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Original Article

High Risk of Ventricular Repolarization Abnormalities among Hemodialytic End-Stage Renal Disease Patients

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Abstract

Introduction: Patients with chronic renal disease (CKD) are at a significantly elevated risk for ventricular arrhythmia. Several electrocardiographic (ECG) methods can be used to assess the ventricular arrhythmia risk on the standard 12-lead ECG.

Aim: This study aimed to evaluate the ECG parameters of ventricular repolarization abnormalities, such as QT, QTc, Tp-e, and Tp-e/QT ratio, Tp-e/QTc ratio, and their predictors in hemodialytic end-stage renal disease (ESRD) patients.

Materials and methods: Fifty-three patients with hemodialytic ESRD and 32 pre-dialytic CKD patients were enrolled in the study. ECG parameters were measured manually using calipers. The independent samples *t*-test was used for comparative analysis. The multivariate linear regression analysis was used to distinguish the independent predictors of each ECG parameters and variables correlating significantly in bivariate analysis.

Results: Mean ages of hemodialytics and pre-dialytics were 47±11 and 51±7 years, respectively. Ventricular repolarization abnormalities in the hemodialytic compared to the pre-dialytic group were found to be significantly different [QTc (448±34 vs. 428±31 ms, *p*=0.007), Tp-e (81±20 vs. 71±19 ms, *p*=0.025), Tp-e/QT (0.23±0.06 vs. 0.20±0.05, *p*=0.043)]. QTc interval was positively correlated with sodium (*p*=0.001) and age (*p*=0.007). Tp-e/QT ratio was the ECG parameter correlated to most of variables including eGFR (*p*=0.003), creatinine (*p*=0.040), potassium (*p*=0.009), chloride (*p*=0.048), and glucose (*p*=0.041).

Conclusions: Ventricular repolarization was found to be increased in patients with hemodialytic ESRD. Hence, observation ECG parameters of ventricular repolarization should be performed in the hemodialytic patients for early detection of ventricular arrhythmia.

INTRODUCTION

Chronic kidney disease (CKD) is a significant health problem across the world. Estimated global CKD prevalence is consistent between 11% and 13%, with most of them being stage 3.[1] In Indonesia, CKD was found in 12.5% (Cockroft-Gault), 8.6% (modification of diet in renal disease/MDRD), or 7.5% (Chinese modified MDRD) subjects with hypertension, proteinuria, and/or diabetes.[2] It is known that cardiovascular disease (CVD) and the risks of cardiac

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or ventricular arrhythmia (VA), including sudden cardiac death (SCD), are highly increased in CKD patients, especially when reaching end-stage renal disease (ESRD). SCD accounts for approximately 25% of all-cause mortality in dialysis ESRD.

The incidence of ventricular arrhythmia that can be cardiac mortality marker was high in the ESRD patients and increasing at the end of hemodialysis.[3] Ventricular arrhythmia was known to relate to coronary artery disease, myocardial fibrosis, and left ventricular hypertrophy.[4] However, SCD in ESRD patients does not always have structural heart disease; 71% of them had a normal left ventricular function to mild-moderate dysfunction.[3] Significant electrolyte imbalance reduced blood circulation, and sympathetic overactivity in the ESRD patients was reported to increase the risk of ventricular arrhythmia and SCD.[4]

Ventricular repolarization is a critical process in which the associated abnormalities are related to a higher risk of ventricular arrhythmias.[5,6] Standard 12-lead electrocardiography (ECG) is a simple and non-invasive tool to assess ventricular repolarization abnormalities. Several parameters have been reported to be a marker for the ventricular repolarization abnormalities that are associated with the ventricular arrhythmia such as QT interval, QTc interval, T peak-T end (Tp-e) interval, Tp-e/QT ratio, and Tp-e/QTc ratio.[7-9] Previous studies on the factors associated with the ventricular repolarization were performed in the European and American population groups. However, reports about ventricular repolarization abnormalities in ESRD patients with regular hemodialysis in Indonesia have been scarce.

AIM

This study aimed to evaluate the ECG parameters of ventricular repolarization abnormalities such as QT, QTc, Tp-e, and Tp-e/QT ratio, Tp-e/QTc ratio in patients with hemodialytic ESRD.

MATERIALS AND METHODS

This prospective case-control study was carried out at the Internal Medicine Ward in one of the third-level referral hospitals for East Indonesia region. The study was conducted over a three-month period from January to March 2020. All participants gave their informed consents. The hospital's Ethics Committee approved the study procedure.

Fifty-three patients (27 men and 26 women) with regular hemodialytic ESRD and thirty-two (21 men and 11 women) pre-dialytic patients as controls were enrolled consecutively in the study. All patients between the ages of 15–90 years were included in this study. Hemodialysis was performed twice weekly with volumetrically controlled machines (Surdial 55 Plus, Nipro, Japan). Bicarbonate dialysate was used and adjusted according to individual sodium requirements. Patients who required anticoagulant therapy received systemic unfractionated heparin. Patients taking antiarrhythmic drugs that prolong the QT interval, having ECG of right or left bundle branch block, acute coronary syndromes (chronic coronary syndrome more than six months was included), structural heart disease, diagnosed with active infection, acute stroke, malignant or benign hematologic disorders, right- or left-sided heart failure (systolic heart failure, heart failure with reduced ejection fraction), and cancer, and patients who received surgery in the past six months were excluded. ESRD was defined by following the classification of Kidney Foundation Disease Outcomes Quality Initiative, based on estimated glomerular filtration rate (eGFR) with the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) formula. Hemodialytic patients determined if they regularly received hemodialysis while pre-dialytic CKD patients have never received hemodialysis and were not indicated to have hemodialysis. In the hemodialytic group, the data from the laboratory blood examination such as the concentrations of potassium, sodium, chloride, creatinine, blood urea nitrogen (BUN), plasma glucose, albumin, and hemoglobin were obtained within 6 hours before hemodialysis procedure.

ECG (GE Mac 1600) with twelve leads surface was performed on every patient at the same time of blood sampling, and the printed result was analyzed. By using calipers, QT interval was measured from the earliest onset of the Q wave to the end of the T wave in all leads, and the longest value was used. If a U wave was observed, an alternate lead was chosen, or a tangent was drawn from the downslope of the T wave at its steepest part until it crossed the TP segment. QTc was calculated by the Bazett formula ($QTc = QT/\sqrt{RR}$). T-peak to T-end (Tp-e) was calculated in the leads with the longest QT interval as the duration from the peak of the T wave to the end of the T wave. Calculation of the Tp-e/QT and Tp-e/QTc ratio was done by dividing Tp-e by QT or QTc.

The statistical analysis of the data was carried out with SPSS v.25 (IBM Corp., Armonk, N.Y., USA). The Shapiro-Wilk test was used to analyze the normality of data. Continuous data of variables with normal and deviation from normal distribution were described as mean ± standard deviation (SD) and median (interquartile range [IQR]), respectively. The independent t-test or Mann-Whitney test for normal and non-normal data distribution was used in the comparative analysis of two independent groups. Nominal data were expressed as numbers and percentages. The χ^2 test was used for nominal data comparison. Pearson and Spearman correlation tests were used for bivariate correlation analysis. Within the hemodialytic group, variables in the bivariate analysis with $p<0.05$ were included in the multivariate analysis using linear regression with stepwise method to distinguish the independent predictors of each ECG parameters. A p-value <0.05 was accepted as statistically significant.

RESULTS

Characteristics of patients

Fifty-three patients (27 men and 26 women) with regular hemodialytic ESRD and thirty-two (21 men and 11 women) pre-dialytic CKD (stage 2-4) as controls were enrolled in the study. The mean ages were not different between the hemodialytic and pre-dialytic groups, which were 47±11 and 51±7 years, respectively. There was no difference in the distribution of age and sex between the two groups.

The hemodialytic patients were a special group with several significantly different characteristics, even when compared to the pre-dialytic patients as summarized in **Table 1**. Significantly higher creatinine serum was observed. Hypertension (HTN) as another comorbid was also found to be higher in hemodialytic patients (64.2%) than in the pre-dialytic patients (37.5%). Interestingly, the diagnosis of diabetes mellitus (DM) was found to be lower in 20.8% of hemodialytics and 62.5% of the controls group ($p<0.001$).

Compared to controls, laboratory parameters showed that BUN ($p<0.001$) and creatinine ($p<0.001$) were higher, while eGFR ($p<0.001$) and hemoglobin ($p<0.001$) were lower in the hemodialysis group. Concordant with the DM diagnosis, the blood glucose level was also lower in the hemodialytic patient. While for electrolytes (sodium, potassium, chloride) and albumin, there were no significant differences between the hemodialytic and control groups.

Different ECG characteristic in hemodialytic patients

ECG analysis revealed that all (100%) hemodialytic patients and controls had normal sinus rhythm. Three patients (3.7%) in the hemodialytic group had first degree AV block. One patient (3.1%) in the control group had a second-degree type 1 AV block. Premature ventricular contractions were found in hemodialytic and control group, which were one (1.9%) and two patients (6.3%), respectively.

Focusing on the ventricular abnormality, the ECG parameters listed in **Table 2** were assessed. ECG parameters for ventricular repolarization abnormalities in hemodialyt-

Table 1. Baseline characteristics of the study population

Characteristics	Hemodialytic patients (n=53)	Pre-dialytic controls (n=32)	*P*-value
Age (year)	47±12	51±7	0.066
Sex (men/women)	27/26	21/11	0.186
DM, n (%)	11 (20.8%)	20 (62.5%)	<0.001
HTN, n (%)	34 (64.2%)	12 (37.5%)	0.017
eGFR (mL/min)	4.9 (4.2:22.1)	23.7 (20.8:35.5)	<0.001
BUN (mg/dL)	66.2±31.0	37.1±17.4	<0.001
Creatinine (mg/dL)	10.1±4.5	2.4±0.7	<0.001
Sodium (mEq/L)	133.4±6.2	131.3±7.5	0.179
Potassium (mEq/L)	4.4±0.9	4.5±1.0	0.552
Chloride (mEq/L)	99.5±6.7	98.8±8.1	0.661
Albumin (g/dL)	3.4±0.8	3.1±0.6	0.149
Hemoglobin (g/dL)	7.0±1.8	10.1±2.1	<0.001
Plasma glucose (mg/dL)	120 (100:213)	186 (105:287)	0.005

BUN: blood urea nitrogen; DM: diabetes mellitus; eGFR: estimated glomerular filtration rate; HTN: hypertension

Table 2. Electrocardiography parameters of the study population

ECG parameters	Hemodialytic patients (n=53)	Pre-dialytic controls (n=32)	*P*-value
HR (bpm)	96±18	89±16	0.071
QT (ms)	360±48	356±37	0.646
QTc (ms)	448±34	428±31	0.007
Tp-e (ms)	81±20	71±19	0.025
Tp-e/QT	0.23±0.06	0.20±0.05	0.043
TP-e/QTc	0.18±0.05	0.17±0.04	0.145

HR: heart rate; QTc: corrected QT interval; Tp-e: T peak-T end

ic: QTc interval (448±34 vs. 428±31 ms, *p*=0.007) was higher compared to the pre-dialytic group significantly. Tp-e (81±20 vs. 71±19 ms, *p*=0.025), and Tp-e/QT (0.23±0.06 vs. 0.20±0.05, *p*=0.043) were also higher in the hemodialytic group. While QT interval (360±48 vs. 356±37 ms, *p*=0.646) and Tp-e/QTc (0.18±0.05 vs. 0.17±0.04, *p*=0.145) were increased in hemodialytic group but were not significantly different as shown in **Table 2**.

Factors related to ventricular repolarization abnormalities in hemodialytic patients

The variables of age, sex, DM, HTN, eGFR, BUN, creatinine, sodium, potassium, chloride, albumin, hemoglobin, and plasma glucose of the hemodialytic patients were analyzed along with each of the ECG parameters. No relationship was found between the ECG parameters and any of the following variables: sex, DM, HTN, BUN, and hemoglobin. As shown in **Supplementary Table 1,** Tp-e/QT ratio was the ECG parameter correlated with most of variables including eGFR (*p*=0.033), creatinine (*p*=0.040), potassium (*p*=0.009), chloride (*p*=0.048), and plasma glucose (*p*=0.041). The length of QT and QTc intervals on ECG were positively correlated with serum sodium levels (*p*=0.002 and *p*=0.001, respectively). There was a significant negative correlation between the age and QTc interval (*p*=0.007), while serum albumin was positively correlated with QT interval (*p*=0.004). Tp-e interval was negatively correlated with serum potassium level (*p*=0.001). Tp-e/QTc ratio was positively correlated eGFR (*p*=0.021) but correlated with creatinine and potassium level negatively (*p*=0.046 and *p*=0.001, respectively).

Various laboratory parameters within hemodialytic patients were analyzed using multivariate linear regression, as shown in **Table 3**. As a result, increased sodium (*β*=2.086, *p*=0.039) and albumin levels (*β*=18.301, *p*=0.023) were independent predictors of the increased QT interval. Sodium level (*β*=1.736, *p*=0.014) and age (*β*=−0.946, *p*=0.013) were also the independent predictors of an increase of QTc interval. Furthermore, Tp-e interval was only independently predicted by potassium levels (*β*=−9.74, *p*=0.001). Potassium level (*β*=−0.020, *p*=0.011) was also an independent predictor of decrease in Tp-e/QTc ratio.

DISCUSSION

Decreasing kidney function was correlated with increased risk of CVD due to high inflammation reaction and prothrombotic factors, low hemoglobin levels, albuminuria, and abnormal bone and mineral metabolism. Evaluation of ECG ventricular repolarization abnormalities to deal with the potential risk of fatal arrhythmias, including SCD, can provide useful clinical information especially for the hemodialytic ESRD population.[10] Ventricular repolarization abnormalities shown by prolongation of QT, QTc, and QTd are predictors of cardiovascular mortality and SCD among patients with CKD and in the general population.[8,11,12] Hence, this study evaluated those measurements of ECG intervals that are related to an abnormality of ventricular repolarization in 53 patients with hemodialytic ESRD compared with 32 pre-dialytic patients.

It is important to determine factors related to ventricular abnormalities in ESRD patients. Previous studies were performed in the United States or with European population while studies on Indonesian population were scarce.[4,8,13,14] It was proposed that human genetic factor also contributes to the increase of the risk for ventricular arrhythmia in ESRD patients; hence, different populations may show different risk factors. Gene polymorphism of angiotensin-converting enzyme and angiotensin type-1 receptor might play a role in the prolongation of QTc interval in patients with hemodialysis.[15] To date, it is the first study to evaluate the factors related to ventricular repolarization in the Indonesian population.

Several parameters for ventricular repolarization abnormalities have been determined by many studies, such as QT, QTc, Tp-e, Tp-e/QT ratio, and Tp-e/QTc. The QT interval reflects the depolarization and ventricular repolarization dispersion. Prolongation of QT (or QTc) interval indicates a potential risk of ventricular arrhythmias, SCD, and even one of the causes of mortality related to a cardiovascular event in South East Asian population.[16-18] Meanwhile, a prolonged Tp-e is the result of an event when the epicardium is already fully repolarized but the subendocardium is not; hence, the electric created after depolarization drives re-entrant ventricular arrhythmias.[19] Thus, prolonged Tp-e interval is known as a predictor for cardiac arrhythmias.[7-9,20] Tp-e/QT ratio, which is lowered to a narrower

Table 3. Multivariate linear regression analysis between various study variables and ECG parameters in hemodialytic patients

	Factors	β (95% CI)	*P*	R square
QT	Sodium (mEq/L)	2.086 (0.105, 4.068)	0.039	0.194
	Albumin (g/dL)	18.301 (2.576, 34.027)	0.023	
QTc	Age (years)	−0.946 (−1.688, −0.205)	0.013	0.235
	Sodium (mEq/L)	1.736 (0.371, 3.100)	0.014	
Tp-e	Potassium (mEq/L)	−9.747 (−15.543, −3.951)	0.001	0.183
Tp-e/QTc	Potassium (mEq/L)	−0.022 (−0.035 to −0.009)	0.011	0.184

range of values, can be expressed as a more sensitive index for arrhythmogenesis. Because the Tp-e and QT intervals can increase with larger body size and decrease when heart rate is faster, another ECG parameter, the Tp-e/QT ratio, would be more reliable.[8,19,21]

In this study, QTc interval in hemodialytic group was found to be significantly higher compared to pre-dialytic group ($p=0.007$). Our result was in accordance with some previous studies which found that QT, QTc, and QTc dispersion were increased in dialysis patients compared to controls.[22-26] QTc interval was found to be increased for each sequential stage of CKD, while the QTc interval was not significantly different in hemodialytic patients compared to patients with stage 5 CKD not under renal replacement therapy.[27] Rapid replacement of electrolytes from tubulointerstitium during hemodialysis treatment is very likely to change the Tp-e and QT intervals and increase the risk of ventricular arrhythmias. These patients have an increased risk before routine hemodialysis sessions due to excess volume, increased serum potassium, and metabolic acidosis.[8,11] Hence, patients with hemodialysis are also susceptible to fatal arrhythmias. In our study, the QTc, Tp-e interval, and Tp-e/QT were significantly prolonged in the hemodialytic patients compared to controls. The mechanism of prolonged QT interval in hemodialytic patients is uncertain, but in various studies, several factors have effects on QT, QTc, and QT dispersion in hemodialysis patients.

Our study demonstrated that several factors correlated and may predict the prolongation of QT. Alteration of electrolyte control in the ESRD patients and regulation by hemodialytic procedure may cause an electrolyte imbalance that could affect the cardiac function. Hence, we observed the patient's electrolytes levels. The increase of sodium ($p=0.039$) and albumin level ($p=0.023$) were the independent predictors of the increased QT interval. Sodium level ($p=0.014$) and age ($p=0.013$) were also the independent predictors of an increased QTc interval. These results were concordant with the observation of Jaroszynski et al. that showed alterations of serum potassium, phosphorus, calcium, and extracellular volume during hemodialysis may affect QTc dispersion and advance ventricular arrhythmogenesis.[22] That correlation was more likely happened by the evidence that renal transplantation could shorten QTc duration and maximum QTc interval compared to hemodialysis patients.[9,28] However, controversial results were reported by another study that mentioned an increasing QT and QTc dispersion with decreasing sodium and potassium.[24]

Interestingly, a negative correlation of age with the QTc value was observed in the hemodialytic patients; older patients had a lower QTc interval. This result was also consistent in the multivariate analysis. Our observation showed a contrary result with the normal population that showed an increasing QTc in older ages. However, the mechanisms were unknown, and further study with larger samples may be necessary. Diabetes also has possible association with prolonged QTc as a cause of ESRD. We should bear in mind

that patients undergoing hemodialysis can become hypoglycemic without realizing it.[27] However, we did not find a significant association between DM diagnosis status and either QT or QTc.

The Tp-e interval ($p=0.025$) and Tp-e/QT ratio ($p=0.043$) were found to be higher in the hemodialytic ESRD group compared to controls in our study. A study by Kollu et al. also showed that the Tp-e/QT ratio was higher in CKD stages 3–5 patients on no Renal Replacement Therapy compared to the healthy subjects.[4] In a study published by Tun et al., Tp-e in ESRD patients was increased compared to controls.[29] In another study that reports no differences in QT dispersion and QTc interval, Tp-e interval and Tp-e/QT ratio were increased after hemodialysis, and that hemodialysis was also suspected to have caused ventricular arrhythmias.[30] Previous study by Karagaac et al. also showed an increase in the Tp-e, Tp-e/QTc, QTd, and Tp-e/QT in chronic renal failure patients requiring hemodialysis.[25] Our study demonstrated that Tp-e interval was only independently predicted by potassium levels ($p=0.001$). Potassium level itself ($p=0.011$) was also an independent predictor of an increase in the Tp-e/QTc ratio. However, because of the small number of studies that address this issue, we assume that no adequate hypothesis suspicion can be made at the increased Tp-e and the Tp-e/QT ratio in the hemodialytic ESRD patients.

Several limitations can be found in our study. First, this was a single-center study with a relatively small sample size in one measurement. The effect of serum electrolytes on changes in cardiac repolarization can ideally be compared with ECG after rapid transmembrane electrolyte changes. Other confounding factors such as the time from beginning dialysis to the present study could not be obtained. Further risk factors for ventricular repolarization abnormalities were not taken into account for the analysis. Due to the not routine part of blood tests conducted at the hospital, serum magnesium was not measured in all patients, including controls, but we assume serum magnesium will increase as CKD develops. In addition, blood PH and calcium could not be measured in both groups for technical reasons. We also did not evaluate the relationship between arrhythmia incident and the ventricular abnormalities parameters.

CONCLUSIONS

The parameters for ventricular repolarization abnormalities in hemodialytic patients represented by QTc, Tp-e, and Tp-e/QT were significantly different compared to those of the predialytic group. Different independent factors within hemodialytic patients were found for each parameter, but the most important independent factors were sodium, albumin, and potassium. Hence, observation of QT, QTc, Tp-e, Tp-e/QT, and Tp-e/QTc should be performed in hemodialysis patients, especially with the high sodium, albumin, and potassium level for early detection of ventricular arrhythmia and prevention of SCD.

Supplementary material

Supplementary Table 1. Bivariate analysis result of various study variables and ECG parameters in hemodialytic patients

Variables n = 53	QT		QTc		Tp-e		Tp-e/QT		Tp-e/QTc	
	r	p	r	p	r	p	r	p	r	p
Age (years)	−0.119	0.395	−0.367	0.007	−0.030	0.833	−0.065	0.646	−0.136	0.333
Sex (Men)	-	0.582*	-	0.774*	-	0.251**	-	0.136*	-	0.185*
Diabetes mellitus	-	0.351*	-	0.341*	-	0.432**	-	0.466*	-	0.451*
Hypertension	-	0.146*	-	0.803*	-	0.267**	-	0.130*	-	0.333*
eGFR (mL/min)	−0.163	0.243	−0.140	0.317	0.261	0.059	0.294	0.033	0.316	0.021
BUN (mg/dL)	0.071	0.614	0.144	0.305	−0.193	0.166	−0.211	0.130	−0.239	0.085
Creatinine (mg/dL)	0.177	0.205	0.174	0.212	−0.221	0.112	−0.283	0.040	−0.275	0.046
Sodium (mEq/L)	0.422	0.002	0.455	0.001	−0.015	0.918	−0.210	0.131	−0.168	0.228
Potassium (mEq/L)	−0.139	0.322	−0.019	0.894	−0.426	0.001	−0.357	0.009	−0.434	0.001
Chloride (mEq/L)	0.230	0.098	0.102	0.469	−0.149	0.286	−0.273	0.048	−0.190	0.172
Albumin (g/dL)	0.391	0.004	0.123	0.379	0.110	0.432	−0.069	0.624	0.081	0.567
Hemoglobin (g/dL)	−0.237	0.088	−0.072	0.609	−0.255	0.065	−0.151	0.280	−0.239	0.085
Glucose (mg/dL)	−0.221	0.112	−0.071	0.611	0.235	0.091	0.281	0.041	0.236	0.088

*p-value was derived from independent t-test; **p-value was derived from Mann-Whitney test.

Ethical approval and consent to participate

Human and Animal Rights

No animals were used in this research. All human research procedures were followed in accordance with the ethical standards of the committee responsible for human experimentation (institutional), and with the Helsinki Declaration of 1975, as revised in 2013.

Availability of data and materials

The datasets generated during and/or analyzed during the current study are not publicly available due to protecting participant confidentiality but are available from the corresponding author on reasonable request.

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Conflict of Interest

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Высокий риск нарушений реполяризации желудочков у пациентов с гемодиализом в терминальной стадии почечной недостаточности

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Резюме

Введение: Пациенты с хронической болезнью почек (ХБП) имеют значительно повышенный риск желудочковой аритмии. Для оценки риска желудочковой аритмии на стандартной ЭКГ в 12 отведениях можно использовать несколько электрокардиографических (ЭКГ) методов.

Цель: Это исследование было направлено на оценку параметров ЭКГ нарушений реполяризации желудочков, таких как QT, QTc, Tp-e и отношение Tp-e/QT, отношение Tp-e/QTc, и их предикторов при гемодиалитической терминальной стадии почечной недостаточности. (ТСПН) пациентов.

Материалы и методы: В исследование были включены 53 пациента с гемодиализной ТСПН и 32 пациента с ХБП на додиализном этапе. Параметры ЭКГ измеряли вручную с помощью штангенциркуля. Для сравнительного анализа использовали t-критерий независимых выборок. Многофакторный линейный регрессионный анализ использовался для различения независимых предикторов каждого параметра ЭКГ и переменных, которые значительно коррелируют в двумерном анализе.

Результаты: Средний возраст получателей гемодиализа и преддиалитика составил 47±11 и 51±7 лет соответственно. Было обнаружено, что нарушения реполяризации желудочков в группе гемодиализа по сравнению с группой до диализа значительно различаются [QTc (448 ± 34 против 428 ± 31 ms, *p*=0.007), Tp-e (81 ± 20 против 71 ± 19 ms, *p*=0.025), Tp-e/QT (0.23±0.06 против 0.20±0.05, *p*=0.043)]. Интервал QTc положительно коррелировал с содержанием натрия (*p*=0.001) и возрастом (*p*=0.007). Соотношение Tp-e/QT представляло собой параметр ЭКГ, коррелирующий с большинством переменных, включая eGFR (*p*=0.003), креатинин (*p*=0.040), калий (*p*=0.009), хлориды (*p*=0.048) и глюкозу (*p*=0.041).

Заключение: Было обнаружено, что реполяризация желудочков повышена у пациентов с гемодиализной ТСПН. Следовательно, у больных, находящихся на гемодиализе, необходимо проводить наблюдение за ЭКГ-параметрами реполяризации желудочков для раннего выявления желудочковой аритмии.

Ключевые слова

электрокардиография, терминальная стадия почечной недостаточности, реполяризация желудочков, интервал QTc

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