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Original Article

Relationship Between the Presystolic Wave and the Electrocardiographic Diastolic Index in Hypertensive Patients

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Abstract

Objectives: To examine the association between the presystolic wave (PSW), an echocardiographic parameter indicative of diastolic dysfunction (DD), and the electrocardiographic diastolic index (EDI), which is calculated using 12-lead electrocardiography (ECG), in hypertensive cases.

Methods: The study included 250 consecutive patients diagnosed with hypertension, evaluated in two groups: According to PSW presence. Statistical analyses were conducted to compare demographic data, laboratory parameters, and 12-lead ECG parameters between the groups with and without PSW.

Results: PSW was found to be linked to advanced age (p<0.001), systolic blood pressure (p=0.045), diastolic blood pressure (p=0.020), fasting blood glucose (p=0.015), blood urea nitrogen (p=0.044), left ventricular wall thickness (p<0.001), mitral valve late diastolic wave (A wave, p=0.002), mitral valve early diastolic wave (E wave)/early diastolic myocardial wave (E' wave) ratio (p<0.001), E/A ratio (p=0.031), AVL R amplitude (p=0.003), V1 S amplitude (p=0.020), V5 R amplitude (p=0.004), D1 P wave duration (p=0.017), PQ interval (p=0.011), QRS duration (p=0.015), and EDI (p<0.001). Age, A wave, and EDI (p<0.001) were found to independently predict PSW presence.

Conclusion: We determined that, in addition to the echocardiographic assessment of PSW, EDI, an index that can be easily calculated using a 12-lead ECG, may also be a useful parameter for evaluating DD in hypertensive patients.

Keywords: Electrocardiographic diastolic index; hypertension; presystolic wave.

Hipertansif Hastalarda Presistolik Dalga ile Elektrokardiyografik Diyastolik İndeks Arasındaki Ilişki

Özet

Amaç: Bu çalışmanın amacı hipertansif hastalarda diyastolik disfonksiyonu gösteren ekokardiyografik bir parametre olan presistolik dalga (PSD) ile 12 derivasyonlu elektrokardiyografi (EKG) kullanılarak hesaplanan elektrokardiyografik diyastolik indeks (EDİ) arasındaki ilişkiyi araştırmaktır.

Gereç ve Yöntem: Çalışmaya hipertansiyon tanısı konulan toplam 250 hasta ardışık olarak dahil edildi ve PSD varlığına veya yokluğuna göre iki grupta değerlendirildi. İstatistiksel analiz; PSD'li ve PSD'siz gruplar arasında demografik verileri, laboratuvar parametrelerini ve 12 derivasyonlu EKG parametrelerini karşılaştırmak için gerçekleştirildi.

Bulgular: PSD'nin varlığını; ileri yaş (p<0.001), sistolik kan basıncı (p=0.045), diyastolik kan basıncı (p=0.020), açlık kan şekeri (p=0.015), kan üre azotu (p=0.044), sol ventrikül duvar kalınlığı (p<0.001), mitral kapak geç diyastolik dalgası (A dalgası, p=0.002), mitral kapak erken diyastolik dalgası (E dalgası)/erken diyastolik miyokard dalgası (E' dalgası) oranı (p<0.001), E/A oranı (p=0.031), AVL R genliği (p=0.003), V1 S genliği (p=0.020), V5 R genliği (p=0.004), D1 P dalgası süresi (p=0.017), PQ aralığı (p=0.011), QRS süresi (p=0.015) ve EDİ (p<0.001) ile ilişkili olduğu bulunmuştur. Ek olarak, yaş, A dalgası ve EDİ (p<0.001) PSD varlığının bağımsız öngörücüleri olarak saptanmıştır.

Sonuç: Hipertansif hastalarda diyastolik disfonksiyonun araştırılmasında ekokardiyografik PSD'nin kullanılabileceği gibi 12 derivasyon EKG ile kolayca hesaplanan EDİ'nin de kullanılabilir olduğunu saptadık.

Anahtar sözcükler: Elektrokardiyografik diyastolik indeks; hipertansiyon; presistolik dalga.

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Introduction

The presystolic wave (PSW) is an echocardiographic wave that occurs due to a retrograde flow toward the aortic valve caused by blood passing into the left ventricle (LV) during atrial contraction in late diastole when examining cardiac physiology.[1] This wave has been associated with atrial contraction strength and is also considered to be related to LV relaxation impairment. Its more frequent detection in patients with LV subclinical dysfunction further supports this association.[2,3] The first study on PSW, conducted in 2002, identified a direct relationship between Beyond being a physiological wave, PSW holds additional clinical significance, as it has been reported that it can predict various cardiovascular disease markers, including arterial stiffness, non-dipper hypertension, and carotid intima-media thickness.[4–6] PSW has been compared with electrocardiographic (ECG) parameters such as interatrial block and P-wave dispersion, which serve as indicators of atrial function.[7,8] However, to date, no study has examined LV- diastolic dysfunction (DD) in relation to ECG parameters.

The electrocardiographic diastolic index (EDI) is an index calculated using measurements of the distances between the T wave, P wave, and Q wave on a 12-lead ECG, in conjunction with age.[9] EDI has been validated against echocardiographic diastolic parameters[9] and has also been suggested as a potential predictor of atrial arrhythmias in clinical studies.[10]

This study aimed to compare PSW, an echocardiographic marker of DD, and EDI, an index derived from 12-lead ECG, with each other and with other diastolic parameters.

Materials and Methods

Patient Population and Study Design

This single-center study included hypertensive patients who applied to the cardiology outpatient clinic of our hospital between December 2024 and March 2025. Excluded from the study were patients with coronary artery disease, atrial fibrillation, heart failure, advanced respiratory failure, a history of hematologic or chronic inflammatory diseases, malignancy, or overt electrolyte imbalance.

After evaluating the patients based on these exclusion criteria, the sample consisted of 250 patients. The patient's demographic information, blood pressure measurements, 12-lead ECG, and echocardiographic parameters were recorded. Two groups were formed according to whether the patients presented with PSW.

The conduct of the study followed the principles of the Helsinki Declaration, as well as the present good clinical practice guidelines. All authors hold good clinical practice certificates. Ethical approval numbered "2024–147" and dated "December 05, 2024" was received from the local ethics committee of our clinic.

Evaluation of Laboratory Parameters and Echocardiographic Measurements

The study was conducted using routine peripheral venous blood samples obtained during cardiology outpatient follow-ups. An automatic hematology analyzer (Mindray BC-5800) was used for the analysis of complete blood count parameters. Blood glucose (fasting), creatinine, and blood urea nitrogen (BUN) levels were measured, and lipid panel values were obtained for all patients. Echocardiography was performed using the Philips Affiniti 50 system (X-5 probe, Philips® Medical Systems, Andover, MA). The modified Simpson technique was used to calculate LV ejection fraction (LV-EF). Measurements of the LV end-systolic diameter, LV end-diastolic diameter, interventricular septum (IVS), posterior wall, and left atrium were obtained from the parasternal long-axis view. Doppler echocardiography was used to calculate mitral early filling and late diastolic flows (E and A waves, respectively). In tissue Doppler imaging, early and late diastolic myocardial velocities (E' and A' waves, respectively) obtained from the mitral lateral annulus were recorded. PSW was defined as the wave detected immediately before the systolic wave in images obtained using pulse wave Doppler, which was placed perpendicular to the outflow tract of the LV at a position 1 cm behind the aortic valve using the apical five-chamber view. The peak velocities of the PSW detected in patients were recorded (Fig. 1).

Electrocardiographic Diastolic Parameters

Diastolic parameters were calculated from 12-lead ECG recordings obtained at a calibration of 10 mm/mV and a speed of 25 mm/ms. The distance from the T wave end to the P wave beginning was noted as "TendP," that from the T wave end to the Q wave beginning as "TendQ," and that from the P wave beginning to the Q wave end as "PQ." The amplitude of the R wave in the AVL lead was recorded as "AVL R," that of the S wave in V1 as "V1 S," that of the R wave in V5 as "V5 S," and that of the P wave amplitude in D1 as "D1 P." EDI was obtained as follows: EDI = TendP/(PQ × age). Bazett's formula was used to calculate the QTc interval.

Statistical Analysis

Statistical analysis was undertaken using the Statistical Package for the Social Sciences (SPSS) v. 21.0 for Windows (SPSS Inc., Chicago, IL, USA). Parametric and non-parametric data distributions were evaluated using Kolmogorov-Smirnov and variance homogeneity tests. The independent-sample t-test (mean± standard deviation values) and the Mann-Whitney U test (minimum-maximum) were used to compare groups with parametric and non-parametric distributions, respectively. The Chi-square test (number and percentage) was used to analyze parameters expressed with categorical variables. Logistic regression analysis was performed through univariate and multivariate methods to identify dependent and independent predictors of the presence of PSW. Variables that independently predicted PSW presence were further explored using multivariable logistic regression analysis. Cut-off values of EDI for predicting the presence of PSW were determined through receiver operating characteristic (ROC) analysis. The statistical significance level was set at $p<0.05$.

Results

Of the 250 patients, 158 were included in the group with PSW (59 women and 99 men; mean age: 56.85±12.38 years), and 92 were in the group without PSW (46 women and 46 men; mean age: 47.51±9.26 years). The prevalence of PSW was found to be 63.2%. Table 1 presents the demographic characteristics, blood

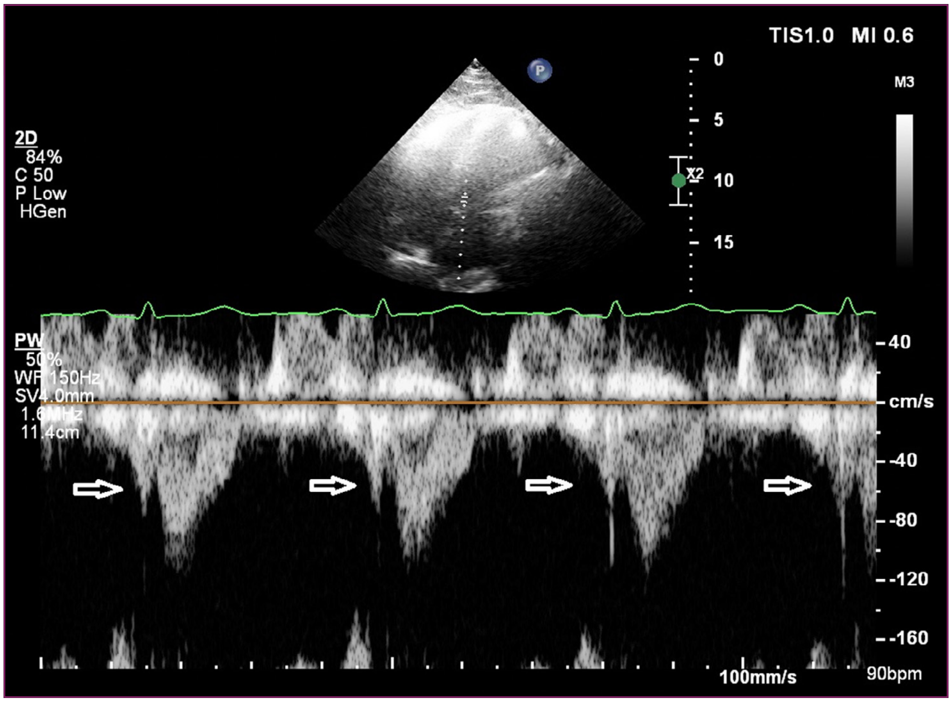

Figure 1. Detection of presystolic waves by echocardiography.

Table 1. Clinical characteristics of the study population

	Patients with PSW n=158		Patients without PSW n=92		p
	n	%	n	%	
Age (years)	56.85±12.38		47.51±9.26		<0.001
Sex					0.063
Female	59		46		
Male	99		46		
BMI (kg/m^2)	29.02±4.69		27.97±4.07		0.076
Diabetes mellitus	14	8.8	4	4.3	0.212
Hyperlipidemia	11	6.9	9	9.8	0.475
Smoking	28	17.7	13	14.1	0.483
Systolic blood pressure (mmHg)	138.5 (120–154)		123 (100–150)		0.045
Diastolic blood pressure (mmHg)	80 (60–98)		72 (60–84)		0.020
ACEi/ARB use	122	77.2	64	69.5	0.180
Calcium channel blocker use	94	59.5	44	47.9	0.061
Beta-blocker use	36	22.8	12	13	0.089
Oral antidiabetic use	8	5	4	4.3	0.990
Hemoglobin (g/dL)	14.1 (11–17.5)		13.5 (9.1–16.7)		0.100
WBC count (×10^9/L)	6.51±1.51		6.75±1.44		0.229
Platelet count (×10^9/L)	216.12±41		244.13 ± 53.99		0.095
Lymphocyte count (×10^9/L)	2.16 (1–6.1)		2.29 (1.27–3.5)		0.208
Neutrophil count (×10^9/L)	3.5 (1.75–7.5)		3.75 (1.58–7.11)		0.364
MPV (fL)	8.53±0.87		8.54±0.72		0.904
Creatinine (mg/dL)	1.1 (0.5–1.7)		0.7 (0.5–1.6)		0.092
Glucose (mg/dL)	98 (70–168)		89 (78–128)		0.015
BUN (mg/dL)	16 (9–35)		14 (7–31)		0.044
Total cholesterol (mg/dL)	197 (119–303)		203 (138–307)		0.300
LDL-C (mg/dL)	129±35.61		127.6±32.11		0.781
HDL-C (mg/dL)	42.5 (27–82)		49 (25–90)		0.385
Triglyceride (mg/dL)	139 (58–352)		127 (51–520)		0.213

PSW: Presystolic wave; BMI: Body mass index; ACEi: Angiotensin-converting enzyme inhibitor; ARB: Angiotensin receptor blocker; WBC: White blood cell; MPV: Mean platelet volume; BUN: Blood urea nitrogen; LDL-C: Low-density lipoprotein cholesterol; HDL-C: High-density lipoprotein cholesterol.

Table 2. General echocardiography data

	Patients with PSW n=158	Patients without PSW n=92	p
LV-EF (%)	60 (52–72)	60 (55–66)	0.984
LV-EDD (mm)	50 (47–54)	50 (46–56)	0.178
LV-ESD (mm)	30 (25–35)	30 (24–36)	0.200
IVS(mm)	10 (8–16)	9 (8–12)	<0.001
PW(mm)	10 (8–13)	9 (8–12)	<0.001
LA diameter (mm)	36 (22–51)	35 (22–49)	0.243
E wave (cm/s)	66 (35–161)	65 (33–151)	0.187
A wave (cm/s)	79 (30–130)	95 (34–144)	0.002
S' wave (cm/s)	10 (6–21)	10 (6–15)	0.526
E' wave(cm/s)	10 (4–20)	14 (6.5–18)	0.282
A' wave (cm/s)	12 (5–19)	12 (6–21)	0.526
E/E'	6.73 (2.38–29.27)	5 (1.46–21.54)	<0.001
E/A	0.68 (0.42–3.67)	0.66 (0.38–2.58)	0.031

PSW: Presystolic wave; LV-EF: Left ventricular ejection fraction; LV-EDD: Left ventricular end-diastolic diameter; LV-ESD: Left ventricular end-systolic diameter; IVS: Interventricular septum; PW: Posterior wall; LA: Left atrium; E wave: Mitral valve early diastolic wave; A wave: Mitral valve late diastolic wave; S' wave: Tricuspid lateral annular systolic velocity; E' wave: Early diastolic myocardial velocity; A' wave: Late diastolic myocardial velocity.

pressure follow-up data, medication histories, and laboratory values of the patients according to the groups. Age (p<0.001), systolic blood pressure (p=0.045), diastolic blood pressure (p=0.020), fasting blood glucose (p=0.015), and BUN (p=0.044) showed significant differences between the two groups.

Table 2 shows the echocardiographic parameters of the groups. LV wall thickness (p<0.001), A wave (p=0.002), E/E' (p<0.001), and E/A (p=0.031) significantly differed between the groups with and without PSW.

Among the ECG parameters, AVL R, V1 S, V5 R, D1 P, and PQ values were statistically significantly different between the two groups (Table 3). EDI also significantly differed between the groups (0.036 [0.01–0.08] vs. 0.050 [0.02–0.10], p<0.001) (Fig. 2).

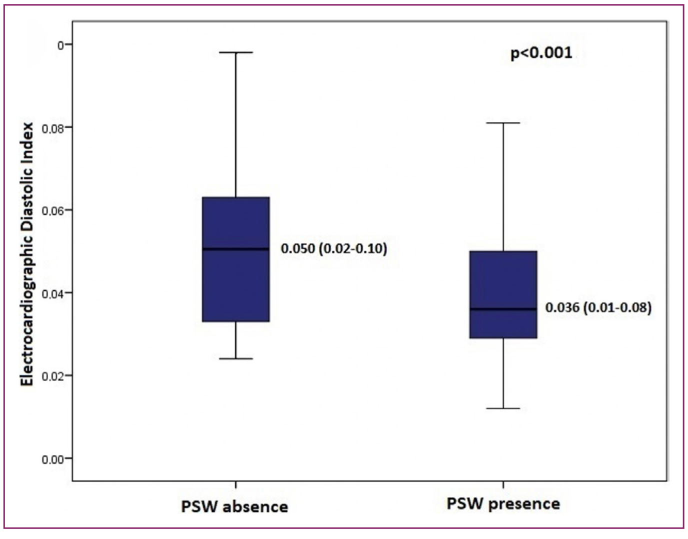

Figure 2. Comparison of the electrocardiographic diastolic index between the groups with and without the presystolic wave.

PSW: Presystolic wave.

Table 3. Electrocardiographic parameters of the groups

	Patients with PSW n=158	Patients without PSW n=92	p
Heart rate (beats/minute)	75 (51–118)	75 (54–102)	0.376
AVL R amplitude (mV)	0.5 (0.1–1.3)	0.4 (0.2–1.2)	0.003
V1 S amplitude (mV)	0.5 (0.2–0.9)	0.5 (0.2–1.2)	0.020
V5 R amplitude (mV)	0.7 (0.3–1.2)	0.77 (0.1–1.3)	0.004
D1 P amplitude (mV)	0.1 (0.05–0.2)	0.1 (0.05–0.2)	0.017
PQ interval (ms)	0.2 (0.12–0.24)	0.16 (0.12–0.24)	0.011
TendP (ms)	0.36 (0.12–76)	0.36 (0.2–0.64)	0.851
TendQ (ms)	0.56 (0.28–0.96)	0.56 (0.36–0.98)	0.973
QTc interval (ms)	0.41 (0.34–0.46)	0.40 (0.33–0.56)	0.580
QRS duration (ms)	100 (80–130)	96 (80–120)	0.015
EDI	0.036 (0.01–0.08)	0.050 (0.02–0.10)	<0.001

PSW: Presystolic wave; EDI: Electrocardiographic diastolic index.

In the ROC curve analysis for predicting the presence of PSW, the cut-off value of EDI was determined to be 0.0425 with 61% sensitivity and 60% specificity (area under the curve: 0.671, 95% confidence interval: 0.601–0.741, p < 0.001) (Fig. 3). In the regression analysis, IVS (p<0.001), A wave (p=0.006), and EDI (p<0.001) were found to independently predict PSW presence (Table 4).

Discussion

In the present study, we demonstrated the association between PSW and EDI in hypertensive patients. In addition, we established the association of PSW with other echocardiographic diastolic parameters. We found that lower EDI values predicted the presence of PSW and, consequently, LV-DD.

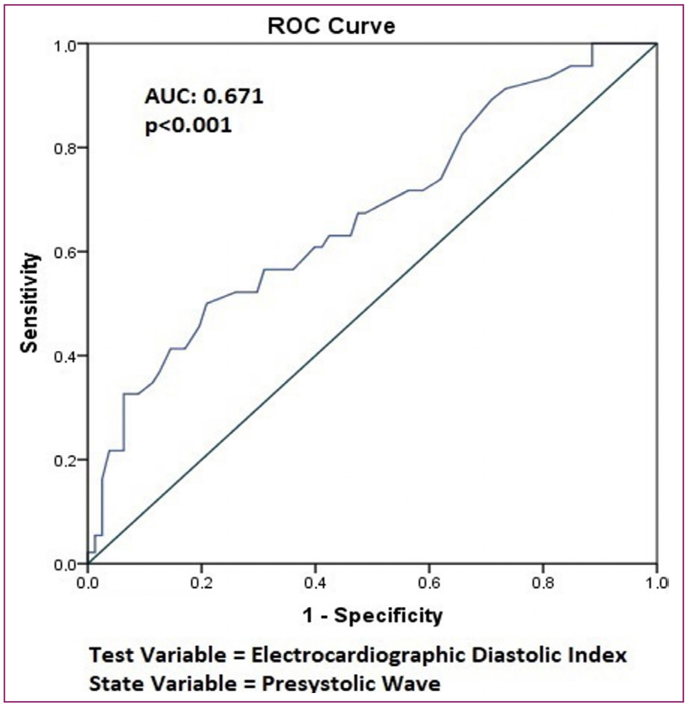

Figure 3. Receiver operating characteristic curve of the electrocardiographic diastolic index in predicting the presystolic wave.

ROC: Receiver operating characteristic; AUC: Area under the curve.

Table 4. Results of univariable and multivariable regression analyses showing the relationship between the presence of PSW and investigated variables

Variable	Univariable analysis			Multivariable analysis		
	OR	95%CI	p	OR	95%CI	p
Age	1.082	1.052–1.113	<0.001	0.981	0.934–1.031	0.448
SBP	3.057	1.746–5.353	<0.001	1.473	0.671–3.236	0.334
BUN	1.122	1.048–1.202	0.001	1.027	0.935–1.129	0.579
IVS	1.945	1.525–2.482	<0.001	1.916	1.351–2.715	<0.001
A wave	0.985	0.975–0.995	0.005	0.980	0.966–0.994	0.006
E/E'	1.206	1.103–1.319	<0.001	1.056	0.962–1.160	0.254
AVL R amplitude	4.811	1.423–16.270	0.011	1.668	0.305–9.112	0.555
V1 S amplitude	0.115	0.028–0.474	0.003	0.240	0.030–1.886	0.175
D1 P amplitude	0.050	0.010–0.131	0.013	0.040	0.002–23.993	0.324
V5R amplitude	0.146	0.037–0.576	0.006	0.068	0.008–1.164	0.130
EDI	0.030	0.010–0.060	<0.001	0.002	0.001–0.003	<0.001

PSW: Presystolic wave; OR: Odds ratio; CI: Confidence interval; SBP: Systolic blood pressure; BUN: Blood urea nitrogen; IVS: Interventricular septum; E wave: Mitral valve early diastolic wave; E' wave: early diastolic myocardial velocity; EDI: Electrocardiographic diastolic index.

In our sample, PSW had a prevalence of 63.2%. Similar prevalence rates, ranging from 59.1% to 66%, have been reported in patient groups with comparable mean ages in the literature.[11,12] PSW has been found to correlate with various echocardiographic parameters, including the myocardial performance index and LV global longitudinal strain.[11] Şaylık et al.[11] found that DD parameters such as E/E' to be significantly higher in the PSW group. Consistently, in the present study, E/E' was higher in the patient group with PSW. However, contrary to our findings, a study by Alimi et al.[13] reported lower E/E' values in patients without PSW and suggested an inverse relationship with DD. While our study methodology does not allow us to fully explain the underlying pathophysiology, we observed that the study population of Alimi et al. consisted of older patients with lower LV-EF. We consider that the presence of PSW in younger patient groups may be linked to both atrial and LV dysfunction, whereas in older cases with higher morbidity, the presence of PSW may serve as an indicator of preserved atrial contraction.

In this study, patients with PSW had significantly higher mean values for systolic and diastolic blood pressure. Randomized controlled trials have shown that DD is more frequently observed in patients with uncontrolled hypertension, which could explain the presence of PSW in this population.[14] Considering similar pathophysiological mechanisms, our study found that patients with higher blood pressure exhibited a more hypertrophic LV, which was associated with DD. Recent studies have demonstrated a relationship between blood pressure and increased LV wall thickness[15] and its impact on DD.[16] In our study, A wave, a crucial echocardiographic parameter, was also found to be associated with PSW. Similarly, in a 2014 study, A wave and PSW were reported to strongly correlate in patients with normal LV-EF, whereas no significant association was observed in patients with reduced LV-EF.[17] This finding supports both our study results and our interpretation of the paradoxical correlation between PSW and DD. In our study, although the numerical differences were not substantial, age, fasting blood glucose, and BUN levels were also found to be statistically different between the groups with and without PSW.

Despite the widespread use of echocardiography today, 12-lead ECG remains a fundamental tool in daily clinical practice. In addition to basic rhythm analysis and ischemic evaluations, ECG allows for advanced investigations into atrial and ventricular functions.[18] Several electrocardiographic parameters have been defined for predicting LV-DD.[9,19] Recent studies utilizing artificial intelligence have demonstrated the prognostic significance of ECG-derived DD measurements on mortality in cases of mitral regurgitation.[20] We calculated EDI using the "TendP/(PQ × age)" formula, which incorporates ECG wave distances and patient age. We determined EDI as an independent predictor of PSW. The primary components of our formula, namely, the PQ interval and age, are noteworthy. An increase in the PQ interval has been suggested to result in a shorter diastolic duration, serving as a predictor of DD.[21] Consistently, our study revealed that the PQ interval was prolonged in the PSW-positive group. Furthermore, ECG parameters previously identified by Hayırlıoğlu et al.[19] as associated with DD, namely, the amplitudes of AVL R, V1 S, V5 R, and D1 P, as well as QRS duration, were also found to be significantly related to PSW in our study.

Study Limitations

Although the power of our patient number is sufficient for the analysis, the fact that it is a single-center regional study draws attention as an important limitation. Furthermore, as our study was conducted based on routine examinations, advanced echocardiographic parameters such as strain analysis or specific laboratory biomarkers were not available.

Conclusion

We identified a relationship between echocardiographic PSW and electrocardiographic EDI in hypertensive patients. Our findings also confirmed the strong association between PSW and echocardiographic diastolic parameters. Furthermore, we demonstrated that EDI, an easy-to-obtain ECG parameter that does not require an echocardiographic evaluation in outpatient settings, provides valuable insight into diastolic parameters.

Disclosures

Ethics Committee Approval: The study was approved by the University of Health Sciences Trabzon Faculty of Medicine Scientific Research Ethics Committee (no: 2024–147, date: 05/12/2024).

Informed Consent: Informed consent was obtained from all participants.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

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