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HIGHLIGHTS AND IMPORTANCE OF INORGANIC ELECTROLYTES IN REPLACEMENT THERAPY

Keziah Pauline D., Savitha Shree N., Krishna Balaji M, Dhanalakshmi S., Jasmin Sajini R.*

Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra institute of Higher Education and Research, Porur, Chennai-600116.

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***Corresponding Author: Jasmin Sajini R.**
Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra institute of Higher Education and Research, Porur, Chennai- 600116.
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ABSTRACT

Electrolytes are chemicals that dissociate into cations and anions when they dissolve in the body fluids. In terms of nutrition, these are essential minerals in our blood, sweat, and urine. They are divided into intracellular and extracellular. Intracellular electrolytes are present within the cell and extracellular electrolytes are present in the interstitial compartment. Elements are present in electrolytes for cations such as sodium, potassium, magnesium, and hydrogen, as well as anions such as chloride, bicarbonate, phosphate, and sulphate. The role of electrolytes in the body for pH control, osmotic balance, blood coagulation, acid-base balance etc. Electrolytes are lost in the form of sweat so, we have to replace them by taking fluids that contain electrolytes. The most common electrolyte imbalance is seen in potassium and calcium. The electrolyte imbalance can be detected with the help of an electrolyte panel. These electrolytes play a major role in finding medical conditions and diagnosis. This review aims to highlight the importance of inorganic electrolytes and their other medical applications.

KEYWORDS: Replenisher, Minerals, Cations, Anions, Global Health, Health Care.

1. INTRODUCTION

Electrolytes are substances that have a natural positive or negative electrical charge when dissolved in water. Electrolytes are important for body processes like conducting nerve impulses, contacting muscles, hydrating and regulating the pH levels. The electrolytes can be acid, base or salt. There are three types of electrolytes strong electrolytes, weak electrolytes and non electrolytes. Strong electrolytes completely dissociate and break into anions and cations. Examples are strong acids, strong bases and salts. Weak electrolyte dissociates incompletely. Examples are weak acid and weak base. Nonelectrolytes do not dissociate examples are oil, Fats, and alcohol.[1] Electrolytes maintain the electrical neutrality in cells. It helps in generating and conducting action potentials in the nerves and muscles. The electrolyte maintains the extracellular fluid volume and regulates the membrane potential of cells. It helps in skeletal mineralization, contraction of muscles, the transmission of nerve impulses, blood clotting and secretion of hormones. It maintains the acid-base balance. Plays a crucial role in metaboli pathways.[2]

1.1 Magnesium-Relax, repair and recharge

Magnesium is an intracellular cation essential for various physiological functions, including ATP metabolism, muscle function, neurological processes and neurotransmitter release. During muscle contraction, magnesium facilitates the reuptake of calcium by activating the ATPase of the sarcoplasmic reticulum.[3] Hypomagnesemia defined as serum magnesium levels below 1.46 mg/dL can occur due to factors like alcohol use disorder, gastrointestinal issues and excessive renal loss. It often presents with ventricular arrhythmias such as torsade de pointes. Certain medications such as omeprazole can also contribute to hypomagnesemia.[4]

1.2 Bicarbonate-Balance blood pH

Bicarbonate levels are closely tied to the acid-base balance in the blood with the kidneys playing a central role in regulating its concentration. The kidneys achieve this by reabsorbing filtered bicarbonate and generating new bicarbonate through net acid excretion which involves the elimination of titratable acids and ammonia. Conditions such as diarrhoea can lead to the loss of bicarbonate, disrupting the acid-base balance.[5] Additionally, various kidney disorders can affect bicarbonate metabolism, potentially leading to an excess of bicarbonate in the body.[6]

1.3 Sodium-Spark cellular energy

Sodium is a vital mineral in the body that helps regulate the balance of fluids both inside and outside cells. It plays a crucial role in controlling the volume of extracellular fluid and maintaining the proper electrical potential across cell membranes. Sodium works together with potassium to ensure that cells function correctly by moving back and forth across cell boundaries through active transport mechanisms.[7] In the kidneys, sodium levels in the body are regulated. The proximal tubule is where most of the sodium is reabsorbed. In the distal convoluted tubule, sodium is reabsorbed further. The movement of sodium is facilitated by sodium-chloride symporters, which are influenced by the hormone aldosterone.[8] One of the most common electrolyte imbalances is hyponatremia which occurs when the level of sodium in the blood is below 135 mmol/L. Hyponatremia can lead to neurological symptoms and manifestation.[9]

1.4 Potassium-Power heartbeats daily

Potassium is primarily found inside cells and its balance with sodium is maintained by the sodium-potassium adenosine triphosphates pump, which actively exchanges sodium out of cells for potassium. In the kidneys, potassium is filtered at the glomerulus and then reabsorbed in the proximal convoluted tubule and the thick ascending loop of Henle.[10] It is secreted in the distal convoluted tubule, a process that is enhanced by aldosterone. Potassium secretion is also facilitated by potassium channels and potassium-chloride cotransporters located on the apical tubular membrane.[11] Imbalances in potassium levels can lead to cardiac arrhythmias. Hypokalemia defined as serum potassium levels below 3.6 mmol/L, can cause symptoms such as weakness, fatigue and muscle twitching. Hypokalemic paralysis characterized by widespread muscle weakness can be either inherited or occur sporadically.[12] On the other hand, hypokalemia with serum potassium levels above 5.5 mmol/L, can also lead to arrhythmias and is often accompanied by muscle cramps, muscle weakness, rhabdomyolysis and myoglobinuria.[13]

1.5 Calcium-Strength, signal and stability

Calcium plays a vital role in various physiological processes including bone mineralization, muscle contraction, nerve impulse transmission, blood clotting and hormone secretion. The main source of calcium is the diet and it primarily exists as an extracellular cation. The absorption of calcium in the intestines is mainly regulated by the active form of vitamin D known as 1,25-dihydroxy vitamin D3, while the parathyroid hormone controls calcium reabsorption in the kidney distal tubules.[14] Calcitonin helps reduce blood calcium levels by acting on bone cells. When diagnosing hypocalcemia, it is important to check the serum albumin level to correct the total calcium level. Hypocalcemia is identified when the corrected total calcium in the blood is less than 8.8 mg/ dL, which can occur in conditions like vitamin D deficiency or hypoparathyroidism. Measuring serum calcium levels is particularly recommended for patients who have undergone a thyroidectomy.[15] Hypercalcemia on the other hand, is diagnosed when corrected total calcium levels are above 10.7 mg/dL, often associated with primary hyperparathyroidism. In cases of malignancy, humoral hypercalcemia is typically due to the secretion of PTH-related protein (PTHrP).[16]

1.6 Chloride-Hydrate, charge and flow

Chloride is an anion primarily located in the extracellular fluid, with its level largely controlled by the kidneys. The majority of chloride filtered by the glomerulus is reabsorbed, mainly in the proximal tubules, through both active and passive transport mechanisms.[17] Hyperchloremia may arise from the loss of bicarbonate in the gastrointestinal tract while hypochloremia is often associated with conditions like vomiting or excessive water retention, such as in congestive heart failure.

1.7 Phosphorus-Fuel, cell metabolism

Phosphorus is an extracellular fluid cation, with about 85% of it stored in the bones and teeth as hydroxyapatite, while the remaining 15% is found in soft tissues. Phosphate is essential for various metabolic processes as it is a key component of ATP, nucleotides and several metabolic intermediates. Its regulation is closely linked with calcium and is controlled by Vitamin D3, parathyroid hormone (PTH) and calcitonin. The kidneys are responsible for phosphorus excretion. Imbalances in phosphate levels are usually caused by factors such as inadequate dietary intake, gastrointestinal issues or abnormal renal excretion.[18]

Table 1: Food sources for electrolyte.

Physiological ions	Sources	Amount needed to body	Reference number
Sodium	Table salt, Pickle, Cheese, Sause	2,000 mg per day	[19]
Chloride	Table salt, Olives, Lettuce, Tomatoes	96-106 millimole/L or mEq/L	[20]
Potassium	Sweet potato, Avocado, Banana, Citrus fruits, Plain yogurt	3,500–4,700 mg per day	[21]
Magnesium	Avocado, Almonds, Spinach, Pumpkin seeds and Nuts	270 -300mg per day	[22]
Calcium	Yogurt, Almonds, Milk, Greens, Spinach	8.6 to 10.3 mg/dL	[23]
Phosphate	Salmon, Meats, Vegetable, Gains, Nuts	2.5 to 4.5 mg/dL	[24]
Bicarbonate	Avocados, Bananas, Potatoes, Spinach	22-29 mEq/L	[25]

2. Electrolytes present in extracellular and intracellular

The intracellular medium is composed of water (70%), electrolytes such as potassium, magnesium, phosphate and sulphate, and Organic molecules such as proteins and carbohydrates and the extracellular medium is composed of water (83%), electrolytes such as sodium, chloride, bicarbonate, calcium, nutrients, hormones and gas.

Table 2: Electrolytes in extracellular and intracellular medium.[26]

S. No.	Structural components	Medium in Extracellular	Medium in Intracellular
1	Sodium	138-142	10
2	Potassium	4.5-5	140
3	Calcium	5	</=0,0001
4	Magnesium	1.5-2	58
5	Chloride	103-108	4
6	Bicarbonate	24-27	10
7	Sulphate	0.5-1	2
8	Mono hydrogen phosphate	2	11
9	Dihydrogen phosphate	2	11

Table 3: Sodium containing inorganic compounds for replacement therapy.

S. no	Condition	Formulation	Inorganic Compound	Dose	Ref. no.
1.	Hyponatremia	Intravenous fluids	Sodium chloride	Concentration of 3% at 1–2 mL/kg/h	[27]
2.	Hypernatremia	Intravenous fluids	Sodium chloride	1 mEq per L per hour	[28]
3.	Oedema	Intravenous Oral	Sodium Potassium Magnesium	Approximately 2,500 to 3,000 mg per day	[29]
4.	Metabolic acidosis	Intravenous	Sodium bicarbonate	1 mEq/kg body weight	[30]
5.	Gastrointestinal (GI) disturbances	Oral	Sodium	For adults and children, the typical ORS formulation contains 75 mEq/L of sodium.	[31]
6.	Chronic kidney disease (CKD)	Oral	Sodium bicarbonate	650 mg to 1,300 mg taken two to three times daily	[32]
7.	Urinary alkalinisation	Oral	Sodium citrate	15 to 30 mEq of citrate per day	[33]
8.	Hypophosphatemia	Oral	Sodium phosphate	500 to 1,000 mg of sodium phosphate is taken two to three times daily	[34]

Table 4: Potassium containing inorganic compounds for replacement therapy.

S. No	Condition	Formulation	Inorganic compound	Dose	Ref. no
1.	Hypokalemia Renal Insufficiency Adrenal Insufficiency	Injections ntravenous fluids	Potassium acetate	Newborn:2–6 mEq/kg/24 hr. Children:2–3 mEq/kg/24 hr. Adult:40 – 80 mEq/24 hr.	[35]
2.	Hypokalemia Renal insufficiency	Injections Intravenous fluids	Potassium chloride	20 mEq in 0.9% of Kcl injection 40 mEq in 0.9% of Kcl injection 20 mEq in 5% dextrose injection	[36]
3.	Kidney stones hypophosphatemia	Injections Oral	Potassium phosphate	3mmol/ml 250mg – 1500mg per day	[37]
4.	Hypocitraturia Nephrolithiasis	Tablet	Potassium citrate	30 mEq – 80 mEq/day	[38]
5.	Hypokalemia Renal tubular acidosis	Tablet Elixir	Potassium gluconate	1mEq(500mg) 20mEq/15ml	[39]
6.	Hypokalemia Kidney stones Stroke Gastrointestinal intolerance	Capsules	Potassium bicarbonate	13.5 mmol	[40]
7.	Thyroid sorders	Tablets Oral	Potassium	Adult: 130mg	[41]

	Iodine deficiency	solutions	iodide	Children: 65mg Infants: 16mg	

Table 5: Calcium containing inorganic compounds for replacement therapy.

S.no	Condition	Formulation	Inorganic compound	Dose	Ref. no
1.	Hypocalcemia Cardiac arrest Hyperkalemia	Intravenous fluids Oral administration	Calcium gluconate	Hypocalcemia 10-20ml (90-180mg) Hyperkaemia 10ml of 10% Calcium gluconate (90mg) Pediatric dose 0.5-1ml / kg (20ml) Oral Adult dosage 500-2000mg/day Pediatric dosage 500-1500mg/day	[42,43]
2.	Osteoporosis Vitamin C deficiency	Oral administration	Calcium ascorbate	Adult dosage 1000-4000 mg/day Pediatric dosage 500-1000 mg/day	[44]
3.	Calcium deficiencies	Oral administration	Calcium lactate	Adult dosage 500-1500mg/day Pediatric dosage 250-1000mg/day	[45]
4.	Hypocalccemia Hyperkalemia Lead colic Magnesium intoxication	Intravenous Fluids	Calcium chloride	Intracardiac use 200-800mg (2 to 8 ml) Intavenous use 200mg- 1g (2 to 10 ml of 10% solutions) Magnesium Intoxication 500mg (5 ml)	[46]
5.	Hypocalcemia Dyspepsia Calcium deficiencies	Oral administration	Calcium carbonate	Adult dosage tablet: 1000 to 3531 mg Gum: 500mg Liquid: 1250 mg Powdered packets: 1000mg Pediatric dosage Tablet: 400-2000 mg Granule 375-750 mg Gum: 500mg	[47]
6.	Calcium deficiency Osteoporosis	Oral administration	Calcium citrate	Children: 1300mg Men and Women: 1000mg Above age 50: 1200mg	[48]

Table 6: Magnesium containing inorganic compounds for replacement Therapy.

S. no	Condition	Formulation	Inorganic compound	Dose	Ref. no
1.	Eclampsia Hypomagnesemia Asthma Torsade de pointes	Intravenous fluids	Magnesium sulphate	Ecl Eclampsia: 4-6 grams Hypomagnesemia: Mild:1-2 grams Severe:4-8 grams Torsade de pointes: 1-2 grams Asthma: 2 grams	[49]
2.	Cardiac Arrhythmias Asthma Gastrointestinal diseases	Intravenous fluids Dialysis	Magnesium chloride	0.51-100g/L	[50]
3.	Constipation	Oral rehydration solution	Magnesium citrate	300 mg – 600 mg per litre	[51]
4.	Gastrointestinal tract disorder Constipation	Laxative Antacid	Magnesium hydroxide	Antacid Adult dose: 5-15ml of suspension Laxative Adult dose:30-60ml of suspension	[52]
5.	Hypomagnesemia	Supplements	Magnesium oxide	400-800mg	[53]
6.	Magnesium deficiency	Supplements	Magnesium ascorbate	Adult: 500mg – 1000mg	[54]
7.	Gastrointestinal tract disorder	Antacid Tablet Effervescent powders	Magnesium carbonate	Antacid: 1000-2000mg Supplements: 500-1000mg	[55]

6. ORS-Oral dehydration solution

Acute diarrhoeal diseases are one of the leading diseases in infants and young children in many cases, death is caused by dehydration. Dehydration from diarrhoea can be prevented by giving extra fluids at home, or it can be treated simply, effectively and cheaply in all age groups.[56] ORS is used for the treatment of dehydration. The clinical efficacy of a diluted ORS solution was compared in a pilot study with that of intravenous therapy and standard World Health Organization (WHO)/United Nations Children's Fund (UNICEF) ORS solution in children with acute diarrhoea.[57] ORS was initially designed to treat children with diarrhoea from cholera .ORS has an osmolarity of 311 mosm/L and concentrations of sodium at 90 mEq/L, potassium at 20 mEq/L, chloride at 80 mEq/L, and glucose at 20 g/L.[58] ORT works as the molecular mechanisms that govern sugar and sodium absorption inside the gut. The increase in sugar and sodium content in the cells leads to increased absorption of water and chloride ions as well. When a patient receives a mixture of sugar and salts dissolved in water it offsets the loss of these essential ions and molecules in patients with diarrhoea.[59] As per WHO, Infants (up to 2 years) are generally recommended, 50-100 mL per kg of body weight over 4 hours. Children (2-10 years) need to take approximately 100-200 mL per kg of body weight over 4 hours. Adults are recommended 2-4 liters over 4 hours, depending on the severity of dehydration. Mostly ORS can be obtained in packets from UNICEF or can be made up locally.[60]

Table 7: Ingredients and the amount in ORS as per UNICEF.

Ingredient	Amount present
Sodium chloride	3.5g

Potassium chloride	1.5g
Glucose monohydrate	22g
Sucrose (replace of glucose)	40g
Sodium bicarbonate	2.9g

8. Advantages of electrolytes

Potassium is used as a therapeutic agent and pharmacological agent. Potassium chloride, the most commonly used potash and the raw material for the manufacture of most of the other potassium compounds is principally obtained from the mining of sylvinite. It is used for fertilizer.[61] Sodium bicarbonate in neonatology. Evidence against use in resuscitation and metabolic acidosis treatment.[62] Calcium is the most commonly used ion, in a multitude of biological functions, so much so that it is impossible to imagine life without calcium.[63]

9. Biochemical test to for electrolyte imbalance

An Electrolyte test or electrolyte panel test is a blood test that detects if there is an electrolyte imbalance in our body. It is also a part of preventive health check-ups. This helps to monitor the condition of patients during diuretic therapy, intravenous fluid, dialysis, nutritional status, heart functions, kidney function and seriously ill patients. An electrolyte panel test is done by taking a blood sample. A syringe with a fine needle is used to draw blood from a vein in the arm. The blood sample is analyzed for electrolyte level and the results are available within a few hours or a day.[64]

Table 8: condition due to imbalance physiological ion in the body.

S. no	Name of the test	Range	High level	Low level
1.	Serum potassium	3.5-5.0mEq/L	Hyperkalemia	Hypokalemia
2.	Serum sodium	135-145mEq/L	Hypernatremia	Hyponatremia
3.	Total serum calcium	8.9-10.3mEq/L	Hypercalcemia	Hypocalcemia
4.	Serum magnesium	1.3-2.1mEq/L	Hypermagnesemia	Hypomagnesemia
5.	Serum phosphate	2.5-4.5mEq/L	Hyperphosphatemia	Hypophosphatemia
6.	Serum chloride	97-110mEq/L	Hyperchloremia	Hypochloremia
7.	Carbon dioxide content	22-31mEq/L	Alkalosis	Acidosis

CONCLUSION

Electrolytes are the minerals present in blood and other body fluids that carry an electric charge. These electrolytes are important to the body as they help in regulating the fluid balance, supporting muscle contractions, and facilitating nerve signals. They play a crucial role in maintaining hydration, acid-base balance, and proper functioning of the heart and muscles.

As imbalance can lead to issues like muscle cramps, fatigue, and even life threatening conditions. In some cases excess electrolytes can lead to imbalance that causes health issues like high intake of Sodium causes high blood pressure and increases the risk of heart disease. More amount of potassium can lead to hyperkalemia, too much calcium may lead to kidney stones and impaired kidney function. And excess magnesium can cause diarrhea, nausea, and cardiovascular issues. So maintaining a healthy lifestyle and diet can help us in achieving and sustaining the electrolyte balance in our body.

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ABBREVATIONS

1. mg/dL- Milligram per decilitre
2. mmol/L- Millimole per litre
3. Mg- Milligram
4. mEq/L- Milliequivalent per litre

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