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Atrial Myocardial Deformation Changes in Patients with Non-Valvular Atrial Fibrillation

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Abstract

Background: Atrial fibrillation (AF) is the most common cardiac arrhythmia. It increases cardiovascular morbidity, especially embolic stroke and mortality. Two-dimensional speckle tracking echocardiography (2D STE) is a useful method that has been used to detect changes in atrial myocardial deformation in AF patients. **Objectives:** To study atrial myocardial deformation changes in patient with non-valvular AF using 2D STE. **Patients and Methods:** This study included 25 patients with non-valvular AF and 25 normal healthy controls. 2D STE was used for assessment of strain and strain rate of septal and free walls of both right atrium (RA) and LA and left ventricle (LV). **Results:** Mean LA septal and lateral strain and strain rate were significantly reduced in the AF group compared to the control group (−7.2% ± 5.2% vs. −20.4% ± 3.9%, −8.7% ± 8.8% vs. −21.7% ± 3.4%) and (−0.9 ± 0.5 S^{-1} vs. −1.9 ± 0.4 S^{-1}, −1.1 ± 0.6 S^{-1} vs. −2.04 ± 0.3 S^{-1}) respectively. Mean RA septal and lateral strain and strain rate were significantly reduced in the AF group compared to the control group (−5.9% ± 6.1% vs. −23.4% ± 4.5%, −8.9% ± 9.3% vs. −21.7% ± 3.4%) and (−0.98 ± 0.6 S^{-1} vs. −1.9 ± 0.3 S^{-1}, −1.3 ± 0.9 S^{-1} vs. −2.1 ± 0.5 S^{-1}) respectively. Mean LV global longitudinal strain (GLS) and strain rate were significantly reduced in the AF group compared to the control group (−8.8% ± 4.6% vs −19.6% ± 2.4%) and (−0.8 ± 0.3 S^{-1} vs −1.5 ± 0.4 S^{-1}) respectively ($P < 0.001$ for all). **Conclusion:** AF is a bi-atrial disease, LA and RA myocardial deformation properties as well as LV GLS and strain rate measured by 2D STE were significantly impaired in AF patients compared to healthy controls.

Keywords

Myocardial Deformation, Non-Valvular Atrial Fibrillation, Speckle Tracking Echocardiography, Strain, Strain Rate

1. Introduction

Atrial fibrillation (AF) is the most common cardiac arrhythmia. It increases cardiovascular morbidity, especially embolic stroke and mortality [1]. Ischemic stroke (IS) is one of the five leading causes of death worldwide [2] and 20% - 30% of the incidents are estimated to be caused by atrial fibrillation (AF) [3]. AF is actually a bi-atrial disease. As seen in the LA, histological studies of right atrium (RA) myocardium in AF show the same substrate of patchy fibrosis, inflammatory cell infiltrate, necrosis, and vascular degeneration that may contribute in pathogenesis of AF [4]. Tissue Doppler imaging (TDI) and two-dimensional (2D) speckle tracking are two echocardiographic techniques to assess atrial strain. The technique is highly feasible for studying the contractility of myocardial tissue, allowing the quantification of low-velocity, high amplitude, and long-axis intrinsic myocardial velocities in both systole and diastole [5]. Two-dimensional speckle tracking echocardiography (2D STE) is a useful method that has been used to detect changes in atrial myocardial deformation in AF patients [6]. Myocardial strain (ε) and strain rate (SR) are measures of myocardial performance that have been proven to accurately assess myocardial contractility [7] [8]. During AF, electrical activation pathway is disrupted and atrial mechanical performance becomes abnormal. As a consequence, complete loss of atrial pump function occurs, demonstrated by the absence of one of the two negative strain rate curves during diastole, which is the most characteristic pattern during AF [5]. LA longitudinal strain has been described to be associated with the amount of fibrosis within the LA wall allowing a complex assessment of LA structure and function [9]. RA remodeling has been reported in AF, but few studies have focused upon it as a risk factor for AF recurrence [10].

2. Patients and Methods

2.1. Study Population

This study had been conducted on 25 patients with documented non-valvular AF, and 25 healthy subjects without cardiovascular disease, hypertension, or diabetes mellitus had been enrolled as controls. We included patient with long standing persistent non-valvular AF and AF duration > 1 year. We excluded Congenital heart diseases, valvular AF mainly rheumatic heart diseases, patient with cardiogenic shock and needed inotropes or hemodynamic instability and needed DC shock or mechanical ventilation. Each included patient was subjected to full history taking, thorough clinical examination, 12 lead Electrocardiogram.

2.2. Conventional Echocardiography

Transthoracic echocardiography was performed on the subjects at rest in the left lateral decubitus position using a Vivid S 6 (GE Vingmed, Horten, Norway) equipped with a harmonic S3 variable frequency (1.7 - 4 MHz) Phased-array transducer and conventional parameters measured in apical 4 chambers, apical two camber, apical three chambers and parasternal views: end diastolic dimension and volume (LVIDd, and EDV), end systolic dimension and volume (LVIDs and ESV), Fractional shortening (FS), EF, septal and posterior wall thickness (LVSWT and LVPWT), RA and LA diameters.

2.3. Assessment of LA, RA and LV Strain and Strain Rate

Offline analysis of raw ultrasound data was performed at Menoufia University—Department of Cardiology using GE Echopac and the following views were taken for analysis; apical 4 chamber view, apical 2 chamber view, and apical long axis view. All analyzed images were recorded with a frame rate of at least 40 fps for reliable analysis by the software. First, LA and RA walls borders were traced manually in apical 4 chamber view just before the QRS complex, at its minimum volume. Definition of RA and LA endocardial border enabled the software to calculate average values of strain and SR for six segments of LA and RA in apical four chamber view as seen in **Figure 1**, **Figure 2**. Then the LV end-systolic frame was defined by determining the closure of the aortic valve in the apical long-axis view. Then the LV endocardial border was manually traced at end-systole and the created region of interest was manually adjusted to the thickness of the myocardium. Any segments which subsequently failed to track were automatically discarded by the software for the calculation of global strain. Global longitudinal strain and strain rate for the complete LV segments were provided by the software as seen in **Figures 3-5**.

2.4. Statistical Analysis

Data were collected, tabulated and statistically analyzed using an IBM compatible personal computer with Statistical Package for the Social Sciences (SPSS) version 23 (SPSS Inc. Released 2015. IBM SPSS statistics for windows, version 23.0, Armnok, NY: IBM Corp.).

Two types of statistical analysis were performed:

1) Descriptive statistics e.g. qualitative data were expressed in: Number (N), percentage (%), while quantitative data were expressed as mean ($\bar{x}$), standard deviation (SD) and range (minimum-maximum).

2) Analytic statistics e.g.

a) Student's t-test is a test of significance used for comparison of quantitative variables between two groups of normally distributed data, while Mann Whitney's test was used for comparison of quantitative variables between two groups of not normally distributed data.

b) Chi-square test (χ^2) was used to study association between qualitative variables. Whenever any of the expected cells were less than five, Fischer's Exact test was used.

c) Pearson correlation was used to show correlation between two continuous normally distributed variables while Spearman correlation was used for not normally distributed ones.

Significant test results were quoted as two-tailed probabilities. Significance of the obtained results was judged at the 5% level ($P \le 0.05$).

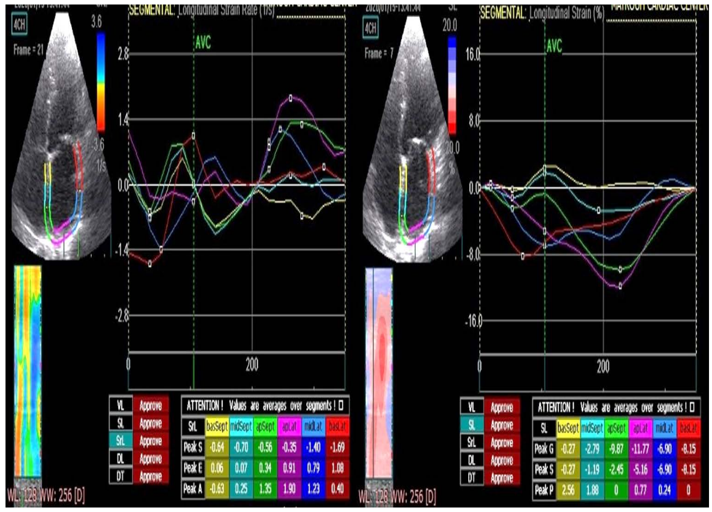

Figure 1. LA strain and strain rate for each wall.

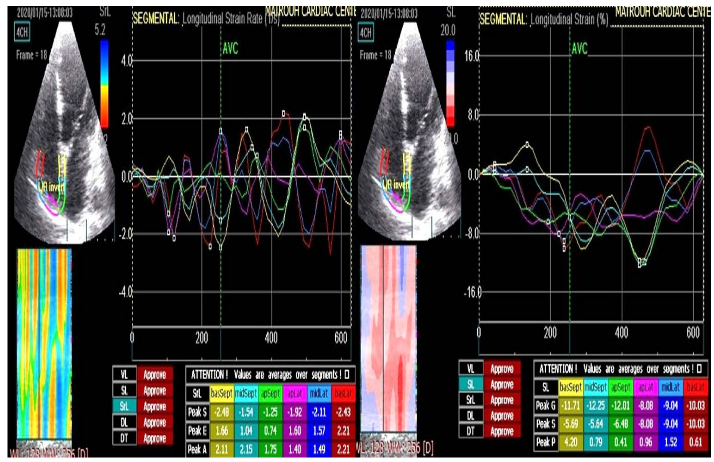

Figure 2. RA strain and strain rate for each wall.

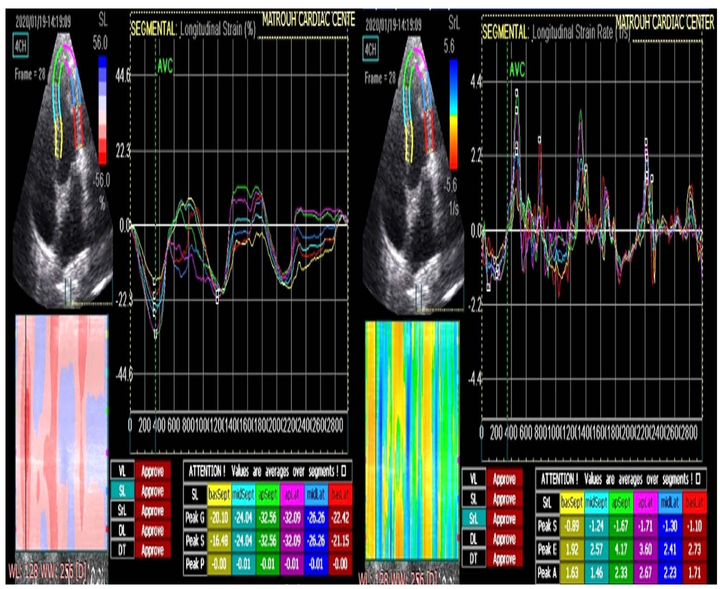

Figure 3. LV A4C strain and strain rate.

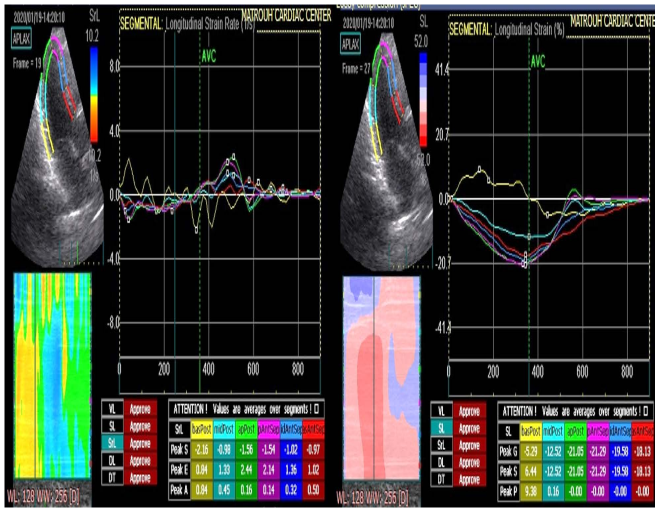

Figure 4. LV A3C strain and strain rate.

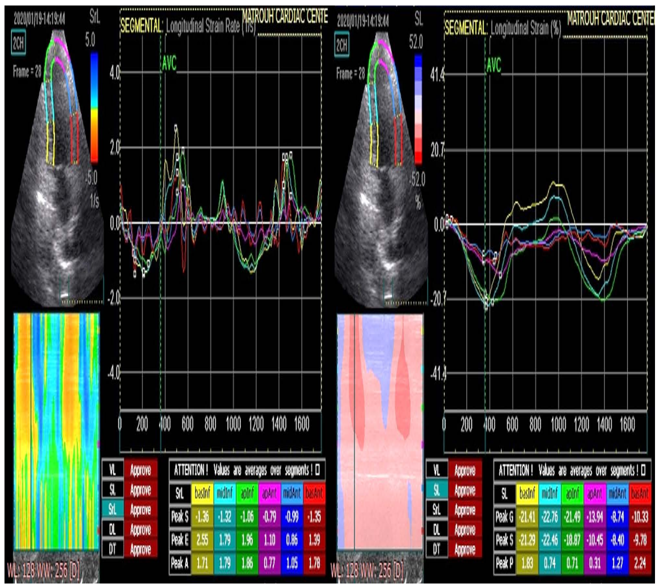

Figure 5. LV A2C strain and strain rate.

3. Results

3.1. Demographic Data

Regarding the age and sex, as shown in Table 1. This study included AF group mean age was 54.3 ± 4.9 years (ranged from 48 - 67 years). Males represented 52% (13 patients) of the study population while females represented 48% (12 patients). The control group mean age was 51.9 ± 6.9 years (ranged from 39 - 63 years). Males represented 68% (17 men) of the study population and females represented 32% (8 women). The mean body surface area in AF group and control group was 1.84 ± 0.14 M2 and 1.82 ± 0.13 M2 respectively.

3.2. Assessment of LV, RA and LA Strain

Table 2 showed that the LV global strain and strain of each wall, the septum, the lateral wall, the anterior wall, the inferior wall, the antero-septal wall and the posterior wall were detected to be statistically significantly reduced (P-value < 0.001) in the AF group compared to the control group. Also, RA strain (ε) of each wall the septum and lateral wall were detected to be statistically significantly reduced (P-value < 0.001) in the AF group compared to the control group, and LA strain (ε) of each wall the septum and lateral wall were detected to be statistically significantly reduced (P-value < 0.001) in the AF group compared to the control group (Figure 6, Figure 8).

Table 1. Demographic data.

	Patients (AF = 25) N (%)	Control (NSR = 25) N (%)
Age:		
Mean ± SD	54.3 ± 4.9	51.9 ± 6.9
Range (Min.-Max.)	48 - 67	39 - 63
Sex:		
Female	12 (48)	8 (32)
Male	13 (52)	17 (68)
DM:		
Yes	13 (52)	0 (0)
No	12 (48)	25 (100)
HTN:		
Yes	15 (60)	0 (0)
No	10 (40)	25 (100)
Body surface area:		
Mean ± SD	1.84 ± 0.14	1.82 ± 0.13
Range	1.6 - 2.1	1.6 - 2.1

Table 2. LV, RA and LA strain.

Wall	Patients (AF = 25)%	Control (NSR = 25)%	Test of significance	P-value
LV strain (ε)				
Septal:				
Mean ± SD	−8.6 ± 5.1	−20.01 ± 4.9	t = 8.08	<0.001**
Range	−0.6: −21.7	−9.3: −26.3		
Lateral:				
Mean ± SD	−9.8 ± 7.3	−20.2 ± 4.9	t = 5.93	<0.001**
Range	0.1: −29.2	−11.3: −28.8		
Anterior:				
Mean ± SD	−6.8 ± 5.6	−19.2 ± 3.2	t = 9.73	<0.001**
Range	5.3: −16.9	−13.2: −23.8		
Inferior:				
Mean ± SD	−10.3 ± 5.8	−19.8 ± 2.3	t = 7.61	<0.001**
Range	−1.8: −27.5	−15.5: −24		
Anteroseptal:				
Mean ± SD	−8.3 ± 6.5	−19.7 ± 2.7	t = 8.09	<0.001**
Range	1.7: −24.3	−15.3: −24.8		
Posterior:				
Mean ± SD	−9.5 ± 6.9	−19.3 ± 2.8	t = 6.52	<0.001**
Range	9.4: −24.3	−13.3: −24.6		
LV GLS:				
Mean ± SD	−8.8 ± 4.6	−19.6 ± 2.4	t = 8.07	<0.001**
Range	−3.3: −16.4	−14.8: −21.6		

Continued

		RA strain (ε)		
Septal:				
Mean ± SD	−5.9 ± 6.1	−23.4 ± 4.5	t = 11.49	<0.001**
Range	11.8: −17.7	−12.7: −33.3		
Lateral:				
Mean ± SD	−8.9 ± 9.3	−23.7 ± 4.5	t = 7.16	<0.001**
Range	16.7: −25.9	−13.1: −32.6		
		RA strain (ε)		
Septal:				
Mean ± SD	−7.2 ± 5.2	−20.4 ± 3.9	t = 10.02	<0.001**
Range	3.6: −17.4	−14.2: −29.8		
Lateral:				
Mean ± SD	−8.7 ± 8.8	−21.7 ± 3.4	U = 4.96	<0.001**
Range	3.3: −33.4	−15.7: −25.8		

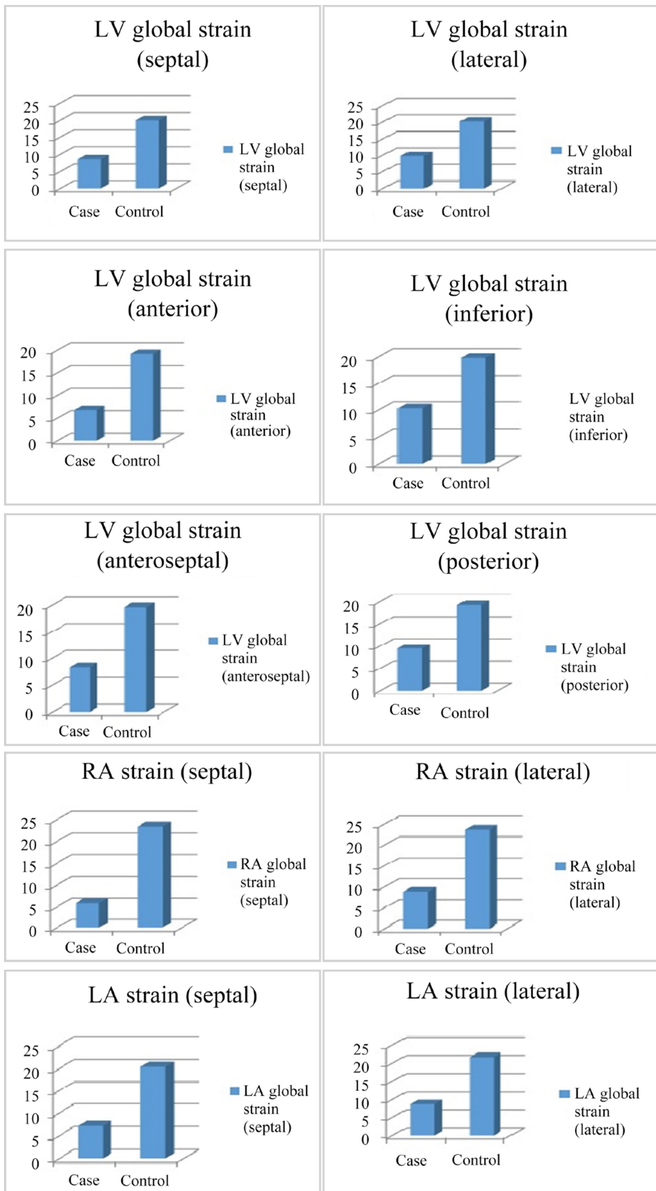

Figure 6. LV, RA and LA strain.

3.3. Assessment of LV, RA and LA Strain Rates

Table 3 showed that LV strain rate (SR) of each wall, the septum, apical, the lateral wall, the anterior wall, the inferior wall, the antero-septal wall and the posterior wall were detected to be statistically significantly reduced (P-value < 0.001) in the AF group compared to the control group. Also, RA strain rate (SR) of each wall the septum and lateral wall were detected to be statistically significantly reduced (P-value < 0.001) in the AF group compared to the control group. And regarding the lateral wall (basal and mid) were detected to be statistically significantly reduced (P-value = 0.037, P-value = 0.001 respectively) in the AF group compared to the control group), and LA strain rate (ε) of each wall the septum and the lateral wall were significantly reduced (P-value < 0.001) in the AF group compared to the control group (Figure 7).

Table 3. LV, LA and RA SR.

Wall	Patients (AF = 25) S^{-1}	Control (NSR = 25) S^{-1}	Test of significance	P-value
LV strain rate (SR)				
Septal:				
Mean ± SD	−0.9 ± 0.3	−1.6 ± 0.4	t = 7.29	<0.001**
Range	−0.2: −1.4	−0.9: −2.1		
Lateral:				
Mean ± SD	−0.8 ± 0.5	−1.7 ± 0.2	t = 7.25	<0.001**
Range	0.8: −1.6	−1: −2		
Anterior:				
Mean ± SD	−0.7 ± 0.4	−1.5 ± 0.3	t = 8.29	<0.001**
Range	0.2: −1.5	−1: −2.3		
Inferior:				
Mean ± SD	−0.9 ± 0.3	−1.5 ± 0.3	t = 7.13	<0.001**
Range	−0.1: −1.5	−0.9: −2.1		
Anteroseptal:				
Mean ± SD	−0.6 ± 0.6	−1.5 ± 0.3	t = 6.4	<0.001**
Range	1.2: −1.4	−1: −2.2		
Posterior:				
Mean ± SD	−0.9 ± 0.5	−1.7 ± 0.3	t = 6.95	<0.001**
Range	−0.5: −1.8	−1.3: −2.4		
LV strain rate				
Mean ± SD	−0.8 ± 0.3	−1.5 ± − 0.4	t = 7.25	<0.001**
Range	−0.3: −1.2	−1.1: −1.9		
RA strain rate (SR)				
Septal:				
Mean ± SD	−0.98 ± 0.6	−1.9 ± 0.3	t = 7.05	<0.001**
Range	0.2: −2.4	−1.4: −3.2		
Lateral:				
Mean ± SD	−1.3 ± 0.9	−2.1 ± 0.5	t = 4.19	<0.001**
Range	0.6: −3.1	−1.4: −3.7		
LA strain rate (SR)				
Septal:				
Mean ± SD	−0.9 ± 0.5	−1.9 ± 0.4	t = 5.72	<0.001**
Range	0.8: −1.8	−1.5: 3.3		
Lateral:				
Mean ± SD	−1.1 ± 0.6	−2.04 ± 0.3	t = 7.22	<0.001**
Range	0.1: −2.4	−1.3: −2.5		

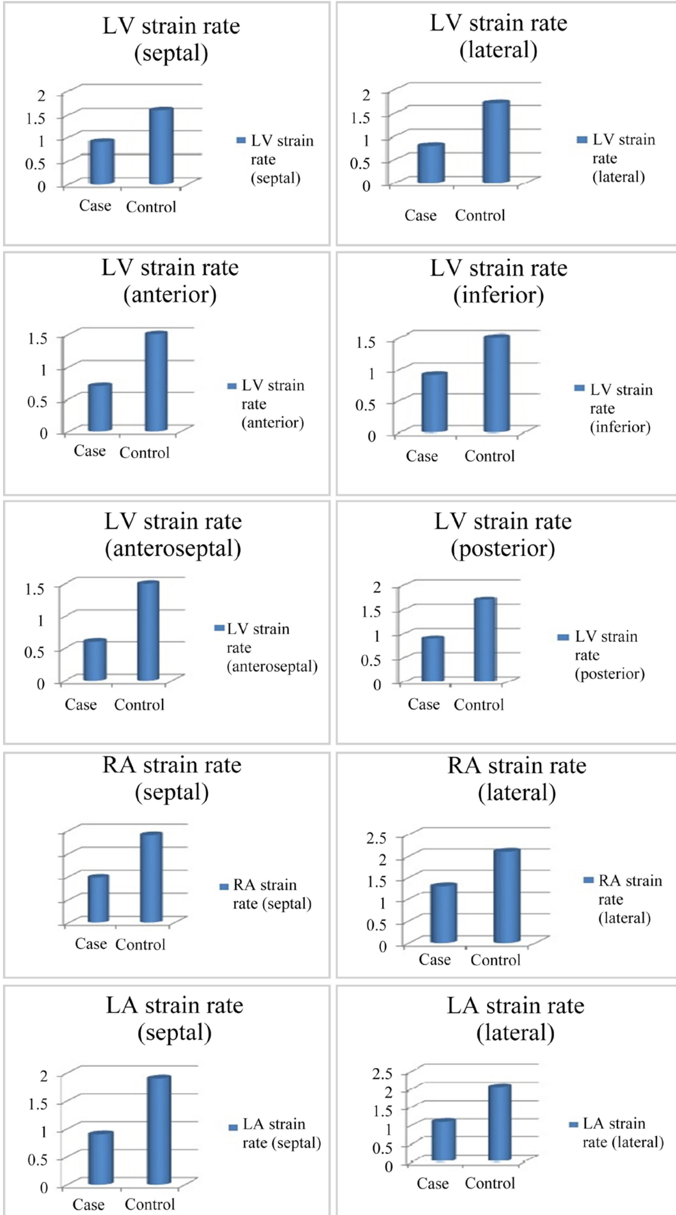

Figure 7. LV, RA and LA SR.

3.4. Comparison between LA, and RA Strain and Strain Rate in AF Patients

Table 4 showed the RA strains (ε) of the septum and the lateral wall, compared to the LA strains (ε) of the same walls and there was no statistically significant difference between both strains in the AF patients (**Figure 8**).

3.5. Comparison between RA and LA Strain Rates (SR) in AF Patients

Table 5 showed the RA strain rates (SR) of the septum and the lateral wall compared to the LA strain rates (SR) of the same walls and there was no statistically significant difference between both strains in the AF patients except in the strain rate for the basal lateral wall, it was significantly higher (P-value = 0.04) in the RA than the LA (Figure 9).

Table 4. Comparison between LA, and RA strain in AF patients.

	Patients (AF = 25)		Test of significance	P-value
	RA (%)	LA (%)		
Septal:				Septal:
Mean ± SD	−5.9 ± 6.1	−7.2 ± 5.2	t = 0.79	Mean ± SD
Range	11.8: −17.7	3.6: −17.4		Range
Lateral:				Lateral:
Mean ± SD	−8.9 ± 9.3	−8.7 ± 8.8	t = 0.07	Mean ± SD
Range	16.7: −25.9	3.3: −33.4		Range

Table 5. Comparison between LA, and RA strain rate in AF patients.

	Patients (AF = 25)		Test of significance	P-value
	RA (s^{-1})	LA (s^{-1})		
Septal:				Septal:
Mean ± SD	−0.98 ± 0.6	−0.9 ± 0.5	t = 0.64	Mean ± SD
Range	0.2: −2.4	0.8: −1.8		Range
Lateral:				Lateral:
Mean ± SD	−1.3 ± 0.9	−1.1 ± 0.6	t = 0.84	Mean ± SD
Range	0.6: −3.1	0.1: −2.4		Range

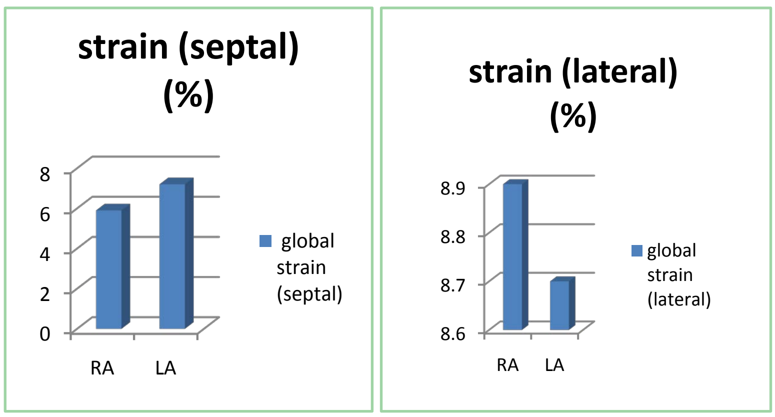

Figure 8. Comparison between LA and RA strain.

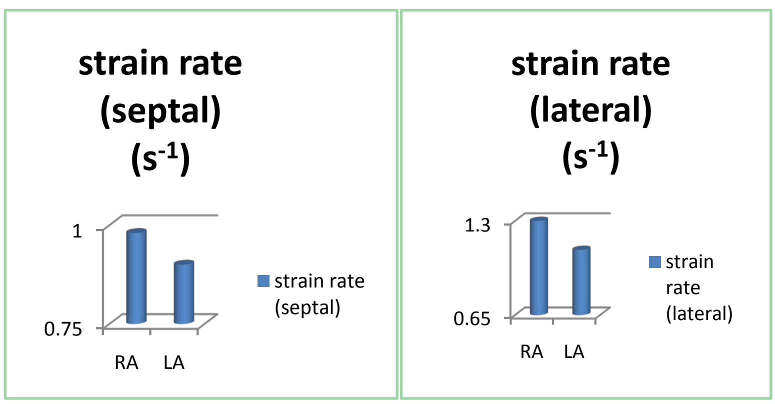

Figure 9. Comparison between LA and RA SR.

3.6. Correlation between LA and RA Diameter and LA and RA Total Strains and Strain Rates

Correlation coefficient (r) interpretation: <0.5: weak correlation, 0.5 - <0.6: fair, 0.6 - <0.7: good, 0.7 - <0.8: strong (very good) correlation *significant correlation, **highly significant correlation.

Table 6 showed that there was a positive correlation between strain of septal wall and lateral wall, strain rate of septal and lateral and RA diameter with statistical significance (P-value < 0.001). Also there was a positive correlation between strain rate lateral and RA diameter with statistical significance (P-value = 0.003) (Figure 10).

Table 7 showed that there was a positive correlation between strain of septal and lateral wall, strain rate of septal and lateral walls and LA diameter with statistical significance (P-value < 0.001) (Figure 11).

Table 6. Correlation between RA diameter and RA total strains and strain rate.

RA	RA diameter	
	r	P-value
Strain Septal	0.69	<0.001**
Strain Lateral	0.56	<0.001**
Strain rate Septal	0.61	<0.001**
Strain rate Lateral	0.42	0.003*

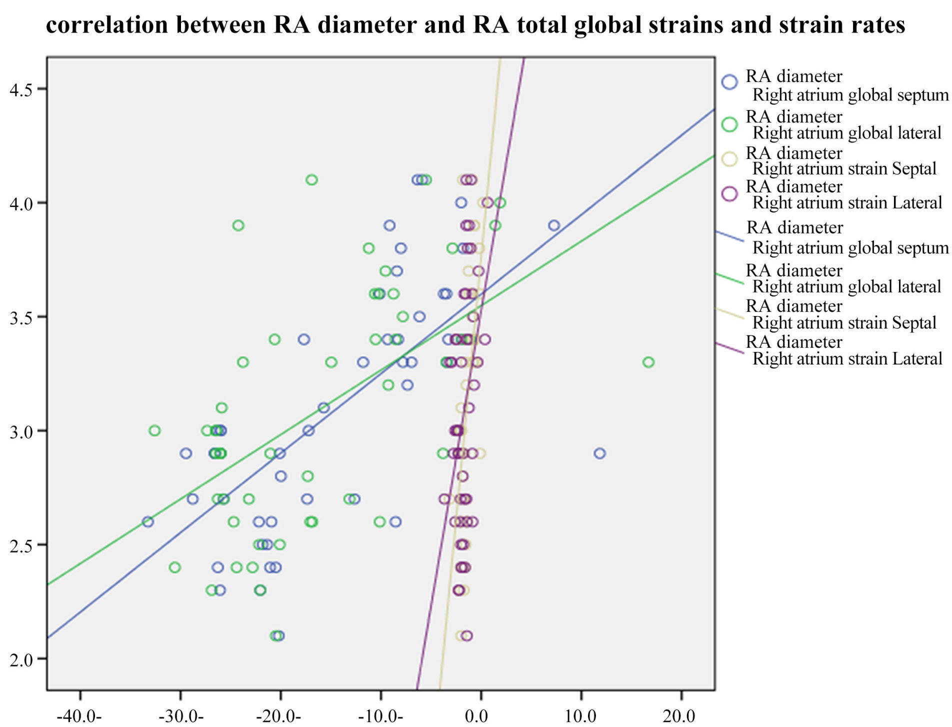

Figure 10. Correlation between RA diameter and RA total strains and strain rate.

Table 7. Correlation between LA diameter and LA strain and strain rates.

LA	LA diameter	
	r	P-value
Strain Septal	0.73	<0.001**
Strain Lateral	#0.66	<0.001**
Strain rate Septal	#0.69	<0.001**
Strain rate Lateral	0.66	<0.001**

#rs: spearman correlation coefficient (not normally distributed data).

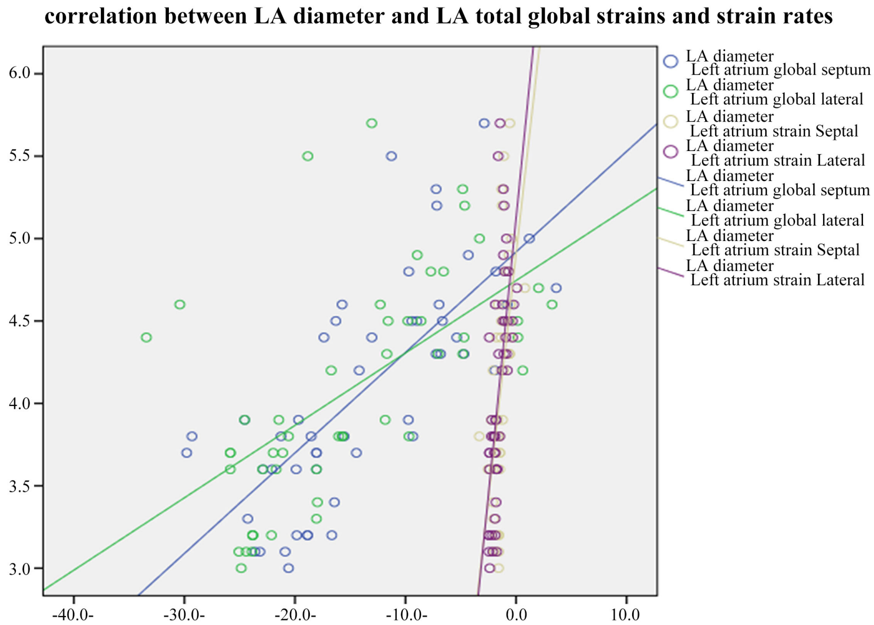

Figure 11. Correlation between LA diameter and LA total strains and strain rates.

4. Discussion

Assessment of strain based on 2D speckle tracking allows reliable distinction between active contraction and passive motion [11]. In this study, we describe mainly the relation between non-valvular AF and atrial myocardial deformation (both atria) properties that was significantly impaired in AF patient compared to normal healthy controls. This study demonstrated that there was a relation between atrial dimension and myocardial deformation. We also studied LV global strain in patients with AF. Moreover, we have demonstrated that GLS (ε) is significantly impaired in AF compared to healthy controls. This study also, demonstrated that there was positive correlation between LA and RA dimensions and LA and RA deformation changes respectively in AF patients. In the present study we found mean longitudinal strain (ε) of septal wall of left atrium equal (−7.2% ± 5%), and mean longitudinal strain (ε) of lateral wall of left atrium about (−8.7% ± 8.8%). Similarly, Hammerstingl *et al.*'s study of left atrial deformation imaging with ultrasound based two-dimensional speckle-tracking predicts the rate of recurrence of paroxysmal and persistent atrial fibrillation after successful ablation procedures found that the mean longitudinal strain of septal wall of left atrium was (−14.0% ± 14.1%) and mean longitudinal strain of lateral wall of left atrium was (−8.1% ± 7.9%) [12]. However, study of atrial deformation role in prediction of the maintenance of sinus rhythm after catheter ablation of atrial fibrillation demonstrated that the mean LA strain was (−16% ± 3%) in persistent AF patient and (−20% ± 3%) in patient with paroxysmal AF [1]. In our study mean strain rate (SR) of septal wall of left atrium was (−0.9 ± 0.5 S^{-1}) and mean strain rate (SR) of septal wall of left atrium was (−1.1 ± 0.6 S^{-1}). Also, a study of Abnormalities of left atrial function after cardioversion by Thomas, Mckay, Byth, *et al.*, demonstrated the mean strain rate of basal septal wall of left atrium was (−0.53 ± 0.3 S^{-1}) and that of basal lateral was (−1.2 ± 0.78 S^{-1}) [13] and a comparative study in controls and patients with atrial fibrillation by Inaba et al found that normal values for mean LA strain rate in 50 healthy subjects (29 males and 21 females, age 19 - 70 years) was (−3.1 ± 1.0 S^{-1}) and in 27 AF patient was (−1.7 ± 0.8 S^{-1}) [14]. This study found that the mean longitudinal strain of septal wall of right atrium was (−5.9% ± 6.1%) and mean longitudinal strain of lateral wall of right atrium was (−8.9% ± 13.6%) and mean strain rate of septal wall of right atrium was (−0.98 ± 0.6 S^{-1}) and mean strain rate of septal wall of right atrium was (−1.3 ± 0.9 S^{-1}). Malini *et al.* agreed with our study and described that the booster right atrial strain was (−8% ± 2%) in a study of role of right atrial strain in prediction of recurrence of attacks of AF in patient with paroxysmal AF [15]. On the other hand, a speckle tracking echocardiography study demonstrated the role of the right atrium in development of postoperative atrial fibrillation showed that mean right atrial strain (−15% ± 28%) [16]. Our study demonstrated that the mean GLS of LV in AF patients was (−8.8% ± 4.6%), mean longitudinal strain (ε) of LV septal wall in AF patient was (−8.6% ± 5.1%), mean strain (ε) of LV lateral wall was (−9.8% ± 7.04%), mean strain (ε) of LV anterior wall was (−6.8% ± 5.6%), mean strain (ε) of LV inferior wall was (−10% ± 5.8%), mean strain (ε) of anteroseptal wall (−8.2% ± 6.5%) and mean strain (ε) of posterior wall (−9.5% ± 6.9%). Similarly, Left ventricular systolic function assessed by global longitudinal strain was found in Ross Agner *et al.* study to be impaired in AF patient compared to NSR either in patient with EF > 50%) or in those with EF < 50% (mean GLS = −12.85% ± 3.5% in 75 NSR patient and −10.10% ± 3.1% in 75 AF patient) [17]. In contrast, Lee *et al.*'s study aimed to compare GLS between patients with and without AF in a normal LVEF, to verify whether AF patients have a more impaired GLS and determine whether AF per se is a major determinant of GLS, and evaluate the major determinants of GLS in AF patients, the study found that the mean GLS in 137 NSR patient was (−15.0% ± 2.8%) and in 137 AF patient was (−18.1% ± 3.4%). In our study we described strain rate (SR) of LV in AF patients was (−0.8% ± 0.3%) and strain rate of LV septal wall in AF patient was (−0.9 ± 0.3 S^{-1}), mean strain rate (SR) of LV lateral wall was (−0.8 ± 0.5 S^{-1}), mean strain rate (SR) of LV anterior wall was (−0.7 ± 0.04), mean strain rate (SR)of LV inferior wall was (−0.09 ± 0.3 S^{-1}), mean strain rate (SR) of anteroseptal wall (−0.6 ± 0.6 S^{-1}) and mean strain rate (SR) of posterior wall ($-0.9 \pm 0.5\ S^{-1}$). While, left ventricular systolic function is assessed by strain rate in Ross Agner *et al.* study that compared AF patients to NSR and described mean SR in AF patients with reduced EF as ($-0.61 \pm 0.2\ S^{-1}$) and ($-0.90 \pm 0.2\ S^{-1}$) in AF patients with normal systolic function, and ($-1.08 \pm 0.3\ S^{-1}$) in NSR patients with EF > 50% [17].

5. Conclusion

AF is a bi-atrial disease, LA and RA myocardial deformation properties as well as LV GLS and strain rate values were significantly impaired in atrial fibrillation patients compared to healthy controls.

6. Recommendation

From this study, we recommend the following:

1) Future studies have to focus on both atrial myocardial deformation and its impact on understanding behavior of AF pathology and prediction of incidence.

2) Speckle tracking echocardiography is a valuable technique for the assessment of atrial function which may be of clinical relevance for the development of effective strategies to identify patients at high risk of atrial fibrillation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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