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Original Research Article

Electrolyte Imbalances In Type 2 Diabetes

Assessment of Electrolytes Level Among Type 2 Diabetes Patients

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Abstract: Diabetes mellitus(DM) is a global public health concern that is considered by prolonged hyperglycemia triggered by compromised insulin action or secretion. Numerous studies have shown a link between electrolyte intensities and diabetes. Therefore, this study aimed to investigate the association between fasting glucose in plasma and electrolytes and absorption electrolyte imbalances in individuals with type 2 diabetic ailments. High blood sugar (BS) injures the nephrons, affecting electrolyte exchange. The study enrolled 62 participants into two groups: the study group with Type 2 diabetes (Type 2) and consistently high random blood sugar levels (BSL) above 300 and the control group with lower BSLs. The findings suggest that higher blood glucose levels(BGL) are associated with increased potassium and chloride levels. In conclusion, individuals with Diabetes (Type 2) and BGL above 300 exhibits lower levels of sodium but higher serum potassium and chloride levels (PCL) compared to those with lower BGL. The study's results shed light on the potential electrolyte imbalances in individuals with Diabetes (Type 2), particularly those with poorly controlled BGL. Understanding these imbalances is crucial for healthcare providers to manage and treat diabetic patients effectively. This study provides valuable insights into the relationship among fasting plasma glucose (FPG), electrolyte levels, and Diabetes (Type 2). Further research is warranted to elucidate the underlying mechanisms and potential clinical implications of these electrolyte imbalances in individuals with diabetes.

Keywords: Electrolyte imbalance, Diabetes mellitus; Fasting blood glucose; Blood glucose levels; Sodium; Potassium

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1. INTRODUCTION

DM is a significant and growing global public health concern[1], with chronic hyperglycemia being its defining feature resulting from dysfunctional insulin action, secretion, or both[2]. Diabetic individuals face an elevated risk of chronic complications that affect multiple organ systems, influencing the majority of mortality of the individual. Kidney failure, circulatory system damage, and retinopathy are among the major complications of diabetes. As the disease progresses, patients become more vulnerable to various complications such as metabolic imbalances, degeneration of blood vessels, and disturbances in electrolyte concentrations[3,4]. Electrolytes play a crucial role in retaining pH balance, the clotting process of blood, contraction of muscle, conduction of nerves, and body fluids regulation. Imbalances in electrolytes have emerged as an influential cause of impaired human health[5]. Intracellular fluid has critical electrolytes, which include magnesium, potassium, sulfate, and phosphate, while chloride, sodium, and hydrogen carbonate ion are present in extracellular fluid[6]. Sodium is primarily responsible for maintaining acid-base and osmotic balance, consistent distribution, and conservation of body interstitial fluids. Potassium is essential for cardiovascular wellness, equilibrium of pH, neuronal activity, and pyruvate kinase support. Chloride helps regulate the quantity of blood, control the pH level, and regulate fluid balance inside and outside of cells. Electrolyte issues with distribution may affect how you control your diabetes.[7] The correlation between blood glucose and electrolytes is intricate and influenced by various factors such as age and coexisting conditions[8]. Additionally, diabetic nephropathy, a consequence of diabetes marked by reduced kidney activity, may result in imbalances in electrolytes because elevated blood sugar harms nephrons, which affects the uptake of electrolytes and reabsorption .[9] Numerous studies have demonstrated a correlation between electrolyte levels and diabetes[10-13]. Hence, the study aimed to investigate the relationship between fasting plasma glucose (FPG) and electrolytes and explore electrolyte disturbances in individuals with Diabetes (Type 2). This study aims to enhance the knowledge surrounding the complex interplay between diabetes, electrolytes, and related health outcomes. The primary objective of this study is to examine the association between fasting plasma glucose (FPG) and electrolyte levels and to investigate potential electrolyte imbalances among individuals diagnosed with Type 2 Diabetes.

2. MATERIAL AND METHODS

2.1. Study population

In this cross-sectional study, 62 participants were enrolled and categorized into two groups. The study group consisted of 31 individuals diagnosed with Type 2 diabetes for at least one year and consistently had a random blood sugar (RBS) level above 300. Instead, the control group comprised 31 diabetic individuals whose RBS levels remained below 300. The study aimed to compare various parameters between these two groups and analyze the potential impact of RBS levels on diabetes management

Methods[14]

The Random Blood Glucose (RBG) levels were determined for both groups using the colorimetric method, a widely accepted technique. Additionally, the serum levels of potassium, sodium, and chloride were estimated using the ion-selective electrode method, known for its accuracy and reliability. To examine the data obtained, statistical software was employed to compute mean comparison and correlation among the variables. It allowed for a comprehensive examination of the relationships and patterns within the collected data. By utilizing advanced statistical techniques, the researchers were able to gain valuable insight and draw meaningful conclusions from the findings.

2.2. Sample collection[15]

In the research, every participant willingly contributed a 5 ml blood sample, ensuring the collection followed strict sterile protocols. The venous blood was carefully drawn and divided into two containers: a plain container designated for electrolyte analysis and a fluoride oxalate container for glucose measurement. The collected samples underwent centrifugation at 3500 rpm for 15 minutes to obtain the required serum and plasma for analysis. This step effectively separated the components, enabling subsequent measurements of sodium, potassium, chloride, and RBG levels using the respective samples. The meticulous handling and processing of the blood samples ensured accurate and reliable data.

2.3. Ethical statement

The Institutional Ethics Committee of Dr VM Govt approved the study. Medical College Solapur (Ref: Biochem/12/23 dated 10/07/23). The research was conducted as per the protocol and to comply with all requirements of the latest ICMR, CDSCO, GCP and MUHS, IEC guidelines, etc., for research involving human participants.

2.4. Inclusion Criteria:

Type 2 DM patients between 40 -60 years of either gender

2.5. Exclusion Criteria:

Patients with any syndrome related to metabolism, lactating mothers, pregnant women, individuals who have experienced myocardial infarction, smokers, individuals who abuse alcohol, and those with chronic diseases or thyroid dysfunction were not involved.

2.6. Estimation of random blood glucose[16]

The plasma samples collected underwent glucose estimation. It was done using the glucose ERBA XL 640 machine and Electrolytes EASYLYTE PLUS Na/K/Cl Analyzer, chosen after thorough quality control validation. The analyzer provided accurate and reliable results for glucose analysis in the samples, ensuring the integrity of the findings.

2.7. Method

The GOD-POD method was employed for this purpose. This method involves glucose reaction with oxygen in the presence of glucose oxidase, generating glucuronic acid and hydrogen peroxide.

$$\text{Glucose} + O_2 \xrightarrow{\text{glucose oxidase}} \text{glucuronic acid} + H_2O_2$$

$$2H_2O_2 + \text{Phenol} + \text{peroxidase} \xrightarrow{} \text{4-aminoantipyrine peroxidase red Quinonimine} + 4H_2O$$

In this assay, hydrogen peroxide, phenol, and peroxidase combine to produce 4-amino antipyrine peroxidase red Quinonimine and four water molecules. The quinonimine amount is directly proportional to glucose levels and is determined by measuring the photometric response at 505 nm using a reference value. This method employs a fixed-time kinetic/endpoint reaction, providing accurate results.

2.8. Determination of serum electrolytes[17]

After ensuring the quality control validation, the glucose ERBA XL 640 machine and Electrolytes EASYLYTE PLUS Na/K/Cl Analyzer, a state-of-the-art medical device, were employed to examine the serum portion of the blood samples. With its advanced technology and precision, this analyzer utilizes the principle of ion-selective electrode measurement to accurately determine electrolyte values by referencing a standard value. The glucose ERBA XL 640 is the machine, and Electrolytes EASYLYTE PLUS Na/K/Cl Analyzer has proven to be an invaluable tool in the field of medical diagnostics, providing healthcare professionals with reliable and timely information regarding electrolyte levels in patient samples (Table 1). Its efficiency and accuracy make it an indispensable asset in delivering optimal patient care and aiding in analyzing and monitoring various medical conditions.

2.9. Statistical analysis

Statistical analyses were performed using GraphPad Prism software. The results are shown as the mean and standard error of the mean. Error bars represented the standard error of the mean. Differences between groups were examined for statistical significance using the student t-test. The t-test was applied to analyze nonparametric quantitative datasets, and the one-tailed p-value was calculated ($p<0.05$, $p<0.01$, and $p<0.001$ indicated statistical significance.

3. RESULTS

The Biochemical parameters of sixty-two patients were analyzed separately for each group using per protocol analysis. Specifically, we focused on patients with Diabetes (Type 2) mellitus (DM) whose BGL was above 300 and compared their results with those of diabetic individuals whose BGL was below 300. The analysis involved assessing serum sodium, potassium, and chloride levels in both groups(SSPCL). The results were expressed in terms of Mean (SD), representing the average value and its corresponding standard deviation. Upon examining the data, we made several noteworthy observations. Firstly, we found that the serum sodium levels were significantly lower in patients with type 2 DM (p-value of 0.002). It indicates that individuals with higher BGL tend to have reduced sodium levels in their blood. Secondly, when comparing the concentration of serum potassium and chloride levels (SPCL) between the two groups, we discovered a significant increase in both parameters in patients with type 2 DM. The p-values for SPCL were 0.025 and 0.0391, respectively. These findings suggest that higher BGL may lead to elevated levels of SPCL in the blood. In conclusion, our analysis demonstrated that patients with type 2 DM and BGL above 300 exhibits lower serum sodium levels but higher SPCL compared to diabetic individuals with lower BGL. These findings shed light on the potential impact of BGL on electrolyte balance in individuals with type 2 DM (Figures 1 and 2).

Table 1: Comparison of Blood Electrolyte Levels in Control and Cases

Parameter	Control	Cases	P Value
Glucose	121.6 (31.50)	356.6 (95.92)	<0.0001 ***
Sodium	136.5 (4.30)	132.6 (4.26)	0.0024 **
Potassium	3.50 (0.69)	4.00 (0.84)	0.0250 *
Chloride	100.3 (5.61)	103.6 (5.31)	0.0391 *

Normal range of electrolytes:

- *Sodium: 136 to 144 mmol/L*
- *Potassium: 3.5 to 5.0 mmol/L*
- *Chloride: 98 to 106 mmol/L*
- *Calcium: 8.5 to 10.2 mg/dL*

Compared to healthy persons, the blood sodium levels of type 2 diabetes patients were found to have been lower, but SPCL levels were higher. The connection between FPG and sodium was unfavorable (r = -0.36, p 0.001). FPG, on the other hand, had a significant association with both chloride and potassium levels (r = 0.194, p = 0.006 and r = 0.36, p = 0.001, accordingly). The mean plasma glucose levels in cases and control groups were estimated to be 356.6±95.92 and 121.6±31.50, respectively. The P-value was less than 0.0001, which was statistically significant ($p<0.05$).

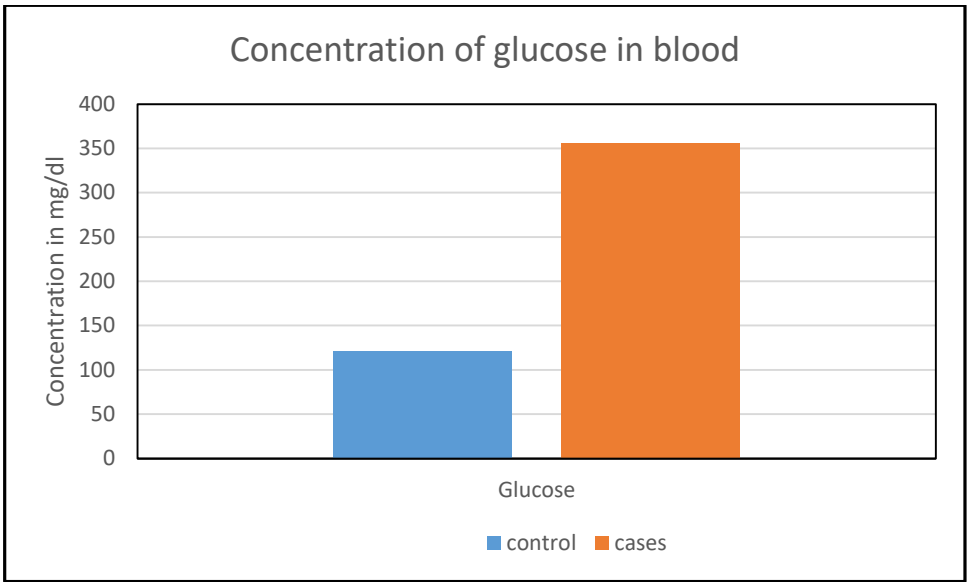

Fig 1: Concentration of glucose in the blood

The figure shows the concentration of glucose in the blood. The blue bar represents the control group, while the orange bar represents the cases. A control group is a group of people who do not have a particular medical condition, while the cases are those who do have the condition. The figure shows that glucose concentration in the blood is significantly higher in the cases than in the control group. It suggests that the medical condition is causing the glucose levels to rise. The higher glucose levels could be a sign of diabetes or another metabolic disorder. The figure is well-designed and easy to interpret. The title and labels are clear and concise, and the bars are easily distinguished. The figure also includes a footnote that provides additional information about the data. Overall, the figure effectively communicates the results of a study on glucose concentration in the blood of people with a particular medical condition.

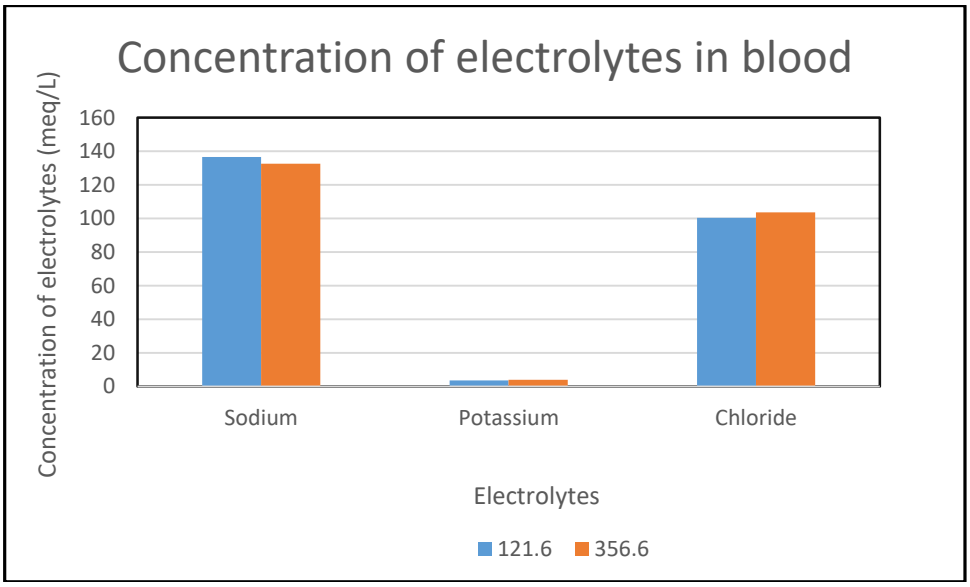

Fig 2: Concentration of electrolytes in the blood

The figure shows the concentration of electrolytes in the blood. The three bars represent the concentration of sodium, potassium, and chloride, respectively. The concentrations are measured in milliequivalents per liter (meq/L). The figure shows that the sodium concentration is the highest, followed by chloride and potassium. It is consistent with the normal range of electrolytes in the blood, where sodium is the most abundant cation, chloride is the most abundant anion, and potassium is the third most abundant cation. The figure also shows that the concentrations of sodium and chloride are relatively constant, while the potassium concentration varies more widely. Potassium is more easily lost from the body than sodium or chloride. Potassium is also more important for cellular function, so the body tightly regulates its concentration. Overall, the figure is a helpful way to visualize the concentration of electrolytes in the blood. It is well designed, easy to interpret, and provides important information about the normal range of electrolytes.

4. DISCUSSION

The current study's findings revealed that individuals diagnosed with Diabetes (Type 2) mellitus experienced a significant rise in their serum levels of RBG, potassium, and chloride, accompanied by a noteworthy decrease in serum

sodium levels. These results align with previous studies that reported an elevation in serum RBG, potassium, and chloride while observing a decrease in serum sodium among individuals with Diabetes (Type 2) [18-20]. It is extensively acknowledged that hyperglycemia primarily affects the extracellular space, initially causing water movement from the intracellular compartment to the extracellular space, resulting in the dilution of plasma sodium[21]. Due to osmotic diuresis that typically occurs during hyperglycaemia, water loss tends to exceed sodium loss until, eventually, water loss becomes predominant. Consequently, patients with diabetes mellitus may exhibit abnormally reduced plasma sodium concentrations. The decrease in serum sodium levels in response to elevated glucose levels is believed to be primarily driven by hyperglycaemia-induced osmotic diuresis, which leads to increased excretion. The analysis for this study includes an overall of 62 patients. However, 10 participants dropped out, leaving a final dataset of 50 cases. After that, a per-protocol determination was performed on the data, with 25 patients in each group. The study aimed to assess and contrast serum SSPCL this research in patients with Diabetes (Type 2) mellitus (DM) and healthy, non-diabetic persons. The study aimed to identify any notable variations between the two groups. The outcomes of the analysis were reported as Means (SD) values. With a p-value of 0.002, researchers found that people with type 2 DM had substantially lower blood salt levels than healthy individuals. It shows that, compared to the healthy control group, the type 2-related DM group had significantly lower blood sodium concentrations[22]. The study also discovered that patients with type 2 DM had considerably higher SPCL. SPCL had p-values of 0.025 and 0.0391, respectively. These results suggest that persons with type 2 DM had significantly higher blood potassium and chloride levels (SPCL) than the healthy control group. As a result, our research showed that, compared to healthy people, patients with type 2 DM have lower serum sodium levels but higher serum PCL. These outcomes draw attention to possible electrolyte abnormalities related to type 2 DM [23] and may affect how this illness is managed and treated. The fundamental processes and the clinical consequences of these discoveries require more study. The proximal convoluted tubule of the kidney is where sodium gets reabsorbed; however, in diabetes mellitus, frequent urination due to hyperglycemia may trigger a higher sodium excretion through urine. It is the physiological reason the serum sodium level in diabetes (type 2) is lowered. It can cause hyponatremia, a medical condition characterized by abnormally low sodium levels in the blood. If not treated, it produces nausea, vomiting, fatigue, confusion, and even coma. Treatment of hyponatremia involves replenishing the body's sodium levels[25]. It is important to seek medical attention immediately once patients experience these symptoms. Physicians may recommend drinking a special electrolyte solution or taking medication to help raise your sodium levels. In severe cases, a hospital stay may be essential to monitor your condition closely. It is better to follow the doctor's treatment instructions and monitor sodium levels closely. It is also important to stay hydrated and avoid drinking too much water. Diabetes causes a reduction in the discharge of potassium through the tubules owing to the pathophysiology of hyporeninemic hypoaldosteronism[26]. It may additionally be triggered by increased potassium flux from cells towards the serum due to hyperosmolality, which produces hyperglycemia. It is further exacerbated by reduced glomerular filtration rate and impaired tubular potassium reabsorption, leading to hyperkalaemia. Treatment of hyperkalaemia in diabetes involves correcting the cause of the condition and managing the symptoms. Medications such as insulin, beta-blockers, or diuretics may be prescribed to control hyperkalemia[27]. In severe cases, dialysis may be necessary to remove the excess potassium from the body. Dietary changes may also be recommended to reduce potassium intake. Monitoring the potassium levels is essential to confirm that the treatment is working. Regular follow-ups with the doctor are necessary to adjust the medication dosage or other treatment strategies if needed. Lifestyle changes may also be recommended to help manage hyperkalemia. Due to hypertonicity, hyperchloremia had been more prevalent in type II diabetes individuals.

5. CONCLUSION

From our comprehensive study analyzing individuals with type II diabetes and an RBS level exceeding 300, we arrived at a significant conclusion. The findings revealed a notable decrease in plasma sodium levels, conversely indicating a rise in plasma chloride and potassium levels. These observations shed light on the intricate biochemical imbalances accompanying type II diabetes in patients exhibiting elevated RBS levels. Our study underscores the influence of closely monitoring SSPCL in diabetic patients, particularly those with severe hyperglycemia, to understand better and manage the associated metabolic changes and their potential impact on overall health.

6. AUTHORS CONTRIBUTION STATEMENT

Dr. Sunita Sethi and Dr. Swati D Sawant developed the theoretical formalism, performed the analytic calculations, and performed the numerical simulations. Dr. Sunita Sethi, Dr. Swati D Sawant, Dr. Kamalakar Mane, and Dr. Yasmeen Mukthar contributed to the final version of the manuscript. Dr. Kamalakar Mane and Dr Yasmeen Mukthar supervised the project.

7. CONFLICT OF INTEREST

Conflict of interest declared none.

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