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Does vitamin D deficiency affect ventricular repolarization in the elderly?

D vitamini eksikliği yaşlılarda ventriküler repolarizasyonu etkiler mi?

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Abstract

Purpose: In this study, we aimed to establish if vitamin D deficiency interacts with the electrocardiographic indices of abnormal ventricular repolarization in elderly patients.

Material and methods: 138 patients were divided into three groups: patients with vitamin D deficiency, patients with vitamin D insufficiency, and patients with adequate vitamin D levels. 12-lead electrocardiography and laboratory data were collected.

Results: The resting heart rate, PR interval, Tp-e interval, QRS duration, Tp-e/QTc, QT dispersion, and Tp-e dispersion were similar among the groups. However, the QTc interval was significantly prolonged in patients with vitamin D deficiency when compared to patients with sufficient vitamin D levels. Vitamin D level was found as the only independent predictor of the QTc interval. The cut-off value of Vitamin D level determining the significant prolongation of QTc interval was found to be 20 ng/ml on ROC analysis (Area Under Curve: 0.629±0.051 (95% CI: 0.530-0.728, *p*=0.013).

Conclusion: Low vitamin D levels are related to QTc prolongation in the elderly. Vitamin D-deficient elderly patients may benefit from routine ECG screening. Timely diagnosis and treatment of vitamin D deficiency may aid in reducing the rate of arrhythmias in this patient population.

Keywords: Vitamin D deficiency, elderly, ventricular repolarization.

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Öz

Amaç: Bu çalışmanın amacı, D vitamini eksikliğinin yaşlı hastalarda anormal ventriküler repolarizasyonun elektrokardiyografik indeksleri ile ilişkili olup olmadığını belirlemektir.

Gereç ve yöntem: 138 hasta üç gruba ayrıldı: D vitamini eksikliği olan hastalar, D vitamini yetersizliği olan hastalar ve yeterli D vitamini düzeyine sahip hastalar. 12 derivasyonlu elektrokardiyografi ve laboratuvar verileri toplandı.

Bulgular: İstirahat kalp hızı, PR aralığı, QRS süresi, QTd ve Tp-e dispersiyonu gruplar arasında benzerdi. Ancak, D vitamini eksikliği olan hastalarda QTc aralığı, D vitamini düzeyi yeterli olan hastalara kıyasla anlamlı derecede uzamıştı. D vitamini düzeyi QTc aralığının tek bağımsız belirleyicisi olarak bulundu. ROC analizinde QTc aralığında anlamlı uzamayı belirleyen D vitamini düzeyinin eşik değeri 20 ng/ml olarak bulundu (Eğri Altındaki Alan: 0,629±0,051 (%95 GA: 0,530-0,728, *p*=0,013).

Sonuç: Düşük D vitamini düzeyleri yaşlılarda QTc uzaması ile ilişkilidir. D vitamini eksikliği olan yaşlı hastalar rutin EKG taramasından fayda görebilir. D vitamini eksikliğinin zamanında teşhis ve tedavisi, bu hasta popülasyonunda aritmi oranını azaltmaya yardımcı olabilir.

Anahtar kelimeler: D vitamini eksikliği, yaşlılık, ventriküler repolarizasyon.

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Introduction

Vitamin D is well-known for its role in calcium and bone metabolism. Nonetheless, owing to its widespread receptors (VDR) throughout the body, it plays a crucial role in several organ systems, including the cardiovascular (CV) system [1]. VDR is expressed abundantly in cardiac muscle [2]. The binding of active vitamin D [1,25-dihydroxyvitamin D; 1,25(OH)2D] to the VDR in cardiomyocytes regulates several vitamin D response genes, hence promoting CV system benefits such as modulation of renin synthesis and improvement in vascular compliance [3, 4]. Not surprisingly, low vitamin D levels are associated with increased CV risk [5]. Vitamin D deficiency has been related to many CV disorders, such as coronary artery disease, hypertension, arrhythmias, and sudden cardiac death [6].

Vitamin D deficiency is highly prevalent worldwide and across all age groups. Moreover, specific risk groups, such as the elderly, are more prone to vitamin D deficiency. Therefore, general screening for vitamin D deficiency is recommended for adults older than 65 years old [7].

Ventricular repolarization (VR) is a complex phase of cardiac electrical activity. Abnormalities in ventricular myocardial repolarization may increase the risk of developing malignant ventricular arrhythmias and, thus, sudden cardiac death [8]. Multiple indices on surface electocardiography have been applied to predict alterations in VR, including QT interval, corrected QT interval (QTc), QT dispersion (QTd), Tp-e interval, Tp-e/QT ratio, and Tp-e/QTc ratio [9, 10].

Numerous studies have revealed that low vitamin D levels were related to disturbances in cardiac repolarization [11-13]. Nonetheless, the association between vitamin D deficiency and VR has not been explicitly evaluated in a geriatric population before.

The purpose of the current study is to establish whether deficient vitamin D levels is accociated with the electrocardiographic indices of abnormal ventricular repolarization in elderly patients.

Material and methods

Study population

In this single-center study, we retrospectively assessed the medical records of a total of 156 patients who were admitted to our institution's geriatrics clinic between June 2021 and October 2021. 46 participants were recruited from another study population that was intended to investigate the octogenarians' clinical traits. The remaining cases were recruited using medical records. Fasting blood samples and 12-lead ECG recordings were obtained from the medical records. 18 patients were excluded due to insufficient electrocardiographic (ECG) data and the use of antipsychotics or antiarrhythmics. As there are a vast number of medications known to prolong the QTc interval, we did not exclude patients who were taking other QTc-prolonging drugs. Eventually, a final total of 138 patients were included in the analysis. The subjects were seperated into three groups:

1st Group: Vitamin D deficiency

2nd Group: Vitamin D insufficiency

3rd Group: Adequate vitamin D levels

Vitamin D deficiency was defined as serum vitamin D levels <20 ng/ml, insufficiency as 20-30 ng/ml, and normal vitamin D levels were considered as >30 ng/ml [7].

Permission was obtained from Ankara University Non-Interventional Clinical Research Ethics Committee for the study and was performed in concordance with ethical rules and principles of the Declaration of Helsinki.

Electrocardiography (ECG)

A standard 12-lead ECG recording was obtained for each patient while in the supine position at 25 mm/s paper speed and 10 mV/mm amplitude, using standard ECG equipment. The ECG strips were scanned and loaded into computer and analyzed with a digital caliper using a software program (EP Calipers, EP Studios, Inc.). Heart rate, PR interval, QRS duration, QT and QTc intervals, QT dispersion (QTd), QTc dispersion (QTc), T wave peak-to-end interval (Tp-e), and Tp-e dispersion (Tpe-d) were measured from the D2 and V5

derivations. All measurements were obtained from the average of five consecutive beats. The PR interval was calculated as the time from the start of the P wave to the beginning of the QRS wave. The QT interval was calculated as the time from the beginning of the QRS wave to the end of the T wave. QT values were corrected by using the Bazett formula (QTc=QT/√RR). QTd was determined by subtracting the minimum QT interval from the maximum QT interval. The Tp-e interval was calculated as the interval from the peak of T wave to the end of T wave. Tpe-d was calculated as the difference between the maximum and minimum Tp-e intervals. Tp-e/QTc was calculated by dividing Tp-e interval to QTc interval.

Statistical analysis

Statistical analyses were conducted with the Statistical Package for Social Sciences (SPSS) software, version 10.0. The Kolmogorov-Smirnov test was used to test the normality of the distribution for continuous variables. The results were given as mean ± standard deviation (SD), whereas categorical ones were given as percentages (%). In order to compare the mean levels of the continuous variables between the groups, ANOVA (1-way analysis of variance) was used. Tukey post-hoc test was employed for multiple comparisons. ROC curve analysis was used to measure the diagnostic accuracy of the determinants used in the study. The Youden index method defined the optimal cut-off points for the studied determinants. The Pearson or Spearmen test was used to assess correlations between the variables. The association between independent variables and the outcome variable was first evaluated with univariate analysis. Linear regression analysis was used to examine the relationship between the QTc interval and clinical parameters. Variables selected with univariate analysis having a *p*-value less than 0.3 were incorporated into the multivariable analysis. A *p*-value of less than 0.05 was considered significant.

Results

The baseline characteristics and biochemical parameters of the 3 groups are presented in Table 1. Patients in group 2 were significantly longer than patients in group 3. No other significant difference was observed between the groups in terms of baseline characteristics.

The ECG characteristics of the groups are shown in Table 2.

The resting heart rate, PR interval, QRS duration, QTd and Tp-e dispersion were similar among the groups. However, QTc interval was meaningfully prolonged in patients with deficient levels of vitamin D, when compared to patients with sufficient vitamin D levels. Potential parameters that may be associated with QTc were evaluated by univariate analysis. Neither the number of drugs used by the patient nor the presence of coronary artery disease were related to the QTc interval in the linear regression analysis (Table 3).

Then a multivariate logistic regression analysis was performed by including all parameters that were associated with QTc in the univariate analysis. Vitamin D level was found as the only independent predictor of the QTc interval (Table 4).

The cut-off value of Vitamin D level determining the significant prolongation of QTc interval was found to be 20 ng/ml on ROC analysis (Area Under Curve: 0.629±0.051 (95% CI: 0.530-0.728, *p*=0.013) (Figure 1).

Table 1. Baseline demographic and characteristics

Variables	Group 1 (vitamin D deficiency) (n=87)	Group 2 (vitamin D insufficiency) (n=27)	Group 3 (Sufficient vitamin D levels) (n=24)	*p* value
Age (years)	75.9±7.2	74.4±6.3	77.8±5.5	0.212
Men n (%)	36 (41.3)	10 (37)	10 (41.6)	0.916
Height (cm)	159.7±8.9	162.4±7.3	156±9.1	**0.036***
Weight (kg)	73.5±13.2	75.2±9.1	68.5±16.3	0.164
Number of drugs (n)	5.3±3.2	5.8±2.8	5.1±3.1	0.647
Co-morbidities (n)				
HT	68	21	17	0.747
DM	40	15	10	0.576
Dementia	10	3	2	0.907
COPD	17	3	7	0.268
AF	14	3	2	0.619
HF	9	3	3	0.970
CAD	26	14	6	0.068
Laboratory values				
eGFR, mg/dl/1.73m^2	66.9±20.5	66.2±23.7	62.9±17.9	0.705
Creatinine, mg/dl	1.01±0.3	1.07±0.5	1.02±0.3	0.821
Hemoglobin, gr/dl	12.4±2.1	13.2±2.5	11.8±2.2	0.085
White blood count, 10^9/L	8±6.6	7.6±2.1	7±1.8	0.705
Vitamin D, ng/ml	9.8±3.8	25.6±6.5	39.3±8.1	**0.000***
Total cholesterol, mg/dl	177.3±49.2	195.9±46.2	162.7±53.6	0.057
Calcium, mg/dl	10.1±8.8	9.3±0.5	9.3±0.5	0.801
Albumin, mg/dl	4.1±0.5	4.1±0.6	4.1±0.5	0.911

HT: hypertension, DM: diabetes mellitus, COPD: chronic obstructive pulmonary disease, AF: atrial fibrillation, HF: heart failure
CAD: coronary artery disease, eGFR: estimated glomerular filtration rate

Table 2. ECG parameters of the patients

ECG Parameters	Group 1 (vitamin D deficiency) (n=87)	Group 2 (vitamin D insufficiency) (n=27)	Group 3 (Sufficient vitamin D levels) (n=24)	*p* value
Resting heart rate (beats/min)	75.6±14.3	75.8±13	78±11.7	0.764
PR interval (msn)	163.7±30.8	165±24.2	155.8±25	0.504
QRS duration (msn)	94.5±20.1	92.9±18.1	92±16.4	0.839
QTc interval (msn)	435.4±35.7(a)	430±28.8	409.2±38.9	**0.01***
QTd (msn)	59±20.6	59.8±21.3	58.7±30.6	0.984
Tp-e	79.8±22.03	85±24.5	80.1±16.3	0.890
Tp-e/QTc	0.16±0.04	0.21±0.06	0.18±0.04	0.193
Tp-e dispersion (msn)	47.2±16.1	48±13.3	41.4±15.5	0.260

The post-hoc analysis revealed a difference between group 1 and group 3

Table 3. Univariate analysis of clinical and laboratory parameters affecting QTc interval

	HR (95% CI)	*p*
Age	0.974 (0.924-1.027)	0.330
Gender	0.605 (0.295-1.240)	0.170
Number of drugs	1.021 (0.913-1.142)	0.716
HT	1.178 (0.507-2.736)	0.703
DM	1.098 (0.543-2.221)	0.794
HF	1.956 (0.544-7.028)	0.304
CAD	1.100 (0.526-2.302)	0.800
AF	1.105 (0.491-2.485)	0.810
Vitamin D level	0.952 (0.922-0.983)	**0.003***
eGFR	1.014 (0.997-1.032)	0.117
Hemoglobin	0.903 (0.711-1.059)	0.211
TSH	0.974 (0.779-1.218)	0.819

HT: hypertension, DM: diabetes mellitus, HF: heart failure, CAD: coronary artery disease
AF: atrial fibrillation, Egfr: estimated glomerular filtration rate

Table 4. Predictors of QTc interval on multivariate analysis

	HR	95% CI	*p*
Age	0.945	0.853-1.048	0.286
Gender	0.736	0.209-2.601	0.635
HF	2.425	0.462-12.734	0.295
Vitamin D level	0.927	0.870-0.989	**0.021***
eGFR	1.014	0.980-1.049	0.424
Hemoglobin	0.854	0.620-1.177	0.336

HF; heart failure, eGFR; estimated glomerular filtration rate

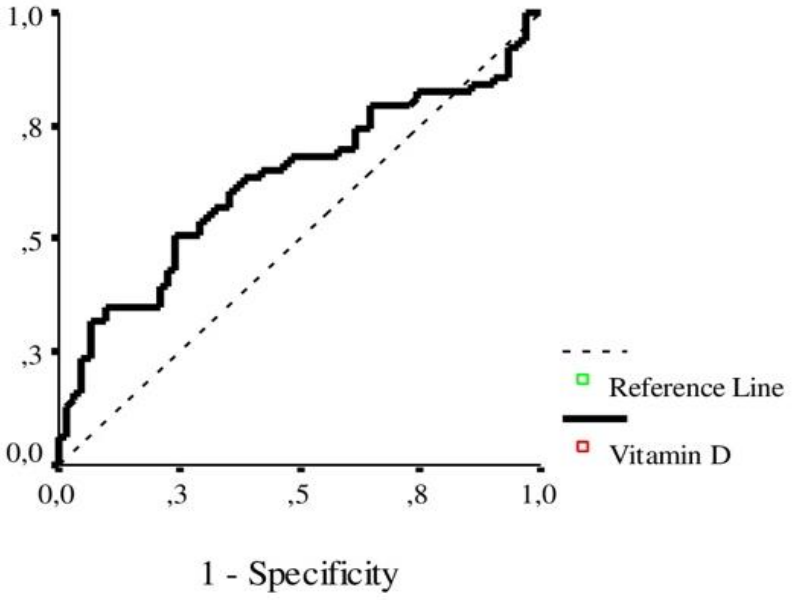

Figure 1. The Receiver operating curves (ROC) of significant prolongation of QTc interval

Vitamin D level AUC=0.629±0.051 (95% CI: 0.530-0.728)

Discussion

In the present study, we aimed to investigate the relationship between vitamin D levels and ventricular repolarization in the elderly population. We revealed that deficient vitamin D levels were independently associated with QTc interval prolongation in elderly patients. QT and Tpe dispersion, Tp-e interval, and Tp-e/QTc ratio as further indices of abnormal ventricular repolarization, were not associated with the vitamin D levels. Additionally, we showed that 20 ng/ml was the optimal cut-off value for vitamin D levels that was associated with significant prolongation of the QTc interval.

The receptors of Vitamin D are extensively present in the cardiovascular system. When combined with its receptor, vitamin D regulates the transcription of genes that control oxidative stress, cell adhesion, cell proliferation, and cell apoptosis in cardiomyocytes [14]. Low vitamin D levels were associated with an increased risk of many cardiovascular diseases such as hypertension, coronary artery disease, and arrhythmias in individuals with vitamin D deficiency [6, 15]. Both vitamin D insufficiency and mortality due to sudden cardiac death are more prevalent among the elderly. Therefore, in the present study we have chosen this patient population in particular.

Numerous studies have investigated the link between atrial fibrillation (AF) and vitamin D deficiency [16-18]. Low vitamin D levels have also been related to repolarization abnormalities, ventricular arrhythmias, and sudden cardiac death. Previously, vitamin D deficiency was revealed to be related to prolongation of the QTc interval [19]. Moreover, lower vitamin D levels were linked to sudden cardiac death in older adults who had no prior cardiovascular disease [20]. A recent study on the pediatric population revealed a correlation between vitamin D levels and surface ECG indicators of ventricular repolarization, including QT interval, QTc interval, QT dispersion, JT interval, JTc interval, Tpeak-to-Tend interval, and Tp-e/QTc [12]. Similarly, Bagrul et al. [13] have shown that adolescents with deficient and insufficient vitamin D levels had a prolonged Tp-e interval compared to patients with sufficient levels of vitamin D. In another study by Yetkin et al. [21], vitamin D deficient diabetic patients had prolonged QTc and higher QTC dispersion, compared to patients with adequate vitamin D levels. Similarly, we found a prolonged QTc interval in vitamin D-deficient patients compared to patients with adequate levels of vitamin D. Nonetheless, QTc intervals were similar between patients with sufficient levels of vitamin D and patients with vitamin D insufficiency. We did not observe a significant relationship between QTd, Tp-e, Tp-e/QTc, and Tpe-d and vitamin D levels.

Ventricular repolarization abnormalities are considered mechanistic for arrhythmogenesis. QTc interval is the most frequently employed marker of ventricular repolarization on the surface ECG. Various studies have indicated that prolonged QTc is associated with an increased risk of ventricular arrhythmias and sudden cardiac death [22, 23]. Vitamin D deficiency may activate aldosterone receptors and thus affect calcium and potassium currents through the cardiomyocytes. Also, the active metabolite of vitamin D may increase the potassium currents in cardiomyocytes. Furthermore, vitamin D deficiency may result in structural and ionic channel remodeling and autonomic function disorders. In conclusion, vitamin D deficiency induces changes in the repolarization of the ventricular myocardium that may increase susceptibility to malignant ventricular arrhythmias and sudden cardiac death [24-26].

The main limitation of our study was that it was a single-center study with a relatively low number of cases. Also, beacuse this was a cross-sectional study, we cannot estalish a casual relationship between vitamin D levels and the QTc interval. Another limitation was the absence of control ECG findings following treatment for vitamin D deficiency. Also, the serum electrolytes of the patients were missing. Moreover, as a parameter that could influence the QTc interval, we simply mentioned the number of medications utilized by the patients. We did not report individual medications. Last but not least, the patients have not been followed up long term for the development of ventricular arrhythmias and sudden cardiac death.

In conclusion, low vitamin D levels are associated with QTc prolongation in the elderly. As vitamin D deficiency is highly prevalent among adults >65 years old, this patient population is at increased risk for ventricular arrhythmias

and sudden cardiac death. Therefore, vitamin D deficient elderly patients may benefit from routine ECG screening. Timely diagnosis and treatment of vitamin D deficiency may aid in reducing the rate of arrhythmias in this patient population. Despite its limitations, our study is the first to reveal the clear relationship between vitamin D deficiency and QTc prolongation in an elderly population. Further studies involving more patients with longer follow-up times are needed in order to reveal the mechanistic relationship between vitamin D and malignant ventricular arrhythmias.

Conflict of interest: No conflict of interest was declared by the authors.

References

1. Khanolkar S, Hirani S, Mishra A, et al. Exploring the role of vitamin D in atherosclerosis and its impact on cardiovascular events: a comprehensive review. Cureus 2023;15:e42470. https://doi.org/10.7759/cureus.42470
2. Reddy Vanga S, Good M, Howard PA, Vacek JL. Role of vitamin D in cardiovascular health. Am J Cardiol 2010;106:798-805. https://doi.org/10.1016/j.amjcard.2010.04.042
3. Sánchez Martínez R, Castillo AI, Steinmeyer A, Aranda A. The retinoid X receptor ligand restores defective signalling by the vitamin D receptor. EMBO Rep 2006;7:1030-1034. https://doi.org/10.1038/sj.embor.7400776
4. Muscogiuri G, Annweiler C, Duval G, et al. Vitamin D and cardiovascular disease: from atherosclerosis to myocardial infarction and stroke. Int J Cardiol 2017;230:577-584. https://doi.org/10.1016/j.ijcard.2016.12.053
5. Chowdhury R, Kunutsor S, Vitezova A, et al. Vitamin D and risk of cause specific death: systematic review and meta-analysis of observational cohort and randomised intervention studies. BMJ 2014;348:g1903. https://doi.org/10.1136/bmj.g1903
6. Wang TJ, Pencina MJ, Booth SL, et al. Vitamin D deficiency and risk of cardiovascular disease. Circulation 2008;117:503-511. https://doi.org/10.1161/CIRCULATIONAHA.107.706127
7. Płudowski P, Kos Kudła B, Walczak M, et al. Guidelines for preventing and treating Vitamin D deficiency: a 2023 update in Poland. Nutrients 2023;15:695. https://doi.org/10.3390/nu15030695
8. Zareba W, Moss AJ, le Cessie S. Dispersion of ventricular repolarization and arrhythmic cardiac death in coronary artery disease. Am J Cardiol 1994;74:550-553. https://doi.org/10.1016/0002-9149(94)90742-0
9. Galinier M, Vialette JC, Fourcade J, et al. QT interval dispersion as a predictor of arrhythmic events in congestive heart failure. Importance of aetiology. Eur Heart J 1998;19:1054-1062. https://doi.org/10.1053/euhj.1997.0865
10. Kors JA, Ritsema van Eck HJ, van Herpen G. The meaning of the Tp-Te interval and its diagnostic value. J Electrocardiol 2008;41:575-580. https://doi.org/10.1016/j.jelectrocard.2008.07.030
11. Barsan M, Brata AM, Ismaiel A, et al. The pathogenesis of cardiac arrhythmias in vitamin D deficiency. Biomedicines 2022;10:1239. https://doi.org/10.3390/biomedicines10061239
12. Bekdas M, Inanir M, Ilhan Z, Ildes E. Effects of serum vitamin D level on ventricular repolarization in children and adolescents. Bratisl Lek Listy 2021;122:816-820. https://doi.org/10.4149/BLL_2021_130
13. Bagrul D, Atik F. Association of vitamin D deficiency with ventricular repolarization abnormalities. Kardiol Pol 2019;77:853-858. https://doi.org/10.33963/KP.14888
14. Nibbelink KA, Tishkoff DX, Hershey SD, Rahman A, Simpson RU. 1,25(OH)2-vitamin D3 actions on cell proliferation, size, gene expression, and receptor localization, in the HL-1 cardiac myocyte. J Steroid Biochem Mol Biol 2007;103:533-537. https://doi.org/10.1016/j.jsbmb.2006.12.099
15. McGreevy C, Williams D. New insights about vitamin D and cardiovascular disease: a narrative review. Ann Intern Med 2011;155:820-826. https://doi.org/10.7326/0003-4819-155-12-201112200-00004
16. Chen WR, Liu ZY, Shi Y, et al. Relation of low vitamin D to nonvalvular persistent atrial fibrillation in Chinese patients. Ann Noninvasive Electrocardiol 2014;19:166-73. https://doi.org/10.1111/anec.12105
17. Kara H, Yasim A. Effects of high-dose vitamin D supplementation on the occurrence of post-operative atrial fibrillation after coronary artery bypass grafting: randomized controlled trial. Gen Thorac Cardiovasc Surg 2020;68:477-484. https://doi.org/10.1007/s11748-019-01209-0
18. Turin A, Bax JJ, Doukas D, et al. Interactions among Vitamin D, atrial fibrillation, and the renin-angiotensin-aldosterone system. Am J Cardiol 2018;122:780-784. https://doi.org/10.1016/j.amjcard.2018.05.013
19. D'Imperio S, Monasky MM, Micaglio E, Negro G, Pappone C. Impact of dietary factors on brugada syndrome and long QT syndrome. Nutrients 2021;13:2482. https://doi.org/10.3390/nu13082482
20. Deo R, Katz R, Shlipak MG, et al. Vitamin D, parathyroid hormone, and sudden cardiac death: results from the Cardiovascular Health Study. Hypertension 2011;58:1021-1028. https://doi.org/10.1161/HYPERTENSIONAHA.111.179135

21. Yetkin DO, Kucukkaya B, Turhan M, Oren M. The effect of 25-hydroxyvitamin D levels on QT interval duration and dispersion in type 2 diabetic patients. Croat Med J 2015;56:525-530. https://doi.org/10.3325/cmj.2015.56.525

22. Locati ET, Bagliani G, Cecchi F, Johny H, Lunati M, Pappone C. Arrhythmias due to inherited and acquired abnormalities of ventricular repolarization. Card Electrophysiol Clin 2019;11:345-362. https://doi.org/10.1016/j.ccep.2019.02.009

23. Galluzzo A, Gallo C, Battaglia A, et al. Prolonged QT interval in ST-elevation myocardial infarction: predictors and prognostic value in medium-term follow-up. J Cardiovasc Med (Hagerstown) 2016;17:440-445. https://doi.org/10.2459/JCM.0000000000000317

24. Perrier E, Kerfant BG, Lalevee N, et al. Mineralocorticoid receptor antagonism prevents the electrical remodeling that precedes cellular hypertrophy after myocardial infarction. Circulation 2004;110:776-783. https://doi.org/10.1161/01.CIR.0000138973.55605.38

25. Tishkoff DX, Nibbelink KA, Holmberg KH, Dandu L, Simpson RU. Functional vitamin D receptor (VDR) in the t-tubules of cardiac myocytes: VDR knockout cardiomyocyte contractility. Endocrinology 2008;149:558-564. https://doi.org/10.1210/en.2007-0805

26. Li YC, Kong J, Wei M, Chen ZF, Liu SQ, Cao LP. 1,25-Dihydroxyvitamin D(3) is a negative endocrine regulator of the renin-angiotensin system. J Clin Invest 2002;110:229-238. https://doi.org/10.1172/JCI15219

Ethics committee approval: Permission was obtained from Ankara University Non-Interventional Clinical Research Ethics Committee for the study (permisson date: 27/03/2023, permission number: 2023000147-1(2023/147).

Authors' contributions to the article

M.A. and B.Y. constructed the main idea and hypothesis of the study. V.A. developed the theory and arranged the material and method section. B.Y. has done the evaluation of the data in the results section. M.A. has written the article. M.V. reviewed, corrected and approved. In addition, all authors discussed the entire study and approved the final version.