is best to avoid doing so. To correct the electrolyte imbalance, dialysis may be necessary if the individual being treated has an advanced stage of kidney disease. The body can be rehydrated with the aid of intravenous (IV) fluids, usually sodium chloride. The body can swiftly regain electrolyte balance with the aid of IV medicines. The treatment of chronic mineral imbalances in the body frequently involves the use of oral drugs and supplements such as gluconate, magnesium oxide, and potassium chloride. When a patient gets a diagnosis of active renal disease, this is used more frequently [65].

Prevention of electrolyte imbalance in HIV/AIDS patients

If there is a need for exercise by the patient, the patient should have a sports beverage with electrolytes and carbs if the exercise or sporting event lasts more than 30 minutes. The patient should drink when thirsty. Do not drink just to maintain a continuous fluid supply. If you experience weight loss greater than 2% of the body weight or weight increase following exercise, get quick medical advice [65].

Electrolyte imbalance in HIV/AIDS patients using HAART

There have been reports of African women using antiretroviral therapy (ART) regimens that included lamivudine, stavudine, or zidovudine plus nevirapine or efavirenz developing hyponatremia and hypochloremia due to electrolyte abnormalities

[66]. Didanosine has been linked to a number of electrolyte abnormalities, such as hypomagnesemia and hypocalcemia [67]. According to reports, tenofovir use is linked to severe hypokalemia, hypophosphatemia, and acute kidney injury [68]. It has been demonstrated that the use of PIs together, such as ritonavir and tenofovir, increases the risk of renal damage [68]. Adults from Zambia using medications called efavirenz or nevirapine in addition to lamivudine, either with zidovudine or stavudine, were found to have hypophosphatemia [67].

Electrolyte imbalance in HIV/AIDS patients not using HAART

Numerous electrolyte and acid-base abnormalities can occur in patients with HIV infection. A higher mortality rate is linked to hyponatremia and hypokalemia, which can occur for a variety of reasons. Similar to electrolyte disturbances, acid-base abnormalities can be caused by HIV infection, AIDS-related illnesses, drugs, or other conditions, and they can aggravate the clinical phase of AIDS. Close follow-up may be beneficial for HIV patients whose baseline blood sodium or potassium levels were low to enhance outcomes [69].

Conclusion

HAART can directly cause renal toxicity by causing acute interstitial nephritis, crystal nephropathy, and renal tubular abnormalities. Several HAARTs used to treat HIV are hard on the kidneys. Tenofovir has been linked to kidney issues. A patient on HAART should have his or her electrolyte levels checked regularly.

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Authors' contributions

The authors are equally liable for any plagiarism because they all contributed equally to writing the content.

Conflict of interest

The authors declare no potential conflict of interest.

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