

Echocardiographic Assessment of the Effect of Mitral Stenosis Severity on Left Ventricular Systolic Function Using Isovololumic Myocardial Acceleration

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Abstract:

Background: Isovolumic myocardial acceleration (IVA) is a new tissue Doppler parameter in the assessment of systolic function of both right and left ventricles. It remains unaffected with the changes in pre-and after load within the physiological range. With the advent of newer parameter like IVA, better assessment are naturally expected. Thus it creates a fertile ground where upon many studies are being done as it chosen here. The aim of study was to assess the effect of MS severity on LV systolic function using IVA.

Methods: In this cross sectional study, considering all ethical issues, data were collected from 96 patient (Isolated mitral stenosis and mitral valve area <2cm²) and 32 healthy control subjects. In addition to standard echocardiographic methods TDI (tissue Doppler imaging) were performed to assess LV function in all participants.

Results: This study showed a clear female preponderance (76%) of mitral stenosis and most of them belonging to age group 21-39 years. All TDI derived LV systolic (IVV, Sm and IVA) velocities were significantly decreased in patients with mitral stenosis, compared to the healthy control (P<.001, for all). However IVA was not different when the degree of MS was evaluated (P=.056). In addition IVA was not correlated with MVA (r=+0.196. P= 0.056).

Conclusions: Isovolumic myocardial acceleration was more accurate and consistent than conventional echocardiography in assessing subclinical left ventricular systolic dysfunction, IVA showed that left ventricular function is impaired with mitral stenosis regardless of severity of the disease. So this new echo parameter can be a good supplement to the existing 2D scoring system to detect systolic dysfunction in rheumatic mitral stenosis.

Key words: Mitral stenosis; left ventricular function ; tissue Doppler imaging; Isovolumic acceleration.

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Introduction:

Acute rheumatic fever (ARF) and rheumatic heart disease (RHD) have long been considered as an important cause of cardiac morbidity and mortality all over the world, especially in developing countries. Although rheumatic fever was thought to be nearly eradicated from developed countries. It continues to be a challenge because of its high prevalence in the developing world.¹A variety of epidemiologic studies have shown that the incidence of rheumatic fever and the prevalence of rheumatic heart disease have declined dramatically over the last few decades in the developed countries.²Recent reports has

documented incidence of RF as high as 206/100,000 and RHD prevalence as high as 18.6 /1000 though there are variations in the different geographical areas.

The mitral valve is the most frequently affected valve in rheumatic heart disease. It is solely affected in 25% and with other valves in 40% cases.³Rheumatic heart disease (RHD) causes a significant number of morbidity and mortality in Bangladesh and accounts for 34 to 42% of hospital admission of all cardiac cases and the prevalence of rheumatic fever and rheumatic heart disease in Bangladesh is 1.2 and 1.3 per thousand population respectively.⁴ Mitral stenosis still leads to significant

morbidity and mortality worldwide.¹ Rheumatic mitral valve stenosis affects left ventricular functions at various levels due to its inflammatory and hemodynamic factors.^{5,6}

Recently in the studies using TDI, which is most sensitive methods compared to the conventional echocardiography in detecting subclinical left ventricular systolic dysfunction in MS patients with preserved LVEF.^{7,8,9} Systolic dysfunction of LV was suggested to be associated with the severity of myocardial involvement in isolated mitral valve stenosis during the rheumatic attack, not with the degree of the mitral stenosis,^{10,11} and hemodynamic factor is also responsible for LV systolic dysfunction.¹¹ Furthermore, subclinical LV systolic dysfunction improved following the percutaneous balloon mitral valvuloplasty.⁸

Isovolumic acceleration (IVA) is a new tissue Doppler parameter for the assessment of systolic function of both left and right ventricles.^{12,13} IVA is calculated as a ratio of tissue Doppler derived peak myocardial velocity during isovolumic contraction (IVV) divided by the acceleration time (AT). This parameter has been validated in a variety of experimental¹² and clinical settings.^{14,15} IVA remains unaffected by the changes in the preload and afterload with the physiological range including age, sex and BMI.^{12,14,15} It can detect even small changes in the contractile function and is well correlated with the invasive or noninvasive measures of LV dp/dt.

Therefore IVA can be used as a valuable and easy parameter for the quantification of global systolic function in various cardiac diseases.^{16,17} In the current study it is aimed to assess the effect of mitral valve stenosis on left ventricle systolic function using TDI derived isovolumic acceleration (IVA).

Methods:

A total number of 96 isolated mitral valve stenosis patients with preserved LVEF and sinus rhythm (mean age 28 ± 4 years) 75% (78.3%) females and 32 healthy volunteers (mean age 28 ± 3) 22 (68.7%) females were included in our study. All of the participants underwent both conventional echocardiography and TDI. The patients with MS were divided into three groups (mild, moderate & severe) based on their mitral valve area (MVA) determined by ECHO & mean diastolic gradient. 22 patients with mild stenosis ($MVA > 1.5 \text{ cm}^2$ mean gradient $< 5 \text{ mmHg}$) 36 patients with moderate stenosis ($MVA 1-1.5 \text{ cm}^2$, mean gradient 5-10 mmHg) and 38 patients with severe stenosis ($MVA < 1 \text{ cm}^2$, mean gradient $> 10 \text{ mmHg}$).

Patient who had coronary artery disease, moderate to severe aortic & mitral regurgitation, aortic stenosis, hyperthyroidism, COPD, atrioventricular conduction abnormalities, segmental wall motion abnormalities, LBBB, HTN (persistent elevated BP $> 140/90 \text{ mmHg}$ or taking anti hypertension medicine) & severely calcified mitral valve structure were excluded in the study.

Written informed consent form was obtained from the patients following approval of the study by the institutional review board. The study was consistent with the declaration of Helsinki.

All the ECHO evaluations were performed by 2 different investigators. In order to detect the intraobserver variability, the first investigator repeated the ECHO measurement of 20 patients and the second investigator measured TDI-derived parameters of 20 patients to detect interobserver variability.

Conventional echocardiographic examination:

All of the trans-thoracic echocardiographic (TTE) examinations were performed using GE vivid S7 Vingmed system 7 (Norway, Horten) equipped with 2.5-4 MHz transducers. All of the patients were examined in the left lateral and supine positions with two-dimensional, M-mode, pulsed, and color flow Doppler echocardiography. Single lead electrocardiogram was recorded continuously. An average of at least 3 to 5 cardiac cycles were obtained for all measurements. LVEF was estimated by Biplane Simpson's method. Mitral valve area was measured by planimetry method in mid diastole using 2-dimensional short axis image, careful scanning from apex to the base of the LV was done to measure the cross sectional area at the leaflet tips while the gain was set at lowest limit to visualize the whole mitral orifice and the measurement plane was perpendicular to the mitral orifice. Mean transmitral diastolic gradient was calculated by Doppler tracings in the apical four chamber.¹⁸

Tissue Doppler Imaging :

In the two-dimensional, apical four-chamber view, a 5 mm sample volume was placed just apical to the medial and lateral mitral annulus using pulsed-wave TDI at the end of expiration. Doppler echocardiography was performed using transducer frequencies between 3.5 to 4.0 MHz, by adjusting the spectral pulsed Doppler signal filters until a Nyquist limit of 15 to 20 cm/s was reached, and using the minimal optimal gain. Three to five consecutive cycles were recorded with a frame rate greater than 150 fps. The monitor sweep speed was set at 50 to 100 mm/s to optimize the spectral display of myocardial velocities. Every efforts were made to align the pulsed wave cursor so that the Doppler angle of incidence as close to 0° as possible to

the direction of these walls. Peak myocardial isovolumic contraction velocity (IVV), peak myocardial systolic velocity (Sm), isovolumic acceleration time (AT), Myocardial acceleration during isovolumic contraction (IVA) were calculated from three consecutive cycles and the average of these measurements were recorded .

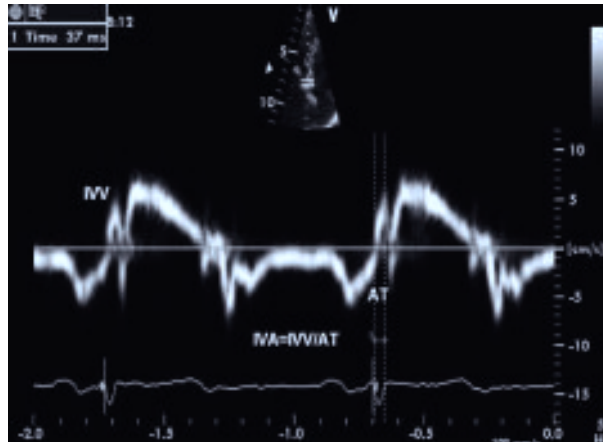


Fig.-1: TDI derived velocities obtained from basal septal wall of LV in apical four chamber view.¹¹ IVV peak myocardial velocity during isovolumic contraction ;AT-Isovolumic acceleration time, IVA-myocardial acceleration during isovolumic contraction.Sm peak myocardial systolic velocity

Statistical Analysis:

Statistical analysis were performed using SPSS software version 16. Categorical data were expressed in percentage or number Numeric data were expressed in mean ± SD. The variables were investigated using visual and analytical methods to determine whether they were normally distributed or not.

Groups were compared using one way ANOVA, Chi-square test as applicable. Correlation analysis were derived by using Pearson’s correlation- coefficient (r) test. The results were considered significant, when the P value is less than 0.05.

Results:

Clinical & conventional echocardiographic parameters such as age & sex were similar in both MS and healthy groups. LVEF were similar in both the patients & the control group. A stepwise decrease was found in the MVA from mild to severe MS (P<0.001) & stepwise increase in the mean transmitral gradient from mild to severe MS (P<0.001). All the TDI-derived global LV systolic (IVV IVA, Sm) velocities were significantly decreased in the patients with MS compared to healthy groups (P<0.001, for all) (Table V, VI & VIII).MVA was positively correlated with IVV & Sm velocities (P <0.01 & 0.05 respectively), however there were no correlations between IVA & MVA (P 0.056).

Table I
Comparison of the tissue Doppler derived Isovolumic contraction velocity (IVV) of the study subjects . (N=96 in group-A and N=32 in group-B

Group-A				Group-B	
Mild MS (n=22)	Moderate MS (n=36)	Severe MS (n=38)	p value	Control (N=32)	P value
5.70±0.54	5.48±0.59	5.12±0.55	0.001 ^s	6.80±1.08	<0.001 ^s

Table-II
Comparison of the tissue Doppler derived peak myocardial systolic velocity (Sm) of the study subjects. (N=96 in group-A and N=32 in group-B).

Group-A				Group-B	
Mild MS (n=22)	Moderate MS (n=36)	Severe MS (n=38)	Pvalue	Control (N=32)	p value
8.38±0.68	7.90±0.70	7.42±0.64	0.05 ^s	9.75±0.68	<0.001 ^s

Table VIII
Comparison of the tissue Doppler derived Isovolumic acceleration (IVA) of the study subjects. (N=96 in group-A and N=32 in group-B).

Group-A				Group-B	
Mild MS (n=22)	Moderate MS (n=36)	Severe MS (n=38)	Pvalue	Control (N=32)	p value
2.58±0.42	2.51±0.45	2.32±0.44	0.053 ^{ns}	3.07±0.32	<0.001 ^s

Table-IV
Correlations between TDI derived left ventricular systolic velocities and conventional echocardiographic parameters of MS patients (N=96).

		IVV	Sm	AT	IVA	
MVA	r		+0.310	+0.368	+0.023	+0.196
	P	<0.01 ^s	<0.05 ^s	0.823 ^{ns}	0.056 ^{ns}	
Mean Gradient	r		-0.326	0.204	0.146	0.143
	P	<0.01 ^s	<0.05 ^s	0.157 ^{ns}	0.164 ^{ns}	

Discussion:

Our study revealed subclinical LV systolic dysfunction in patients with rheumatic mitral stenosis which was independent of the severity of MS. In MS patients varying degree of LV systolic dysfunction occurs (Ozer et al. 2004; Ozdemir et al. 2002; Ozdemir et al. 2003).^{7,9,19} Study conducted by T. M. Lee et al. in 1966,²⁰ found that most patients with impaired LVEF showed improvement after balloon mitral valvuloplasty but others did not. Sengupta et al. in 2004 studied MS patients with reduced LVEF by TDI.⁸ LVEF is widely used conventional parameter in evaluating LV global function in MS. However, it has an important limitation as not being able to detect subclinical LV systolic dysfunction. TDI-derived measurements also became wide spread for quantifying global and segmental LV functions (Donovan et al. 1995; Alam et al. 2000).^{21,22} Although it is angle and load dependent and has velocity aliasing limitation yet it is less load-dependent than conventional parameters.

Subclinical LV systolic dysfunction related to MS had been evaluated via several different methods. Gash et al. detected that ejection phase indices decreased in patients with rheumatic mitral stenosis when compared with healthy control.²³ Kurtulus et al. used TDI,²⁴ Dogan et al. and Simsek et al. used Doppler strain,^{25,26} and Ozdemir et al.⁹ used 2D strain imaging in the assessment of subclinical LV systolic dysfunction in patient's with mitral stenosis which is similar to this study.

In this study it was observed that majority of patients were female which was similar to the study conducted by Erturk et al. and mean age was found 28.40±4.13 years in MS patients and 29.44±3.04 years in healthy control. Mean age of MS patient showed dissimilarity to the aforementioned study which might be due to aggressive and early involvement of mitral valve. Age & sex differentiation was not significant statistically. As an expected result this study showed mean transmitral gradient were significantly higher as the degree of mitral stenosis progresses (Table-IV). A stepwise decrease was found in the mitral valve area from mild to severe MS.

Correlations between TDI velocities and conventional echocardiographic parameters of MS patients it was

observed that MVA and mean gradient were positively correlated with IVV, Isovolumic contraction velocity and Sm, peak myocardial systolic velocity (Table-IX).

From this study it was revealed that all the TDI-derived LV systolic velocities (IVV, Sm and IVA) were significantly reduced in patients with MS when compared to healthy control ($p < 0.001$). IVA, the most important tissue Doppler parameter represents LV systolic function did not differ among the three MS group ($p = 0.053^{ns}$) Table-VIII. IVV, peak myocardial velocity during isovolumic contraction, Sm, peak myocardial systolic velocity decreased as the degree of MS progress. A recent study similar to this conducted by Erturk M et al. in 2013¹¹ showed all the TDI derived LV systolic velocities (IVV, Sm, IVA) were significantly decreased in MS patients and IVA was not correlated with the severity of MS

In the year 2006, a study conducted by Dogan et al.²⁵ demonstrated the changes in left ventricular function by means of TDI in isolated rheumatic MS patients, showed that significantly lower peak systolic myocardial velocities in both the lateral wall and interventricular septum of the left ventricle, indicating reduced LV systolic function. They also found that peak systolic myocardial velocity measured at septum and lateral wall of LV was significantly reduced and it was correlated with the severity of MS.

Tayyareci et al. in 2008,¹⁶ investigated the IVA of RV in prediction of the degree of MS and demonstrated that Sm, IVV and IVA significantly decreased in the patients with MS compared to the control group, however, they found that only RV dysfunction and IVA can predict the degree of MS. Decreased IVA of LV was found in MS patients in our study but it was not correlated with severity of stenosis.

Our study revealed subclinical LV systolic dysfunction in patients with rheumatic mitral stenosis. TDI is a recent technique in echocardiography for accurate quantification of systolic myocardial function. There were few reports on its utilization in evaluating systolic functions in MS (Sengupta et al. 2004).⁸

In the light of these findings it can be concluded despite the presence of seemingly normal LV functions on standard

echocardiography, TDI detects subclinical LV systolic dysfunction in patients with MS, representing early sign of myocardial abnormality.

Conclusion:

In conclusion, it is demonstrated that subclinical left ventricular systolic dysfunction, detected by tissue Doppler derived IVA is present in all patients with mitral stenosis and this condition is not affected by the degree of mitral stenosis. So detection of subclinical left ventricular systolic dysfunction in patients with mitral stenosis, IVA has emerged as a reliable, useful echocardiographic parameter in detecting in patients with rheumatic mitral stenosis.

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