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Negativity of the electromechanical window: relation to frequent premature ventricular complexes

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Abstract. – OBJECTIVE: The electromechanical window (EMW) was investigated as a new predictor of arrhythmia in the presence of long QT. However, the use of EMW to predict idiopathic frequent ventricular premature complexes (PVCs) in those with normal QT intervals has not been clarified.

PATIENTS AND METHODS: This single-center study included consecutive patients who presented to the Cardiology Clinic with palpitations and were found to have idiopathic PVC on 24-hour Holter monitoring. Those with a PVC/24-hour frequency of < 1% were defined as group 1, 1-10% as group 2, and > 10% as group 3. The EMW was defined as the time difference (in ms) between the aortic valve closure and the end of the QT interval, measured from an ECG on the concurrent echocardiogram.

RESULTS: A total of 148 patients were included in the study, 64% (n = 94) of which were female. The patients' mean age was 50.11 ± 14.7. The groups were similar in terms of the patients' age, BMI, and comorbidities. There was a statistically significant difference between the three groups in terms of the EMW measurements (group 1: 3.78 ± 19.6, group 2: -7 ± 30.9, group 3: -34.83 ± 55.2 ms: $p < 0.001$). In the multivariate regression analysis, the EMW (OR 0.971, $p = 0.007$) and every 10-ms decrease in the EMW (OR 1.254, $p = 0.011$) were thus determined to be independent predictors of PVC > 10%. An EMW value of ≤ -15 ms was associated with the frequency of 24-h PVC > 10%, with a sensitivity of 70% and a specificity of 70% (AUC 0.716, 95% CI: 0.636-0.787 $p < 0.001$).

CONCLUSIONS: The results showed that a negative increase in the EMW may be associated with frequent idiopathic PVCs.

Key Words:
Electromechanical window, Echocardiography, Premature ventricular complex.

Introduction

Idiopathic ventricular arrhythmias most often occur as premature ventricular contractions (PVCs) with focal mechanisms not associated with myocardial scarring and usually without structural heart disease. Idiopathic PVCs represent the most common ventricular arrhythmias and can be detected on Holter recordings of most healthy and young adults[1]. Frequent PVCs have been shown[1] to have a good prognosis in the absence of structural heart disease. However, in some patients with or without structural heart disease, frequent PVCs cause ventricular dysfunction and dilatation[2] or lead to an increased risk of mortality[3]. Reports[4,5] show that many parameters that can be obtained in electrocardiography (ECG) are responsible for the development of ventricular arrhythmias and are associated with cardiovascular mortality and morbidity.

The electromechanical window (EMW), a measure of electrical-mechanical interaction, is the difference between the interval between the onset of QRS and the closure of the aortic valve, as determined by a continuous wave Doppler image in the apical long-axis view and the QT interval during the same cardiac cycle[6]. Previous studies in literature have shown a more negative EMW in patients with a long QT (LQTS), and this negativity has been associated with prognosis. EMW has been demonstrated[6,7] to be a predictor and a better discriminator of life-threatening cardiac events, independent of corrected QT interval (QTc) on surface ECG.

However, the value of EMW has not been investigated in patients with normal QTc intervals and frequent idiopathic PVCs. This simple, inexpensive, and non-invasive parameter may have useful indices in patients with idiopathic PVCs.

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We aimed to conduct a study to determine the relationship between EMW negativity and arrhythmia frequency in patients with idiopathic PVCs.

Patients and Methods

Study Population

We retrospectively evaluated patients between May 2021 and May 2022 who underwent 24-h ambulatory Holter monitoring and transthoracic echocardiography following complaints of palpitations. Patients with atrial fibrillation/flutter or arrhythmias other than PVC who underwent 24-h Holter monitoring, as well as those with bundle branch block, genetic cardiac channelopathies, permanent pacemaker therapy, intracardiac defibrillators (ICD), sustained ventricular tachycardia (VT), acute coronary syndrome, coronary artery disease, pericardial disease, myocarditis, congenital heart disease, chronic pulmonary disease, pulmonary hypertension, moderate-to-severe valvular heart disease, pulmonary embolism, cardiomyopathy, malignancy, thyroid disease, anemia or electrolyte imbalances were excluded from the study. In addition to these exclusion criteria, patients without echocardiographic data suitable for EMW measurement were also excluded from the study. After considering these exclusion factors, a total of 148 patients with idiopathic PVC were included in the study. The flow chart of the study is shown in Figure 1. The burden of PVC was calculated as the total number of PVCs divided by the number of all QRS complexes during the total recording time. PVC/24-hour frequency was defined as < 1% for group 1 (n = 64), 1-10% for group 2 (n = 47), and > 10% for group 3 (n = 37). The study complied with the principles outlined in the Declaration of Helsinki. Since the study design was retrospective, an informed consent form was not obtained from the participants. The Istanbul University, Istanbul Faculty of Medicine, Local Ethics Committee approved the study (dated 06/07/2022 and numbered 1020588).

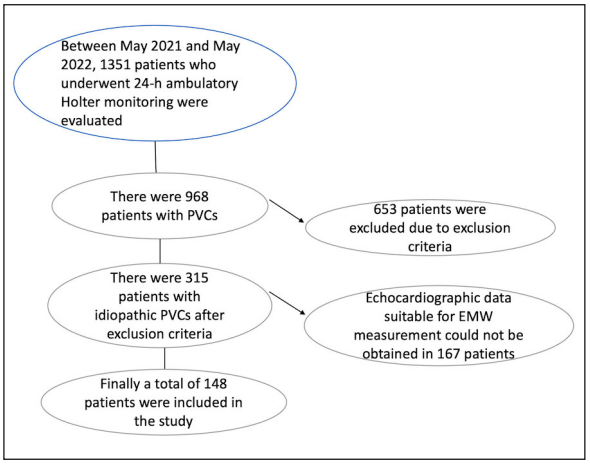

Figure 1. Flow-chart of the study.

Holter Monitoring Assessment

Twenty-four hours of Holter monitoring was obtained by using a three-channel device. After computerized primary analysis, the recordings were edited manually. Premature ventricular complex burden was assessed as percentage and number of PVCs per day. The percentage of PVCs was determined by dividing the total number of PVCs by the total number of beats recorded during Holter monitoring. It was validated that the lowest PVC burden resulting in a reversible cardiomyopathy was 10% previously; therefore, frequent PVCs were defined as PVC burden greater than 10%[8].

Electrocardiographic (ECG) Analysis

Twelve-lead ECGs were acquired at 10 mm/mV amplitude and 25 mm/s rate, with the patient in the supine position. The recordings were analyzed by two cardiologists who were blinded to echocardiographic and clinical data of the study patients. QT interval was defined as the time from the start of the QRS wave to the end of the T wave to the point at which the T wave returned to the isoelectric line and QTc interval was calculated by using Bazett's formula (cQT = QT / $\sqrt{R}$ - R interval).

Echocardiography

Echocardiography examinations were performed with a Vivid 7 (General Electric, Boston, MA, USA), a IE33 (Philips, Amsterdam, Netherlands), or a ACUSON SC200 (Siemens, Munich, Germany) ultrasound systems in our institution according to guidelines of the American Society of Echocardiography[9]. A modified Simpson's method was used to assess the left ventricular (LV) ejection fraction (LVEF). LV end-systolic diameter (LVESD), end-diastolic diameter (LVEDD), end-systolic volume (LVESV), end-diastolic volume (LVEDV), as well as right ventricular (RV) function and dimension were evaluated according to the latest chamber quantification guideline[10].

Electro-Mechanical Window (EMW) Calculation

EMW was calculated following previously described methodology[6] (Figure 2). For this calculation, the continuous-wave Doppler images in the apical long-axis view and concurrent ECG tracings were reviewed. EMW was calculated as the difference between the interval from QRS onset to aortic valve closure (QAoC interval) and the QT interval from the ECG, for the same beat: EMW = QAoC interval - QT interval.

Statistical Analysis

The Kolmogorov-Smirnov test was used to analyze the normality of the data. Parametric continuous data are expressed as mean ± standard deviation (SD); non-parametric continuous data, median (minimum-maximum) and categorical data as percentages. A Chi-square test was used to assess the differences in categorical variables between the groups. The ANOVA analysis was performed to compare all reported data for parametric variables, whereas the Kruskal-Wallis test was used for comparison among non-parametric variables between groups. The relationships among the parameters were assessed using Pearson's or Spearman's correlation analysis according to the normality of the data. Logistic regression analysis was used to determine independent predictors for PVC > 10%. The receiver operating characteristic curve (ROC) curve was obtained to determine the best cut-off value of EMW in the prediction of PVC 10%. Significance was assumed at a two-sided $p < 0.05$. All statistical tests except for ROC curve analysis were conducted using the Statistical Package for the Social Sciences 26.0 for Windows (IBM Corp., Armonk, NY, USA). ROC curve analysis was performed with MedCalc® Statistical Software version 20.015 (MedCalc Software Ltd, Ostend, Belgium).

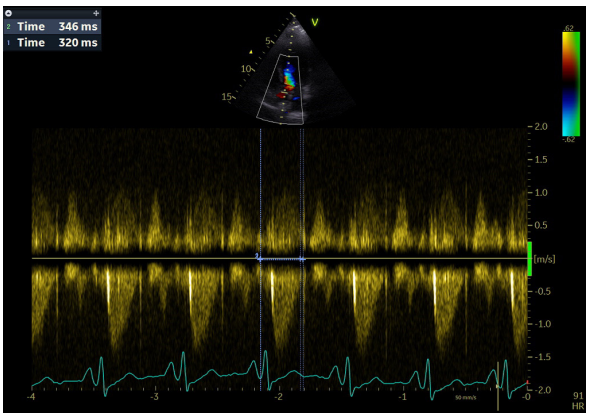

Figure 2. Continuous-wave Doppler image in the apical long-axis view and concurrent electrocardiographic (ECG) tracings were reviewed. Electro-mechanical window (EMW) was calculated as the difference between the interval from QRS onset to aortic valve closure (QAoC interval) and the QT interval from the ECG, for the same beat. (EMW = QAoC interval - QT interval; 320-346 = - 26 ms in this patient).

Results

A total of 148 patients were included in the study, 64% (n = 94) of which were female. The mean age of the patients was 50.11 ± 14.7. The groups were similar in terms of patients' age, BMI, and comorbidities. When laboratory parameters were compared, pro brain natriuretic peptide (proBNP) levels were higher in group 3 than in group 1 [256.45 (10-769) *vs.* 88.7 (10-364.6) pg/mL, $p = 0.027$], which supported the echocardiographic results. At enrollment, 48 (32%) patients were using β-blocker therapy, 12 (8%) patients were using calcium channel blocker (CCB) therapy, and 11 (7%) patients were using other antiarrhythmics. The rate of antiarrhythmic use was not statistically different between the groups. The demographic and clinical characteristics of the study patients are shown in Table I.

The mean LVEF was 65.05 ± 5.2%. LVEF was significantly lower in group 3 compared to group 1 (60.33 ± 8.3 *vs.* 66.78 ± 3.8%, $p = 0.013$). LVEDD, LVESD, LVESV, and RV diameter were significantly higher in group 3 compared to group 1 ($p = 0.012$, $p = 0.005$, $p = 0.038$, and $p = 0.032$, respectively). There was a statistically significant difference between the three groups in terms of their EMW measurements (group 1: 3.78 ± 19.6, group 2: -7 ± 30.9, group 3: -34.83 ± 55.2; $p < 0.001$). In the ECG examination, QT and QTc intervals did not differ between the three groups. During the 24-h Holter monitoring, the median PVC burden was 1,513 beat/d (IQR: 105-32,420). Average and maximal heart rates were significantly lower in group 3 compared to group 1 ($p = 0.026$, $p < 0.001$, respectively). The echocardiographic, electrocardiographic, and Holter monitoring parameters are shown in Table II.

PVC was negatively correlated with LVEF and EMW (r = -0.358, $p < 0.001$; r = -0.358, $p < 0.001$, respectively), while it positively correlated with pro-BNP level, LVEDD, and RV diameter (r = 0.289, $p = 0.017$; r = 0.254, $p = 0.009$; r = 0.279, p

Table I. Clinical, demographic features and laboratory findings of study groups.

	Total (n = 148)	PVC < 1% (n = 64)	PVC 1-10% (n = 47)	PVC > 10% (n = 37)	*p*-value
Clinical characteristics					
Age, (years)	50.11 ± 14.7	46.86 ± 11.7	52.93 ± 16.4	51.78 ± 16.2	0.080
Male, n (%)	54 (36.5%)	20 (31.3%)	20 (42.6%)	14 (37.8%)	
Female, n (%)	94 (63.5%)	44 (68.8%)	27 (57.4%)	23 (62.2%)	0.465
BMI (kg/m^2)	26.75 ± 4.6	26.33 ± 4.2	27.47 ± 5.1	26.84 ± 5.2	0.829
BSA (m^2)	1.68 ± 0.3	1.48 ± 0.6	1.61 ± 0.5	1.42 ± 0.7	0.624
Comorbidities					
HTN, n (%)	29 (19.6%)	14 (21.9%)	11 (23.4%)	4 (10.8%)	0.293
DM, n (%)	8 (5.4%)	4 (6.3%)	1 (2.1%)	3 (8.1%)	0.448
Laboratory findings					
Hgb (gr/dL)	13.27 ± 1.6	13.13 ± 1.6	13.73 ± 1.4	12.98 ± 1.9	0.224
Creatinine (mg/dL)	0.77 ± 0.2	0.76 ± 0.2	0.81 ± 0.2	0.75 ± 0.15	0.212
CRP, (mg/L)	1.61 (0.16-16.33)	1.7 (0.16-16.33)	1.35 (0.23-12.9)	1.51 (0.31-12.14)	0.731
LDH (IU/L)	171 (90-294)	171 (90-294)	170.5 (115-225)	182 (114-279)	0.901
Ferritin (µg/L)	58.95 (3.55-550.9)	45.55 (3.55-347.7)	77.13 (24.08-184)	104.9 (13.32-550.9)	0.103
Fibrinogen (mg/dL)	316 (206-666)	370.17 (263-666)	319 (206-390)	299 (206-546)	0.310
Calcium (mg/dL)	9.57 ± 0.5	9.54 ± 0.4	9.66 ± 0.6	9.51 ± 0.5	0.426
Magnesium (mg/dL)	0.85 ± 0.1	0.84 ± 0.1	0.86 ± 0.1	0.86 ± 0.1	0.166
Potassium (mmol/L)	4.43 ± 0.4	4.36 ± 0.4	4.46 ± 0.3	4.56 ± 0.5	0.141
Pro-BNP (pg/mL)	110.1 (6.5-828.2)	109.2 (6.5-828.2)	88.7 (10-364.6)[c]	256.45 (10-769)[c]	0.027*
Hs-troponin (ng/L)	3 (3-16.46)	3 (3-9.68)	3 (3-9.36)	3 (3-16.46)	0.746
D-dimer (ng/mL)	340 (190-2,370)	340 (190-2,370)	345 (260-1,470)	355 (260-490)	0.844
fT3 (pmol/L)	4.89 ± 0.8	4.96 ± 0.7	4.75 ± 0.8	4.9 ± 0.9	0.681
fT4 (pmol/L)	15.44 ± 2.4	15.37 ± 2.8	15.54 ± 1.6	15.52 ± 2.3	0.957
TSH (mIU/L)	2.66 ± 1.4	2.47 ± 1.2	3 ± 1.9	2.73 ± 0.7	0.336
Vitamin-D (ng/mL)	25.15 ± 12.5	25.92 ± 13.1	24.14 ± 14.6	22.37 ± 5.9	0.829
Treatment					
Beta blocker, n (%)	48 (32.4%)	15 (23.4%)	17 (36.1%)	16 (43.2%)	0.100
CCB, n (%)	12 (8.1%)	4 (6.2%)	4 (8.5%)	4 (11%)	0.341
Other antiarrhythmic drugs, n (%)	11 (7.4%)	2 (3%)	5 (10.6%)	4 (11%)	0.222
Propafenone, n (%)	5 (3.4%)	1 (3.1%)	2 (4.3%)	2 (5.4%)	0.548
Amiodarone, n (%)	4 (3.8%)	0 (0%)	2 (4.3%)	2 (5.4%)	0.201
Sotalol, n (%)	2 (1.4%)	1 (1.6%)	1 (2.1%)	0 (0%)	0.690

[c]: $p < 0.05$ between group 2 and group 3. *p-value < 0.05. BMI: body mass index; BSA: body surface area; HTN: hypertension; DM: diabetes mellitus; Hgb: hemoglobin; CRP: C-reactive protein; LDH: lactate dehydrogenase; pro-BNP: pro brain natriuretic peptide; hs-troponin: high sensitive troponin; fT3: free triiodothyronine; fT4: free thyroxine; TSH: thyroid stimulating hormone; CCB: calcium channel blocker.

= 0.004, respectively). EMW was negatively correlated with LVEDD (r = -0.214, p = 0.027), while it positively correlated with maximum heart rate at Holter monitoring, QAoC duration, and LVEF (r = 0.241, p = 0.003; r = 0.171, p = 0.037; r = 0.246, p = 0.011, respectively). The correlation analyzes of EMW and PVC with echocardiographic and laboratory parameters are shown in Table III.

The independent predictors of PVC > 10% were evaluated using logistic regression analysis along with univariate and multivariate analysis. The parameters that were statistically significant, and likely to affect PVCs, were included in the models. In the multivariate regression analysis models of including LVEF and LVEDD, the EMW (OR 0.971, p = 0.007) and every 10-ms decrease in the EMW (OR 1.254, p = 0.011) were determined to be independent predictors of PVC > 10% (Table IV). In ROC analysis, an EMW value of ≤ -15 was associated with the frequency of 24-h PVC > 10%, with a sensitivity of 70.27%, and a specificity of 70.27% (AUC 0.716, 95% CI: 0.636-0.787 $p < 0.001$) (Figure 3).

Discussion

The primary aim of the present study was to determine the relationship between the EMW and PVC frequency. The main finding was that EMW negativity increased significantly in the group

Table II. Echocardiographic, electrocardiographic, and Holter monitoring parameters of the study groups.

	Total patients (n = 148)	Group 1 PVC < 1% (n = 64)	Group 2 PVC 1-10% (n = 47)	Group 3 PVC > 10% (n = 37)	*p*-value
Echocardiography					
LVEDD (mm)	45.07 ± 4.1	43.7 ± 3.3[b]	45.85 ± 3.7	48.67 ± 5.8[b]	0.012*
LVESD (mm)	28.76 ± 3.8	27.35 ± 2.7[b]	29.46 ± 3.1	32.67 ± 5.8[b]	0.005*
LVEDV (ml)	93.91 ± 20.7	86.96 ± 15.5	97.44 ± 18.6	112.89 ± 31.1	0.169
LVESV (ml)	35.48 ± 15.8	28.34 ± 6.9[a,b]	34.04 ± 8.5[a]	44.9 ± 20.6[b]	0.038*
LVEF, (%)	65.05 ± 5.2	66.78 ± 3.8[b]	64.15 ± 4.4	60.33 ± 8.3[b]	0.013*
IVSd (mm)	10.33 ± 1.3	10.13 ± 1.4	10.62 ± 1.3	10.5 ± 0.8	0.096
LVPWd (mm)	9.69 ± 1.3	9.44 ± 1.4	10.15 ± 1.2	9.67 ± 1.2	0.108
LV mass index (g/m^2)	117.36 ± 32.9	103.25 ± 21.5	112.39 ± 22.1	110.79 ± 21.2	0.376
RV, (mm)	25.69 ± 4.3	24.73 ± 5.2[b]	26.23 ± 1.9	28.17 ± 3.2[b]	0.032*
LAVI (ml/m^2)	24.26 ± 6.9	23.04 ± 6.2	23.46 ± 5.7	30.67 ± 9.7	0.321
TAPSE (mm)	22.38 ± 3.3	21.74 ± 3.2	22.54 ± 3.2	24.5 ± 3.4	0.291
PASP (mmHg)	24.76 ± 8.3	23.78 ± 5.4	23.85 ± 10.5	30.5 ± 11.6	0.235
E/A ratio	1.04 ± 0.4	1 ± 0.3	1.03 ± 0.4	1.2 ± 0.5	0.188
E/e' ratio	9.49 ± 2.9	9.14 ± 2.5	8.85 ± 2.1	12.17 ± 4.6	0.104
preET (ms)	77.07 ± 16.3	74.22 ± 15.7	80.69 ± 16.4	80.17 ± 18.9	0.549
ET (ms)	282.79 ± 28.1	275.17 ± 24.6	285.69 ± 29.2	305.67 ± 28.7	0.172
QAoC interval (ms)	358.29 ± 35.4	382 ± 44	359 ± 27.8	351.7 ± 27.8	0.170
EMW (ms)	-5.07 ± 32	3.78 ± 19.6[a,b]	-7 ± 30.9[a,c]	-34.83 ± 55.2[b,c]	< 0.001*
ECG and 24-h Holter					
QT (ms)	390.54 ± 26.8	383.3 ± 26.7	393.59 ± 30.9	399.17 ± 18.4	0.071
QTc (ms)	416.55 ± 21.1	413.1 ± 18.6	418.67 ± 26.5	419.92 ± 17.8	0.709
Average HR (bpm)	75.93 ± 10.3	77.7 ± 11.7[b]	76.44 ± 9.5	72.42 ± 8[b]	0.026*
Minimum HR (bpm)	50.31 ± 8.6	51.73 ± 9.8	50.81 ± 8.3	47.38 ± 6.2	0.093
Maximum HR (bpm)	129.4 ± 19.8	135.5 ± 17.2[b]	129.85 ± 17.6	118.71 ± 22.1[b]	< 0.001*
PVC per 24 hours	1,513 (105-32,420)	326 (105-914)[a,b]	3,307 (1,174-7,526)[a,c]	12,576 (8,134-32,420)[b,c]	< 0.001*
V-pair per 24 hours	0 (0-993)	0 (0-5)[a,b]	0 (0-393)[a,c]	4 (0-993)[b,c]	< 0.001*
V-run per 24 hours	0 (0-164)	0 (0-2)[b]	0 (0-10)c	0 (0-164)[b,c]	< 0.001*
Longest V-run (beats)	0 (0-6)	0 (0-3)	0 (0-4)	0 (0-6)	0.116

[a]: $p < 0.05$ between group 1 and group 2, [b]: $p < 0.05$ between group 1 and group 3, [c]: $p < 0.05$ between group 2 and group 3. LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-sysdtolic diameter; LVEDV: left ventricular end-diastolic volume; LVESV: left ventricular end-systolic volume; LVEF: left ventricular ejection fraction; IVSd: interventricular septum diameter; LVPWd: left ventricular posterior wall thickness diameter; RV: right ventricular; LAVI: left atrial volume index; TAPSE: tricuspid annular plane systolic excursion; PASP: pulmonary artery systolic pressure; E: early diastolic transmitral flow; e': early diastolic tissue velocity; preET: pre-ejection time; ET: ejection time; QAoC interval = interval from QRS onset to aortic valve closure; EMW: electro-mechanical window, QTc: heart rate-corrected QT interval; PVC: prematüre ventricular contraction, HR: heart rate. *p-value < 0.05.

with frequent PVC burdens. The EMW and every 10-ms decrease in the EMW were determined to be independent predictors of frequent PVC.

PVCs are common causes of palpitations. PVCs are found in the majority of individuals undergoing long-term ambulatory monitoring, and their frequency increases with age[11]. While the root causes of PVCs are largely unknown, the potential mechanisms for any PVC include triggered activity, automaticity, and re-entry. Various factors that destabilize the myocardium, such as altered hemodynamic status, increased sympathetic tone, or electrolyte imbalances, may cause PVCs to become more frequent or to evolve into ventricular arrhythmias[12]. PVCs are strongly associated with ventricular dilatation and dysfunction. Likewise, an increased frequency of PVC may be a risk factor for heart failure and death[13].

Previous studies[6,7] have shown that the EMW is a superior and independent predictor of ventricular arrhythmia risk compared to heart rate-corrected QT. However, as far as we know, there was no study evaluating EMW in patients with idiopathic frequent PVCs.

The end of electrical systole occurs just before the end of mechanical systole (closure of the aortic valve), resulting in a positive EMW. A negative EMW occurs as a result of shortening of mechanical systole, prolongation of electrical systole, or both[7]. A negative EMW refers to

Table III. Correlation of EMW and PVC with echocardiographic and laboratory parameters.

	EMW		PVCI	
	r	*p*-value	r	*p*-value
Age	-0.153	0.069	0.078	0.356
EMW	-	-	-0.358	< 0.001*
PVC	-0.358	< 0.001*	-	-
QTc	-0.115	0.273	0.154	0.142
Average HR	0.158	0.055	-0.127	0.126
Minimum HR	0.085	0.307	-0.119	0.151
Maximum HR	0.241	0.003*	-0.353	< 0.001*
preET	-0.038	0.645	0.057	0.490
ET	0.104	0.208	0.119	0.151
QAoC	0.171	0.037*	-0.135	0.103
LVEDD	-0.214	0.027*	0.254	0.009*
LVEDV	-0.138	0.149	0.029	0.765
IVSd	-0.163	0.095	0.087	0.377
LVEF	0.246	0.011*	-0.341	< 0.001*
RV	-0.185	0.059	0.279	0.004*
LAVI	-0.261	0.070	0.152	0.298
E/A ratio	0.170	0.110	-0.024	0.824
E/e' ratio	-0.165	0.118	0.230	0.028*
LV mass index	-0.204	0.057	0.223	0.037*
TAPSE	0.055	0.606	0.199	0.061
sPAP	-0.063	0.543	0.242	0.018*
Calcium	-0.081	0.439	0.074	0.482
Potassium	0.133	0.205	0.204	0.051
Magnesium	0.031	0.773	0.136	0.198
Hs-troponin	-0.203	0.122	0.114	0.388
Pro-BNP	-0.135	0.272	0.289	0.017*

EMW: electro-mechanical window; PVC: prematüre ventricular contraction; QTc: heart rate–corrected QT interval; HR: heart rate; preET: pre-ejection time; ET: ejection time; QAoC interval: interval from QRS onset to aortic valve closure; LVEDD: left ventricular end-diastolic diameter; LVEDV: left ventricular end-diastolic volume; IVSd: interventricular septum diameter; LVEF: left ventricular ejection fraction; RV: right ventricular; LAVI: left atrial volume index; E: early diastolic transmitral flow; e': early diastolic tissue velocity; TAPSE: tricuspid annular plane systolic excursion; PASP: pulmonary artery systolic pressure; hs-troponin: high sensitive troponin; pro-BNP: pro brain natriuretic peptide. **p*-value < 0.05.

Table IV. Multivariate regression analysis of risk factors associated with PVC > 10%.

Model 1			
	OR	95% CI	*p*-value
EMW per 10ms	1.254	1.053-1.493	0.011*
LVEDD	1.080	0.937-1.244	0.289
LVEF	0.981	0.899-1.071	0.668
QAoC	1.019	1.003-1.036	0.020*
Model 2			
	OR	95% CI	*p*-value
EMW	0.971	0.951-0.992	0.007*
LVEDD	1.085	0.940-1.252	0.266
LVEF	0.983	0.900-1.074	0.710
QAoC	1.020	1.003-1.037	0.019*

EMW: electro-mechanical window; LVEDD: left ventricular end-diastolic diameter; LVEF: left ventricular ejection fraction; QAoC: interval from QRS onset to aortic valve closure. **p*-value < 0.05.

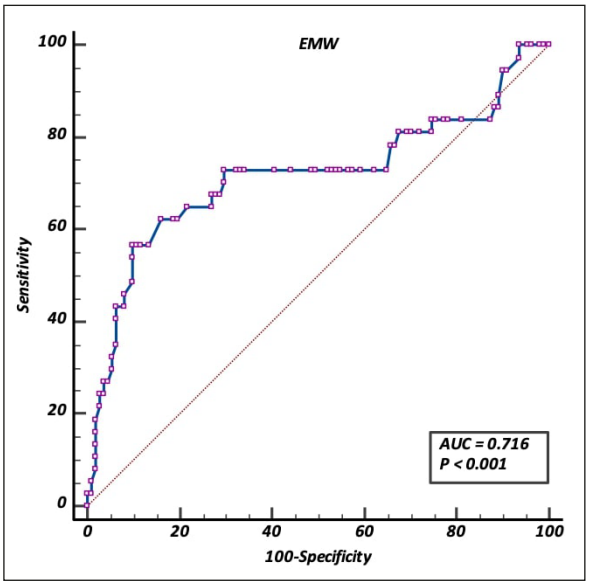

Figure 3. ROC curve analysis showing the specificity and sensitivity of EMW in predicting 24-h PVC > 10%.

a ventricle that is volume loaded during the rapid filling phase while repolarization continues. This may create a sensitive substrate on which electrical or mechanical stimuli can trigger abnormal impulses and promote arrhythmogenesis[14-16]. Continued myocardial contraction and calcium release after aortic valve closure may trigger arrhythmias by promoting post-depolarization due to the prolongation of the action potential duration or by activation of cardiac mechanoreceptors[17,18]. The EMW was investigated as a biomarker for drug-induced Torsades de Pointes (TdP) in animal models[19-21]. In rabbits with VF, the EMW was significantly more negative than in rabbits without VF. The EMW had higher sensitivity and specificity than QTc measurement, and predictive power for VF[21]. Recently, the EMW has emerged as a novel torsadogenic marker in LQTS, superior to QTc, in distinguishing symptomatic from asymptomatic patients. In a study[7] that analyzed patients with LQTS and healthy controls, nearly all patients with LQTS had a negative EMW compared to controls, and patients with symptomatic LQTS had deeper EMW negativity compared to patients with asymptomatic LQTS. While EMW was an independent predictor of symptomatic status, it outperformed QTc in predicting symptomatic patients. EMW was also studied[22] in patients with hypertrophic cardiomyopathy (HCM). EMW was more negative in patients with HCM than in healthy individuals, and profound EMW negativity was an independent risk factor for life-threatening events (LTEs). The cutoff value of EMW in the identification of patients with LTEs was -54 ms. That study[22] concluded that examining EMW could be useful for the risk stratification of sudden cardiac death in patients with HCM.

In our study, less negative values of VT/VF than predictive EMW values reported in previous studies in literature, with a cut-off of -15 ms, were associated with frequent PVC. This study showed that a negatively increase in the EMW measured by echocardiography, when the PVC frequency increased by more than 10% during the 24-hour Holter recording. EMW was a significant, independent predictor of frequency in patients with idiopathic PVC. These findings may allow EMW to become a risk marker that can be easily obtained and reported during a clinically indicated echocardiogram.

Limitations

Our study had limitations. First, it was a retrospective study with a relatively small population. In addition, 24-hr of Holter recordings might not be sufficient to evaluate the day-to-day variability. We did not have data on cardiac events for this study, as we could not follow-up patients regarding future arrhythmic events. Using an antiarrhythmic drug may also have affected the results. More comprehensive and prospective follow-up studies are necessary to clarify the clinical significance of EMW in patients with idiopathic PVC.

Conclusions

Our study showed a relationship between increased PVC burden and EMW negativity in patients with normal QTc intervals. The evaluation of EMW negativity in patients with idiopathic PVC may contribute to a comprehensive approach for patient management, follow-up and risk assessment.

Conflict of Interest
The Authors declare that they have no conflict of interests.

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None.

Ethics Approval
This research was carried out with the permission of Istanbul University, Istanbul Faculty of Medicine, Local Ethics Committee, dated 06/07/2022 and numbered 1020588.

Informed Consent
Not applicable due to the retrospective nature of this study.

Authors' Contribution
P.K. Ozer is the principal author of this study, and designed the study with resources acquisition, data collection and processing data, data analysis and interpretation, writing-original draft preparation, and editing. P.K. Ozer, and A. Oncul: conceived the idea for the article, framing the hypothesis, P.K. Ozer, E.A. Govdeli, A. Elitok, and A. Oncul: designed the methods to generate results, A. Elitok, A.K. Bilge, and K. Adalet: supervision of the project and the manuscript, P.K. Ozer, E.B. Karaayvaz, E.A. Govdeli, and A. Nalbant: resources acquisition, A. Nalbant, M.L. Yavuz, and B.B. Bayraktar: materials and referring patients, E.A. Govdeli, A. Nalbant, M.L. Yavuz, B.B. Bayraktar, and P.K. Ozer: data collection and processing data, P.K. Ozer, E.B. Karaayvaz, A. Elitok: data analysis and interpretation, E.A. Govdeli, and P.K. Ozer: writing-original draft preparation, A. Elitok, A.K. Bilge, K. Adalet, and A. Oncul: critical review and editing. All authors have read and approved the paper.

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