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THE ROLE AND IMPORTANCE OF AN ELECTROCARDIOGRAM TO REFLECT THE POTASSIUM LEVEL IN DIABETIC KETOACIDOSIS PATIENTS

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ABSTRACT

Diabetic ketoacidosis is a common cause of morbidity and mortality in the emergency department of Iraqi hospitals. Electrolyte disturbances are frequently accompanying diabetic ketoacidosis, specifically hyper and hypokalemia. Electrocardiography is an easy and available tool for early identification of these electrolyte disturbances. Aim of the study is to assess the role and importance of ECG monitor, which is a simple, quick, non-invasive and readily available tool in the diagnosis and confirmation of hypokalemia and hyperkalemia in patients with DKA in the Emergency Department. A cross-sectional study conducted in the Baghdad Teaching Hospital- Medical Complex Baghdad city /Emergency Department. The duration of the study was through six months from the 1st of January to the 30th of June 2019 on a sample of 88 DKA patients. Interpretation of the ECG was made by the supervisor, the researcher and the physicians in the emergency department. Results: Prevalence of hypokalemia among DKA patients was 75%. Significant ECG changes associated with hypokalemia among DKA patients were prolonged QT interval, flat T wave, U wave and ST depression. A highly significant association was observed between female gender DKA patients and hypokalemia ($p<0.001$). Mean random blood sugar of DKA patients with hypokalemia was significantly higher than the RBS mean of DKA patients with average K+ level ($p<0.001$). Mean blood PH of DKA patients with hypokalemia was significantly lower than blood PH mean of DKA patients with normal K+ level ($p<0.001$).

KEYWORDS: Electrocardiogram, Potassium, Diabetic Ketoacidosis Patients.

INTRODUCTION

Diabetic ketoacidosis (DKA) is a significant cause of morbidity and mortality among diabetic patients despite well-developed diagnostic criteria and treatment protocols. The twelve-monthly incidence of DKA from population-based studies is expected to range from four to eight events per 1,000 patient admissions with diabetes. The incidence of DKA in the US stays rise, and it accounted for around 140,000 hospitalizations in 2009 and 168,000 hospitalizations in 2014.[1] DKA incidence rates in Arab countries were found to range from a low of 17% in Egypt to a high of 100% in Morocco, Algeria and Tunisia with a n overall rate of 46.7%.[2] Although the incidence of DKA in Iraq is more common in girls, the severity of the condition is more in boys,[3] in our Emergency Department in Baghdad Teaching Hospital we received about 123 cases of DKA during the first six months of 2019 as it was recorded in the statistical record. This study was done to To assess the role and importance of ECG monitoring, as a simple, quick, non-invasive and readily available tool in the diagnosis and confirmation of hypokalemia and hyperkalemia in patients with DKA in the Emergency Department.

MATERIALS AND METHODS

A cross-sectional study conducted in the Emergency Department (ED) of Baghdad Teaching Hospital-Baghdad Medical Complex in Baghdad city. The duration of the study was through six months period from the 1st of January to the 30th of June 2019. All patients with type-1 diabetes presented with DKA were

the study population patients with DKA (RBS >250, PH <7.3, NaHco3 <15 mEq/L, +ve ketone in urine, anion gap >10). We exclude all patients in a state of coma, Patients taking drugs affecting ECG, a pattern like antiarrhythmics, a tricyclic antidepressant, anticonvulsant, Patients, taking drugs affecting Potassium levels like loop diuretics, ACE inhibitors and ARBs. A convenient sample of 88 DKA patients was selected from fulfilling inclusion and exclusion criteria. The researcher carried out the data collection through direct interview with established patients, relatives and patient's records.

A questionnaire, according to the study requirements, was prepared and filled. The questionnaire included the followings:

1. Demographic characteristics of DKA patients: Age and gender.
2. Electrocardiography changes of DKA patients: Tachycardia, QT interval, T wave, U wave, Prolonged PR, ST depression and P wave.
3. Result of Investigations such as Random plasma glucose, ABG (blood PH and Potassium level, anion gap, sodium bicarbonate level) and ketone bodies in urine. After taking full history and examination of DKA patients in emergency department, blood sample was drawn by using the necessary equipment, Position the patient's arm with the wrist extended, Locate the radial artery using index and middle fingers, Inset the needle at 30 degrees at the point of maximum pulsation of the radial artery then advance the needle until arterial blood flushes into the syringe, then remove the needle/syringe placing the needle into the bung, press firmly over the puncture site with the gauze for 5 minutes, and send immediately for analysis ensuring that the sample is packed in ice.

The ECG was measured using 12 leads electrocardiography. Interpretation of the ECG was made by the supervisor, the researcher and the physicians in ED.

Statistical analysis

The data of patients were analyzed by application of Microsoft excel program and Statistical Package for Social Sciences (SPSS) version 23. Outcomes of analysis were arranged in scales variables (means & standard deviation) and categorical variables. Multiple contingency tables conducted and appropriate statistical tests performed, a Chi- square test was used for categorical variables (Fisher's exact test was used when the expected variable was less than 20% of total variable). Independent sample t-test was used to compare between two means. . In all statistical analysis, level of significance (p-value) set at ≤ 0.05 and the result presented as tables and graphs.

RESULTS

This study included 88 (DKA) patients in (ED) with a mean age of 18.4±2.8 years; 34.1% of them were in the age group 14-17 years, 39.8% of them were in the age group 18-20 years and 26.1% of them were in the age group of 21-23 years. Female DKA patients were more than male DKA patients (51.1% vs 48.9%). (Table 1)

Table 1: Demographic characteristics of DKA patients.

Variable	No.	%
Age mean±SD (18.4±2.8 years)		
14-17 years	30	34.1
18-20 years	35	39.8
21-23 years	23	26.1
Total	88	100.0
Gender		
Male	43	48.9
Female	45	51.1
Total	88	100.0

Mean random blood sugar of DKA patients was 463.2±48.3 mg/dl; all studied DKA patients had hyperglycemia. Mean blood PH of DKA patients was 7.08±0.1; all studied DKA patients had low blood PH. Mean Potassium of DKA patients was 2.98±0.45 mEq/L; 25% of DKA patients had normal K+ level and 75% of DKA patients had hypokalemia (less than 3.5 mEq/L). (Table 2).

Table 2: Random blood sugar and blood PH of DKA patients.

Variable	No.	%
Random blood sugar mean±SD (463.2±48.3 mg/dl)		
Normal	0	-
Hyperglycemia	88	100.0
Total	88	100.0
Blood PH mean±SD (7.08±0.1)		
Normal	0	-
Low	88	100.0
Total	88	100.0

Mean Potassium of DKA patients was 2.98±0.45 mEq/L; 25% of DKA patients had normal K+ level and 75% of DKA patients had hypokalemia (less than 3.5 mEq/L). (Table 3)

Table 3: Potassium level of DKA patients.

Variable	No.	%
Potassium mean±SD (2.98±0.45 mEq/L)		
Normal	22	25.0
Hypokalemia	66	75.0
Total	88	100.0

Insignificant differences were observed between DKA patients with normal K+ level and DKA patients with hypokalemia regarding their age (p=0.2). A highly significant association was observed between female gender DKA patients and hypokalemia (p<0.001).

(Table 4).

Table 4: Distribution of demographic characteristics according to hypokalemia.

Variable	K+				P
	Normal		Hypokalemia		
	No.	%	No.	%	
Age groups					0.2* ***Not significant***
14-17 years	6	27.3	24	36.4	
18-20 years	12	54.5	23	34.8	
21-23 years	4	18.2	19	28.8	
Gender					**<0.001*** ***Highly significant***
Male	20	90.9	23	34.8	
Female	2	9.1	43	65.2	

**Chi-square test*.

The ECG changes of DKA in ED were mainly tachycardia for all DKA patients (100%). The QT interval was prolonged in 23.9% of DKA patients, while normal in 76.1% of DKA patients. The T wave was flat in 46.6% of DKA patients while normal in 53.4% of DKA patients, with no patients reported with tented or inverted T wave. The U wave in ECG was recorded in 11.4% of DKA patients and not recorded in 88.6% of DKA patients. Prolonged PR was not shown in ECG of all studied DKA patients. ST depression was found in ECG of 11.4% of DKA patients while absent in ECG of 88.6% of DKA patients. (***Table*** 5)

Table 5: Electrocardiography changes in DKA patients.

Variable	No.	%
Tachycardia		
Yes	88	100.0
No	0	-
Total	88	100.0
QT interval		
Prolonged	21	23.9
Normal	67	76.1
Total	88	100.0
T wave		
Flat	41	46.6
Normal	47	53.4
Tented	0	-
Inverted	0	-
Total	88	100.0
U wave		
Yes	10	11.4
No	78	88.6
Total	88	100.0
Prolonged PR		
Yes	0	-
No	88	100.0
Total	88	100.0
ST depression		
Yes	10	11.4
No	78	88.6
Total	88	100.0

There was a significant association between prolonged QT interval in ECG of DKA patients and hypokalemia (p=0.002). A highly significant association was observed between flat T wave in ECG of DKA patients and hypokalemia (p<0.001). There was a significant association between U wave in ECG of DKA patients and hypokalemia (p=0.05). A significant association was observed between ST depression in the ECG of DKA patients and hypokalemia (p=0.05). (Table 6)

Table 6: Distribution of ECG characteristics according to hypokalemia.

Variable	K+				P
	Normal		Hypokalemia		
	No.	%	No.	%	
QT interval					**0.002*** ***Significant***
Prolonged	0	-	21	31.8	
Normal	22	100.0	45	68.2	
T wave					**<0.001*** ***Highly significant***
Flat	0	-	41	62.1	
Normal	22	100.0	25	37.9	
U wave					**0.05**** ***Significant***
Yes	0	-	10	15.2	
No	22	100.0	56	84.8	
ST depression					**0.05**** ***Significant***
Yes	0	-	10	15.2	
No	22	100.0	56	84.8	

Chi-square test,Fishers exact test*.

Mean random blood sugar of DKA patients with hypokalemia was significantly higher than the RBS mean of DKA patients with normal K+ level (p<0.001). Mean blood PH of DKA patients with hypokalemia was significantly lower than blood PH mean of DKA patients with normal K+ level (p<0.001). (Table 7).

Table 7: Distribution of investigations findings means according to hypokalemia.

Variable	Normal	Hypokalemia	P
	Mean±SD	Mean±SD	
RBS	421±14.7	485.8±42.9	<**0.001***S
Blood PH	7.1±0.04	7±0.09	<**0.001***S

**Independent sample t-test, S=Significant.*

DISCUSSION

Studying ECG changes in diabetic ketoacidosis is an essential tool for improving the management and outcome of DKA patients.[4] In the current study, 75% of diabetic ketoacidosis patients had hypokalemia. This finding is similar to reports of Davis et al.[5] study in the USA, which revealed profound hypokalemia associated with severe cases of diabetic ketoacidosis. However, the prevalence of hypokalemia detected in our study is higher than the results of Arora et al.[6] study in the USA, which found that hypokalemia was diagnosed in 5.6% of patients with diabetic ketoacidosis. This higher prevalence of hypokalemia in the present study is attributed to the collection of severe diabetic ketoacidosis cases and also due to fact that our centre is a tertiary centre that its emergency department is receiving more deteriorated cases from all hospitals in our country. Reasons for hypokalemia in diabetic ketoacidosis are the results of the combination of both hyperglycemia and acidosis. Low insulin secretion leads to electrolytes disturbances, significantly affecting the Potassium level.[7] The insulin has a vital role in Potassium shift from extracellular to intracellular compartment[8] Additionally, the stress stimulates the Potassium shift into the cells.[9] However, an increase in glucose level stimulates diuresis. Increase diuresis leads to Sodium-ion retain while increase excretion of Potassium ions.[8] The acidosis also leads to more loss of Potassium.[10] Murthy et al.[11] study in the USA reported that hypokalemia associated with diabetic ketoacidosis had risky clinical condition especially in comatose patients who need Potassium a repletion and intravenous insulin with correction of other electrolyte disturbances. This study showed a significant association between prolonged QT interval in ECG of diabetic ketoacidosis patients and hypokalemia (p=0.002). This finding is consistent with results of Aygün et al. [12] study in Turkey which found that prolongation of QT length of ECG in patients with diabetic ketoacidosis was significant. Inconsistently, another survey carried out in Egypt by Yossif and Farid.[13] found that prolongation of QT interval during diabetic ketoacidosis of type 1 diabetic children is related to ketosis and not related to electrolyte disturbances. However, they found that this QT elongation is predicting cardiac complications and mortality. Kuppermann et al.[14] study in the USA also stated that prolonged QTc interval is frequently found among diabetic ketoacidosis patients, and this prolongation is related to ketosis and not related to hyperglycemia or electrolyte disturbances. This inconsistency might be because previous studies.[13,14] did not specify the electrolyte disturbances and neglected the hypokalemia.

In the present study, a highly significant association was observed between flat T wave in ECG of DKA patients and hypokalemia (p<0.001). This finding coincides with results of Talebi et al.[14] study in USA which reported that flat T wave emerges significantly among diabetic ketoacidosis patients with hypokalemia and also stated that ECG is a reliable measure for diagnosis of hypokalemia in diabetic ketoacidosis patients. Many authors revealed abnormal changes in electrocardiography related to hypokalemia, precisely flat T wave that indicates the severity of hypokalemia and diabetic ketoacidosis.[15]

This study showed a significant association between U wave in ECG of diabetic ketoacidosis patients and hypokalemia (p=0.05). This finding is similar to reports of Gandhi and Suvarna study in India[16] which stated that U wave is prominent ECG feature of hypokalemia in patients with diabetic ketoacidosis and this U wave is linked to cardiovascular changes of diabetic ketoacidosis. This study also showed a significant association among ST depression in ECG of diabetic ketoacidosis patients and hypokalemia (p=0.05). Our finding is in accordance with results of Çakır et al. study in Turkey,[17] which revealed abnormal electrocardiography changes like ST depression in ECG. Fronczyk et al.[18] study in Poland documented that ST change in ECG of patients with diabetic ketoacidosis must be considered carefully to avoid severe cardiovascular complications. In our study, a highly significant association was observed between female gender DKA patients and hypokalemia (p<0.001). Similarly, Lopes et al.[19] study in Brazil found that female gender was more prevalent in children with DKA especially when complicated with hypokalemia. Wysowzki et al,[20] study in USA found millions of American children and adults suffering from Potassium deficiency and revealed high prevalence of female gender with hypokalemia. Another significant finding in our study was more DKA effecting females than males. Similar findings were shown in a study in Germany,[21] Iran and Saudi Arabia[22,23] where a female to male ratio of 1.4 to 1 was found. So, Female sex is a risk factor in glycemic control and complications of diabetes type I, this may be attributed to earlier pubertal hormonal changes or bad care of a females in some societies and so females should be managed more seriously regarding self monitoring of blood glucose, nutritional and psychological factors and puberty issues.

This study showed that the mean random blood sugar of diabetic ketoacidosis patients with hypokalemia was significantly higher than random blood sugar mean of diabetic ketoacidosis patients with normal K+ level (p<0.001). This finding is consistent with results of

Saito et al[22] study in Japan, which found a higher incidence of hypokalemia among patients with severe diabetic ketoacidosis and hyperglycemia. Liamis et al[3] study documented a significant relationship between hypokalemia and hyperglycemia, which might be related to lack of insulin, acidosis and diuresis effects. Our study also showed that the mean blood PH of diabetic ketoacidosis patients with hypokalemia was significantly lower than blood PH mean of diabetic ketoacidosis patients with normal K+ level ($p<0.001$). Consistently, Usman study in Malaysia reported a significant relationship between lower PH (acidity) and hypokalemia among patients with diabetic ketoacidosis.[8]

CONCLUSIONS

- The electrocardiography has an essential role in early detection and diagnosis of hypokalemia in patients with diabetic ketoacidosis.
- The significant abnormal electrocardiography changes related to hypokalemia in patients with diabetic ketoacidosis are prolonged QT interval, flat T wave, U wave and ST depression.
- Hypokalemia in patients with diabetic ketoacidosis tends to be more in female gender patients.
- The hypokalemia in patients with diabetic ketoacidosis is affected by random blood sugar and blood PH.

Ethical consideration

- Verbal communication with each participant regarding the aim of this study was conducted.
- Verbal consent from each participant (Patient or relative) was obtained before data collection.
- As this was not an interventional study, written informed consent from each participant was not required.
- The data collected was kept confidential and not be used except for the study purpose.
- Approval of The Scientific Board of Emergency Medicine-Ethical Committee was obtained prior to the start of the study.
- Ethical clearance of the study was acquired from The Ethical Committee in the Iraqi MOH, after getting the scientific approval.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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