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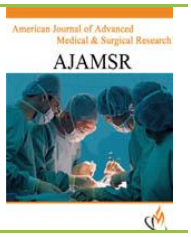

TISSUE DOPPLER IMAGING IN RHEUMATIC MITRAL VALVE DISEASE PATIENTS FOR THE ASSESSMENT OF LEFT VENTRICULAR FUNCTION

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ABSTRACT

The aim of the study is to investigate whether the Tissue doppler imaging (TDI) technique is advantageous in evaluation of LV systolic function in patients with rheumatic mitral valve disease in comparison to Simpson's method of conventional echocardiography. In this prospective, cross-sectional study, 60 age and sex matched individuals were enrolled into two groups (30 in each group) -healthy controls (Group 1) and the patients of rheumatic mitral valve disease (Group 2). In addition to the standard echocardiographic assessment methods, both the groups underwent the tissue Doppler evaluation, in order to assess the LV function. Student's t-test was used to compare continuous variable whereas chi-square test was used for the categorical variables. Myocardial performance index (MPI) assessed by conventional echocardiography and tissue doppler method were significantly (<0.001) lower in group 1 (0.39 ± 0.03) as compared to group 2 (0.46 ± 0.02) subjects. Peak systolic myocardial velocity (13.73 ± 2.51 vs 7.8 ± 1.42), early diastolic (16.4 ± 2.99 vs 8.03 ± 1.47) and late diastolic myocardial velocities (11.17 ± 2.04 vs 7.56 ± 1.38) were significantly higher in group 1 than in group 2. The strain and strain rate of base lateral, mid and apical LV free wall, apical-, mid- and base septal were significantly ($p<0.05$) lower in group 2 as compared to group 1. Tissue Doppler imaging (TDI) can be useful in the detection of subclinical LV dysfunction in patients of rheumatic mitral valve disease. Myocardial strain offers an objective mean to quantify global and regional LV function and to improve the accuracy and reproducibility of conventional echocardiographic studies.

INTRODUCTION

Rheumatic mitral valve disease is a common valvular disease in developing countries, because it is a major consequence of rheumatic endocarditis. Chronic rheumatic heart disease (RHD) is characterized by repeated inflammation with fibrinous repair. The cardinal anatomic changes of the valve include leaflet thickening, commissural fusion, and shortening and thickening of the tendinous cords [1]. It is caused by an autoimmune reaction to Group A β-hemolytic streptococci (GAS) that results in valvular damage [2]. Fibrosis and scarring of valve leaflets, commissures and cusps leads to abnormalities that can result in valve stenosis or regurgitation [3]. About half of patients with acute rheumatic fever develop inflammation involving valvular endothelium. The majority of morbidity and mortality associated with rheumatic fever is caused by its destructive effects on cardiac valve tissue [3]. In rheumatic mitral valve disease, the pathophysiologic roles of mechanical and myocardial factors for impairment of LV performance are not yet clear [4].

Myocardial performance assessment has a crucial role in the diagnosis and treatment of patients with cardiac diseases. Generally, echocardiography is performed for evaluation of cardiac dimension, systolic and diastolic function. The Tei index alternatively known as

echocardiographic doppler index combines systolic and diastolic function. In humans, the Tei index is simple to calculate, reproducible, independent of heart rate, blood pressure and characterized by a low inter-observer and intra-observer variability [5]. However, one major limitation of the Tei index is that both relaxation and contraction velocities cannot be measured simultaneously within one cardiac cycle [6]. Therefore, accuracy of the index may be influenced by heart rate (HR) alteration [7].

Recently, tissue Doppler echocardiography (TDE) has been developed, by which quantitative evaluation of the wall motion velocities in various heart disease has become possible [8,9]. Tissue Doppler Imaging (TDI) enables us to measure both relaxation and contraction velocities simultaneously. Echocardiographic strain and strain-rate imaging (deformation imaging) is also a new non-invasive method for assessment of myocardial function. Due to its ability to differentiate between active and passive movement of myocardial segments, to quantify intraventricular dyssynchrony and to evaluate components of myocardial function, such as longitudinal myocardial shortening, that are not visually assessable, it allows comprehensive assessment of myocardial function and the spectrum of potential clinical applications is very wide [10].

The aim of the present study was to investigate whether the echocardiographic strain and strain-rate imaging technique is advantageous in evaluation of LV systolic function in patients with rheumatic mitral valve disease in comparison to conventional echocardiographic methods.

MATERIAL AND METHOD

The study included 30 patients with rheumatic mitral valve disease with sinus rhythm in addition to 30 healthy control subjects. The study was conducted in the department of cardiology at the U N Mehta Institute of Cardiology and Research Centre from August 2012 to December 2014.We excluded patients who had one or more of the following conditions like abnormal global systolic function, moderate to severe aortic regurgitation or stenosis, tricuspid stenosis, clinical, electrocardiographic, or angiographic evidence of coronary artery disease. All scheduled cases were subjected to twelvelead surface ECG, conventional echo-doppler and TDI for the assessment of LV function.

Echo Doppler study

Echo Doppler studies were performed in the left lateral position using Vivid - 7 GE system with tissue Doppler imaging capability with 2.5 MHz probe.

Conventional Echo Doppler assessment:

Echocardiographic studies were performed in the parasternal long-and short-axis, apical 2-chamber, 4-chamber, and long axis views employing M-mode, 2-D, and Doppler studies.LV chamber length and LV diameter were measured. Systolic volume, diastolic volume and ejection fraction were measured by Simpson's method.

2-D study

Assessment of mitral valve apparatus, measurement of mitral valve area by planimetry, and evaluation of any associated valvular lesions was done by 2D echocardiography. Colour flow was used to assess mitral regurgitation.

Doppler study

Mitral valve area by pressure half time (PHT) and mean diastolic pressure gradient (DPG) across mitral valve were measured using continuous wave doppler. The systolic pulmonary artery pressure was derived from the tricuspid regurgitant jet velocity by means of the modified Bernoulli equation ($\Delta P= 4v^2$) assuming a right atrial pressure of 10 mmHg. Tissue Doppler velocities were measured at the lateral mitral annulus1) Peak systolic myocardial velocity (Sm) 2) Early diastolic velocity (Em)3) Late diastolic velocity (Am).From the off line trace profile displacement at zero level, we measured the following: Isovolumetric contraction time (ICT), ejection time (ET), Isovolumetric relaxation time (IRT). The myocardial performance index (MPI) was measured by conventional Doppler method which is equals to (ICT +IRT / ET).

B- Strain imaging (SI)

Longitudinal deformation was obtained by using the same probe and activating strain imaging function. The wall on which the measurements from 2D imaging would be performed was positioned parallel to the transducer and the tissue velocity imaging (TVI) function was selected. The images were acquired including one wall by obtaining the probable narrowest angle and the maximum frame rate values. These images, consisting of a minimum of three sequential sinus beats at the end of the expiration, were recorded on digital media. These colour Doppler myocardial images were analysed offline via workstation. Measurements were performed just below the endocardium, by leaving a 10 mm distance between the two points. Segments presenting either a weak image or an angle gradient greater than 25° were not evaluated. The sample volume of the strain was placed at the following sites in apical 4 chamber view-apical lateral, apical septal, mid lateral, mid septal, basal lateral, basal septal. The trace profile was displaced for each segment to obtain the peak systolic myocardial deformation.SI measures were averaged from the 6 LV segments obtained from apical 4-chamber view.

Statistical Analysis

Statistical analysis was done using software SPSS v.20. Continuous variables were expressed as Mean±SD. The chi-square test was used for the comparison of proportions and the Student's t test was used for the analysis of the continuous variables. Statistical significance was accepted at the level of $p<0.05$.

RESULTS

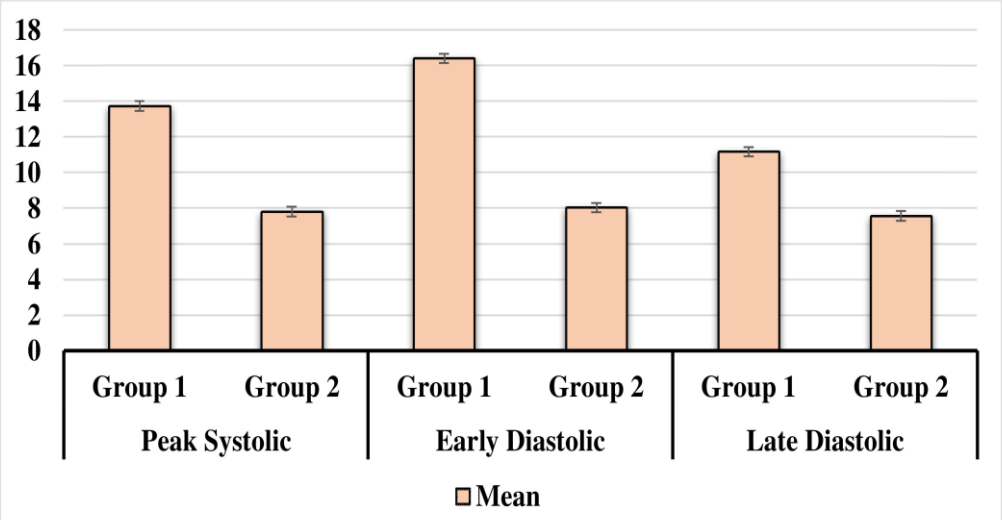
In present study 30 rheumatic mitral valve disease patients having mitral stenosis with or without mitral valve regurgitation were compared with 30 healthy individuals. The demographic and echocardiographic characteristics of the study population are presented in table 1.Significantly ($p=0.0007$) higher number of females were found in the study group. In the control group significantly higher LV chamber length (78.1 ± 4.69 vs 73.1 ± 8.8), LV systolic volume (42.92 ± 19.47 vs 34.83 ± 7.75) and LV ejection fraction (58.8 ± 2.65 vs 57.03 ± 2.32) was observed in comparison to the study group. However the difference between LV diameter and diastolic volume were found to be non-significant. According to the mitral valve area (MVA), 24 patients had severe stenosis (MVA: $\leq 1cm^2$), 6 had moderate (MVA: $\geq cm^2$).

Tei index (myocardial performance index) in study group was significantly higher than control group ($p<0.0001$) and is mentioned in Table 2. Myocardial performance indexobtained by TDI did not differ significantly than that obtained by conventional method but it was easier to measure it from tissue doppler tracing especially in patients with significant mitral regurgitation or tachycardia. The peak systolic (13.73 ± 2.51 vs 7.8 ± 1.42), early diastolic (16.4 ± 2.99 vs 8.03 ± 1.47) and late diastolic (11.17 ± 2.04 vs 7.56 ± 1.38) myocardial velocities were significantly ($p<0.0001$) reduced in the study group than controls(figure 1).

DISCUSSION

The current study results establish TDI as an important mode of technique for the detection of subclinical LV dysfunction in patients of rheumatic mitral valve disease. Left ventricular function in patients with mitral valve disease has been extensively investigated during the last decade. Classically used method - echocardiography allows better visualization of the mitral valve, cardiac structure and function. Early echocardiographic studies have not found load-independent LV contractile dysfunction; however, strain and strain rate imaging might show impaired long axis systolic velocity in patients with normal global systolic function [11]. Despite the common concept of preserved LV systolic function in patients with rheumatic mitral valve disease when assessed by conventional echocardiographic parameters, impaired LV long-axis function has been reported in many studies using recent echocardiographic modalities [12]. Earlier angiographic studies have recorded lower EF% in patients with rheumatic mitral valve disease as compareto controls [13]. Some angiographic studies found generalized rather than regional LV dysfunction in rheumatic mitral valve patients [14].

Figure 1. Systolic and diastolic myocardial velocity in both the groups



The comparison of peak systolic strain (PSS) and peak systolic strain rate (PSSR) of control and study group are presented in table 3. The PSS and PSSR values of basal, apical and lateral segment of LV were significantly ($p<0.05$) lower in the study group as compared to control.

Table 1. Myocardial performance index evaluated by conventional and TDI methods

S. No.	Variable	Group 1 (n=30)	Group 2 (n=30)	Significance
1	By conventional method	0.39 ± 0.03	0.46 ± 0.02	<0.0001
2	By TDI	0.39 ± 0.03	0.46 ± 0.02	<0.0001

Table 2. Demographic characteristics of the patients with mitral stenosis and healthy control

S. No.	Variable	Group 1 (n=30)	Group 2 (n=30)	Significance
1	Age	32.6 ± 9.61	27.77 ± 7.07	0.0305
2	Male	20(66.7)	6(20)	0.0007
3	Female	10(33.3)	24(80)	0.0007
4	LV chamber length	78.1 ± 4.69	73.1 ± 8.80	0.008
5	LV Diameter	40.73 1.83	39.33 4.10	0.094
5	LV Diastolic Volume	84.43 ± 19.35	76.83 ± 13.28	0.082
6	LV Systolic Volume	42.92 19.47	34.83 7.75	0.039
7	LVEF Simpson,%	58.8 ± 2.65	57.03 ± 2.32	0.008

Table 3. Values of peak systolic strain and peak systolic strain rate in patients and healthy controls

S. No	Variable	Group 1 (n=30)	Group 2 (n=30)	Significance
Peak Systolic Strain				
1	Strain- Base Lateral	23.46 ± 2.54	18.43 ± 1.37	<0.0001
2	Strain- Mid LV free wall	23.03 ± 1.74	17.75 ± 1.14	<0.0001
3	Strain-Apical LV Free Wall	22.02 ± 1.84	16.42 ± 0.99	<0.0001
4	Strain-Apical Septal	22.20 ± 2.37	16.37 ± 1.13	<0.0001
5	Strain-Mid Septal	21.84 ± 2.11	17.57 ± 1.24	<0.0001
6	Strain-Base septal	20.84 ± 1.62	17.78 ± 1.60	<0.0001
7	Strain-Rate Average	22.09 ± 1.43	17.38 ± 0.90	<0.0001
Peak Systolic Strain Rate				
1	Strain Rate- Base Lateral	2.48 ± 3.50	1.02 ± 0.17	0.026
2	Strain Rate- Mid LV free wall	1.64 ± 0.16	0.95 ± 0.14	<0.0001
3	Strain Rate- Apical LV Free Wall	1.35 ± 0.13	0.82 ± 0.19	<0.0001
4	Strain Rate- Apical Septal	1.35 ± 0.15	0.79 ± 0.09	<0.0001
5	Strain Rate- Mid Septal	1.5 ± 0.18	0.94 ± 0.10	<0.0001
6	Strain Rate- Base septal	1.22 ± 0.13	0.95 ± 0.10	<0.0001
7	Strain Rate- Average	1.49 ± 0.14	0.91 ± 0.07	<0.0001

Tissue doppler imaging is a popular modality used for the evaluation of myocardial wall motion velocities. Mitral annulus velocities, as determined by pulsed-wave TDI, are relative preload-independent variables in the evaluation of systolic and diastolic LV function [8,9]. Both peak systolic myocardial velocity and myocardial performance index (MPI) values, can be used as simple and reliable methods for evaluating LV myocardial performance. Assessment of the LV systolic function by conventional echocardiographic techniques in current investigation revealed preserved function in both - patients with rheumatic mitral valve disease and control group. Using TDI, our study revealed that the MPI was significantly increased among patients compared to control group. Assessment of the LV diastolic function in the study groups showed that the average peak systolic, early- and late diastolic velocity were significantly decreased among patients with rheumatic mitral valve disease compared to control group.

Since strain imaging echocardiography has been recently proved to offer an objective means to quantify global and regional LV function and improve the accuracy and reproducibility of conventional echocardiographic studies, it was added as a novel technique for evaluation of the LV long-axis function in our study. Assessment of the LV function by strain imaging in our study revealed significant decrease of the peak strain among patients with rheumatic mitral valve disease compared to the control group. This result is consistent to the result of Simşek Z etal(2010) who studied LV function in patients with rheumatic mitral stenosis using strain/strain rate imaging [15]. Our result was in agreement with that of Li et al (2013) who found that patients with mitral stenosis had lower LV- generalized linear least squares (GLLS) and

corresponded with LVEF% ($r = 0.601$, $P < 0.001$) [16]. In addition Bilen et al (2011) found a significantly lower LV strain and strain rate in patients with mitral stenosis compared with healthy subjects [17].

Using Tissue Doppler Imaging, Ozdemir et al (2002) showed that pure mitral stenosis results in significant reduction of LV systolic and diastolic myocardial velocities [18]. The systolic myocardial velocity showed a reduction in LV walls, but these were not uniform because of well-known limitation of Tissue Doppler Imaging. Myocardial velocities decrease from base to apex, and this complicates data interpretation. Previous studies demonstrated that systolic strain is constant throughout the myocardial wall [19, 20]. Weidemann et al (2009) also showed a similar distribution of strain rate values in healthy children, and a weak correlation was found with age [21].

In a recent published study, it was demonstrated that evaluation of global long axis function by strain rate imaging is a feasible method for detecting subclinical LV dysfunction and could accurately predict contractile reserve in asymptomatic patients with severe mitral regurgitation [22]. The current study demonstrates that like mitral regurgitation, LV function can be affected subclinically in mitral stenosis. In principle, systolic strain reflects the extent of myocardial fiber shortening, whereas strain rate reflects velocity of shortening. Therefore, myocardial strain and strain rate reflect somewhat different points of myocardial function.

In our study both strain, strain rate measured provided detailed information about regional LV function of patients who had moderate to severe mitral stenosis. Greenberg et al suggested that strain rate might be a sensitive marker of inotrophy [23]. Both strains and strain rates were found decreased in patients with mitral stenosis reflecting the subclinical LV systolic dysfunction in our study, but it is interesting that all of the control subjects had SR values above 1.1and most patients with mitral stenosis had strains below 20%.Therefore, both of these indexes, which are related to the myocardial scarring and calcification of cardiac structure, could be interpreted as early preclinical changes.

In the current study, strain rate imaging proved superior to other echocardiographic techniques in identification of impairment in myocardial function in patients with mitral stenosis. The effect of mitral stenosis on LV function is very complicated. Numerous mechanisms have been proposed, including chronically decreased chamber loading, endocardial fibrosis from rheumatic inflammation, abnormal right and left sided heart interactions, decreased systemic preload, elevated afterload, and valvular tethering [24, 25].Morphologic changes from functional ones cannot be distinguished in our study. However, it might be speculated that the peak systolic strain rate and end systolic strain decrease in mitral stenosis, and it may be speculated that the effects on these parameters are something required with valve hemodynamics beyond slight changes in myocardial contractility.

CONCLUSION

Our study revealed that the subclinical impairment of myocardial contractility in the patients with rheumatic mitral valve disease whom LVEF was within normal ranges according to conventional echocardiography could be effectively diagnosed by TDI technique. Hence TDI could be used as a strong indicator of LV dysfunction in the asymptomatic rheumatic mitral valve disease patients.

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DECLARATION OF INTEREST STATEMENT

The authors declare that they have no significant competing financial, professional or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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