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ORIGINAL ARTICLE

Role of Left Atrial Function as A Predictor of Symptoms for Patients with Dilated Cardiomyopathy

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Abstract

Background: ***By performing three closely linked functions, the left atrium (LA) plays a central role in regulating the filling of the left ventricle and the overall functioning of the cardiovascular system.***

The aim of the work: ***The objective of this study is the assessment of LA functions and their relation to pulmonary congestive symptoms in patients with dilated cardiomyopathy.***

Patients and Methods: ***From January 2023 to September 2023, the Cardiology Department at Bab EL-Sha'riya Hospital, Al-Azhar University, performed this study on fifty patients diagnosed with DCM who sought care at the Outpatient Clinic and Echocardiography Laboratory.***

Results: ***We observed significant associations among NYHA classification, LVD-36 score, METS, and exercise duration in patients with DCM. Significant correlations were seen with LA reservoir strain (r = -0.727, P<0.001). The strongest correlations with LA reservoir strain were seen in the LVD-36 score instance (r = -0.836, P<0.001). The two most significant relationships between METS and LA reservoir strain (r = 0.828, P<0.001) and Modified Simpson EF (r = 0.874, P<0.001). We established positive associations with modified Simpson EF (r = 0.41, P = 0.003) and LA reservoir strain (r = 0.375, P = 0.007) in relation to exercise duration. On the other hand, we found a negative correlation between the E/A ratio (r = -0.445, P = 0.001) and the LV global strain (r = -0.393, P = 0.005).***

Conclusion: ***To predict pulmonary symptoms in individuals with chronic heart failure, it is important to use 2D echocardiographic parameters, particularly a 2D speckle tracking approach for evaluating left atrial function with a specific focus on reservoir strain function.***

Keywords: left atrium; 2D speckle tracking strain; HFrEF; DCM

1. Introduction

Dilated cardiomyopathy patients show left ventricular dilatation and decreased contractility, which results in an ejection fraction of the left ventricle (LVEF) of less than 40%. [1]
Researchers have linked several anatomical and functional irregularities in the left atrial (LA) to heart failure, which is characterized by a reduced ejection fraction of the left ventricle (HFrEF). The LA plays a crucial role in the regulation of cardiac output and left ventricular (LV) filling. The atrium and the ventricle's mutually reliant actions, closely coordinated with the cardiac cycle, carry noteworthy implications. The advent of novel non-invasive imaging techniques has significantly expanded our current knowledge of the function and clinical relevance of the LA. [2,3]

Dilated cardiomyopathy (DCM) presents a challenging path for individuals diagnosed with this medical illness. DCM is characterized by the expansion and weakening of the left ventricle of the heart, which can greatly impair the heart's ability to pump blood effectively. They frequently contend with symptoms like breathlessness and fluid retention, all of which can profoundly disrupt their quality of life. Typically, the treatment entails a combination of medications, lifestyle changes, and, in some cases, a heart transplant. DCM patients frequently rely on a robust support network, including healthcare professionals and their loved ones. Their unwavering determination to navigate their condition is praiseworthy. [4]

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2D echocardiography is a valuable diagnostic instrument widely used in cardiology to scrutinize various aspects of cardiac performance, including the comprehensive evaluation of the left atrium. This non-invasive imaging methodology harnesses high-frequency sound waves to generate intricate, real-time depictions of the heart and its chambers. 2D echocardiography provides invaluable insights into assessing left atrial function. It empowers healthcare practitioners to gauge left atrial dimensions, appraise its proportions and configuration, and scrutinize its mechanical attributes. Two-dimensional echocardiography primarily assesses the left atrium's functionality, especially in diagnosing and continuously monitoring cardiac conditions like AF and heart failure. By examining the size and contractile patterns of the left atrium, medical professionals are able to infer the presence of abnormal blood flow, the development of blood clots, or other issues related to these medical diseases. In addition, 2D echocardiography is very helpful for checking the left atrial strain, which is a key factor in understanding how well the atrium can pump blood into the left ventricle. [5,6]

Speckle tracking introduces a more comprehensive approach for clinicians to delve into the intricacies of the left atrium by quantifying its strain, strain rate, and deformation patterns. These parameters are beneficial for the early detection of subtle signs of impairment. The assessment of left atrial strain via speckle tracking excels at detecting nuanced alterations that might go unnoticed when using conventional imaging techniques, making it an indispensable instrument in the diagnosis of conditions such as atrial fibrillation, heart failure, and various other cardiac disorders. Furthermore, the use of 2D speckle tracking presents a quantitative approach to examining the left atrium's functionality. This method allows for a more accurate assessment of temporal changes and aids in the development of treatment plans. [7]

The goal of this study is to evaluate LA functions and their relationship to pulmonary congestive symptoms in patients with dilated cardiomyopathy.

2. Patients and methods

We conducted the present investigation from January 2023 to September 2023 in the echocardiography laboratory of Bab El Sharia University Hospital, affiliated with Al-Azhar University.

2.1.Inclusion criteria: We enrolled all symptomatic individuals who were over 18 years of age and exhibited echocardiographic indications of dilated cardiomyopathy.

2.2.Exclusion Criteria: We excluded individuals under 18 years of age, those with medical conditions affecting their mobility, patients with significant primary valvular or pericardial heart conditions, individuals without sinus rhythm, and those with advanced renal, hepatic, or pulmonary issues from the study.

Ethical Considerations: Each participant provided informed consent, and the research received approval from the Ethics Committee at Al-Azhar University Hospitals. The study protocol adhered to the Declaration of Helsinki, which serves as the ethical code for human experimentation established by the World Medical Association.

2.3.Study Tools and Procedures: We examined all participants in a supine resting position, specifically in the left lateral decubitus posture. We performed conventional 2D transthoracic echocardiography (TTE) assessments using a "Philips Infinity 50" ultrasound machine equipped with "S5-1" matrix array transducers from Philips Medical Systems, located in Andover, USA. This equipment featured speckle tracking echocardiography (STE) technology and operated within a multi-frequency range spanning from 1 to 5 MHz. We primarily employed an electrocardiogram (ECG)-synchronized examination. Chamber quantification adhered to the guidelines set forth by the last EACVI or ASE of echocardiography. [8]

2.4. The subsequent criteria were recorded: We measured the left ventricle's end-diastolic and end-systolic volumes using a modified version of Simpson's biplane volumetry method. We then obtained the left ventricle ejection fraction, expressed as a percentage. The term pulsed-wave refers to a technique commonly used in medical imaging, specifically in the data collection process, which involves obtaining mitral inflow Doppler and mitral annulus tissue Doppler measurements through the apical 4-chamber view. We recorded specific parameters such as the peak early filling velocity (E), peak atrial velocity (A), E/A ratio, E deceleration time, E', A', and E/E'. We assessed the tricuspid annular plane systolic excursion (TAPSE) using M-mode echocardiography in the apical four-chamber view. We estimated the tricuspid regurgitation velocity and systolic pulmonary artery pressure (SPAP) using the peak continuous-wave Doppler velocity of the tricuspid regurgitation jet.

We quantified left atrial volumes using apical 4- and 2-chamber views during the echocardiography evaluation of the left atrium at various stages of the cardiac cycle. These stages include end-systole, which happens right before the mitral valve opens (called max AV), the end of diastole at the moment the valve closes (called min AV), and the start of the P wave (called V pre-A). We conducted an evaluative assessment of the left atrium's phasic functions, including its roles as a reservoir, conduit, and booster pump, using the following mathematical formulas: We express the formula for calculating the total left atrial (LA)

emptying fraction as (Volmax-Volmin) divided by Volmax, multiplied by 100. You can determine the LA expansion index by dividing (Volmax-Volmin) by Volmin and then multiplying the result by 100. To calculate the LA passive emptying fraction, the formula is (Volmax-VolP) divided by Volmax, multiplied by 100. Finally, we can obtain the LA active emptying fraction by dividing (VolP-Volmin) by VolP and then multiplying the result by 100.

We calculated mean strain values to assess all aspects of left atrial strain, such as reservoir (LASr), conduit (LASr), and contraction (LASct), using the QRS complex as the reference point. In addition, all patients were involved in an exercise test following the modified Bruce protocol on a treadmill in order to evaluate metabolic equivalents (METS), exercise duration, symptoms of lung congestion, arrhythmias, and the reason for terminating the test. We used the Left Cardiac Disease Scale (LVD-36) to assess one's quality of life (QOL). A higher LVD-36 score suggested a poorer quality of life. [9]

Statistical analysis

IBM Co. in Armonk, NY, USA, developed SPSS version 28 for the statistical study. The quantitative data was presented as the median and interquartile range. We reported categorical statistics in terms of frequency and percentage. We computed the Spearman's rank correlation coefficient to evaluate the degree of correlation between two variables. We conducted various analyses to examine different parameters of the left atrium to determine if a left atrial function can serve as a predictive factor for pulmonary symptoms in individuals diagnosed with dilated cardiomyopathy (DCM). We calculated the areas under the curve and determined the 95% confidence intervals, optimal cutoff points, and diagnostic indices. Additionally, we evaluated the diagnostic indices provided by ASE/EACVI to identify indexes and evaluate the left atrium's function. This study conducted all statistical tests using a two-sided approach. We deemed a two-tailed P-value less than 0.05 to be statistically significant. [10]

3. Results

Table 1. Demographic data of the studied patients.

		TOTAL PATIENTS (N=50)
AGE (YEARS)	Median (IQR)	58.5 (50 - 65.25)
	Min-Max	37 – 76
SEX	Male	33 (66%)
	Female	17 (34%)
RISK FACTORS	DM	33 (66%)
	HTN	26 (52%)
	Smoking	24 (48%)

The mean age of the participants was 58.5 years, with a greater proportion of males at 66%. A total of 66% of the participants had received a diagnosis of diabetes, 52% were found to be experiencing hypertension, and 48% reported being habitual smokers.

Table 2. HF manifestations of the studied patients.

		TOTAL PATIENTS (N=50)
NYHA CLASS	II	20 (40%)
	III	22 (44%)
	Iva	7 (14%)
	IVb	1 (2%)
METS	Median (IQR)	5.15 (1 - 8)
	Min-Max	1 - 9.3
DURATION OF EXERCISE (MIN)	Median (IQR)	12 (9.89 - 12.26)
	Min-Max	2.25 – 14
LVD-36 SCORE (%)	50 (36.75 – 77)	22 - 94

Every patient had an assessment of their symptoms related to heart failure. In terms of the NYHA categorization, it was seen that 40% of the patients fell under class II, 44% were categorized as class III and 16% were classified as class IV, with 14% belonging to class IVa and 2% to class IVb. The study found that the median energy expenditures (METs) attained during exercise were 5.15, while the median activity duration was 12 minutes. It is worth noting that in all cases, the exercise was terminated due to the occurrence of shortness of breath. The range of LVD-36 scores varied between 22% to 94%, with an average score of 50%.

Table (3): Speckle Tracking of the studied patients (n=50).

	MEDIAN (IQR)	MIN-MAX
LV GLOBAL STRAIN (%)	-8.55 (-12.05 to -7.58)	-17.6 to -4.7
LA STRAIN		
LA CONDUIT STRAIN (%)	-4 (-5 to -3)	-16 to -2
LA CONTRACTILE STRAIN (%)	-4.5 (-6 to -3)	-8 to -1
LA RESERVOIR STRAIN (%)	8 (6.75 to 11)	5 to 23

The median global strain for left ventricle was -8.55%. Concerning left atrial strain, the median conduit strain was -4%, contractile strain was -4.5%, and reservoir strain was 8%.

Table 4. Correlations between NYHA classification and LVD-36 score of patients with dilated cardiomyopathy and Echo parameters.

	NYHA CLASSIFICATION	
	r_s	P value
LV		
MODIFIED SIMPSON EF (%)	-0.633	<0.001*
E/E` RATIO	0.511	<0.001*
LV GLOBAL STRAIN (%)	0.66	<0.001*
LA		
EXPANSION INDEX (%)	-0.708	<0.001*
ACTIVE EMPT-FR (%)	-0.678	<0.001*
PASSIVE EMPT-FR (%)	-0.536	<0.001*
LA CONDUIT STRAIN (%)	0.525	<0.001*
LA CONTRACTILE STRAIN (%)	0.687	<0.001*
LA RESERVOIR STRAIN (%)	-0.727	<0.001*
	LVD-36 score (%)	
MODIFIED SIMPSON EF (%)	-0.844	<0.001*
E/E` RATIO	0.666	<0.001*
LV GLOBAL STRAIN	0.852	<0.001*
LA		
EXPANSION INDEX (%)	-0.821	<0.001*
ACTIVE EMPT-FR (%)	-0.777	<0.001*
PASSIVE EMPT-FR (%)	-0.624	<0.001*
LA CONDUIT STRAIN (%)	0.737	<0.001*
LA CONTRACTILE STRAIN (%)	0.683	<0.001*
LA RESERVOIR STRAIN (%)	-0.836	<0.001*

Echocardiographic measures and the NYHA classification of patients with dilated cardiomyopathy were found to be significantly correlated. The LA reservoir strain (r=-0.727, P<0.001), LA expansion index (r=-0.708, P<0.001), active LA-EMPT-FR (r=-0.678, P<0.001), and Modified Simpson EF (r=-0.633, P<0.001) showed especially strong associations. Furthermore, significant correlations between echocardiographic markers and the LVD-36 score of patients with dilated cardiomyopathy (DCM) were found. LV Global strain (r=0.852, P<0.001), Modified Simpson EF (r=-0.844, P<0.001), LA reservoir strain (r=-0.836, P<0.001), expansion index (r=-0.821, P<0.001), LA Conduit strain (r=0.737, P<0.001), active EMPT-FR (r=-0.777, P<0.001), and E/E} ratio (r=0.666, P<0.001) showed the most significant correlations.

Table 5. Correlations between METs and duration of exercise of patients with dilated cardiomyopathy and Echo parameters.

	METS	
	r_s	P value
LV		
MODIFIED SIMPSON EF (%)	0.874	<0.001*
E/E` RATIO	-0.69	<0.001*
LV GLOBAL STRAIN	-0.832	<0.001*
LA		
EXPANSION INDEX (%)	0.824	<0.001*
ACTIVE EMPT-FR (%)	0.771	<0.001*
PASSIVE EMPT-FR (%)	0.64	<0.001*
LA CONDUIT STRAIN (%)	-0.731	<0.001*
LA CONTRACTILE STRAIN (%)	-0.688	<0.001*
LA RESERVOIR STRAIN (%)	0.828	<0.001*
	Duration of exercise (min)	
MODIFIED SIMPSON EF (%)	0.41	0.003*
E/E` RATIO	-0.432	0.002*
LV GLOBAL STRAIN	-0.393	0.005*
LA		
EXPANSION INDEX (%)	0.276	0.052
ACTIVE EMPT-FR (%)	0.389	0.005*
PASSIVE EMPT-FR (%)	0.063	0.665
LA CONDUIT STRAIN (%)	-0.389	0.005*
LA CONTRACTILE STRAIN (%)	-0.271	0.057
LA RESERVOIR STRAIN (%)	0.376	0.007*

Significant correlations were discovered between echocardiographic measures and the METS attained during exercise. The Modified Simpson EF (r=0.874, P<0.001), LV Global strain (r=-0.832, P<0.001), LA reservoir strain (r=0.828, P<0.001), expansion index (r=0.824, P<0.001), and active EMPT-FR (r=0.771, P<0.001) showed the most notable relationships. There were clear and significant relationships between the length of exercise and certain echocardiographic parameters. The length of exercise was positively correlated with LA reservoir strain (r=0.376, P=0.007), active EMPT-FR (r=0.389, P=0.005), and Modified Simpson EF (r=0.41, P=0.003). The length of exercise, on the other hand, was found to significantly negatively correlate with the E/E} ratio (r=-0.432, P=0.002), LV Global Strain (r=-0.393, P=0.005), and LA Conduit Strain (r=-0.389, P=0.005).

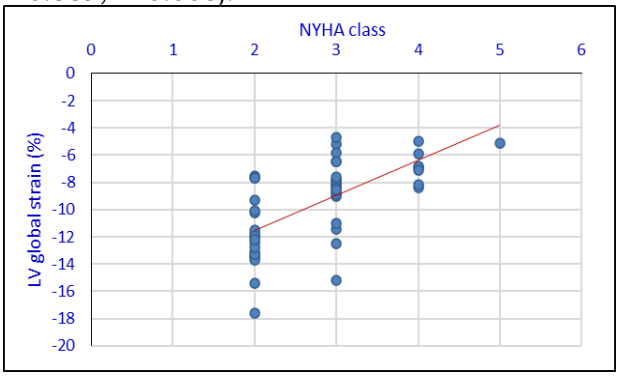

Figure 1. Scatter plot demonstrating the correlation between NYHA classification and LV global strain.

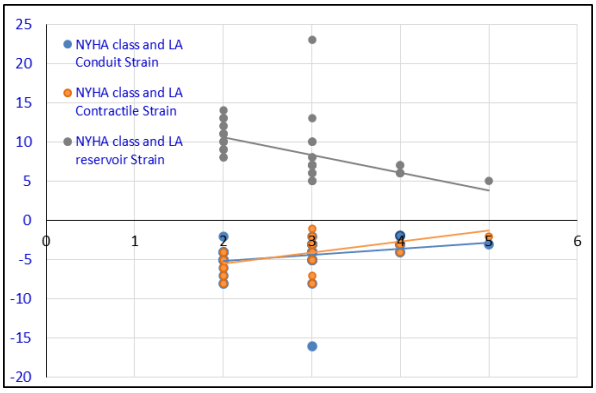

Figure 2. Scatter plot demonstrating the correlation between NYHA classificationand LA conduit, contractile and reservoir strains.

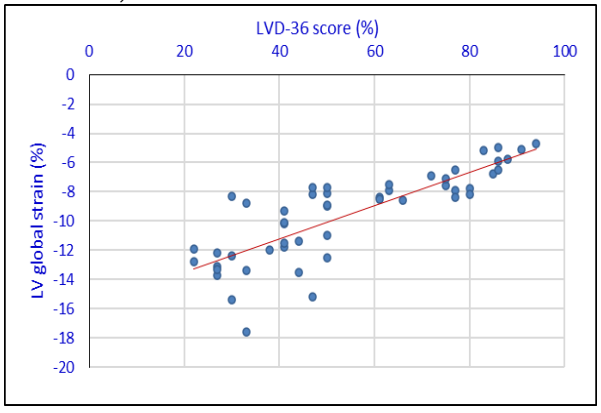

Figure (3): Correlation between LVD-36 score and LV global strain.

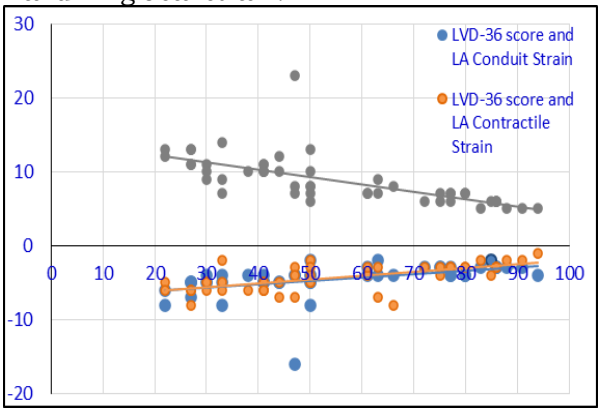

Figure 4. Scatter plot demonstrating the correlation between LVD-36 score and LA conduit, contractile and reservoir strains.

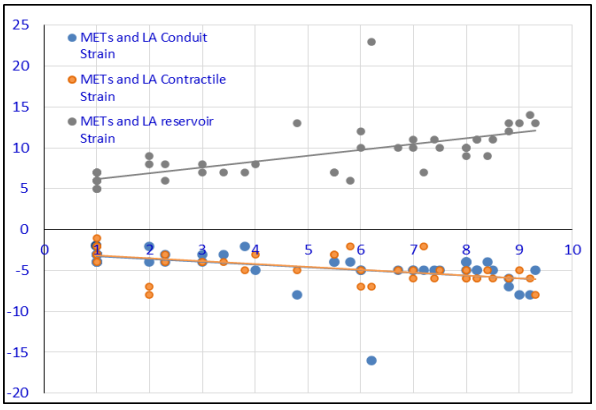

Figure 5. Scatter plot demonstrating the correlation between METs and LA conduit, contractile and reservoir strains.

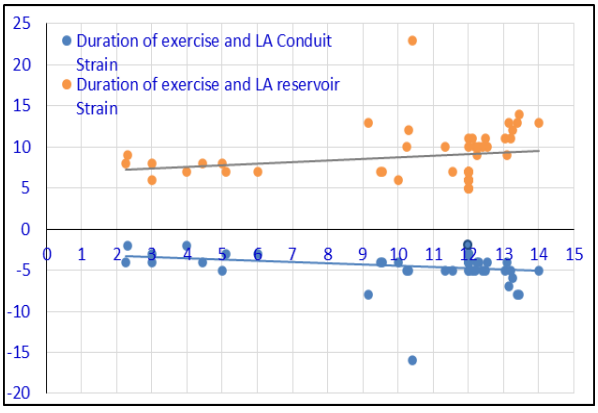

Figure 6. Scatter plot demonstrating the correlation between duration of exercise and LA conduit and reservoir strains

4. Discussion

2D speckle tracking is a well-established characteristic of 2D echocardiography, which evaluates left atrial (LA) function and forecasts the likelihood of pulmonary congestion symptoms in patients with dilated cardiomyopathy. [5]

Following the evaluation of all patients' heart failure (HF) symptoms, the NYHA classification placed 40% of them in class II, 44% in class III, and 16% in class IV (with 14% falling into subcategory IVa and 2% into subcategory IVb).

Each patient in the study had their LVD-36 scores evaluated; the study population's median score was 50%, and the values varied from 22% to 94%. In addition, all patients underwent a modified Bruce protocol treadmill exercise test, with a median exercise duration of 12 minutes. Every patient experienced dyspnea, leading to the cessation of the exercise. The activity resulted in a median of 5.15 metabolic equivalents (METS).

It was also important to look at how well the left atrium worked using different echocardiography techniques, like Doppler, volumetric, and speckle approaches, during a full evaluation by 2D thoracic echocardiography (2D TTE). The left ventricle was also evaluated. Using 2D-modified Simpson techniques, the average ejection fraction (EF) results were 26.5%.

Our research showed that there were different levels of strong links between the NYHA classification of patients with dilated cardiomyopathy and echocardiographic parameters that show how the left ventricle and left atrium work. There were strong links between the LA reservoir strain (r = -0.727, P<0.001), the LA expansion index (r = -0.708, P<0.001), the active LA-EMPT-FR (r = -0.678, P<0.001), and the modified Simpson EF (r = -0.633, P<0.001).

When it comes to the LVD-36 score, we found that there were notable correlations between the scores of individuals with dilated cardiomyopathy and echocardiographic characteristics that represent the roles of the left ventricle (LV) and left atrium (LA). The variables that were most strongly linked were LV Global Strain (r = 0.852, P<0.001), Modified Simpson EF (r = -0.844, P<0.001), LA Reservoir Strain (r = -0.836, P<0.001), expansion index (r = -0.821, P<0.001), M-Mode EF (r = -0.82, P<0.001), LA Conduit Strain (r = 0.737, P<0.001), active EMPT-FR (r = -0.777, P<0.001), and E/E} ratio (r = 0.666, P<0.001).

Furthermore, we identified significant correlations between METS achieved during exercise and echocardiographic parameters. It was clear that the modified Simpson EF (r = 0.874, P<0.001), LV Global strain (r = -0.832, P<0.001), LA reservoir strain (r = 0.828, P<0.001), expansion index (r = 0.824, P<0.001), and active EMPT-FR (r = 0.771, P<0.001) had the strongest relationships.

Moreover, we discovered strong associations between the amount of exercise and echocardiographic characteristics. We found a positive correlation between the length of exercise and the LA reservoir strain (r = 0.376, P = 0.007), active EMPT-FR (r = 0.389, P = 0.005), and modified Simpson EF (r = 0.41, P = 0.003). In contrast, a notable inverse relationship was discovered between the quantity of exercise and the E/E ratio (r = -0.432, P = 0.002), the LV Global Strain (r = -0.393, P = 0.005), and the LA Conduit Strain (r = -0.389, P = 0.005).

Daniel Modin conducted a prior study in 2019 using ultrasonography on 818 individuals suffering from heart failure with decreased ejection fraction (HFrEF), all of whom had left cardiac ejection fractions below 45%. Our findings align with this study. To calculate left atrial volumes, they employed the area-length method. They carried out a number of computations, including LAVI (left atrial volume indexed to body surface area), MinLAVI (minimum indexed left atrial volume), and LAEF (left atrial emptying fraction). [11]

The primary outcome of the study was to evaluate all-cause mortality. 121 patients (14.8%) passed away during the 3.3-year median follow-up period (interquartile range: 1.8–4.6 years), and 100% of the participants had their follow-up completed. We discovered that LAEF and MinLAVI were both important indicators of all-cause death in HFrEF patients.

However, after accounting for these factors, LAEF became the most reliable predictor of patient outcomes in patients with HFrEF.

Additionally, our study aligns with the findings of Vincenzo Nuzzi's February 2023 study. Of the 560 patients included in the study, 54 years of age was the average age, the left ventricular ejection fraction was 31% (±10%), and the left atrial volume index (LAVI) was 45 mL/m2 (±18). There was a nonlinear (P<.01) link between the baseline left ventricular ejection fraction (LAVI) and the chance of dying or being hospitalized, regardless of age, mitral regurgitation, LAVI, or medical treatment. [12]

LAVI decreased by 67% in a follow-up of 374 patients over a 1-year period, with a median change of -24% (interquartile range: -37% to -11%). Both higher baseline LAVI and lower baseline left ventricular ejection fraction independently correlated with LAVI reduction. LAVI showed a linear association with the probability of death, heart transplantation, or hospitalization for heart failure after adjusting for a number of clinical and echocardiographic factors (hazard ratio, 0.96 per 5% reduction; 95% confidence interval, 0.93-0.99; P =.042).

Upon considering clinical and echocardiographic variables, a significant proportion of patients in a large cohort with dilated cardiomyopathy demonstrated a 1-year decrease in LAVI. Researchers have linked reduced LAVI to an increased risk of death or hospitalization, suggesting that LA structural reverse remodeling could serve as an additional marker to help DCM patients identify their unique risk factors.

5. *Conclusion*

The estimation of left atrial indexes and function, particularly the reservoir strain function, is crucial for patients with dilated cardiomyopathy (DCM). Our results corroborate our hypothesis, which states that the assessment of left atrial function, particularly the reservoir strain function, can be done effectively and reliably using 2D recommended echocardiographic parameters and the 2D speckle tracking technique.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

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Conflicts of interest

There are no conflicts of interest.

References

1. Ciarambino T, Menna G, Sansone G, Giordano M. Cardiomyopathies: An Overview. Int J Mol Sci. 2021;22(14):7722.
2. Rossi A, Gheorghiade M, Triposkiadis F, Solomon SD, Pieske B, Butler J. Left atrium in heart failure with preserved ejection fraction: structure, function, and significance. Circ Heart Fail. 2014;7(6):1042-1049.
3. Hoit BD. Left atrial size and function: role in prognosis. J Am Coll Cardiol. 2014;63(6):493-505.
5. Nagueh SF. Left Ventricular Diastolic Function: Understanding Pathophysiology, Diagnosis, and Prognosis With Echocardiography. JACC Cardiovasc Imaging. 2020;13(1 Pt 2):228-244.
6. Goudarzi E, Yousefimoghaddam F, Ramandi A, Khaheshi I. 2D speckle-tracking echocardiography as a prognostic imaging modality for COVID-19 adverse outcomes. Future Cardiol. 2022;18(12):949-956.
7. Ble M, Benito B, Cuadrado-Godia E, et al. Left Atrium Assessment by Speckle Tracking Echocardiography in Cryptogenic Stroke: Seeking Silent Atrial Fibrillation. J Clin Med. 2021;10(16):3501.
8. Badano LP, Kolias TJ, Muraru D, et al. Standardization of left atrial, right ventricular, and right atrial deformation imaging using two-dimensional speckle tracking echocardiography: a consensus document of the EACVI/ASE/Industry Task Force to standardize deformation imaging [published correction appears in Eur Heart J Cardiovasc Imaging. Eur Heart J Cardiovasc Imaging. 2018;19(6):591-600.
9. O'Leary CJ, Jones PW. The left ventricular dysfunction questionnaire (LVD-36): reliability, validity, and responsiveness. Heart. 2000;83(6):634-640.
10. Peacock, JP. Peacock, Oxford handbook of medical statistics. Oxford university press. 2011; (xi)1-499.
11. Modin D, Sengeløv M, Jørgensen PG, et al. Prognostic Value of Left Atrial Functional Measures in Heart Failure With Reduced Ejection Fraction. J Card Fail. 2019;25(2):87-96.
12. Nuzzi V, Raafs A, Manca P, et al. Left Atrial Reverse Remodeling in Dilated Cardiomyopathy. J Am Soc Echocardiogr. 2023;36(2):154-162.