Assessment of Electrolyte Level of Diabetic Patients

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Abstract- ***Diabetes is a metabolic disorder/disease characterized by high blood glucose levels (hyperglycemia) with changes in carbohydrate, lipid, and protein metabolism in the body due to disruption in insulin action, insulin secretion or both. These metabolic changes affect the concentration of electrolytes. These derangement results from insulin deficiency, hyperglycemia and hyperketonemia. Hyperglycemia sets the internal environment for osmotic diuresis while causing a dilutional effect on electrolyte concentrations. The aim of this study was to assess the electrolyte levels of diabetic patients in University of Nigeria Teaching Hospital, Enugu (UNTH). This study involving 30 diabetic and 30 Non-Diabetic (ND) subjects (outpatients) was conducted at university of Nigeria teaching hospital, Enugu. The patient's anthropometric data was obtained and the serum electrolytes; potassium (K+), sodium (Na+), chloride (Cl-), and bicarbonate (HCO3) ions were measured using ion-selective electrode (ISE) system along with fasting blood glucose using glucometer. The study observed that, systolic blood pressure, fasting blood glucose, and sodium Na+ were significantly higher ($p<0.05$) while potassium K+ and bicarbonate (HCO3) were significantly lower ($p<0.05$) in diabetic subjects compared to non-diabetic subjects. Serum chlorides were insignificantly higher in diabetic subjects compared to non-diabetic subjects. Systolic blood pressure showed significant ($p<0.05$) negative correlation with diastolic blood pressure, and potassium (K+) and positively with fasting blood glucose significantly ($p<0.05$). Diastolic blood pressure also correlated positively with fasting blood glucose significantly ($p<0.05$) and negatively correlated potassium (K+) significantly. Potassium (K+) negatively correlates chloride (C1-), and negatively correlated bicarbonate (HCO3), and blood pressure (systolic and diastolic) significantly ($p<0.05$). This study concludes that, there is electrolyte imbalance in diabetic patients therefore, successful management of these disorders can best be accomplished by early diagnosis, good glycemic control and dietary modification are usually enough for prevention and treating complications in diabetes.***

Key Words: Diabetes, Electrolyte, Disease, fasting blood Sugar, Blood Pressure, Body Mass Index (BMI).

I. INTRODUCTION

Electrolytes are electrically charged minerals that play a crucial role in regulating cell functions and bodily processes. The major electrolytes in the body includes sodium (Na+), bicarbonate (HCO3), potassium (K+), chlorine (Cl-) and calcium (Ca2+), magnesium (Mg2+) which plays important physiological roles in intermediary metabolism and cellular function in the body such as enhancing enzyme activities, muscle contraction, nerve signaling, regulates fluid balance, creating electrical gradients, promoting several metabolic and cellular activities, and ensuring normal homeostasis (Lobo, 2004). These electrolytes come from our food and fluids. Factors such as nutritional status, gastrointestinal absorption capacity, coexistent acid-base abnormalities, diabetes (hyperglycemia), ketoacidosis, pharmacological agents, acute illness, comorbid disease (mainly renal disease), etc. alone or in combination leads to electrolyte imbalance. Electrolyte imbalance can lead to high (hyper) or low (hypo) levels which disrupt normal bodily functions and can leads to life threatening complications such as coma, seizures, cardiac arrest, etc. (Al-Rubeaan et al, 2015).

Diabetes is a chronic metabolic disease characterized by high blood glucose levels (hyperglycemia) with changes in carbohydrate, lipid, and protein metabolism in the body due to disruption in insulin action, insulin secretion or both. It's a multifactorial disease which is associated with sex, age, blood pressure and among other conditions (Steyn et al, 2004). Recently, the increasing prevalence of this disease is drifting from the high-income countries to middle and low-income countries, especially Nigeria which presents the greatest disease burden in Africa affecting over 1.2 million people (International Diabetes Federation 2016).

Diabetes is included among the factor with increased frequency of electrolyte imbalance. Principal causes of electrolyte disorders in diabetic patients includes, Hyperglycemia-induced movement of water out of the cells, osmotic diuresis, drug-induced (such as diuretics), gastrointestinal loss, renal loss (Liamis et al, 2011).

Glucose is an osmotically active substance. In a diabetic condition, high blood glucose (Hyperglycemia) increases plasma osmolarity which in turn creates an osmotic driving force that drifts water movement from the intracellular spaces to the extracellular spaces (DeFronzo et al, 2012). This osmotic drift and water movement has two major effects on electrolyte concentration in the body. It could lead to a dilutional effect lowering electrolyte concentration, leading to osmotic diuresis causing decrease circulating blood volume and cellular dehydration or increase the extracellular concentration if the water movement carries along intracellular electrolytes to the extracellular space especially in a state of insulin deficiency (Palmer et al, 2015).

Insulin has been shown to activate Na+ /K+ ATPase enzyme. Therefore, low serum insulin level or insulin resistance as seen in T2DM reduces Na+ /K+ ATPase activity with poor Na+ and K+ metabolism as a result and so uptake of monosaccharide (Glucose) into intestinal epithelia cells is hindered. This osmotic drift leads to a condition termed as electrolyte disorder or imbalance. Both hyper- and hypo-electrolyte levels are observed in diabetes. Hypokalemia and hyperkalemia are when the serum concentration of potassium level is below 3.5mmol/L and greater than 5.1mmol/L respectively. Hypernatremia is when the sodium serum concentration is less than 135mmol/L and hypernatremia is when its serum concentration is greater than 150 mmol/L. Certain studies have shown hyperkalemia, hypernatremia, and hypomagnesaemia etc., to occur in diabetic patients as well as hypokalemia and hyponatremia are also possible due to osmotic diuresis, anti-diabetic agents or exogenous insulin administration (Uribarri J et al., 2020). Hence, this study was aimed to assess the serum electrolyte level of diabetic patients.

II. MATERIAL AND METHOD

Study Area

This study was carried out in University of Nigeria Teaching Hospital (UNTH), Enugu State South Eastern Nigeria.

Ethical Approval

The study design was reviewed and approved by the ethical committee of University of Nigeria Teaching Hospital, Enugu (UNTH) with approval number: UNTH/HREC/2023/04/600. The study was conducted in accordance to the guidelines of Helsinki Declaration and written informed consent was obtained from all patients willing to participate in the study.

Sample Size

Using the Cochran formula;

$$N = \frac{Z^2(p)(q)}{E^2}$$

Where N = sample size
Z = significant level at 95% confidence interval = 1.96
P = estimated proportion of target population = 4% (0.04)
Q = 1 – p, proportion of population without attribute
E = tolerated error margin = 5% (0.05)

Therefore, using 0.04 Proportion derived from study and 0.05 as error margin, the sample size N calculated as follows:

$$N = \frac{1.96^2(0.04)(1-0.04)}{0.05^2}$$

N = 59

Approximately 60 participant were recruited in this study. 30 Diabetic patients and 30 non-diabetic (control) apparently healthy individual who were shortlisted by simple random sampling.

Inclusion Criteria

1. Apparently healthy non-diabetic adults (18years and above) both male and female as control.
2. Diabetic patients (18years and above) willing to participate as test group.

Exclusion criteria

1. Pregnant and breast feeding women, smokers, alcoholics, individuals below 18years of age, patient's on diuretics as well as HIV positive patients was excluded from this study.

Data collection

Demographic information of patients, including age, sex, and disease history was obtained by interview. The resting blood pressure; systolic (SBP) and Diastolic (DBP) blood presure were measured using standardized procedure with an automatic

sphygmomanometer. The height and weight of the patient was measured and the body mass index also calculated in kg/m^2.

Materials

The material used in this study were serum, tourniquet, disposal syringe (5ml), plain bottle, tube racks, centrifuge, glucometer (Accu-Chek®) and electrolyte analyzer (ISE).

Sampling techniques and Glucose determination

Following inform consent, 5ml of fasted venous blood was collected from the patient's into plain bottle. Immediately after sample collection, blood glucose concentration was determined to avoid glycolysis- related reduction in glucose levels. Whole blood was analyzed using a calibrated glucometer (Accu-Chek®) flowing manufacturer instructions. The blood collected in the plain bottle was allowed to clot and retract, centrifuged at 5000rpm for 5min.to obtain clear serum for subsequent biochemical analysis.

Laboratory analysis of Electrolytes

Assessment was performed using diabetic patients and control (non-diabetic patients) serum. Ion selective electrode (ISE) system was used for the serum electrolyte assessment.

Principle

An ideal ISE consists of a thin membrane across which only the intended ion can be transported. The transport of ions from a high concentration to a low one through a selective binding with some sites within the membrane creates a potential difference, which is directly proportional to the activity (concentration) of ion being measured. The electrodes used are sodium, chloride, potassium, and reference electrode.

Bicarbonate uses a monomeric method and which is based on the reaction in serum with citric acid contain in reagent pack in the bicarbonate chamber to release co^2 which is directly proportional to the bicarbonate present in the serum.

Data analysis

Data obtained from this study where analyzed using the Statistical Package for Social Science (SPSS) version 22. Data were presented as mean and standard deviations. Student's t-test was used to calculate differences between the mean while estimation of relationship between parameters was carried out using Pearson's correlation analysis. All hypotheses test were performed using two-tailed test and p-value <0.05 considered statistically significant.

III. RESULT

Table 1 shows the anthropometric parameters of diabetic and non-diabetic subjects. The result from the table shows a significant increase ($p<0.05$) in the mean standard deviation of systolic blood pressure (115.40 ± 19.4, 104.00 ±6.0) and fasting blood glucose (14.11 ± 3.53, 5.14 ± 0.56) and a non-significant increase ($p>0.05$) in body mass index (25.61 ± 3.14, 24.80 ± 2.76) and diastolic blood pressure (74.40 ± 9.71, 73.15 ± 5.17) of diabetic and non-diabetic subjects respectively.

Table 2 Shows the electrolyte levels of diabetic and non-diabetic subjects. The result shows a significant increase ($p<0.05$) in the mean ± standard deviation of sodium (142.97 ± 2.69, 138.50 ± 3.00), potassium (3.67 ± 0.51, 4.27 ± 0.47) and bicarbonate (18.08 ± 2.47, 23.59 ± 1.34) of diabetic and non-diabetic subjects respectively. There was insignificant increase ($p>0.05$) in the mean ± standard deviation of chloride (106.56 ± 6.17, 104.80 ± 1.45) of diabetic and non-diabetic subjects respectively.

Table 3 Shows the relationship between the parameters of diabetic subjects. There exists a negative significant correlation ($p<0.05$) in systolic blood pressure vs diastolic blood pressure ($r = -0.985$, $p = 0.000$), systolic blood pressure vs potassium ($r = -0.574$, $p = 0.008$), potassium vs chloride ($r = -0.800$, $p = 0.000$), diastolic blood pressure vs potassium ($r = -0.550$, $p = 0.012$), and chloride vs bicarbonate ($r = -0.631$, $p = 0.003$) while a positive correlation exist in systolic blood pressure vs fasting blood glucose ($r = 0.694$, $p = 0.001$), diastolic blood pressure vs fasting blood glucose ($r = 0.693$, $p = 0.001$), and potassium vs bicarbonate ($r = 0.487$, $p = 0.029$). Non-significant correlation ($p>0.05$) exists between other parameters.

Table 1 Anthropometric parameters of diabetic and non-diabetic Subjects.

Groups	BMI (Kg/m^2)	Systolic blood Pressure(mmHg)	Diastolic blood pressure(mmHg)	Fasting blood glucose(mmol/l)
Diabetic Subjects N= 30	25.61 ± 3.14	115.40 ± 19.14	74.40 ± 9.71	14.11 ± 3.52
Non-diabetic Subjects N= 30	24.80 ± 2.76	104.00 ± 6.0	73.15 ± 5.17	5.14 ± 0.56
t - Statistics	0.867	2.541	0.508	11.254
P - value	0.392	0.018*	0.615	0.000*

Values are given as mean ± standard deviation.

*= significant value ($p<0.05$).

Table 2 Electrolytes levels of diabetic and non-diabetic subjects.

Group	Sodium (mmol/l)	Potassium (mmol/l)	Chloride (mmol/l)	Bicarbonate (mmol/l)
Diabetic subjects Subjects N = 30	142.97 ± 2.69	3.67 ± 0.51	106.56 ± 6.17	18.08 ±2.47
Non-Diabetic Subjects N = 30	138.50 ± 3.00	4.27 ± 0.47	104.80 ± 1.45	23.59 ± 1.34
t-Statistics	4.955	-3.836	1.242	-8.78
P-value	0.000*	0.000*	0.228	0.000*

Values are given as mean ± standard deviation.

*= Significant value ($P<0.05$)

Table 3 Relationship between the parameters of diabetic subjects.

Group	r (Pearson)	P- value
BMI vs Systolic	-0.393	0.086
BMI vs Diastolic	-0.378	0.100
BMI vs Fasting blood Glucose (FBG)	-0.324	0.163
BMI vs Na+	-0.049	0.836
BMI vs K+	0.333	0.151
BMI vs Cl-	-0.179	0.449
BMI vs HCO3	0.264	0.261
Systolic vs Diastolic	-0.985	0.000*
Systolic vs FBG	0.694	0.001*

Systolic vs Na+	0.404	0.077
Systolic vs K+	-0.574	0.008**
Systolic vs Cl-	0.409	0.073
Systolic vs HCO3	-0.292	0.212
Diastolic vs FGB	0.693	0.001**
Diastolic vs Na+	0.360	0.119
Diastolic vs K+	-0.550	0.012*
Diastolic vs Cl-	0.368	0.110
Diastolic vs HCO3	-0.261	0.267
FGB vs Na+	0.331	0.154
FGB vs K+	-0.418	0.067
FGB vs Cl-	0.225	0.341
FGB vs HCO3	-0.105	0.659
Na+ vs K+	-0.289	0.216
Na+ vs Cl-	0.357	0.122
Na+ vs HCO3	-0.343	0.138
K+ vs Cl-	-0.800	0.000**
K+ vs HCO3	0.487	0.029*
Cl- vs HCO3	-0.631	0.003**

**= Correlation is significant at the 0.01 level (2-tailed)
*= Correlation is significant at the 0.05 level (2-tailed)

IV. DISCUSSION

Electrolytes play a vital role in maintaining homeostasis within the body by regulating fluid balance, oxygen delivery, acid-base balance, heart and neurological functions. However, the level of an electrolyte in the body can be too high or too low leading to an electrolyte imbalance.

From the result in table 1, systolic blood pressure and fasting blood glucose significantly increased ($p<0.05$) while diastolic blood pressure and BMI insignificantly increased ($p<0.05$) in diabetic subjects compared to non-diabetic subjects.

Table 2 shows significantly increased ($p<0.05$) sodium (Na+) in diabetic subjects compared to non-

diabetic subjects while HCO3 and K+ levels significantly decreased ($p<0.05$) in diabetic subject compared to non-diabetic subjects. These results are consistent with previously reported studies which stated increased sodium (Na+) level of diabetic patients as a result of excessive loss of water due to osmotic diuresis and decreased potassium K+ level as a result of redistribution of potassium K+ from the extracellular to the intracellular fluid compartment (shift hypokalemia due to insulin administration) (Lindner et al.,2019). Exogenous insulin can induce mild hypokalemia because it promotes the entry of K+ into skeletal muscles and hepatic cells by increasing the activity of the Na+K+ ATPase pump. On the other hand, Cl- was similar among the diabetic and non-diabetic subjects with no significant difference ($p>0.05$). This finding has also been observed in a previous study in which serum Cl- was shown not to be affected by hyperglycemia (Deepti et al., 2020).

Table 3 shows that, BMI did not correlates with blood pressure (systolic and
diastolic), fasting blood glucose, sodium (Na+), potassium (K+), chloride (Cl-), and bicarbonate (HCO3). Systolic blood pressure showed significant ($p<0.05$) negative association with diastolic blood pressure and potassium K+ but positively correlated with fasting blood sugar. Diastolic blood pressure also correlated positively with fasting blood glucose, and negatively with potassium significantly ($p<0.05$). Positive association of fasting blood glucose and blood pressure (systolic and diastolic) is due to the fact that increase fasting blood glucose increases risk of hypertension thus consistent with the result of previous studies (Heianza et al., 2017).

However, fasting blood glucose do not correlates with electrolytes (sodium Na+, potassium K+, chloride Cl- and bicarbonate HCO3). Potassium K+ positively correlates bicarbonate HCO3, and negatively with chloride Cl- and blood pressure (systolic and diastolic) significantly ($p<0.05$).

CONCLUSION

In the study we conducted an assessment of electrolyte levels of patients with diabetes in 30 subjects and 30 non-diabetic subjects with an age range of 18 to 70 years. This study observed that, there was high systolic blood pressure in diabetic group compared to non-diabetic group. Sodium levels of diabetic subjects were higher compared to non-diabetic subjects. In contrast, potassium and bicarbonate levels were lower in diabetic patients. There was no much difference in chloride levels of diabetic group compared to non-diabetic group. This study concludes that, Electrolyte abnormalities are common in diabetes patients and may be associated with increased morbidity and mortality, therefore, successful management of these disorders can best be accomplished by early diagnosis, good glycemic control and dietary modification are usually enough for prevention and treating complications in diabetes.

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