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Original Article

Assessment of Left Atrial Functions and Volume by Conventional Echocardiography in Patients with Atrial Arrhythmias

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ABSTRACT

Background: Atrial tachyarrhythmia is a significant problem. The LA mechanical and pathological changes and its assessment usually share in treatment plan. Advanced tools are available. However, less advanced tools could have their role, especially in resource limited facilities.

Aim of the work: The current work aimed to assess left atrial function and volume by trans-thoracic echocardiography among patients with atrial arrhythmias.

Patients and Methods: One hundred patients with atrial tachyarrhythmia's and 30 healthy individual [as a control group] were included in the current study. All patients had been evaluated by history taking and clinical examination. Then, all were subjected to resting electrocardiogram and standard resting transthoracic echocardiography [TTE].

Results: The study and control groups revealed non-significant difference regarding patient age, gender, diabetes and thyroid disease. There was female sex predilection [69% in study and 63.0% in control group]. Hypertension and smoking were significantly increased among study than control group [40.0%, 20.0% vs 10.0% and 3.3% respectively]. Arrhythmias were in the form of fibrillation [80.0%], tachycardia [14%] and flutter [6.0%]. There was significant difference between study and control groups regarding clinical data, echocardiography, Doppler indices and LA volume. However, LVEF%, LA diameter and pulmonary S wave velocity did not significantly differ between groups. The different types of arrhythmia revealed significant increase of pEF, LA diameter and tissue Doppler among flutter than AF and AT. Otherwise, there was no significant differences regard other clinical data, echocardiography and Doppler indices.

Conclusion: AF has effect on structural and functional remodeling of the LA function, and AF had more harmful effect than tachycardia and flutter and it may add significant value for development of HF. The conventional echocardiography could be considered a reliable assessment tool for atrial function in patients with atrial arrhythmias.

Keywords: Echocardiography; Atrial fibrillation; Flutter; Left Atrium; Volume.

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* Main subject and any subcategories have been classified according to the research topic

INTRODUCTION

The normal structure and function of the left atrium [LA] is crucial for the normal function of the heart. LA contributes up to 30% of the total left ventricular stroke volume [SV] in normal individuals [1]. LA modulates the filling and performance of the left ventricle [LV], by its reservoir role, conduit, and booster pump action. After external cardioversion, the atrial deformation properties predict the maintenance of sinus rhythm [2].

The left atrial structural remolding and dysfunction is involved in the pathogenesis and development of ventricular diseases such as heart failure, regardless of whether ejection fraction is conserved [3]. The absent atrial contribution to left ventricular filling and stroke volume in atrial arrhythmias leads to symptomatic deterioration especially in AF [4]. The assessment of left atrial [LA] function is increasingly being used in various cardiovascular diseases. Left atrial functional abnormalities may also predict the occurrence of atrial arrhythmias [5].

Angiography was used to estimate LA function. Other methods used included micro manometry and measurements of pulmonary pressure. However, all are invasive methods. On the other side, Doppler tools are available, that are cheap and noninvasive tools for evaluation of the mechanics of LA [6].

The atrial function could be assessed with different imaging modalities; e.g., echocardiography, computed tomography and magnetic resonance imaging. However, echocardiography is best appropriate tool for this task, due to its availability, safety, accuracy and ability of real time imaging with high temporal and spatial resolution [7]. In contractile function changes [e.g., in systemic hypertension], left-sided end-diastolic pressure increased, and volume increases are predisposed to AF [8].

AF is the commonest type of arrhythmia encountered in the clinical practice. The estimated prevalence is 0.4–1% in the general population, increased to 9.0% in aging population above the age of 80 years [9]. It is characterized by disorganized activation of the atrial muscle with no effective atrial contraction [10]. The atrial booster pump function is lost due to asynchronous atrial contractions during AF. This is associated with a fall in cardiac output that could contribute in ventricular hypertrophy and ischemic heart disease, with already abnormal diastolic performance [11].

AF is also associated with wide abnormalities in atrial structure and function. The structural atrial changes precede the development of AF and advanced with longer duration of sustained AF [12].

The changes in atrial function impair the booster pump function as well as the atrial reservoir and conduit functions during ventricular systole and early diastole. Progressive atrial remodeling includes fibrotic changes that promote AF progress. The increased LA fibrosis in patients with long-standing persistent AF supports this idea [13,14]. Furthermore, AF affects the quality of life and pose economic burden on the patient and health system. Asymptomatic AF also increases the risk of stroke [15].

Although maximum left atrial volume strongly correlates with cardiovascular diseases and predict cardiovascular outcomes, increasing amount of data from measures of left atrium function provide prognostic information that is more powerful than increasing in left atrial size [16].

The key function of the left atrium is to modulate left ventricular filling and cardiovascular performance, left atrial function is most often assessed by echocardiography using pulse wave Doppler of trans-mitral flow, pulse wave Doppler of pulmonary venous flow, left atrial phasic volumes and myocardial velocities [17].

AIM OF THE WORK

Although technology of imaging and evaluation of cardiac function witnessed a major advance in the recent years, the availability of such technologies in all institution is not possible, especially in developing countries. Thus, the consideration of the role of already available assessment equipment's must be considered. The role of such technologies must be assessed in different cardiac diseases. The aim of this study was the assessment of left atrial function and volume by trans-thoracic echocardiography among the patients with various types of atrial arrhythmias.

PATIENTS AND METHODS

This was a cross-sectional study that included 100 patients with atrial arrhythmias. All were selected from the Department of Cardiology, Al-Azhar University Hospital [New Damietta]. The study carried out from January 2020 to March 2021. In addition, 30 healthy participants, matched with our patients for age and sex were included as a control group. We included any patient complaining of palpitation and their electrocardiogram [ECG] revealed any type of atrial arrhythmias. Otherwise, any patient with ischemic heart disease, valvular heart disease, implanted pacemaker or defibrillator, patients with autoimmune disease, inflammatory or hematological diseases were excluded from the study.

All patients had been thoroughly evaluated by full history taking and clinical examination [General and cardiovascular]. Then, all were subjected to resting electrocardiogram and standard resting transthoracic echocardiography [TTE].

TEE: With a 3.5 MHz Philips transducer in a left lateral position, an evaluation by a two-dimensional, pulsed and continuous wave, and color Doppler were made. The following data were obtained during LV end-diastole immediately before aortic valve opening from the parasternal long-axis view: LV end-diastolic dimension [LVEDD], inter-ventricular septal thickness, and posterior wall thickness. LV ejection fraction [LVEF], the index of global LV systolic function, was computed from apical two and four-chamber views. LVEF was measured using the biplane modified Simpson method. The 2D images were obtained from the apical 2-, 3 and 4-chamber images. All images were recorded while the patient held his/her breath through at least three cardiac cycles. The frame rate for image acquisition was between 50 and 90 frames/s. Tissue Doppler imaging permits the measurement of myocardial velocities providing a less load dependent measure of both LV systolic and diastolic function. Pulsed sample volume was placed at the septal corner of mitral annulus; early diastolic [E] and late systolic [A]myocardial velocities were recorded [Figures 1 and 2]. Pulmonary vein Doppler signal had been acquired in the apical 4-chamber view by interrogating the right upper pulmonary vein [Figure 3].

To evaluate the size of the left atrium, the anteroposterior dimension was obtained in the parasternal long-axis view from the indicating edging of the posterior wall of the aorta to the indicating edging of the posterior wall of LA [18] [Figure 4]. To assess the LA volume [LAV], LA areas were manually measured by tracing the endocardial border in the apical four- and two-chamber views over the cardiac cycle. Special attention was focused on tracing the LA endocardial border. In the apical four-chamber view, if the atrial septum had partially dropped out, its location was approximated from visualized fragments. Instead of tracing the inner surface of the mitral valve, a straight line connecting both sides of the mitral leaflet base attachment points to the valve ring was taken as the inferior border of the LA [Figure 5].

On imaging, atrial appendages and pulmonary veins were carefully excluded from their junction with LA. The long axis was taken as the line from the midpoint of the mitral plane to the upper border of the chamber. LAV was determined using the area-length method of biplane [A - L] and the modified Simpson method. [19]. To assess the phase EF of LA during cardiac cycle, LA volume was measured at mitral valve opening [LAV max] at the beginning of atrial emptying [LAVOAE], and at mitral valve closure [LAV min] from the apical two- and four-chamber views.

According to Lim *et al.* [20] LAV max, LAVOAE, and LAV min were estimated and marked to the body surface area. Complete LA carrying functions were measured as follows: *LA total emptying fraction [LAEF total]* equals 100 × [LAV max– LAV min]/LAV max. *LA passive emptying fraction [LAEF passive]* equals 100 × [LAV max – LAVOAE]/LAV max; and *LA active emptying fraction [LAEF active]* = 100 × [LAVOAE– LAV min]/LAVOAE [Figure 6].

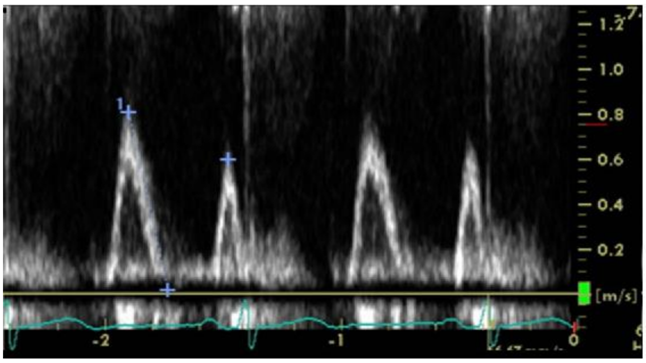

Figure [1]: Mitral inflow velocities [pulsed wave doppler] from septal wall

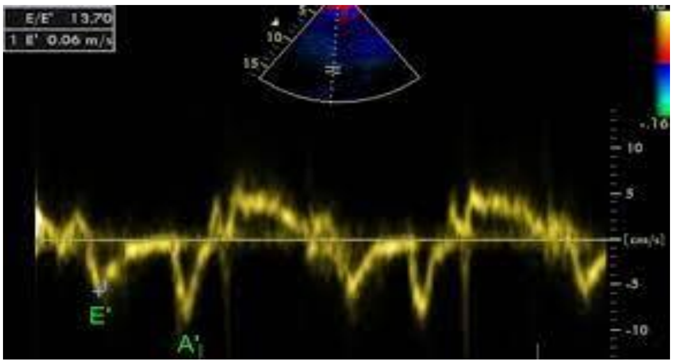

Figure [2]: Mitral inflow by tissue Doppler

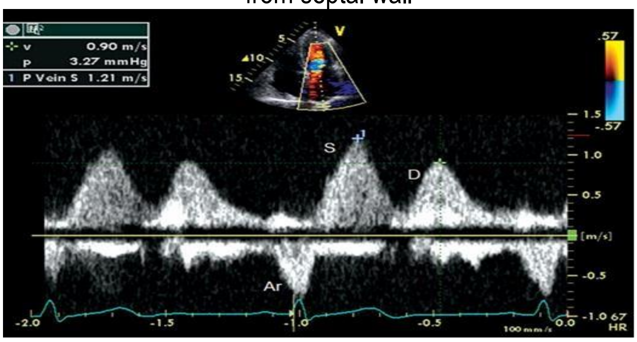

Figure [3]: Pulmonary vein pulse wave Doppler pattern

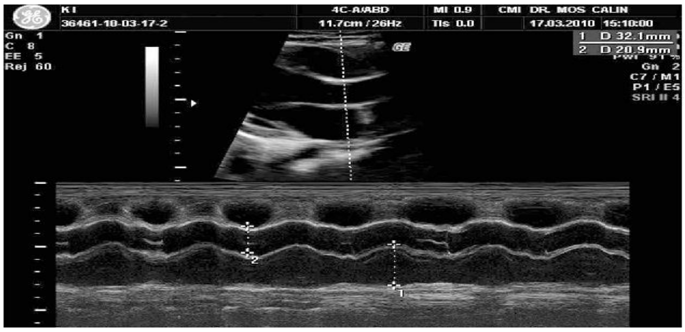

Figure [4]: M Mode echocardiography, long axis shows LT atrial dimension

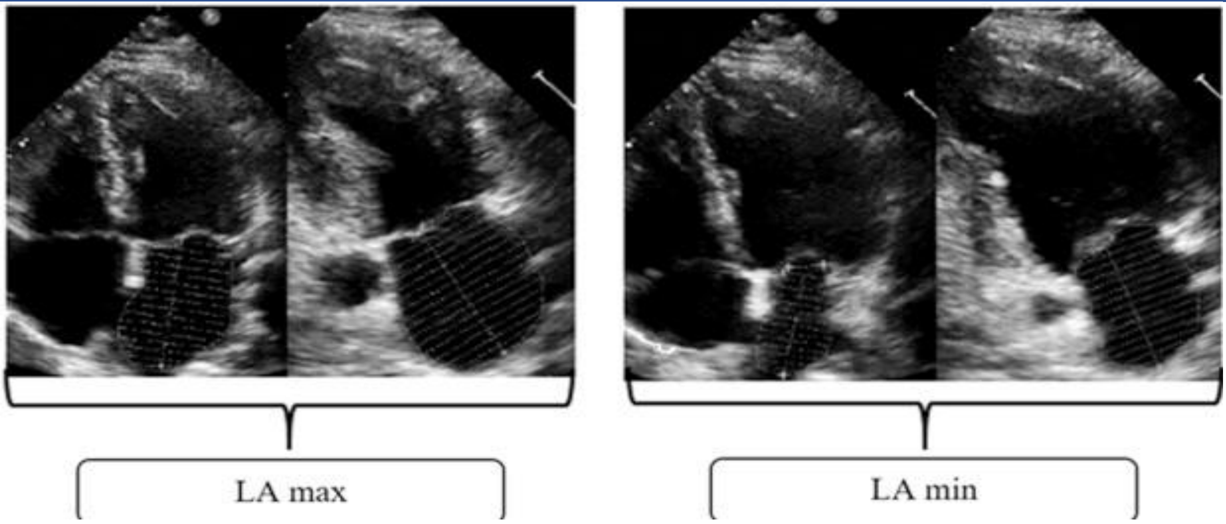

Figure [5]: Measurement of left atrial volume from area-length method using apical 4 chamber

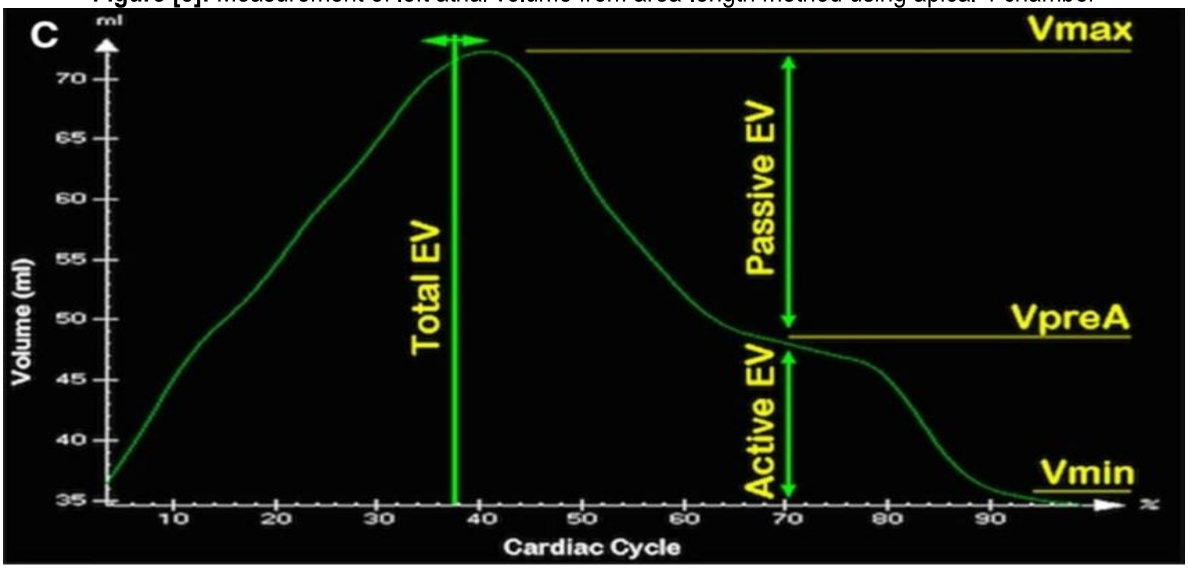

Figure [6]: left atrial volume in Apical 4 and apical 2 chamber view

Ethical considerations

The study protocol was introduced, reviewed and accepted by the institutional review board [IRB] of Damietta Faculty of Medicine. They recommended increase number of control group to at least an equal number of study group. However, we could not do it, due to rejection of healthy individuals to participate. Thus, we retained the number of 30 subjects. All patients and controls signed an informed consent to participate in the study [available on request]. The study procedures were completed according to research ethics of declaration of Helsinki.

Statistical analysis

Quantitative parametric [normally distributed] data were presented as mean and standard deviation [SD], while, median and interquartile ranges were calculated to express the quantitative nonparametric data. Frequency and percentage were the calculated measures to present qualitative data. Suitable tests were used for analysis according to the type of data. For example, student "t" test, one-way analysis of variance [ANOVA] or Mann Whitney "U" tests were used to analyze quantitative data; while Chi square or Fisher exact tests were used to analyze qualitative data. P-value <0.05 was considered statistically significant. All analyses were completed by the Statistical Package for Social Science [SPSS] version 23 for windows [IBM-SPSS Inc, Chicago, IL, USA].

RESULTS

Table [1] demonstrated the patient demographics and potential risk factors. Results revealed that, there was no significant difference between study and control group regard patient age or gender. However, there was female sex predominance in study and control groups. In addition, no difference was found regarding diabetes mellitus and thyroid disease. However, there was significant increase of hypertension and smoking in study than control group [40.0%, 20.0% vs 10.0% and 3.3% respectively].

Arrhythmia was in the form of fibrillation among 80.0% of study group, AT among 14% and flutter among 6.0%. There was significant increase of heart rate, systolic and diastolic blood pressure and pEF, while there was significant decrease of aEF, LAEF%, transmitral wave velocity, pulmonary diastolic velocity, tissue Doppler and maximum and minimum LA volumes, in the study than control groups. However, there was no significant difference regarding LVEF%, IA diameter, pulmonary S wave velocity and minimum LA volume [Table2].

The different types of arrhythmia revealed significant increase of pEF, LA diameter and tissue Doppler among flutter than AF and AT. Otherwise, there was no significant differences regard other clinical data, echocardiography and Doppler indices [Table 3].

Table [1]: Comparison between study and control group regarding patient demographics and potential risk factors

		Study group	Control group	Test	P value
Age [mean±SD; min.-max.]		58.1±7.1; 50-69	59.0±5.9; 50-70	0.67	0.49
Sex [n,%]	Male	31[31.0%]	11[36.7%]	0.33	0.56
	Female	69[69.0%]	19[63.3%]		
Potential Risk Factors	Hypertension	40[40.0%]	3[10.0%]	*9.38*	*0.002**
	Diabetes mellitus	12[12.0%]	1[3.3%]	1.92	0.16
	Smoking	20[20.0%]	1[3.3%]	*4.73*	*0.030**
	Thyroid disease	7[7.0%]	1[3.3%]	0.53	0.46

Table [2]: Comparison between both groups regarding clinical data, echocardiography, Doppler indices and LA volume

		Study group	Control group	Test	P value
Clinical data	Heart rate	110.4±9.0; 100-140	81.0±5.2; 70-96	16.99	**<0.001**
	Systolic BP	134.6±16.1; 110-165	126.7±13.7; 110-160	2.46	**0.015**
	Diastolic BP	88.5±14.3; 60-120	80.3±9.9; 70-110	2.90	**0.004**
Echocardiography	pEF	22.0±2.1; 20-27	20.9±1.7; 17-24	2.60	**0.01**
	aEF	23.0±2.6; 17-26	27.7±2.3; 20-30	8.91	**<0.001**
	LV EF%	53.0±6.0; 45-67	55.1±2.2; 51-60	1.88	0.060
	LA EF%	37.0±5.8; 30-50	48.8±1.3; 45-51	11.08	**<0.001**
	LA Diameter mm	42.7±5.4; 30-50	41.6±1.9; 40-48	1.13	0.26
Doppler	Trans-mitral wave [cm/s]	54.0±4.6; 40-65	58.2±3.1; 51-65	4.67	**<0.001**
	Pulmonary S wave [cm/s]	28.1±3.7; 20-33	28.6±1.9; 24-32	0.69	0.49
	Pulmonary diastolic velocity[cm/s]	46.9±4.0; 40-53	56.0±3.9;51-69	10.89	**<0.001**
	e`-Tissue Doppler [cm/s]	7.8±0.3; 7.5-8.4	8.2±0.2; 7.8-8.6	8.0	**<0.001**
LA volume	max Volume[m²/BSA]	46.5±7.4; 25-55	58.0±3.7; 48-70	8.2	**<0.001**
	min Volume[m²/BSA]	31.7±6.8; 20-50	34.3±5.2; 25-50	1.90	**0.05**

Table [3]: Comparison between different atrial arrhythmias regarding clinical data, echocardiography, Doppler and LA volume

		Study group			Test	
		AF	**AT**	**Flutter**		***P* value**
Clinical data	Heart rate	111.1±9.2	105.7±2.3	109.0±9.4	1.21	0.30
	Systolic BP	136.3±16.2	121.7±6.1	130.7±16.2	2.89	0.06
	Diastolic BP	89.8±14.7	82.5±6.1	83.6±13.4	1.68	0.19
Echocardiography	pEF	21.9±2.0	20.7±0.5	23.07±2.2	*3.35*	***0.04***
	aEF	22.9±2.7	23.5±2.5	23.6±1.7	0.56	0.576
	LV EF%	52.6±5.8	53.5±6.9	54.9±6.7	0.89	0.414
	LA EF%	37.1±5.9	36.5±6.3	36.8±5.2	0.04	0.963
	LA Diameter mm	42.5±5.1	38.7±6.5	45.9±5.2	*4.40*	***0.015***
Doppler	Trans-mitral wave [cm/s]	54.0±4.5	55.0±4.9	53.4±5.3	0.24	0.78
	Pulmonary S wave [cm/s]	27.8±3.6	29.2±5.0	29.5±2.7	1.67	0.19
	Pulmonary diastolic velocity[cm/s]	46.9±3.9	46.7±4.8	47.1±4.7	0.02	0.97
	e`-Tissue Doppler [cm/s]	7.76±0.21	8.02±0.23	8.17±0.14	27.0	**<0.001**
LA volume	max Volume[m2/BSA]	46.6±7.2	41.3±9.3	48.0±7.5	1.79	0.17
	min Volume[m2/BSA]	31.6±7.1	35.0±7.5	30.9±4.1	0.81	0.45

DISCUSSION

In this study, we are trying to assess and compare LA function and volume among 100 patients with atrial arrhythmias and 30 normal subjects [control group]. We used conventional echocardiography parameters, tissue Doppler image and pulmonary Doppler to assess LA function and volume. The conventional echocardiography was able to diagnose atrial fibrillation and play at least screening role in that condition. Rimbaş *et al.* [21] assessed LA deformation by 2D speckle tracking echocardiography and reported that, it can be a quick and easy-to-use method for investigating LA features. These new parameters of atrial function are more sensitive than conventional measures of atrial function and can be included in the routine assessment of various cardiac conditions, such as atrial fibrillation. Gan *et al.* [5] reported that, LA function is an important evolving entity with important clinical and prognostic implications.

Results of the current work revealed significant increase of LA diameter in atrial fibrillation than flutter or AT. Hirose *et al.* [22] found that significant reduction of AF active EF [booster pump function] and it independently predicts the risk of new-onset AF, suggesting a stronger association between LA functional remodeling and AF than between LA size and AF. In agreement with current study, Thomas *et al.* [23] reported that, conventional measures of atrial function assessment as peak transmitral A-wave velocity, A-wave velocity time integral, atrial fraction and the left atrial ejection fraction revealed significant reduction of atrial function after restoration to sinus rhythm in the case of atrial arrhythmia especially AF, after cardioversion. Bhat *et al.* [24] reported that atrial arrhythmia has effect on structure of the left atrium. Also, Sumita *et al.* [25] assessed the effect of left atrial size and function in AF patient on LV function and reported that, it has a harmful effect and can be useful for the prediction of heart fialure. This was due fibrotic changes extension to the LV and LA which considered as an important link between AF and heat failre. Kuppahally *et al.* [26] reported that, mechanical dysfunction of LA may be related to the alterations in LA architecture, such as atrial fibrosis. A recent research reports that LA wall fibrosis detected by delayed magnetic resonance imaging is inversely proportional to LA strain and strain rate and is associated with AF. [27].

Thus, structural and functional remodeling of LA in patients with AF may be the result of atrial pathology itself, independent of left ventricular dysfunction. However, we were unable to demonstrate the presence of LA fibrosis in subjects due to the non-invasive evaluation of LA in the present method. However, our study showed that patients with AF had obvious structural and functional remodeling of LA when compared to controls. The findings of the present study and other studies may suggest the existence of subclinical left ventricular dysfunction may be a pathogenic mechanism that stands behind development of AF.

In line with the current study, Shin *et al.* [28] concluded that paroxysmal AF is associated with impaired transport function of the left atrium more than flutter and AT. They added that the findings of their study may support the hypothesis that paroxysmal AF is related to concealed cardiac dysfunction. Habibi *et al.* [13] reported that LAaEF mean in AF group was 23±8%, which was significantly reduced than healthy group [34±10%]. LApEF also significantly decreased in AF than control group [19±7% vs. 24±6%].

Rodrigues *et al.* [29] found LAEF before ablation was 47±8%, and 24 hours after ablation was 40±7% and 8 months after ablation was 43±8%. However, they found that the LA diameter before ablation was 41±7mm, and 24 hours after ablation was 40±6mm and 8 months after ablation was 40±6mm. They also reported that, that there was significant reduction in LAEF in AF group than control group [p=0.004]. But unlike our finding they found significant increase in LA diameter [p=0.002]. Hirose *et al.* [22] reported that there was insignificant change in LVEF and significant decrease in LAaEF in AF group [p=0.43 and 0.001] respectively, and LApEF decrease in AF than control group. But the difference was insignificant [p0.052]. These results are in line with the current study. Also, Habibi *et al.* [13] found significant decrease in LAaEF in AF group than control group [p=0.001], but unlike our finding they report that the LApEF was significantly reduced in AF group [p=0.002].

Our results are in accordance with Sarvari *et al.* [30] reported that there was no significant difference between control group and AF group regarding LV EF and LA diameter [p=0.4 and 0.3] respectively.

According to Doppler measurements, we found only significant difference between cases and control groups in pulmonary venous diastolic velocity [p= 0.01]; while difference according to transmitral wave and pulmonary venous A wave was insignificant [p=0.7 and 0.5]. Rodrigues *et al.* [29] found that, with AF, transmitral A velocities were not increased compared with controls, and tissue Doppler A velocities were decreased. They support our finding that there was no significant change in trans-mitral and pulmonary venous A wave between AF group and control group. Sarvari *et al.* [30] on the other side, reported that there was no significant change in pulmonary diastolic A wave velocity [p=0.1].

In measurement of LA volume, we found significant decrease in minimum and maximum LA volume in study group than control group while in the minimum volume there was no significant difference. Rodrigues *et al.* [29] found that, patients with paroxysmal AF presented with a larger left atrium and decreased left atrial performance compared with controls. Larger left atrial volumes were independently associated with both the presence of AF and higher filling pressures. On the other side, Sarvari *et al.* [30] found that the LV volume in relation to body surface area in healthy individual was 29±6 ml/m^2, in AF patients without recurrence 27±4ml/m^2 and in AF patients with recurrence 28±3ml/m^2.Without any significant difference between both groups [p=0.6]. This could be attributed to different sample size, and inclusion criteria.

In short, persistent AF has effect on structural and functional remodeling of the LA function, which affect the LV function. AF had more harmful effect than tachycardia and flutter and may LA arrhythmia may add significant value for development of HF.

CONCLUSION

Overall, the conventional echocardiography could be considered a reliable assessment tool for atrial function in patients with different types of atrial arrhythmias. However, due to small number of patients with atrial tachycardia and flutter in comparison to AF, these results must be cautiously interpreted. Finally, we recommend the use of conventional echocardiography especially in resource-limited institutions for assessment of LA function in patients with AF. Its role could be continued till introduction of more advanced assessment tools.

Financial and Non-financial Relationships and Activities of Interest

None

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