Original Article

Plasma electrolytes in healthy individuals and elective surgical patients in Khartoum

Ahmad abdalazim Abdalla and Elmuataz Elmansi Abdalla

Abstract:

Objectives: This study aimed to investigate if the frequently observed low preoperative values of the plasma electrolytes Na^+, K^+, and Ca^{+2} in our surgical patients, in Khartoum, is a reflection of their levels in the population at large or it is a genuine finding in patients.

Methods: 90 male and female subjects were included in this study. 60 healthy, young and elderly individuals were selected randomly from amongst medical students and employees of the University of Khartoum. 30 elective orthopedic and general surgical patients were randomly selected from Khartoum teaching hospital. Plasma Na^+ and K^+ were measured using a digital flammometer, and plasma Ca+2was measured using a spectrophotometer. Results were compared to international data using the Z test. Comparison between the groups in the study was done using the student t-test.

Results: Plasma Na^+, K^+, and Ca+2of the healthy subjects and the surgical patients were found to be low compared to the international reference values. Plasma K^+ is higher and Ca+2is lower in the older subjects when compared to young ones.

Conclusion: a larger study is needed to set the normal values for plasma electrolytes in the Sudan. The high environmental temperature and nature of our diets could be the reason for the observed differences between our subjects and international reference values.

Keywords: plasma Na^+, K^+, Ca^{+2}, digital flammometer.

The electrolytes Sodium (Na^+), potassium (K^+), and calcium (Ca^{+2}) have an essential contribution to human physiology since they are involved in several important physiological processes. For the cells of the body to function properly they must be bathed in an extracellular fluid with a relatively constant concentration of these electrolytes. Sodium is the major determinant of the extracellular fluid volume and osmolality, it is also essential for membrane potential and excitability of nerves and muscles. The internationally accepted normal concentration of sodium in the extracellular fluid is 135 – 145 mmol\L[1]. Potassium is the major intracellular cation and has an important role in the excitability of nerves and muscles, cell metabolism and other physiological processes[2].

Department of Physiology, Faculty of Medicine
University of Khartoum
(almuataz1960@yahoo.co.uk)

Its normal concentration is 3.5 to 5.0 mmol/L extracellularly[3]. Ca^{+2} is mainly an extracellular ion and plays an important role in the excitation of nerve and muscle, muscle contraction, blood coagulation, bone formation and other physiological processes. Plasma Ca^{+2} is normally 8.5 to 10.5 mg/dl or 2.2 - 2.5 mmol/L[1].

In view of the very important roles of these electrolytes, it is not surprising that their plasma levels are kept precisely regulated through the operation of multiple regulatory mechanisms that influence intake, absorption and excretion. Thus, under normal conditions, a normal plasma level of these electrolytes is the hallmark of proper and satisfactory functions of the body organs and homeostatic mechanisms involved. On the other hand changes in the plasma levels of these electrolytes might have grave consequences on health.

Illness and trauma, like accidents and surgical procedures, activate a complex series of

homeostatic adjustments that assist the injured animal to withstand trauma[4]. One of the major goals of these homeostatic mechanisms is the regulation of the level of these electrolytes during that period. During our clinical practice in Khartoum hospitals, it was observed that the laboratory results of serum electrolytes tend to be lower than the average international values, even in apparently healthy individuals.

To ascertain this observation, and to explore the possibility that the observed low electrolytes values are merely a reflection of a population characteristic, this study was designed to determine the plasma levels of Na^+, K^+, and Ca^{+2} in a sample of Khartoum population.

Materials and methods

Ninety male and female subjects (45 males and 45 females) were included in this study. 60 of whom were healthy individuals, and 30 were surgical patients undergoing elective procedures who have no complications or systemic disease. The 60 healthy individuals were 30 males and 30 females. Each sex group was subdivided into two age groups: 15 individuals were chosen as young adults whose age is between 17 and 20 years. The other 15 were older adults whose ages were between 35 and 65 years. The young adult groups were selected from 2nd and the 3rd class medical students in the faculty of medicine, University of Khartoum. The older subjects in each sex group were selected from the employees of the University of Khartoum. The 30 surgical patients were grouped into 15 males and 15 females. Their ages ranged from 30 to 70 years. They were chosen from patients undergoing elective uncomplicated orthopaedic and general surgical procedures in Khartoum teaching hospital. All subjects were selected randomly by being approached in the order of their admission to hospital, and who ever accepted was enrolled provided their records and investigations showed no evidence of chronic disease; renal disease, liver disease, diabetes mellitus, hypertension, nutritional disorders or long-term drug use.

One blood sample was taken from each individual. Samples from the surgical patients were taken one day before their operation. Blood samples were withdrawn using 5 ml disposable sterile syringes from each participant and immediately put into lithium-heparin containing tubes. Each sample was processed within a maximum of 40 minutes. It is centrifuged at 3000 rpm using a Hettich centrifuge (Germany). Plasma was then aspirated and transferred to test tubes for measuring the electrolytes.

Plasma Na^+ and K^+ levels were measured using a digital flammometer (RAL tecnicia laboratorio, S.A, Spain). The standard reagent used was lithium carbonate at a concentration of 15 mmol\L obtained from Hospitex diagnostics (Italy). Plasma calcium was measured using a spectrophotometry technique using a colorimeter (WPA Linton, Cambridge U.K). Three reagents were used in measuring Ca^{+2}: reagent one (R1) was a solution of ethanoleamine at concentration of 500 mmol\L, and reagent two (R2) was a solution of O-cresolphtaline 0.62 mmol\L and hydroxyquinolone 69 mmol\L. The third was a standarad solution which contained Ca^{+2}at concentration of 10 mg\dl. All reagents were supplied by linear chemicals company in Khartoum.

Statistical methods

Results were compared to international data using the Z test. Comparison between the groups in the study was done using the student t-test.

Results

In this study the average serum concentrations of Na^+, K^+, and Ca^{+2} in the healthy subjects were found to be significantly lower than the average concentration of these electrolytes in international reference data as shown in Table (1). However, the levels of these electrolytes are not uniform even in the healthy individuals in this study. There are significant differences in the average plasma levels of K^+ and Ca^{+2} between young and older healthy individuals.

Table 1: Comparison of average serum concentrations of Na^+, K^+, and Ca^{+2} between the healthy individuals in our study and the corresponding concentrations according to the international reference data.

Serum electrolyte	Mean concentration of healthy individuals(N=60)	Mean concentration from reference data	Z- test (2-tailed)
Na^+ (mmol/L)	133.17 (±5.56)	140 (±5.00)	P <0.003
K^+ (mmol/L)	3.82 (±0.48)	4.25 (±0. 75)	P <0.003
Ca^{+2} (mg/dL)	9.04 (±0.72)	9.5 (±1.00)	P <0.003

Table 2: Average plasma K^+ and Ca+2concentrations in the healthy individuals.

Sample group	N	K^+ (mmol/L) (mean conc. ±SD)	Ca^{+2} (mg/dL) (mean conc. ± SD)
Healthy young adult males	15	3.7 (±0.43)	9.3 (±0.65)
Healthy older males	15	4.2 (±0.43)	8.5 (±0.73)
Healthy young adult females	15	3.7 (±0.52)	9.2 (±0.75)
Healthy older females	15	4.0 (±0.35)	8.6 (±0.35)

N: number of individuals in each group.

Table 3: Student T- test for comparison of the plasma concentrations of Na^+, K^+, and Ca^{+2} between the different healthy population groups.

Compared sample group	Na^+ (mmol\L)	K^+ (mmol\L)	Ca^{+2} (mg\dL)
Healthy young males versus healthy older males	Not significant P = 0.847	Significant P = 0.004	Significant P = 0.004
Healthy young females versus healthy older females	Not significant P = 0.81	Not significant P = 0.123	Significant P = 0.019

Table 4: Average plasma concentrations of Na^+, K^+, and Ca^{+2} in the preoperative male and female surgical patients.

Serum electrolyte	Preoperative males (N=15) Mean conc. ± SD	Preoperative females (N=15) Mean conc. ± SD
Na^+ (mmol/L)	133.2 (±5.5)	135.2 (±6.3)
K^+ (mmol/L)	4.1 (±0.4)	3.9 (±0.74)
Ca^{+2} (mg/dL)	8.4 (±0.8)	8.8 (±0.54)

Our data show that healthy young individuals tend to have lower plasma K^+ levels and higher $Ca^{+2}$when compared to healthy older individuals (table 2). Table (3) shows the statistical significance of these differences. No significant differences were observed with regard to sodium between these two groups.

The average plasma concentrations of Na^+, K^+, Ca^{+2} in the preoperative individuals (Table 4) are comparable to those of our older healthy group with no statistically significant difference.

Discussion

The individuals included in this study did not suffer from any disorder that is expected to alter serum electrolyte levels like renal disease, liver disease, nutritional disorders, diabetes mellitus or long-term drug use.

The average plasma concentrations of Na^+, K^+, and Ca^{+2} in the healthy population group of this study were found to be significantly lower than the corresponding average concentrations according in the international reference values (Table 1). The plasma concentrations of these electrolytes in our surgical patients - who did not suffer from systemic disease and not on long-term medication – were on the lower side of the international normal range (Table 4), and they were comparable to the healthy older individuals who fall in almost the same age category. It is, therefore, reasonable to assume that our impression that many surgical patients tend to have low serum electrolytes might be a reflection of a general population parameter which is not confined to patients. However, it is reasonable to assume that because the levels of these plasma electrolytes tend to be on the lower side of normal in Khartoum residents, chronic and severe pathological processes can easily and speedily produce clinically significant reductions in the concentrations of Na^+, K^+, and Ca^{+2} .

Several factors could be suggested to explain our results. Loss of Na+ and K+ in sweat due to high environmental temperature in this region is a possibility[5]. Other factors might include nutritional ones such as decreased salt intake and geographical factors that lead to decreased amount of Na^+ and K^+ in the agricultural food products, and in drinking water. It is not certain that genetic factors, variations in renal handling mechanisms acting on these electrolytes, or variations in the hormonal mechanisms influencing these electrolytes can explain these differences. Whitefield and co-workers have studied the genetic versus environmental factors in explaining the variation in the concentration of thirteen constituents of plasma. They concluded that environmental factors are predominant in case of sodium plasma level whereas genetic factors are important in case of potassium and calcium[6].

The significantly lower serum Ca^{+2} concentration found in healthy population groups in this study compared to the corresponding international average level, might also be attributed to several recognized factors that need to be ascertained. Ca^{+2} content of the diets being consumed in Sudan might be low. Absorption from the intestine may also play a role as food may contain ingredients that may hinder absorption of Ca^{+2}. It is unlikely to be due to vitamin D deficiency as there is generally good exposure to sun light in Sudan despite our dark skin. Genetic factors might also participate through modification of the hormonal mechanisms involved in regulation of calcium metabolism. Almost 40-50% of Ca^{+2} in the plasma is bound to proteins; so total serum Ca^{+2} level varies directly with the level of plasma proteins, and is expected to decrease when the plasma protein level is concomitantly reduced[7].

Investigators have described a variety of age related changes in the concentration of several plasma constituents[8, 9]. In our study a significant difference in the average plasma K^+ concentration was recognized between young and older males (table 3), the level of serum K^+ being lower in healthy adult males than in healthy older males. The same pattern was seen between young and older females although the difference did not reach statistical significance (table 3). It can be

concluded that the influence of age on the serum level of K^+ is augmented in males.

The average serum Ca^{+2} concentration appeared to decrease with advancing age in both male and females (Tables 2, 3). Age might be accompanied by reduced intake of Ca^{+2}-rich foods or it may influence the activity and levels of the hormones acting to regulate the serum Ca^{+2} concentrations.

In conclusion, we were unable to demonstrate clinically significant reductions in serum electrolytes in our selected group of surgical patients, but we were able to demonstrate that the levels of serum electrolytes in Khartoum residents tend to be on the lower side of the internationally accepted normal range and this could explain our "impression" that many of our patients tend to have low serum electrolytes. Nevertheless, many surgical patients have diseases that can gravely affect their hydration and electrolyte balance which should be carefully assessed and not dismissed as normal. A larger study is recommended to define local normal ranges for the Sudan.

Acknowledgement:

We thank Mr. Mohammad Mubarak for helping with electrolytes measurements and Dr Safa Ibrahin and Dr. Lee Ali for their help in the statistical design and analysis of the study.

References

1- William F Ganong. Review of medical physiology. Lange medical books\McGraw Hill, San fransisco, 22nd edition, 2005.

2- Boron WF, Emile L, Boulpaep EL (eds). Medical Physiology: A Cellular and Molecular Approaoch, W B Saunders Co, 2004.

3- Eugene Braunwald, Anthony S. Fauci, Dennis C Kasper et al. Harrison`s principles of internal medicine. McGraw Hill, 29th edition 2001:271-283.

4- Fukagawa M, Kurokawa K and Papadakis MA. Fluid and electrolyte disorders, In: Current Medical Diagnosis and Ttreatment. McGraw Hill Medical, 46th edition, 2007: 887-917.

5- Shearer S. Dehydration and serum electrolyte changes in south African gold miners with heat disorders, Am J Ind Med, 1990; 17(2): 225-39.

6- Whitefield JB, Martin NG. The effects of inheritance on constituents of plasma: a twin study on some biochemical variables. Ann Clin Biochem. 1984; 21 (Pt 3):176-83.

7- Seiler HG, Sigel A, Sigel H. (eds). Handbook on Metals in Clincial and Analytical Chemistry. Marcel Dekker Inc. New York, 1994: 299-312.

8- Kelly A, Munan L, PetitClerc C et al. Patterns of change in selected serum chemical parameters of middle and later years. J Gerontol. 1979;34 (1):37-40.

9- Tallis R and Fillit HM (eds). Brocklehurst's Textbook of Geriatric Medicine and Gerontology. 6th edition, Churchill Livingstone, 2002.