ARAŞTIRMA MAKALESİ / *RESEARCH ARTICLE*

Left Ventricular Diastolic Longitudinal Strain Angle as a Parameter (New Tool) to Predict Left Ventricular Diastolic Function

Sol Ventriküler Diyastolik Fonksiyonu Tahmin Etmek için bir Parametre Olarak Sol Ventriküler Diyastolik Longitidunal Strain Açısı (Yeni Araç)

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ABSTRACT

Aim: *Currently, left ventricular diastolic dysfunction (LVDD) is evaluated using indirect parameters derived from trans-mitral valve inflow velocity (TMIV), pulmonary vein flow, and LV diastolic annular tissue velocity (DATV). None of these parameters is obtained directly from the LV global myocardium. This study aimed to examine the relationship between left ventricular (LV) global longitudinal diastolic strain curve angle (DSCA), which directly assesses myocardial function, and TMIV and DATV parameters, and to determine whether DSCA can serve as a new tool for detecting LVDD.*

Material and Methods: *114 patients with sinus rhythm were included in the study. Conventional pulse wave Doppler parameters [TMIV E and A peak velocity, E/A ratio (E/AR), deceleration time (DT), deceleration slop (DS)], DATV parameters [Septal é (Sé), E/Septal é ratio (E/SéR)], and DSCA parameters, including early (EεA) and late (AεA) diastolic strain angles and their ratio (Eε/AεAR) obtained from apical 2, 4 and 5 apical chamber views (ACV) were compared.*

Results: *A significantly positive strong correlation was found between Eε/AεAR and E/AR, E/SéR on all views (r=0.620, r=0.548, r=0.570, and r=-0.431, r=-0.279, r=-0.255, respectively). Also, a significantly positive correlation was found between the EεA and E velocity, Eε/AεAR, DS on all views, and, except for A4CV, a significantly negative correlation was found between AεA and E velocity, DS on A2CV and A5CV.*

Conclusion: *The EεA, AεA, and Eε/AεAR are a simple, repeatable, useful and new tool for the evaluation of LVDD, and they can be used alone or together with conventional diastolic parameters for the assessment of LVDD.*

Key words: *left ventricle; diastolic dysfunction; transmitral inflow velocity; strain; Eε and Aε angle; Eε and Aε angle ratio*

ÖZET

Amaç: *Günümüzde, sol ventrikül diyastolik disfonksiyonu (LVDD), trans-mitral kapak giriş hızı (TMIV), pulmoner ven akımı ve sol ventrikül (LV) diyastolik anüler doku hızı (DATV) ile elde edilen endirekt parametrelerle değerlendirilir. Bu parametrelerin hiçbiri doğrudan LV global miyokardından elde edilmemektedir. Bu çalışmanın amacı, direkt miyokard fonksiyonunu değerlendiren sol ventrikül global longitudinal diyastolik strain eğri açısı (DSCA) ile TMIV ve DATV parametreleri arasındaki ilişkiyi gözlemlemek ve DSCA'nın yeni bir araç olarak LVDD'yi tespit edip edemeyeceğini belirlemektir.*

Materyal ve Yöntem: *Sinüs ritminde olan 114 hasta çalışmaya dâhil edildi. Konvansiyonel nabız dalgası Doppler parametreleri [TMIV E ve A pik hızı, E/A oranı (E/AR), yavaşlama zamanı (DT), yavaşlama eğimi (DS)], DATV parametreleri [Septal é (Sé), E/Septal é oranı (E/SéR)] ve apikal iki, dört ve beş apikal boşluk görüntülemeden (ACV) elde edilen DSCA parametreleri [(E strain eğri açısı (EεE), A strain eğrisi açısı (AεA), Eε/AεA oranı)] karşılaştırıldı.*

Bulgular: *Tüm görünümlerde Eε/AεAR ile E/AR, E/SéR arasında anlamlı pozitif güçlü bir korelasyon bulundu (sırasıyla r=0,620, r=0,548, r=0,570 ve r=-0,431, r=-0,279, r=-0,255). Ayrıca, EεA ile E hızı, Eε/AεAR, DS arasında tüm görünümlerde anlamlı pozitif korelasyon bulunurken, A4CV hariç, AεA ile E hızı, DS arasında A2CV ve A5CV'de anlamlı negatif korelasyon bulundu.*

Sonuç: *EεA, AεA ve Eε/AεAR, DD'nin değerlendirilmesinde basit, tekrarlanabilir, kullanışlı ve yeni bir araçtır. LVDD'nin değerlendirilmesinde tek başına veya geleneksel diyastolik parametrelerle birlikte kullanılabilir.*

Anahtar kelimeler: *sol ventrikül; diyastolik disfonksiyon; transmitral akım hızı; strain; Eε ve Aε açısı, Eε ve Aε açısı oranı*

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Introduction

The diagnostic classification of heart failure with preserved ejection fraction (HFpEF) requires careful assessment of left ventricular diastolic dysfunction (LVDD), because of its key role in identifying impaired ventricular compliance and hemodynamic mechanisms[1].

Specifically, accurate LVDD diagnosis and management necessitate the capacity to assess regional myocardial function adequately. Early LVDD diagnosis, before the manifestation of global impairment, is desirable for managing myocardial heart disease and related conditions[2].

Although cardiac catheterization is the gold standard for evaluating LVDD, the most commonly used noninvasive method is trans-mitral valve inflow velocity (TMIV) obtained through pulse wave Doppler (PWD) and left ventricular diastolic annular tissue velocity (DATV) measured by tissue Doppler imaging (TDI)[3]. Evaluation of TMIV and DATV offers an indirect assessment of LVDD. Furthermore, it encompasses measurements of various parameters that enable LVDD to be classified[4]. However, it heavily depends on left ventricular end-diastolic pressure, sufficient intravascular fluid volume, and observer experience. Due to the complex nature of LVDD, these noninvasive indices might not show strong correlations with left ventricular (LV) filling pressures[5].

Strain echocardiography is a new imaging technique and has been used for the last 20 years[6]. It is derived from the speckle tracking echocardiography (STE)[7]. It is used to evaluate regional myocardial systolic and diastolic deformation change. Changes in systolic and diastolic strain can discriminate myocardial viability[8]. Also, it can differentiate pathological and physiological hypertrophy from restrictive and constructive cardiomyopathy, without angle-dependent[9]. Currently, STE is used in LVDD assessment. Left ventricular diastolic dysfunction decision is made only with optional peak strain values (e.g., peak S, E, and A) on the diastolic strain curve (DSC)[10]. However, the DSC may provide more information than peak strain values in the evaluation of LVDD[11]. Also, post-systolic strain occurring at the end of systole may cause misinterpretation of LVDD[12]. Therefore, we can obtain more parameters from the left ventricular global longitudinal diastolic strain curve angle (DSCA) than the current evaluation parameters about LVDD[13].

This study aimed to evaluate the relationship between the measurements of DSCA values, TMIV, and DATV diastolic parameters, and to determine whether or not it can be used as a new tool to evaluate LVDD.

This study aimed to evaluate the relationship between DSCA values, TMIV and DATV diastolic parameters, and to investigate the potential utility of DSCA as a novel tool for LVDD assessment.

Method

Study Population

This retrospective study included 114 participants with preserved left ventricular ejection fraction (≥50%) and varying degrees of left ventricular diastolic dysfunction (LVDD), assessed using pulsed-wave Doppler (PWD) and tissue Doppler imaging (TDI) echocardiography. Data were collected from January 2017 to February 2019 by reviewing digital echocardiographic records stored in the EchoPAC platform. Demographic and clinical information was obtained from electronic health records and institutional medical databases. Exclusion criteria included individuals with a history of coronary artery disease (despite preserved ejection fraction), active systemic infections, malignancies, significant arrhythmias (e.g., atrial fibrillation, atrial flutter, multifocal atrial tachycardia, atrioventricular blocks, or reentrant tachycardias), and severe valvular diseases. The institutional ethics board approved the study protocol by the Declaration of Helsinki (Ethics No: 80576354-050-99-219).

Echocardiography

Echocardiographic examinations were conducted with subjects positioned in the left lateral decubitus position, employing a Vivid 7 ultrasound system (GE Healthcare, Waukesha, WI, USA) equipped with a 3.6 MHz transducer. Two-dimensional echocardiography (2D-Ech), TDI, and STE data were acquired at a frame rate of 60 frames per second by a single, experienced cardiologist. All cardiac measurements adhered to the American Society of Echocardiography guidelines and were obtained at rest in the left lateral decubitus position during breath-hold with stable electrocardiographic monitoring[14]. Three consecutive cardiac cycles were recorded from standard apical 2-chamber (A2CV), 4-chamber (A4CV), and 5-chamber (A5CV) views and subsequently analyzed using EchoPAC Dimension software. Left ventricular ejection fraction (LVEF) was calculated using the

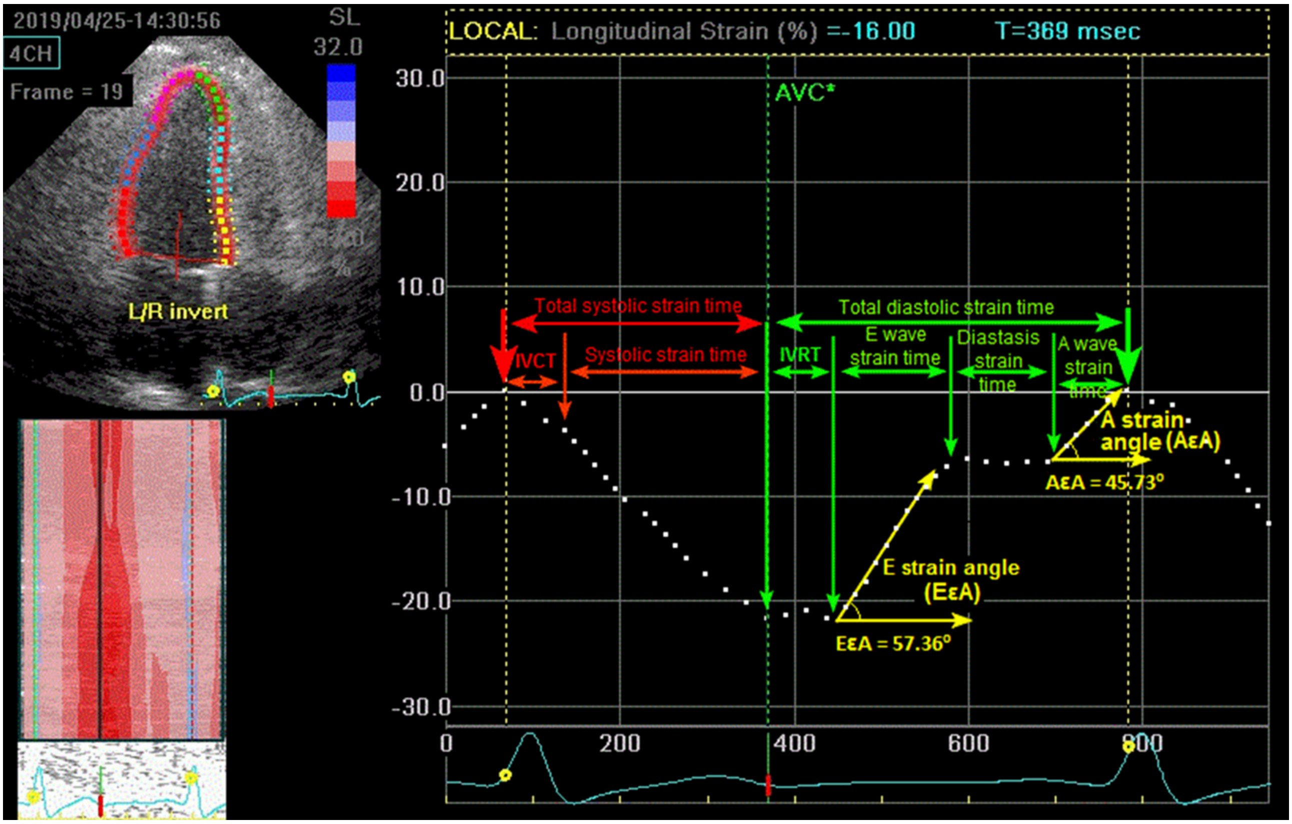

Figure 1. *Schematic demonstration of the E and A strain curve angle (EεA, AεA) on the strain curve formed during a diastolic cardiac cycle.*

modified Simpson's method on the A4CV view, with end-diastolic and end-systolic volumes measured[7].

Transmitral inflow velocity (TMIV) was obtained by PWD echocardiography during breathing hold in an A4CV. Transmitral inflow velocity diastolic parameters assessed included peak velocities during early diastole (E wave) and late diastole (A wave), the E/A ratio (E/AR), E wave deceleration time (DT), and deceleration slope (DS).

Diastolic annular tissue velocity obtained by TDI with the spectral pulse of the septal and lateral mitral annulus was performed, and a peak of the early filling septal and lateral é wave (Sé, Lé) and late filling septal and lateral á wave (Sá, Lá) was measured. Transmitral inflow velocity early E (E velocity) to Lé velocity ratio (E/LéR), E velocity to Sé velocity ratio (E/SéR), Lé velocity to Lá velocity ratio (Lé/LáR), Sé velocity to Sá velocity ratio (Sé/SáR) were calculated automatically.

2D-Speckle Tracking Diastolic Strain Curve Analysis

Offline DSC analysis was performed with EchoPAC Dimension software. The LV systole and diastolic endocardial border were manually traced during the at-end-systole on an end-systolic frame and during the at-end-diastolic on an end-diastolic frame in three views by a point-and-click approach, respectively[15]. After manual tracing of the endocardial contour, the software automatically tracked the motion through the rest of the cardiac cycle, and automatically generated strain curves of every cardiac cycle.

Measurement of Diastolic E- and A- Strain Angles

To measure the strain angle during the early volumetric relaxation period (EεA), the first, start, and end points of the early volumetric phase were identified on the diastolic strain curve. Next, the end of isovolumetric relaxation was used as the starting point of the early volumetric relaxation phase, and the beginning of the diastasis phase was used as the endpoint of this phase. Then, the line segment connecting these two points served as the first line of the early volumetric strain angle. After that, the second line segment was created from a line drawn starting at the point where the "x" axis intersects the first line segment, parallel to the "x" axis. Finally, the angle between these two line segments was measured using J-Image software (Version 1.54 k), and the result was recorded as the early volumetric relaxation angle (Fig. 1).

Table 1. Patients' demographic, clinical and 2D-Echocardiographic baseline characteristics

		Overall (mean ± SD) n: 114	Min & max range n: 114
Age (years)		51.86±13.87	19–89
Male gender		57 (50%)	-
Hypertension		59 (51.8%)	-
Diabetes mellitus		3 (2.6%)	-
Smoker		46 (40.4%)	-
Dyslipidemia		6 (5.3%)	-
Heart rate (bpm)		73.15±12.75	48–125
Blood pressure (mmHg)	SBP	151.85±34.73	100–252
	DBP	90.51±15.91	60–130
	PP	110.95±21.37	80–166.67
2D – Ech	IVSd (cm)	1.26±0.35	0.7–2.3
	IVSs (cm)	1.53±0.37	0.9–2.8
	LVEDD (cm)	4.70±0.61	2.4–6.2
	LVESD (cm)	3.09±0.61	1.3–4.5
	PWDd (cm)	1.01±0.27	0.6–1.7
	PWSd (cm)	1.36±0.48	0.7–5.2
	LVEDV (cm^2)	104.94±30.4	21–197
	LVESV (cm^2)	39.86±18.80	4–94
	LVSV (cm^2)	65.14±19.46	17–140
	LVEF (% & cm^2)	65.45±9.85	45–88
	LVFS (% & cm^2)	34.62±7.8	16–55

2D-Ech: two-dimension echocardiography, DBP: diastolic blood pressure, IVSd: interventricular septum diastolic diameter, IVSs: interventricular septum systolic diameter, LVEDD: left ventricular end diastolic diameter, LVEDV: left ventricular end diastolic volume, LVEF: left ventricular ejection fraction, LVESD: left ventricular systolic diameter, LVESV: left ventricular end systolic volume, LVFS: left ventricular fraction stork volume, LVSV: left ventricular stork volume, PP: pulse pressure, PWDd: posterior wall diastolic diameter, PWSd: posterior wall systolic diameter, SBP: systolic blood pressure

To measure the strain angle during the late diastolic filling period (AεA), the endpoints of the diastasis and late diastolic phases were identified on the strain curve. Next, a line segment connecting these two points was drawn to represent the first line segment of the late diastolic filling phase strain angle. Then, a second line segment was created starting from the point where this first line intersects the "x" axis and drawn parallel to the "x" axis, forming the second line segment of the late diastolic filling phase strain angle. Additionally, another line segment parallel to the "x" axis was drawn from the point where it intersects the "x" axis to form an additional line of the late diastolic filling phase strain angle. Finally, the angle between these two line segments was measured using the J-Image software (Version 1.54 k), and the late volumetric filling phase strain angle (AεA) was recorded (Fig. 1). The EεA/AεA ratio (Eε/AεAR) was calculated by dividing the EεA value by the AεA value.

Statistics

Statistical analyses were conducted using IBM Statistical Package for Social Sciences (SPSS) software version 26.0 (IBM Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to check the distribution of continuous variables. Parametric continuous variables are shown as mean ± standard deviation (SD) and were compared with the paired samples t-test. Categorical variables are reported as absolute frequencies (percentages) and compared using Pearson's chi-square test. Pearson's correlation coefficient was used to evaluate correlations between variables. A p-value less than 0.05 was considered statistically significant for all tests.

Results

The demographic, clinical, and 2D-Echo characteristics of patients are presented in Table 1. 114 patients were included in the study. The mean age in the study population was 51.86±13.87 (min-max: 19–89) years. 50% (n=57) were male. 51.8% (n=59) had hypertension, and 2.6% (n=3) had diabetes mellitus. The average heart rate was 73.15±12.75 beats per minute, with systolic and diastolic arterial blood pressures of 151.85±34.73 mmHg and 90.51±15.91 mmHg, respectively. In the 2D-Echo evaluation; the mean LV) end-diastolic volume was

Table 2. *Comparison of the DSCA obtained on the A2CV, A4CV, A5CV and TMIV values obtained on the A4CV*

		TMIV (mean ± Sd) n: 114	DSCA (mean ± Sd) n: 114	p
E velocity	A2CV EεA	0.72±0.18	50.42±10.23	<0.001
	A4CV EεA		52.46±10.77	<0.001
	A5CV EεA		53.20±10.18	<0.001
A velocity	A2CV AεA	0.73±0.17	51.77±6.86	<0.001
	A4CV AεA		52.59±7.55	<0.001
	A5CV AεA		50.85±8.59	<0.001
E/AR	A2CV Eε/AεAR	1.03±0.36	0.99±0.24	0.158
	A4CV Eε/AεAR		1.02±0.36	0.830
	A5CV Eε/AεAR		1.06±0.30	0.215
DT	A2CV EεA	192.19±66.95	50.42±10.23	<0.001
	A4CV EεA		52.46±10.77	<0.001
	A5CV EεA		53.20±10.18	<0.001
	A2CV AεA		51.77±6.86	<0.001
	A4CV AεA		52.59±7.55	<0.001
	A5CV AεA		50.85±8.59	<0.001
	A2CV Eε/AεAR		0.99±0.24	<0.001
	A4CV Eε/AεAR		1.02±0.36	<0.001
	A5CV Eε/AεAR		1.06±0.30	<0.001
DS	A2CV EεA	4.22±1.85	50.42±10.23	<0.001
	A4CV EεA		52.46±10.77	<0.001
	A5CV EεA		53.20±10.18	<0.001
	A2CV AεA		51.77±6.86	<0.001
	A4CV AεA		52.59±7.55	<0.001
	A5CV AεA		50.85±8.59	<0.001
	A2CV Eε/AεAR		0.99±0.24	<0.001
	A4CV Eε/AεAR		1.02±0.36	<0.001
	A5CV Eε/AεAR		1.06±0.30	<0.001

A: transmitral late diastolic inflow A velocity, A2CV: apical two-chamber view, A4CV: apical two-chamber view, A5CV: apical two-camber view, AεA: left ventricular global longitudinal A strain angle, DS: deceleration slop, DT: deceleration time, E/AR: transmitral early diastolic inflow E velocity to transmitral inflow A velocity ratio, E: transmitral early diastolic inflow E velocity, Eε/AεAR: left ventricular global longitudinal diastolic strain curve E- and A-strain angle ratio, EεA: left ventricular global longitudinal E strain angle, DSCA: diastolic strain curve angle, TMIV: transmitral inflow velocity, ε: strain

104.94±30.4 cm^2, while the end-systolic volume was 39.86±18.80 cm^2. LV stroke volume was 65.14±19.46 cm^2. In addition, the mean value of LVEF was 65.45±9.85.

Using a statistical analysis of samples, it was determined whether there were differences between the E/AR and Eε/AεAR parameters. As expected, no statistically significant differences were found between the mean of Eε/AεAR and E/AR measured from the left ventricle on the A2CV, A4CV, and A5CV (1.06±0.03 vs 1.03±0.36, p=0.215; 1.02±0.36 vs 1.03±0.36, p=0.830; 0.99±0.24 vs 1.03±0.36, p=0.158; respectively). However, significant differences were found between DSCA values (A2CV Eε, A4CV Eε, A5CV Eε, A2CV Aε, A4CV Aε, A5CV Aε) and TMIV values (E Velocity, A Velocity, DT, DS) on all views (Table 2). Also, significant differences were found between most of the DATV and most of the DSCA values (Table 3).

By correlation analysis, it was determined whether there was a correlation between DSCA values, TMIV values, and DATV values. A significantly strong correlation was found between Eε/AεAR and E/AR, E/SéR on the A2CV A4CV, and A5CV (r=0.620, p <0.001; r=0.548, p <0.001; r=0.570, p <0.001; and r=-0.431, p <0.001; r=-0.279, p=0.003; r=-0.255, p <0.008, respectively) (Table 4, Fig. 2). Also, a significantly positive correlation was found between the EεA and E velocity, E/AR and DS on most ACVs, and, except for A4CV, a significant negative correlation was found between AεA and E velocity,

Table 3. *Diastolic strain curve angle obtained on the A2CV, A4CV, A5CV and DATV obtained on the A4CV values comparison*

DATV/ DSCA parameters		DATV values n: 114	DSCA values n: 114	p
A4CV Lé	A2CV EεA	0.11±0.09	50.42±10.23	<0.001
	A4CV EεA		52.46±10.77	<0.001
	A5CV EεA		53.20±10.18	<0.001
A4CV Lá	A2CV AεA	0.12±0.12	51.77±6.86	<0.001
	A4CV AεA		52.59±7.55	<0.001
	A5CV AεA		50.85±8.59	<0.001
A4CV Lé/LáR	A2CV Eε/AεAR	1.19±0.094	0.99±0.24	0.028
	A4CV Eε/AεAR		1.03±0.27	0.070
	A5CV Eε/AεAR		1.06±0.30	0.170
A4CV Sé	A2CV EεA	0.094±0.080	50.42±10.23	<0.001
	A4CV EεA		52.46±10.77	<0.001
	A5CV EεA		53.20±10.18	<0.001
A4CV Sá	A2CV AεA	0.11±0.10	51.77±6.86	<0.001
	A4CV AεA		52.59±7.55	<0.001
	A5CV AεA		50.85±8.59	<0.001
A4CV Sé/Sá R	A2CV Eε/AεAR	0.95±0.63	0.99±0.24	0.495
	A4CV Eε/AεAR		1.03±0.27	0.160
	A5CV Eε/AεAR		1.06±0.30	0.037

DATV: Left ventricular diastolic annular tissue velocity, DSCA: Left ventricular global longitudinal diastolic strain curve angle, E/LéR: Transmitral early diastolic inflow E velocity to lateral annular é velocity ratio, Lá: Lateral annular á velocity, Lé/LáR: Lateral annular é velocity to lateral annular á velocity ratio, Lé: Lateral annular é velocity, Sá: Septal annular á velocity, Sé/Sá R: septal annular é velocity to septal annular á velocity ratio, Sé: Septal annular é velocity

Table 4. *Correlations between DSCA values obtained on the A2CV, A4CV, A5CV and TMIV values obtained on the A4CV.*

			E velocity	A velocity	E/AR	DT	DS
A2CV	EεA	r	0.381	-0.341	0.502	-0.132	0.250
		p	0.000	<0.001	<0.001	0.166	0.008
	AεA	r	-0.288	0.112	-0.292	0.182	-0.251
		p	0.002	0.241	0.002	0.055	0.008
	Eε/AεAR	r	0.507	-0.365	0.620	-0.207	0.364
		p	<0.001	<0.001	<0.001	0.028	<0.001
A4CV	EεA	r	0.370	-0.274	0.446	-0.128	0.227
		p	<0.001	0.004	<0.001	0.185	0.018
	AεA	r	-0.116	0.202	-0.234	0.046	-0.101
		p	0.232	0.035	0.013	0.636	0.296
	Eε/AεAR	r	0.410	-0.385	0.548	-0.171	0.306
		p	<0.001	<0.001	<0.001	0.072	0.001
A5CV	EεA	r	0.428	-0.331	0.530	-0.140	0.252
		p	<0.001	<0.001	<0.001	0.150	0.009
	AεA	r	-0.252	-0.004	-0.170	0.181	-0.258
		p	0.009	0.970	0.076	0.061	0.007
	Eε/AεAR	r	0.534	-0.307	0.570	-0.268	0.416
		p	<0.001	0.001	<0.001	0.004	<0.001

Table 5. *Correlations between left ventricular DSCA ratio values obtained on the A2CV, A4CV, A5CV and DATV values obtained on the A4CV*

		E/LéR	E/SéR	Lé/LáR	Sé/SáR
A2CV Eε/AεAR	r	-0.260	-0.431	0.314	0.554
	p	0.007	<0.001	0.001	<0.001
A4CV Eε/AεAR	r	-0.207	-0.279	0.374	0.504
	p	0.033	0.003	<0.001	<0.001
A5CV Eε/AεAR	r	-0.083	-0.255	0.289	0.509
	p	0.394	0.008	<0.001	<0.001

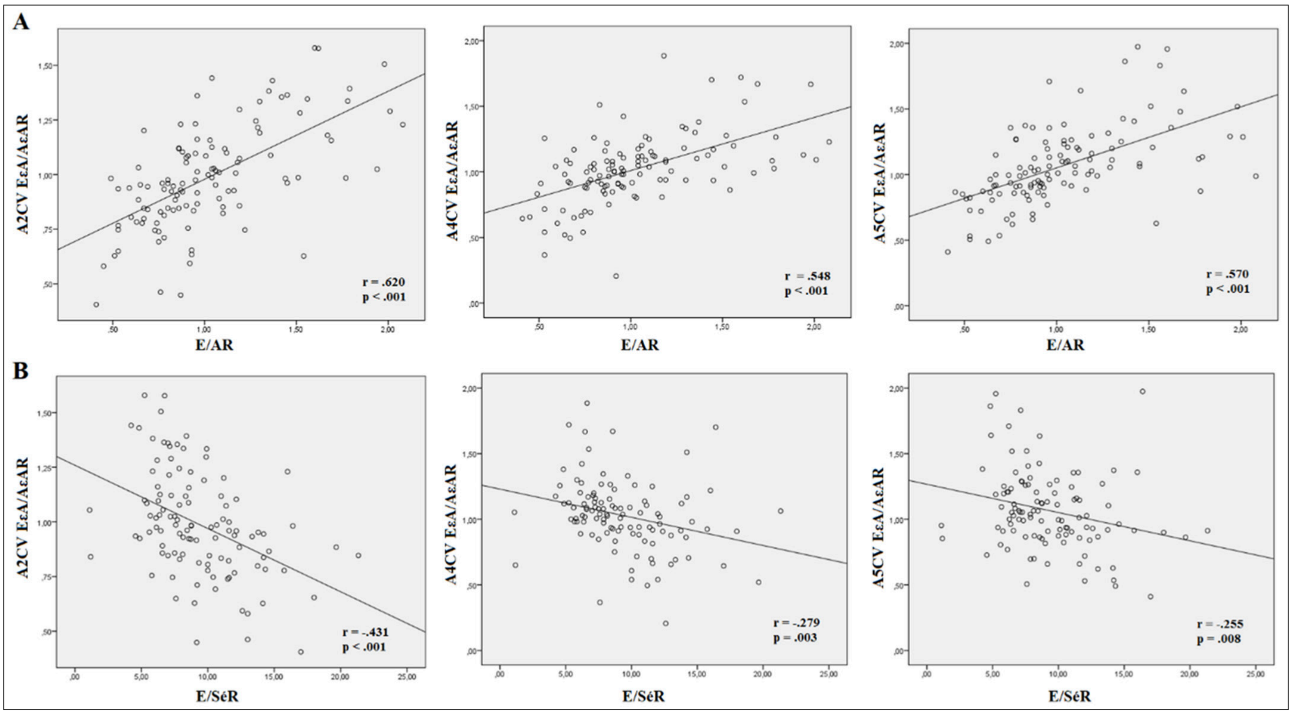

Figure 2. *a, b. Significant correlations between EεA/AεAR obtained on A2CV, A4CV and A5CV, E/AR (a), E/SéR obtained on A4CV during LV diastole (b) (r=correlation coefficient; p=significance level).*

E/AR and DS on A2CV and A5CV (Table 4). Moreover, except for the correlation between Eε/AεAR and E/Lé ratio on the A2CV, a significant correlation was found between Eε/AεAR and E/Lé Ratio, E/ Sé Ratio, Lé/Lá Ratio, Sé /Sá Ratio on all views (r=-0.260, p=.0.007, r=-0.431, p <0.001, r=0.314, r=0.001, r=0.554, p <0.001, on the A2CV), r=-0.207, p=0.033; r=-0.279, p=0.003; r=0.374, p <0.001; r=0.504, p <0.001 on the A4CV and r=-0.255, p=0.008 r=0.289 p <0.001; r=0.509; p <0.001, on the A5CV, respectively) (Table 5).

Discussion

The main finding in the present study of patients with LVEF >50% was that the DSCA of the early volumetric relaxation period (EεA) to DSCA of the late diastolic filling period (AεA) ratio (EεA/AεAR) is strongly correlated with E/AR, E/LéR, E/SéR, Lé/LáR and Sé/SáR. Also, a positive correlation was found between the EεA and E/AR, E velocity. There was a negative correlation between the EεA and A velocity, DT, and DS. Similarly, there is a negative correlation between the AεA and E/A ratio, E velocity, and DS. To our knowledge, no study has compared these longitudinal diastolic DSCAs and traditional echocardiographic diastolic parameters.

In assessing patients with suspected heart failure or symptoms of shortness of breath, measuring LVDD plays a crucial diagnostic role. The mortality rates linked to heart failure with preserved ejection fraction are similar to those seen in cases of heart failure with reduced ejection fraction[16,17]. Diagnosing heart failure with preserved ejection fraction is more complex than diagnosing heart failure with reduced ejection fraction. Additionally, it tends to be underdiagnosed when relying solely on ejection fraction[18].

The most frequently employed methods for evaluating and staging LVDD are trans-mitral inflow peak E velocity, late filling A velocity, E/A ratios, and E/é ratio. However, it should be noted that these parameters are indirect, and there are important limitations to evaluating LVDD. The most significant limitation is its susceptibility to loading conditions. Furthermore, for the E- and A-velocities to be reliable, the Doppler velocity records must be referred to at the correct angle. Moreover, the reliability of these measurements may be compromised by factors such as heart rate, presence of heart arrhythmias (notably atrial fibrillation/flutter), PR distance, cardiac output, mitral annulus diameter, and left atrial function and aging, which can lead to erroneous assessments of LVDD. The relationship between changes in left ventricular diastolic and systolic volumes and pressures and their direct impact on mitral annular velocities and time intervals is a crucial consideration.

Left ventricular myocardial longitudinal diastolic strain measured by 2D-STE provides non-invasive and global information about LVDD. Moreover, direct data about left ventricular diastolic function can be obtained with the strain. Although these benefits of strain, diastolic functions cannot be evaluated correctly in the case of the presence of the post-systolic strain, and during the tachycardia onset and end points of the E and A strain curves cannot be distinguished. In these cases, DSCA eliminates the errors arising from the measurements on the diastolic strain curve, and obtains diastolic data from the LV itself. It is also not affected by tachycardia.

Diastolic annular tissue velocity via TDI may inadequately evaluate regional myocardial relaxation due to inherent limitations of Doppler-based methodologies. Key constraints include angle dependence, which introduces significant measurement inaccuracies at interrogation angles exceeding 20°. Furthermore, regional wall motion abnormalities at sampling sites may yield artificially reduced velocities on tissue Doppler, even in the presence of globally preserved relaxation. Early diastolic relaxation, an active energy-dependent process, initiates rapidly in the basal LV segments and propagates apically, generating a base-to-apex strain gradient. This gradient, coupled with myocardial thinning and untwisting mediated by the myocardium's incompressibility, drives chamber dilatation during diastole[19,20]. Consequently, rate-based assessments of early relaxation (e′) at the annular level may overlook localized disturbances in relaxation.

The clinical utility of e′ and derived metrics, such as the E/e′ ratio, remains contentious due to inconsistent evidence. While studies by Kimura et al. and Ersbøll et al. reported that E/e′ ratios derived from STE more accurately predict LV filling pressures than conventional Doppler-based E/e′ measurements[21,22], Kasner et al. found no incremental diagnostic value of STE over TDI in patients with coronary artery disease[23]. Similarly, strain rate imaging failed to demonstrate superiority over TDI for detecting diastolic dysfunction in HFpEF[24]. Such divergent findings underscore the limitations of relying on isolated Doppler or strain-based parameters for LVDD diagnosis.

Emerging evidence in our study suggests that integrating novel speckle-tracking parameters –including EεA, AεA, and Eε/AεA– with conventional TMIV and DATV may enhance diagnostic sensitivity. This multimodal approach, which synthesizes complementary data on myocardial mechanics, could mitigate errors inherent to Doppler-dependent techniques, refine the classification of diastolic dysfunction, and improve diagnostic accuracy in LVDD.

Study Limitations

This research has several constraints. First, the observational, single-center design limits the generalizability of findings, as longitudinal or multi-institutional data were not incorporated. Second, the modest participant pool may restrict the statistical power needed to establish definitive diagnostic thresholds for diastolic parameters such as EεA, AεA, and the EεA/AεA ratio. Larger, population-based studies are essential to validate these metrics as reliable tools for assessing left ventricular diastolic function. Third, the technical demands of speckle-tracking echocardiography pose challenges: accurate myocardial deformation analysis relies heavily on high-quality image acquisition and operator expertise in optimizing 2D echocardiographic windows for precise endocardial border identification. These factors may affect reproducibility in clinical settings with variable imaging resources.

Conclusions

We documented a significant correlation between the LV diastolic DSCA parameters on the A2CV, A4CV, A5CV, TMIV, and DATV parameters. Diastolic strain curve angle tool is a diastolic parameter derived from speckle tracking echocardiography that can be used to determine regional myocardial functions quantitatively. It is a new echocardiographic tool that, working with standard 2D-Ech without the limitations of Doppler techniques, provides a comprehensive diastolic analysis of global myocardium. Furthermore, it's a reliable and easy-to-apply noninvasive method for evaluating LV diastolic function. Therefore, in addition to traditional methods, the use of the DSCA tool may be recommended for the evaluation of LV diastolic function.

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