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Evaluation of the incidence of heart rhythm disorders based on the type of intradialytic electrolyte variation disease

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ABSTRACT

Introduction*:* individuals who suffer from end-stage renal disease (ESRD) frequently experience cardiac arrhythmia, especially those undergoing hemodialysis. One of the most significant risk factors for cardiac arrhythmias is thought to be electrolytic abnormalities. This research set out to assess the effect of hemodialysis on cardiac arrhythmias according to electrolytic disorders in individuals with chronic kidney disease (CKD).

Methods: This cross-sectional research was carried out on patients with ESRD had undergone hemodialysis for minumum of six months. Before and after hemodialysis, the serum levels of sodium, potassium, calcium, and magnesium were measured for each patient, along with an electrocardiogram (ECG). The data were entered and analyzed using SPSS software.

Results: In corrent research, 96 patients were included. The most common arrhythmia was atrial fibrillation (AF) (%22.9). Our findings revealed that changes in serum potassium levels ($p = 0.036$) had a significant relationship with the occurrence of AF. There was a strong adverse correlation between changes in serum calcium level and the QTc interval ($r = 0.223$- and $p = 0.023$). Additionally, There was a strong positive correlation between changes in serum calcium levels and the QRS complex amplitude ($r = 0.350$ and $p = 0.0001$).

Conclusion: Abnormalities in ECG, especially AF arrhythmias, are frequent in people undergoing hemodialysis, which demonstrates the necessity of ECG monitoring both during and after hemodialysis.

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Introduction

The prevalence of chronic kidney disease (CKD), especially end-stage renal disease (ESRD), is increasing, and it has significant implications in terms of both health economics and human suffering (1,2). Dialysis and kidney transplantation are two of the main treatments for ESRD (3). The prevalence of cardiovascular disease (CVD) among patients receiving continuous dialysis is extremely high, with a three-year mortality rate of about 50% (4–6).

Various investigations have shown that CVD is the major cause of mortality, with arrhythmias accounting for around two-thirds of all cardiac deaths (4,7). This higher prevalence of CVD, especially sudden cardiac death, seems to be specific to ESRD and is not entirely explained by established cardiovascular risk elements (8,9).

Multiple mechanisms are triggered by dialysis, which might raise the risk of cardiac arrhythmias. Hemodialysis-specific risk factors for CVD include fluctuations in fluid volume and electrolyte levels, myocardial stunning, a pro-inflammatory state, and repeated myocardial injury from uremia (10,11).

The question of whether hemodialysis causes malignant arrhythmias due to fast changes in volume and electrolyte concentration is currently being debated. Accordingly, electrocardiographic (ECG) assessment of hemodialysis patients during hemodialysis is known to be very important (12).

In ECG, increases in wave voltage, including QRS, P, and T waves, have been linked to increases in the transfer impedance of the body following liquid extraction following hemodialysis. Moreover, hemodialysis has been demonstrated to affect wave durations in addition to increasing wavelength (13). Since there are different consequences of hemodialysis on cardiovascular function and different studies that have had inconsistent outcomes, and it is still unclear if dialysis causes alterations in the ECG, This study was conducted to evaluate the effects of hemodialysis on cardiac arrhythmias in CKD patients in accordance with electrolytic abnormalities.

Materials and Methods

Population and study design

This cross-sectional study was performed on CKD patients from December 2019 to December 2020 in the Ghaem Hospital and the Sabz-Darman dialysis centers affiliated with Mashhad University of Medical Sciences, Mashhad, Iran.

Inclusion and exclusion criteria

The study included patients with ESRD (CKD stage 5, glomerular filtration lower than 10/ml/min/1.73 m2) and between 18 to 75 years old whose hemodialysis treatment has lasted for at least six months.

Patients with a permanent pacemaker or implantable cardioverter defibrillator, a history of bundle branch block, a history of atrial fibrillation (AF), pregnant women, those who have had a fever, diarrhea, or vomiting in the last 24 hours, and those who have used other medications that prolong the QT interval, such as Sotalol, Amiodarone, antibiotics such as Clarithromycin and Erythromycin, Domperidone, as well as antipsychotic drugs such as Chlorpromazine and Haloperidol, were excluded from the study.

To gather data, a survey was designed based on the study's goals. This information included demographics (gender, age, height, weight, dialysis duration, and cause of renal failure), cardiac arrhythmias on ECG before and after hemodialysis (including AF, supraventricular tachycardia (SVT), first-degree block, ST-T wave fluctuations, premature ventricular contractions (PVC), bradycardia, Nonsustained ventricular tachycardia (VT), QRS complex amplitude, and T amplitude), and serum biochemical data (including sodium, potassium, magnesium, and calcium).

Patients' ECGs were collected before and after hemodialysis during one of the dialysis sessions, and patients were additionally monitored for cardiac rhythm events during dialysis. In addition, 20 cc of venous blood were obtained from patients before and after hemodialysis to evaluate serum electrolytes such as sodium, potassium, magnesium, and calcium. Changes in ECG parameters, the incidence of dysrhythmias, changes in electrolyte levels, and their relationship were all investigated.

Definitions of Arrhythmias

The following terms were used as definitions: PVC was defined as a complex with a width of more than 120 milliseconds, a large T-wave in the opposite direction of the QRS complex, and the absence of its P-wave. Additionally, AF was considered a supraventricular tachyarrhythmia in which atrial waves were seen in the form of F waves with variable voltage and shape, at a rate equal to 300-600 beats per minute and in accompaniment of variable ventricular responses.

First-degree AV block implicated a PR interval of more than 0.2 seconds with regular ventricular waves. Finally, ST-T wave changes were considered changes in the voltage of the ST segment proportional to the TP line greater than 0.5 mV. SVT was also considered to be any supraventricular arrhythmia except AF.

Statistical analysis

After collecting data, analysis of the data was

done by IBM SPSS software version 23.0 (Chicago, IL, USA). Descriptive statistical indicators such as central indices, dispersion, mean, and standard deviation, as well as frequency distribution, were calculated and presented in the form of appropriate tables. Comparative analysis of qualitative variables was performed using the Chi-square test or Fisher's exact test and for quantitative variables, the Mann-Whitney U test and t-test were used due to the normal distribution of data. A p-value of < 0.05 was considered statistically significant.

Ethical consideration

Each and every patient gave their signed, informed consent, according to the World Medical Association Declaration of Helsinki, revised in 2000, Edinburgh. Additionally, the Mashhad University of Medical Sciences Ethics Committee gave the study protocol complete approval (IR.MUMS.MEDICAL.REC.1398.804).

Results

Totally, 96 patients (58 males, 38 females) having a median age of 55.9 ± 9.9 years were considered for our study. The patients' mean body mass index (BMI) was 30.1 ± 2.7 kg, and most of them were obese (54 patients, 57.4%). The average length of dialysis in the investigated patients was 27.63 ± 1.83 months, and the most common cause of CKD and dialysis was hypertension (54.1%, 52 patients) (Table 1).

Table 1. Patients demographic Data.

Variables		Mean ± SD / Frequency (%)
Age		55.9 ± 9.9
Gender	**Male**	58 (60.4)
	Female	38 (39.6)
Height		166.8 ± 8.1
Weight		84.0 ± 10.0
Duration of dialysis (month)		27.63 ± 1.83
BMI	**Normal**	6 (6.4)
	Overweight	34 (36.2)
	Obese	54 (57.4)
Cause of renal failure	**Hypertension**	52 (54.1)
	Diabetes	38 (39.6)
	Idiopathic	19 (19.7)
	Glomerulonephritis	11 (11.4)
	Reflux nephropathy	8 (8.3)
	Polycystic kidney disease	6 (6.5)

The most common finding in the ECG of the patients was reduced T-wave amplitude (66.7%), followed by increased QRS complex amplitude (47.9%).

The most common arrhythmia was AF (22.9%), and a highly typical ECG anomaly was nonspecific ST-T wave changes (18.8%) (Table 2).

Table 2. Prevalence of ECG changes and arrythmias in patients.

Variables	Frequency (%)
AF	22 (22.9)
SVT	10 (10.4)
First-degree block	10 (10.4)
Nonspecific ST-T wave changes	18 (18.8)
PVC	8 (8.3)
Bradycardia	14 (14.6)
Nonsustained VT	2 (2.1)
Reduced T amplitude	64 (66.7)
Increased QRS complex amplitude	46 (47.9)

The results of an investigation into the relationship between changes in serum levels of different electrolytes and the occurrence of AF in dialysis patients revealed that variations in serum potassium levels (p= 0.036) had a significant relationship with the occurrence of AF. Additionally, there was a strong correlation between changes in serum calcium levels and the incidence of SVT (p= 0.004).

There was a noteworthy relationship between changes in sodium (p = 0.03), potassium (p= 0.02), and magnesium (p = 0.04) serum levels and the development of PVC. Also, there was a link between changes in calcium (p = 0.01) and magnesium (p = 0.004) levels in the serum and the incidence of bradycardia.

On the other hand, there was no notable association between changes in serum levels of electrolytes and the occurrence of ST-T wave changes, increased QRS complex amplitude, and reduced T amplitude (Table 3).

In the study of the correlation between changes in serum electrolyte levels with PR, QRS, and QTc intervals, the results showed that there was a significant positive relationship between changes in serum calcium levels and the QRS complex amplitude (r = 0.350 and p = 0.0001).

Furthermore, there was a significant negative relationship between changes in serum calcium level and QTc interval (r = -0.223 and p = 0.023) (Table 4).

Table 3: Assessment of the relationship between changes in serum levels of different electrolytes and incidence of ECG abnormalities

Variables		Sodium		Potassium		Calcium		Magnesium	
		Value	P-value	Value	P-value	Value	P-value	Value	P-value
AF	Yes	1±3.8	0.34	**-1.9±1.3**	**0.036**	**0.7±0.7**	**0.79**	0.6±0.3	0.37
	No	0.1±4.5		**-2.0±0.8**		**0.7±0.6**		0.5±0.3	
SVT	Yes	2±3.6	0.21	-2.2±0.7	0.34	0.2±0.2	0.004	0.5±0.2	0.92
	No	1±4.4		-1.9±0.9		0.7±0.6		0.5±0.3	
First-degree block	Yes	1.6±4.0	0.32	-2.3±0.3	0.30	1±0.6	0.10	0.5±0.4	0.69
	No	0.1±4.4		-1.9±1		0.6±0.6		0.5±0.3	
ST-T wave change	Yes	0±6.5	0.94	-2±0.9	0.94	0.7±0.7	0.53	0.6±0.1	0.26
	No	0.3±3.7		-2±0.9		0.7±0.6		0.5±0.3	
PVC	Yes	-2.7±3	0.01	-1.5±0.4	0.02	0.9±0.4	0.26	0.7±0.04	0.01
	No	0.5±4.3		-2±0.9					
Increased QRS complex amplitude	Yes	0.8±5.1		-2.1±0.7	0.3	0.7±0.7	0.33	0.5±0.3	0.22
	No	0.5±3.6		-1.8±1.1		0.6±0.6		0.5±0.3	
Bradycardia	Yes	4.4±3.6		-2.3±0.6	0.10	1.1±0.4	0.01	0.7±0.2	0.004
	No	3.3±4.1		-1.9±1		0.6±0.6		0.5±0.3	
Reduced T amplitude	Yes	0.4±4.7		-2.1±0.7	0.21	0.7±0.6	0.87	0.6±0.3	0.1
	No	0.1±3.1		-1.8±1.2		0.7±0.6		0.3±0.3	

Table 4: correlation between serum electrolytes level with PR intervals, QRS complex, and QTc

Variables	Potassium	Calcium	Magnesium
PR	p=0.355, r=-0.19	p=0.071, r=+0.211	p=0.848, r=-0.023
QRS complex	p=0.596, r=+0.055	p=0.0001, r=+0.350	p=0.761, r=-0.031
QTc	p=0.482, r=-0.073	p=0.023, r=-0.233	p=0.611, r=+0.053

Discussion

In this research, we assessed the impact of hemodialysis on cardiac arrhythmias and ECG changes according to electrolytic disorders in 96 ESRD patients. The most common finding in the ECG of the patients was reduced T-wave amplitude (66.7%), followed by increased QRS complex amplitude (47.9%). The most common rhythm abnormality was AF (22.9%), and the most typical ECG anomaly was nonspecific ST-T wave changes (18.8%).

In research by Rantanen et al. (14), 152 individuals with CKD on hemodialysis were assessed for cardiac arrhythmias using Holter monitoring for 48 hours. The outcomes of this study showed that PAC and PVC were reported in almost all patients, and 41% had paroxysmal SVT. Paroxysmal AF was seen in 3.9% of patients, persistent AF in 8.6%, bradycardia in 4.6%, non-sustained VT in 19.7%, second-degree block in 1.3% of patients, and third-degree block in 2.6% of patients. In regression analysis, older age, longer duration of dialysis, lower systolic blood pressure, history of palpitation, and a lower calcium level before dialysis were reported as independent factors in the occurrence of arrhythmias in dialysis patients (14).

In the research carried out by Rogovoy et al. (15), 28 patients with CKD on hemodialysis were prospectively assessed by ECG patch for cardiac arrhythmias over 14 days. 46% of patients showed at least one arrhythmic event. 26% of arrhythmias were reported during the 6 hours before dialysis, 17% during dialysis sessions, 19% during the 6 hours after dialysis, and 38% between dialysis sessions.

The most common type of arrhythmia was AF (75%), which was reported in two patients (7%), except in one case. Other cases were asymptomatic, lasting less than 30 seconds, and non-sustained. The second most common arrhythmia was SVT (60.7%), which was noted in 9 patients (32%) (15).

In a systematic review via Robert et al. (16),

on the prevalence of cardiac arrhythmias in hemodialysis patients, the results of five studies (317 patients) were evaluated. They reported that the annual incidence rate of at least one episode of bradycardia/asystole was equal to 0.19 (95% CI: 0.33-0.11). The mean annual incidence of stable VT and AF was 0.02 (95%CI: 0.01-0.05) (16). The prevalence of AF differed significantly between studies (from 0.07 to 0.83 individuals per year), owing to different criteria (16).

Our analysis of serum electrolyte levels and cardiac arrythmias indicated that the amount of potassium in all individuals was lower after dialysis than before dialysis. This change in serum potassium level was less pronounced in patients with AF rhythm (p = 0.036). Furthermore, in patients with SVT rhythm, a lesser increase in calcium was observed (P=0.004). PVC rhythm disturbance was linked with a further decrease in potassium (p=0.02) and a further increase in magnesium (p=0.04).

In patients with bradycardia, a further rise in calcium (p 0.01) and magnesium (p 0.004) was reported. Changes in serum levels of different electrolytes were not significantly associated with the occurrence of first-degree block, the amplitude of T and QRS complex, and nonspecific ST-T changes. Changes in serum calcium levels were significantly correlated with the QRS complex (r = +3.250 and p = 0.0001). Also, a significant negative relationship (r = -0.223 and p = 0.023) was reported between changes in serum calcium level and QTc.

Another study by Tumlin et al. (4), examined the connection between dialysis parameters and cardiac arrhythmias in 66 patients on hemodialysis. Overall, cardiac arrhythmias were reported in 64 patients (97%). Among the various dialysis parameters, the use of a high flux dialyzer was correlated with a higher frequency of arrhythmias. Nonetheless, serum levels of sodium, potassium, calcium, and phosphorus were not strongly correlated with the frequency of arrhythmias. On the other hand, a significant decrease in serum magnesium levels was reported with an increase in the number of arrhythmic events (P=0.003). Khoshhal et al. recently investigated the association between baseline serum levels of different electrolytes and one-year mortality in hemodialytic patients and concluded that higher baseline serum levels of magnesium increase the odds of survival (17).

As our findings also reveal lower rates of cardiac arrhythmias in patients with higher serum concentrations of magnesium, magnesium levels and supplementation of magnesium should be considered in all hemodialytic patients Comparing biochemical variables in dialysis sessions with and without arrhythmia showed that the mean serum levels of potassium, calcium, magnesium, phosphorus, bicarbonate, and sodium before and during dialysis, with or without arrhythmia, were not significantly different (4).

Conclusion

ECG abnormalities, particularly AF arrhythmia, are prevalent in dialysis patients, indicating the necessity for ECG monitoring during and after hemodialysis. These ECG abnormalities are linked to changes in serum electrolyte levels that might occur after dialysis, notably decreased serum levels of potassium in dialysis patients with AF. Furthermore, there was a strong correlation between improvements in serum calcium levels and the QRS complex and a significant negative connection between variations in serum calcium levels and the QTc interval.

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