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Original article

Comparing Left Atrial Strain in Sinus versus Atrial Fibrillation Patients

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Abstract

Background: Assessment of left atrial (LA) function and its variability among patients with sinus rhythm and atrial fibrillation (AF) has been the subject of research recently. **Aim:** This research investigated whether LA function parameters by means of tissue Doppler imaging (TDI) were comparable in atrial fibrillation patients and patients with normal sinus rhythm. **Subjects and methods:** This observational study was done in Benha University Hospital, from March 2022 to January 2023, included 200 patients to study difference in LA parameters between the patients with sinus rhythm and AF patients. All subjects underwent history taking, clinical examination, Electrocardiogram and Echocardiography with TDI values. **Results:** We included (I)100 patients with sinus rhythm and (II)100 atrial fibrillation patients in the study (mean age 57.7 ±13.6 years, mean body mass index 25.21 ±4.12 kg/m^2, 44% males). Patients of group II had significantly higher LA volumes and LA Volume index (P values=.0001 each), patients of group I had higher LA emptying fraction (LAEF) (P value =.006). LA ∑ Strain and Strain rate were lower among patients of group II (P value=.0001 each). LAEF was positively correlated with LA ∑ strain rate (r =0.226) (P value .001). LA volume index was negatively correlated with LA ∑ strain and strain rate (r =-0.35, -0.207), (P values .0001, .003) respectively.**Conclusion:** LA function parameters were significantly lower among patients with AF. LAEF was positively correlated with LA ∑ strain rate. LA volume index was negatively correlated with LA ∑ strain and strain rate.

Keywords: left atrium, strain, atrial fibrillation, tissue Doppler imaging.

Introduction

Left atrial function has been the topic of research for many years [(1)]. The left atrium has five main functions. First, the left atrium serves as a blood-receiving reservoir chamber. Second, it is a contractile chamber that by presystolic kick helps complete left ventricular filling. Third, the left atrium works as a conduit that empties its contents into the left ventricle down the pressure gradient after the mitral valve opens. Fourth, it is a sensor of blood volume in the heart and releases atrial natriuretic peptide (ANP) in response to stretch so that ANP- induced diuresis can help keep blood volume normal. Fifth, the left atrium contains receptors for the afferent nerves of various reflexes [2,3].

Studies suggest that tissue Doppler-derived parameters of LA function may provide clinically helpful data. tissue Doppler has allowed the study of LA strain and strain rate [2,4].

Tissue Doppler echocardiography–derived analysis of LA performance (namely LA strain) provides a window on all phases of LA function (reservoir, conduit, and booster pump) and has shown prognostic significance in different pathological conditions, and the results obtained with this method are not directly comparable to those obtained by volumetric approaches [5].

If LA strain is to become accepted for evaluation of LA performance, then a standardized methodology, common reference values, and the impact of different diseases on LA function need to be precisely described [6].

The clinical value of end-systolic LA volume assessed in 2- and 4-chamber view (normally ≤34 mL/m2) has been highlighted as a key prognostic marker [7, 8]. and is a component of the parameters for the evaluation of LV diastolic function in current guidelines [9].

The parameters described before [10] have been studied in the research context by many but are not widely used in the clinical setting. Those reearchers [10] are to be congratulated for their effort to demonstrate the robustness and the feasibility of LA strain indices in many subjects.

Their results are consistent with a recent Task Force from the American Society of Echocardiography that collaborated on standardization for measuring LA strain. The role of LA strain has also been underscored in a recent European Association of Cardio-Vascular Imaging recommendation paper on the exploitation of imaging in atrial fibrillation [11].

This endorsement is supported by the growing number of studies, which have looked at LA strain for the evaluation of LA remodeling, thromboembolic risk, and prognosis and management in patients with atrial fibrillation. Nevertheless, these studies are often hindered by the small sample size and by several technical and methodological drawbacks [11,12].

There are several important limitations regarding left atrial strain– derived assessment of left atrial function that should be highlighted:

- left atrial strain is load dependent and influenced by LV function. These limits have been highlighted, and it has been proposed that instead of focusing on the reservoir function, researchers should look more carefully at the booster pump function. This approach has not been widely accepted but worthy of consideration in upcoming studies [14].
- The value of left atrial strain in the field of supraventricular arrhythmias. Left atrial strain is a predictor of atrial fibrillation incidence and recurrence, and its value seems to be in collaboration with thromboembolic risk.

  Larger randomized trials are needed to confirm the association with thromboembolic risk and to assess whether LA strain can be used to risk-stratify population [15,16].

- The potential value of LA strain in the evaluation of LV diastolic function and filling pressures [17]. The reduction in LV filling pressures decreases but scarcely normalizes LA volumes. There seems to be a strong relation between reduction in LV filling pressure and improvement in LA function as indicated by the improvement in LA strain, and this may be of use not only clinically, but also from a research perspective.

Patients and methods

This observational study was done in Benha University Hospital in the period from March 2022 to January 2023, and included 200 patients divided into group I of patients with normal sinus rhythm and group II of AF patients.

The Ethics Committee of Benha Faculty of Medicine approved the study protocol {MS. 37.1.2022}. All individuals gave their consent to participate in this research.

Inclusion criteria:

- Consecutive adult male and female patients**.**
- Patients with Ejection Fraction (EF) more than 50%.

Exclusion criteria

- Patients with documented ischemic heart disease.
- Patients with prior PCI or CABG.
- Patients with rheumatic heart disease.
- Patients with significant (more than moderate) degenerative valvular heart disease.

The following data were collected:

A. Patients Characteristics: age, Sex and Body mass index {BMI= Weight (Kg) / (Height in meters) 2} and risk factors including HTN, DM, dyslipidemia, drugs used and smoking.

B. Investigations including ECG: for rhythm, whether sinus or AF, presence of ischemic changes and chamber enlargement signs and laboratory investigations including complete blood count, blood sugar, serum creatinine, urea, lipid profile (cholesterol, triglycerides, LDL & HDL).

C. Conventional transthoracic 2D Echocardiography:

Patients were examined in the left lateral decubitus with a commercially available ultrasound system (Philips, Epic 7, equipped with a 5.5 X transducer).

- Left ventricular ejection fraction (LVEF), that was measured using M-Mode in left para sternal long axis view [18].
- Pulsed wave Doppler across the mitral valve in the apical 4-chamber was used to assess peak (E), and late (A) velocities. The E/e' ratio was then calculated [19].
- Volumetric Measurements of LA:
- LA maximal volume (Vmax) at end-systole, just before the mitral valve opening; LA minimal volume (Vmin) at end-diastole, after mitral valve closure [20].
- LA emptying fraction was calculated according to the following formula = {(LA maximum volume – LA minimum volume) / LA maximum volume × 100%}
- The LA size was represented by LA volume index {indexed by body surface area} by the following formula = (0.85 x A1 x A2) / (L1–L2 / 2) [21].
- Where:
- A1 = planimetered LA area in apical 4-chamber view

- A2 = Max. planimetered LA area in apical 2-chamber view
- L1 = the LA long-axis length determined in apical 4-chamber view
- L2 = the LA long-axis length determined in apical 2-chamber view
- Measurements were repeated 3 times in each individual, and the average was used for analysis.
- We defined LA enlargement as a LA volume index of ≥ 32 mL/m^2 (22).
- The accuracy of this echocardiographic technique has been validated previously against the computed tomography and magnetic resonance imaging methods (23).

D. Tissue Doppler imaging:

- Tissue Doppler imaging (frame rate range: 75-150/s) was obtained in apical 4- and 2-chamber views mid and basal during end-expiration. The Doppler tissue signal angle was less than 20 degrees. Digitally stored loops of Doppler tissue imaging were used for offline derivation of tissue tracking images and strain rate recordings (24).
- Strain was defined as a dimensionless quantity produced by the application of stress, and it represents the fractional or percentage change from the original unstressed dimension. Strain rate is equal with the temporal derivative of strain, and the total strain can, therefore, be determined by combining the strain rate values for a given time interval (25).
- The strain rate is calculated as the difference between myocardial velocities from 2 points divided by the distance separating the points (26,27).
- **Statistical analysis:**
- Statistical analysis was conducted using statistical pack of social studies (SPSS) 25th edition, quantitative variables were presented in mean and standard deviation, it was compared between study groups using Mann Whitney U test. Categorical variables were presented in frequency and percentages and compared using the Chi^2 test. The receiver curve of characteristic curve was constructed to visualize the area under the curve for predicted outcomes. All P values were two sided. P values less than .05 were considered significant (28).

Results

- The mean age was 57.7 ±13.6 years and mean BMI 25.21 ±4.12 kg/m^2. 88 patients (44%) were males. Dyslipidemia was the most common comorbidity reported in the current study accounting for 114 patients (57%), followed by Diabetes reported in 96 patients (48%). 39 patients (19.5%) were smokers while 81 patients (40.5%) were hypertensive, 43 patients (21.5%) had positive family history for cardiac diseases **(table 1)**.
- Among the included patients, ejection fraction showed a mean of 60.8%, mean LVEDD 4.6 cm, mean LVESD 2.7 cm, while mean LA Vmax was 76.6 mL, LA Vmin was 44.8 mL, LA volume index is 30.1 mL/m^2, and mean LA emptying fraction is 30.0 **(table 2)**.
- Patients of group II had significantly lower EF than those of group I (P value=.0001) and had significantly higher LA Vmax, LA Vmin and LA Volume index (P values=.0001 each), on the other hand patients of group I had higher LA emptying fraction (P value =.006) **(table 3).**

- LA ∑ Strain and LA ∑ Strain rate were significantly lower among patients of group II than patients of group I (P value 0.0001 each) **(table 4)**
- Correlation matrix showed that LA emptying fraction was positively correlated with LA ∑ strain rate with (r = 0.226) and (P value 0.001). While LA volume index was negatively correlated with LA ∑ strain and ∑ strain rate with (r = -0.35 and -0.207), (P values 0.0001 and 0.003) respectively **(table 5).**

Table 1: comparison of demographics and clinical characteristics between study groups.

		Group I (Sinus rhythm) Mean ± SD / Count	*Range / %*	*Group II (AF)* Mean± SD / Count	*Range / %*	*P value*
Age	***Years***	***57.2 ±12.7***	***26 -94***	***58.1 ±14.5***	***26 -94***	***0.867***
BMI	*Kg/m²*	*25.24 ±4.04*	*17.2 -34.5*	*25.19 ±4.22*	*16.5 -35.7*	*0.866*
Sex	*Male*	*46*	*46%*	*42*	*42%*	*0.569*
	Female	*54*	*54%*	*58*	*58%*	
Diabetes	*Yes*	*49*	*49%*	*47*	*47%*	*0.777*
Smoking	*Yes*	*18*	*18%*	*21*	*21%*	*0.801*
Dyslipidemia	*Yes*	*56*	*56%*	*58*	*58%*	*0.775*
Hypertension	*Yes*	*40*	*40%*	*41*	*41%*	*0.823*
Family History	*Positive*	*22*	*22%*	*21*	*21%*	*0.863*

Table 2: 2D Echocardiography findings among the included patients (n=200).

	Mean	**SD**	**Min**	**Max**
Ejection fraction (%)	60.8	3.8	55.2	73.4
LVEDD (cm)	4.6	0.4	4.0	5.5
LVESD (cm)	2.7	0.3	2.0	3.5
LVPWDD (cm)	1.1	0.1	0.7	1.4
IVSDD (cm)	1.1	0.1	0.7	1.4
LA Vmax (mL)	76.6	8.6	61.1	92
LA Vmin (mL)	44.8	6.4	33.1	57.8
LA Volume index (mL/m²)	30.1	5.4	20	42.8
LA emptying fraction	30.0	5.4	16.8	42.8

Table 3: comparison of 2D echocardiography findings between study groups.

	Group I (Sinus rhythm)				Group II (AF)				P value
	Mean	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	
Ejection fraction (%)	62.9	3.8	56.7	73.4	58.7	2.4	55.2	69.5	.0001
LVEDD (cm)	4.5	0.3	4.0	5.0	4.8	0.4	4.2	5.5	.0001
LVESD (cm)	2.5	0.3	2.0	3.0	2.8	0.4	2.2	3.5	.0001
LVPWDD (cm)	1.0	0.1	0.8	1.3	0.9	0.1	0.7	1.2	0.0016
IVSDD (cm)	1.0	0.1	0.8	1.3	0.9	0.1	0.7	1.2	0.0015
LA Vmax (mL)	73.3	8.2	61.1	87.2	80	7.5	67	92	.0001
LA Vmin (mL)	41.5	4.9	33.1	50	48.2	6	38.1	57.8	.0001
LA Volume index (mL/m^2)	27.4	4.6	20	38	32.8	4.7	20	42.8	.0001
LA emptying fraction	43.2	9.2	22.6	69.9	39.1	10.0	17.4	57.6	.006

Table 4: comparison of LA strain by TDI between study groups.

	Group I (Sinus rhythm)				Group II (AF)				P value
	Mean	SD	Min	Max	Mean	SD	Min	Max	
TDI LA ∑ Strain (%)	24.3	3.4	18.6	30	19.7	2.7	15.7	25.1	.0001
TDI LA ∑ Strain rate (sec^{-1})	1.9	0.3	1.4	2.3	1.7	0.3	1.3	2.1	.0001

Table 5: correlation matrix between 2D echo parameters and LA strain and strain rate.

		LA ∑ Strain	***LA ∑ Strain rate***
LA emptying fraction	r	.082	.226**
	P value	.246	.001
LA Volume index	r	-.353**	-.207**
	P value	.0001	.003

Discussion

Two dimension (2D) echocardiography remains to be the most used imaging modality for evaluation of LA parameters and its primary variables [29]. Tissue Doppler imaging (TDI) is a useful echocardiographic technique; which is readily available on most commercially echocardiographic systems; to evaluate global and regional myocardial systolic as well as diastolic function [30].

The aim of our study was to assess left atrial strain in patients with sinus rhythm and atrial fibrillation using tissue Doppler imaging. Patients in this study were divided into two groups:

- Group (I): 100 patients with normal sinus rhythm.
- Group (II): 100 patients with atrial fibrillation (Table 1).

In our study patients of group II, have significantly lower LVEF than those of group I, and have significantly higher LVEDD, LVESD (P values .0001 each), which was consistent with a similar study in 2019 [31]. Additionally, a group of scientists later the same year [32] reported that patients with AF had significant higher LVESD than patients without AF (Table 2).

Moreover, another trial [33] which studied difference in LVEF, LVEDD, and LVESD between patients with AF and patients who restored sinus rhythm successfully came to a same conclusion (table 2,3).

In the current study, patients of group II have significantly higher LA Vmax, LA Vmin and LA Volume index (P values .0001 each), which was similar to the results concluded by a group of scientists in 2018 [34] with similar demographic characters. This was also similar to a single-center study in 2020 [35] which reported a significant reduction in LA Volume index in patients who successfully restored sinus rhythm after ablation, and another larger trial in 2020 [36] which reported that LA dilatation is a strong, independent predictor of worse outcome (table 2,3).

It was reported by two independent groups of researchers [37, 38] that patients with AF had lower LA emptying fraction than patients without AF with P value .013, .0051 respectively, which was similar to what we found in our study with P value .006 (table 2, 3).

To our knowledge, there is no study that has reported a correlation between LA emptying fraction and LA volume index with LA ∑ strain and ∑ strain rate.

Conclusion

LA parameters including strain and strain rate, assessed by TDI, were significantly lower among patients with AF than patients with sinus rhythm. LA emptying fraction was positively correlated with LA ∑ strain rate. LA volume index was negatively correlated with LA ∑ strain and strain rate.

Notably, it was concluded in 2020[39] that patient who developed AF had significantly larger LA volumes and lower LAEF than participants free of AF which was like what we found in our study. Also, a similar trial [40] found similar result as patients with AF had lower LAEF compared with patients without AF (table 2, 3).

In the current study, LA ∑ Strain and LA ∑ Strain rate were significantly lower among patients of group II than patients of group I (P value 0.0001 each), this was similar to the results clarified in 2015 by a group of Japanese researchers [41] who found that patients with AF had significantly lower LA ∑ Strain and LA ∑ Strain rate than patients without AF (table 4).

Notably, it was attributed in 2016[5] that patient with AF had significantly lower LA ∑ Strain than people with sinus rhythm, this was concordant to our study where LA ∑ Strain rate was significantly lower among patients of group II than patients of group I (P value .0001). Also, it was recorded in 2017 [42] that LA ∑ Strain was lower among patients with persistent AF than patients with paroxysmal AF.

References

1. **Stefanadis, C., Dernellis, J., & Toutouzas, P.** A clinical appraisal of left atrial function. European heart journal 2001, 22(1), 22-36.
2. **Hoit, B. D.** Left atrial size and function: role in prognosis. Journal of the American College of Cardiology 2014, 63(6), 493-505.
3. **Yang, K. C., Ma, X., Liu, H., Murphy, J., Barger, P. M., Mann, D. L., et al**. Tumor necrosis factor receptor–associated factor 2 mediates mitochondrial autophagy. Circulation: Heart Failure 2015, 8(1), 175-187.

4. **Galli, E., Fournet, M., Chabanne, C., Lelong, B., Leguerrier, A., Flecher, E.,et al**. Prognostic value of left atrial reservoir function in patients with severe aortic stenosis: a 2D speckle-tracking echocardiographic study. European Heart Journal-Cardiovascular Imaging 2016, 17(5), 533-541.
5. **Sarvari, S. I., Haugaa, K. H., Stokke, T. M., Ansari, H. Z., Leren, I. S., Hegbom, F., et al.** Strain echocardiographic assessment of left atrial function predicts recurrence of atrial fibrillation. European Heart Journal–Cardiovascular Imaging 2016, 17(6), 660-667.
6. **Santos, A. B., Roca, G. Q., Claggett, B., Sweitzer, N. K., Shah, S. J., Anand, I. S., et al.** Prognostic relevance of left atrial dysfunction in heart failure with preserved ejection fraction. Circulation: Heart Failure 2016, 9(4), e002763.
7. **Pathan, F., D'Elia, N., Nolan, M. T., Marwick, T. H., & Negishi, K.** Normal ranges of left atrial strain by speckle-tracking echocardiography: a systematic review and meta-analysis. Journal of the American Society of Echocardiography2017, 30(1), 59-70.
8. **McMurray, J. J., Adamopoulos, S., Anker, S. D., Auricchio, A., Böhm, M., ... & Ponikowski, P.** ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure 2012: The Task Force for the Diagnosis and Treatment of Acute and Chronic Heart Failure 2012 of the European Society of Cardiology. Developed in collaboration with the Heart Failure Association (HFA) of the ESC. European heart journal 2012, 33(14), 1787-1847..
9. **Nagueh, S. F., Smiseth, O. A., Appleton, C. P., Byrd, B. F., Dokainish, H., Edvardsen, T., et al.** Recommendations for the evaluation of left ventricular diastolic function by echocardiography: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. European Journal of Echocardiography2016, 17(12), 1321-1360.
10. **Liao, J. N., Chao, T. F., Kuo, J. Y., Sung, K. T., Tsai, J. P., Lo, C. I., et al .** Age, sex, and blood pressure-related influences on reference values of left atrial deformation and mechanics from a large-scale Asian population. Circulation: Cardiovascular Imaging2017, 10(10), e006077.
11. **Donal, E., Lip, G. Y., Galderisi, M., Goette, A., Shah, D., Marwan, M., et al.** EACVI/EHRA Expert Consensus Document on the role of multi-modality imaging for the evaluation of patients with atrial fibrillation. European Heart Journal–Cardiovascular Imaging2016, 17(4), 355-383.
12. **Feneon, D., Behaghel, A., Bernard, A., Fournet, M., Mabo, P., Daubert, J. C., et al.** Left atrial function, a new predictor of response to cardiac resynchronization therapy?. Heart Rhythm2015, 12(8), 1800-1806.
13. **Negishi, K., Negishi, T., Zardkoohi, O., Ching, E. A., Basu, N., Wilkoff, B. L., et al.**. Left atrial booster pump function is an independent predictor of subsequent life-threatening ventricular arrhythmias in non-ischaemic cardiomyopathy. European Heart Journal-Cardiovascular Imaging2016, 17(10), 1153-1160.
14. **Huynh, Q. L., Kalam, K., Iannaccone, A., Negishi, K., Thomas, L., & Marwick, T. H**. Functional and anatomic responses of the left atrium to change in estimated left ventricular filling pressure. Journal of the American Society of Echocardiography2015, 28(12), 1428-1433.
15. **Motoki, H., Negishi, K., Kusunose, K., Popović, Z. B., Bhargava, M., Wazni, O. M.,et al.** Global left atrial strain in the prediction of sinus rhythm maintenance after catheter ablation for atrial fibrillation. Journal of the American Society of Echocardiography2014, 27(11), 1184-1192.
16. **Singh, A., Addetia, K., Maffessanti, F., Mor-Avi, V., & Lang, R. M.** LA strain for categorization of LV diastolic dysfunction. JACC: Cardiovascular Imaging2017, 10(7), 735-743.
17. **Kosmala, W., Saito, M., Kaye, G., Negishi, K., Linker, N., Gammage, M., et al.** Incremental value of left atrial structural and functional characteristics for prediction of atrial fibrillation in patients receiving cardiac pacing. Circulation: Cardiovascular Imaging2015, 8(4), e002942.

18. **Lang, R. M., Badano, L. P., Mor-Avi, V., Afilalo, J., Armstrong, A., Ernande, L.,et al.** Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. European Heart Journal-Cardiovascular Imaging 2015, 16(3), 233-271.
19. **Paulus, W. J., Tschöpe, C., Sanderson, J. E., Rusconi, C., Flachskampf, F. A., Rademakers, F. E., et al.** How to diagnose diastolic heart failure: a consensus statement on the diagnosis of heart failure with normal left ventricular ejection fraction by the Heart Failure and Echocardiography Associations of the European Society of Cardiology. European heart journal2007, 28(20), 2539-2550.
20. **Ujino, K., Barnes, M. E., Cha, S. S., Langins, A. P., Bailey, K. R., Seward, J. B., et al.** Two-dimensional echocardiographic methods for assessment of left atrial volume. The American journal of cardiology2006, 98(9), 1185-1188.
21. **Jiamsripong, P., Honda, T., Reuss, C. S., Hurst, R. T., Chaliki, H. P., Grill, D. E., et al.** Three methods for evaluation of left atrial volume. European Journal of Echocardiography2008, 9(3), 351-355.
22. **Iliadis, C., Kalbacher, D., Lurz, P., Petrescu, A. M., Orban, M., Puscas, T., et al.** Left atrial volume index and outcome after transcatheter edge-to-edge valve repair for secondary mitral regurgitation. European Journal of Heart Failure2022, 24(7), 1282-1292.
23. **Boyd, A. C., & Thomas, L**. Left atrial volumes: two-dimensional, three-dimensional, cardiac magnetic resonance and computed tomography measurements. Current Opinion in Cardiology2014, 29(5), 408-416.
24. **Pan, C., Hoffmann, R., Kühl, H., Severin, E., Franke, A., & Hanrath, P.** Tissue tracking allows rapid and accurate visual evaluation of left ventricular function. European Journal of Echocardiography2001, 2(3), 197-202.
25. **Urheim, S., Edvardsen, T., Torp, H., Angelsen, B., & Smiseth, O. A.** Myocardial strain by Doppler echocardiography: validation of a new method to quantify regional myocardial function. Circulation2000, 102(10), 1158-1164.
26. **Armstrong, G., Pasquet, A., Fukamachi, K., Cardon, L., Olstad, B., & Marwick, T.** Use of peak systolic strain as an index of regional left ventricular function: comparison with tissue Doppler velocity during dobutamine stress and myocardial ischemia. Journal of the American Society of Echocardiography2000, 13(8), 731-737.
27. **Waggoner, A. D., & Bierig, S. M.** Tissue Doppler imaging: a useful echocardiographic method for the cardiac sonographer to assess systolic and diastolic ventricular function. Journal of the American Society of Echocardiography2001, 14(12), 1143-1152.
28. **De Tisi, J., Bell, G. S., Peacock, J. L., McEvoy, A. W., Harkness, W. F., Sander, J. W., et al.** The long-term outcome of adult epilepsy surgery, patterns of seizure remission, and relapse: a cohort study. The Lancet2011, 378(9800), 1388-1395.
29. **Yildiz, M., Oktay, A. A., Stewart, M. H., Milani, R. V., Ventura, H. O., & Lavie, C. J.** Left ventricular hypertrophy and hypertension. Progress in cardiovascular diseases2020, 63(1), 10-21.
30. **Sanfilippo, F., Huang, S., Messina, A., Franchi, F., Oliveri, F., Vieillard-Baron, A., et al.** Systolic dysfunction as evaluated by tissue Doppler imaging echocardiography and mortality in septic patients: a systematic review and meta-analysis. Journal of Critical Care2021, 62, 256-264.
31. **Slee, A., Saad, M., & Saksena, S.** Heart failure progression and mortality in atrial fibrillation patients with preserved or reduced left ventricular ejection fraction. Journal of Interventional Cardiac Electrophysiology2019, 55, 325-331.
32. **Petre, I., Onciul, S., Iancovici, S., Zamfir, D., Stoian, M., Scărlătescu, A., et al.** Left atrial strain for predicting atrial fibrillation onset in hypertensive patients. High Blood Pressure & Cardiovascular Prevention2019, 26, 331-337.
33. **Prabhu, S., Costello, B. T., Taylor, A. J., Gutman, S. J., Voskoboinik, A., McLellan, A. J., et al.** Regression of diffuse ventricular fibrosis following restoration of sinus rhythm with catheter ablation in patients with atrial

fibrillation and systolic dysfunction: a substudy of the CAMERA MRI trial. JACC: Clinical Electrophysiology2018, 4(8), 999-1007.

34. **Kang, M. K., Joung, B., Shim, C. Y., Cho, I. J., Yang, W. I., Moon, J., et al.** Post-operative left atrial volume index is a predictor of the occurrence of permanent atrial fibrillation after mitral valve surgery in patients who undergo mitral valve surgery. Cardiovascular Ultrasound2018, 16, 1-7.
35. **Kagawa, Y., Fujii, E., Fujita, S., & Ito, M.** Association between left atrial reverse remodeling and maintenance of sinus rhythm after catheter ablation of persistent atrial fibrillation. Heart and Vessels2020, 35, 239-245.
36. **Mancusi, C., Canciello, G., Izzo, R., Damiano, S., Grimaldi, M. G., de Luca, N., et al.** Left atrial dilatation: A target organ damage in young to middle-age hypertensive patients. The Campania Salute Network. International Journal of Cardiology 2018, 265, 229-233.
37. **Bufano, G., Radico, F., D'angelo, C., Pierfelice, F., De Angelis, M. V., Faustino, M., et al.** Predictive value of left atrial and ventricular strain for the detection of atrial fibrillation in patients with cryptogenic stroke. Frontiers in Cardiovascular Medicine 2022, 9.
38. **Bruun Pedersen, K., Madsen, C., Sandgaard, N. C. F., Hey, T. M., Diederichsen, A. C. P., Bak, S., et al.** Left atrial volume index and left ventricular global longitudinal strain predict new-onset atrial fibrillation in patients with transient ischemic attack. The International Journal of Cardiovascular Imaging2019, 35, 1277-1286.
39. **Olsen, F. J., Møgelvang, R., Jensen, G. B., Jensen, J. S., & Biering-Sørensen, T.** Relationship between left atrial functional measures and incident atrial fibrillation in the general population: the Copenhagen City Heart Study. Cardiovascular Imaging2019, 12(6), 981-989.
40. **Jasic-Szpak, E., Marwick, T. H., Donal, E., Przewlocka-Kosmala, M., Huynh, Q., Gozdzik, A., et al.** Prediction of AF in heart failure with preserved ejection fraction: incremental value of left atrial strain. Cardiovascular Imaging2021, 14(1), 131-144.
41. **Yasuda, R., Murata, M., Roberts, R., Tokuda, H., Minakata, Y., Suzuki, K., et al.** Left atrial strain is a powerful predictor of atrial fibrillation recurrence after catheter ablation: study of a heterogeneous population with sinus rhythm or atrial fibrillation. European Heart Journal-Cardiovascular Imaging 2015, 16(9), 1008-1014.
42. **Parwani, A. S., Morris, D. A., Blaschke, F., Huemer, M., Pieske, B., Haverkamp, W., et al.** Left atrial strain predicts recurrence of atrial arrhythmias after catheter ablation of persistent atrial fibrillation. Open Heart 2017, 4(1), e000572.

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