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Comparison Between Isovolumic Acceleration and Conventional Echocardiograhic Parameters in Detecting Early Right Ventricular Systolic Dysfunction in Patients with Mitral Stenosis

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Abstract

Aim: The aim of the study was to determine if the tissue Doppler imaging (TDI)-derived myocardial acceleration during isovolumic contraction (IVA) of tricuspid lateral annulus could be used in early detection of RV systolic dysfunction in patients with mitral stenosis (MS), before the clinical signs of systemic venous congestion occur and to compare between IVA and conventional echocardiographic parameters in detecting early RV systolic dysfunction in patients with MS .

Methods: Ninety-six patients with severe rheumatic MS without relevant regurgitation were enrolled in the study. Conventional echocardiographic parameters (mitral valve area, transmitral diastolic gradients, pulmonary artery pressure, RV fractional area change, pulmonary flow acceleration time, tricuspid annular plane systolic excursion) and TDI-derived systolic velocities of tricuspid annulus (isovolumic myocardial acceleration: IVA, peak myocardial velocity during isovolumic contraction: IVV, peak systolic velocity during ejection period: Sa and RV MPI) were recorded from all patients.

Results: TDI-derived IVA, IVV, Sa were significantly decreased in patients with MS and RV MPI is increased in patients with MS. IVA was the only parameter which had a significant negative correlation with the traditional echocardiographic parameters and RV Tei index in patients with MS.

Conclusion: TDI-derived right ventricular IVA may be used as an adjunctive, reliable, noninvasive parameter for the early detection of right ventricular systolic dysfunction in patients with MS but without signs of systemic venous congestion. RV IVA negatively correlate with RV MPI, positively correlate with IVV and Sa. RV IVA shows positive correlation with RVFAC and negative correlation with PAP, LA size. IVA shows no correlation with TAPSE.

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Introduction:

Mitral stenosis is the most important sequel of acute rheumatic fever. Mitral stenosis still leads to significant morbidity and mortality worldwide despite revolution in diagnosis and treatment.[1] According to the annual report by the World Heart Federation 15.6 million people are currently affected by rheumatic heart disease with a significant number of them requiring repeated hospitalization.[2] About 40% of all patients with rheumatic heart disease have isolated mitral stenosis and 60% have combined mitral stenosis and mitral regurgitation.[3]

Mitral stenosis has a pathophysiologic process which results in RV failure.[4] During the initial period of MS, pulmonary venous hypertension is followed by pulmonary artery hypertension due to combined effects of back pressure, pulmonary arteriolar constriction and obliterative changes in pulmonary vascular bed which increases RV afterload. A significant chronic increase in afterload ultimately results in failure with RV dilatation, tricuspid regurgitation and systemic venous congestion. RV failure with signs of systemic venous congestion is easy to detect. However, clinical assessment of RV function is not possible in all patients without signs of systemic venous congestion.

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Hirata et al. [5] state that 'right ventricular systolic function significantly affects symptoms, exercise capacity and mortality rates in patients with mitral stenosis'.

However, in the pathogenesis of the MS, RV dysfunction occurs early before the systemic venous congestion develops. 'RV functions cannot reliably be evaluated by conventional echocardiography techniques because of its asymmetrical shape, narrow acoustic window and geometrical assumptions for volume calculations'. [6,7]

Radionuclide ventriculography, cardiac catheterization, cardiac magnetic resonance imaging (MRI) and 3-dimensional echocardiography could be used for the assessment of RV function.[8-10] However, these methods are time consuming and not widely available.

In previous studies, ejection phase myocardial velocities measured by tissue Doppler imaging (TDI) have been shown to be well correlated with right ventricular ejection fraction.[11-12]However, they were found to be preload and afterload dependent. [13]

Isovolumic acceleration (IVA) is a new tissue Doppler parameter for the assessment of systolic function of both ventricles. IVA is calculated as a ratio of tissue Doppler-derived peak myocardial velocity (IVV) during isovolumetric contraction divided by the acceleration time (AT). This parameter has been validated in a variety of experimental[14] and clinical settings.[15]Vogel et al.[14] showed that myocardial velocity indices measured during the isovolumic contraction (IVC) phase would be less load dependent. It can detect small changes in the contractile function and is well correlated with the invasive or noninvasive measures.

The aim of the study is to determine if the IVA measured by TDI of tricuspid lateral annulus could be used in early detection of RV systolic dysfunction in patients with mitral stenosis, before the signs of systemic venous congestion occur and to compare IVA with conventional echocardiographic parameters in patients with MS.

Materials and Methods:

This study was carried out at the Department of Cardiology, Bangabandhu Sheikh Mujib Medical University, Dhaka, from July 2015 to June 2016. The research protocol was approved by the Institutional Review Board, BSMMU, Dhaka. It was a Cross-sectional study. Ninety-six patients of rheumatic severe mitral stenosis in sinus rhythm were enrolled consecutively following the inclusion and exclusion criteria. Exclusion criteria were low quality echocardiographic image of tricuspid annular velocities by TDI, any disease that could affect myocardial functions (e.g., coronary artery disease, chronic lung disease, cardiomyopathies), atrioventricular conduction abnormalities, atrial fibrillation and having signs of systemic venous congestion and right heart failure.

Study Procedure

All the patients presented with rheumatic mitral stenosis with sinus rhythm who are not excluded by exclusion criteria were enrolled consecutively. Detailed history, and thorough physical examination were done. At first all the patients will be assessed by conventional echocardiogram. Only the patients of severe mitral stenosis (MVA ≤1.5 cm2, diastolic pressure half time ≥150 ms) were enrolled according to the 2014 ACC/AHA guideline for the management of patients with valvular heart disease.

Conventional echocardiography was followed by Tissue Doppler Imaging.

Conventional Echocardiographic Examination

All the transthoracic echocardiographic (TTE) examinations were performed using GE vivid 7 Vingmed system 5 (Norway, Horten) equipped with 2.5-4 MHz transducers. All 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 cardiac cycles were obtained for all measurements. M-mode measurements and conventional Doppler echocardiographic examinations were performed based on the criteria of the American Society of echocardiography guidelines.[17] Left atrial (LA) diameter was calculated from the parasternal long axis view by M-mode echocardiography.

Tricuspid annular plane systolic excursion (TAPSE, mm) was measured in M-mode, using cursor in apical four-chamber view, at junction of tricuspid valve with the right ventricular free wall. Maximum displacement during systole was evaluated.

By using apical four-chamber view, end-diastolic and end-systolic areas of RV cavity were calculated using planimetry and RV fractional area change (RVFAC%) was calculated (end-diastolic area – end-systolic area)/end-diastolic area) x 100.

Mitral valve area (MVA) was obtained by planimetric measurements and pressure half time method. The area was calculated by the mean value of two measurements.[18]

Maximum and mean transmitral diastolic gradients were calculated by Doppler scanning. Pulmonary artery systolic pressure (PASP, mmHg) was obtained by continuous-wave Doppler imaging using the Bernoulli equation.

Tissue Doppler Imaging

Guided by the 2D, four-chamber view, a 5-mm sample volume was placed on the tricuspid annulus at the place of attachment of the anterior leaflet of the tricuspid valve for measuring TDI-derived systolic velocities. Settings was adjusted for a frame rate between 120 and 180 Hz and a cine loop of 3–5 consecutive heartbeats were recorded. Care was taken to obtain an ultrasound beam parallel to the direction of tricuspid annular motion. The pulsed wave TDI-derived systolic indices; peak myocardial velocity during isovolumic contraction (IVV, cm/s); myocardial acceleration during isovolumic contraction (IVA, m/s2), defined as the ratio of IVV divided by the acceleration time, and peak velocity during systolic ejection (Sa, cm/s) were measured.

RV MPI was calculated as the sum of isovolumic contraction time (IVCT) and isovolumic relaxation time (IVRT) divided by ejection time (ET). All the measurements were calculated from three consecutive cycles and average of three measurements was recorded.

All the echocardiographic evaluations were performed by two experienced investigators to detect any intra-observer variability.

Statistical analysis

All statistical data were processed using the SPSS software version 16. Categorical data were expressed in percentage or number. Numerical data were expressed in mean ± SD. Correlation analysis was derived by using Pearson's correlation coefficient (r) test. The results were considered significant when the p-value was less than 0.05.

Results:

Table-I

Age distribution of the study patients (n= 96)

Age group (years)	Frequency	Percentage
20-30	60	62.5
31-40	36	37.5
Total	96	100.0
Mean± SD	29.45±4.84	
Range	(20-40) years	

Data are presented as mean±SD and no (%)
n = Number of study population
SD = Standard deviation

Table-II

Sex distribution of the study patients (n = 96)

Sex	Frequency	Percentage
Male	30	30.0
Female	66	70.0
Total	96	100.0

Male : Female ratio 1:2.2
Data are presented as no and percentage
n = Number of study population

Table-III

Correlation between IVA and other tissue Doppler derived parameters (n= 96)

Parameters		Pearson's Correlation	
		r	p
IVA	Sa	+ 0.189	0.060
	IVV	+ 0.426*	<0.001
	MPI	-0.705*	<0.001

Pearson's correlation coefficient (r) test was performed between IVA and other tissue doppler derived parameters echocardiographic parameters. The test of significance was calculated and p value < 0.05 was accepted as level of significance.

There was a significant positive correlation between IVA and IVV (r = 0.426, p <0.001). However, Sa showed weak positive correlation with IVA (r = 0.189, p = 0.060). IVA showed significant negative correlation with MPI (r= -.705, p <.001).

Table-IV

Correlation between IVA and conventional echocardiographic parameters (n= 96)

Parameters		Pearson's Correlation	
		r	p
IVA	LA	- 0.520*	<0.001
	RVAWT	-0.274*	0.006
	RVFAC	+0.531*	<0.001
	TAPSE	+0.065	0.523
	PAT	+0.357*	<0.001
	PASP	-0.517*	<0.001
	MVA	+0.441*	<0.001

Pearson's correlation coefficient (r) test was performed between IVA and conventional echocardiographic parameters. The test of significance was calculated and p value < 0.05 was accepted as level of significance.

IVA was very well correlated with LA diameter (r = -0.520, p < 0.001. There was a weak negative correlation with RVAWT (r= -0.274, p< 0.006). IVA showed significantly positive correlation with PAT (r= 0.357, p< 0.001). IVA had positive correlation with RVFAC (r = + 0.531, p < 0.001). IVA had significant positive correlation with MVA (r = .44, p <.001). IVA had no correlation with TAPSE (r = 0.065, p < 0.523).

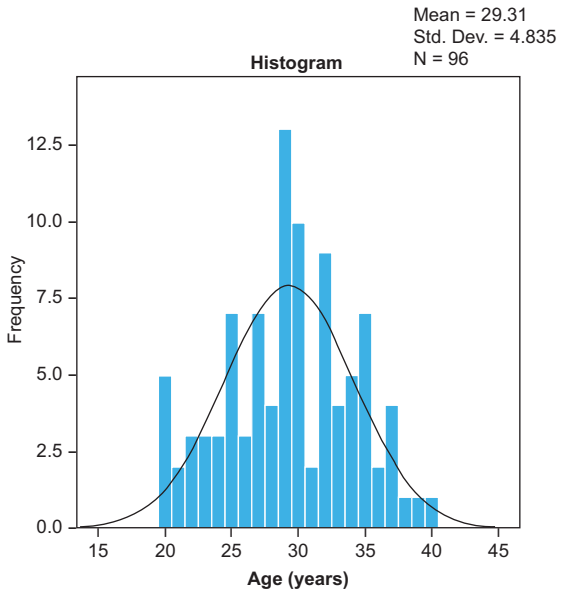

Fig-1: *Histogram showing the age distribution of the study patients*
Data are presented as mean SD and no (%)
n = Number of study population
SD = Standard deviation
IVA vs IVV
R = +.426 p < .001

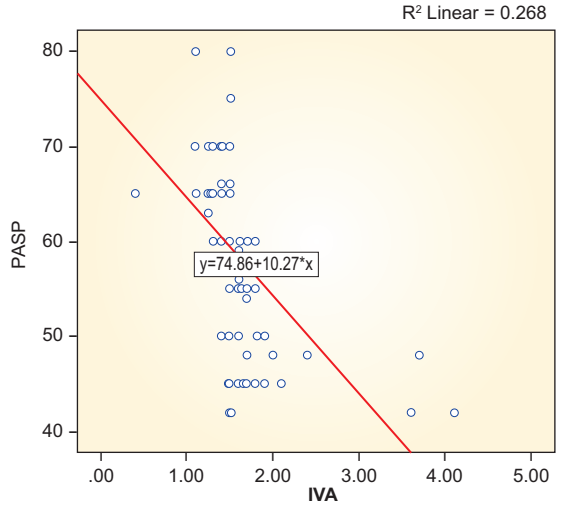

Fig.-2: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with IVV*
IVA = Isovolumic myocardial acceleration
IVV = Isovolumic velocity
IVA vs Sa
R= +.189 p < .06

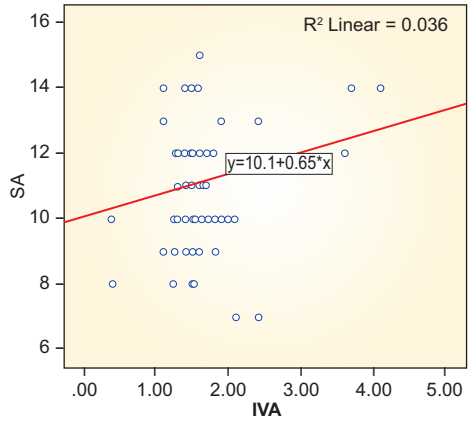

Fig.-3: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with SA*
IVA= Isovolumic myocardial acceleration
Sa = Peak systolic velocity during ejection phase
IVA vs MPI; R= -.705 p < .001

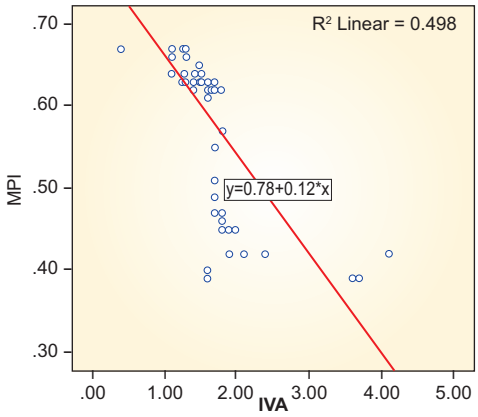

Fig 4: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with MPI*
IVA = Isovolumic myocardial acceleration
MPI = Myocardial performance index
IVA vs TAPSE; (r = .06 P < .52)

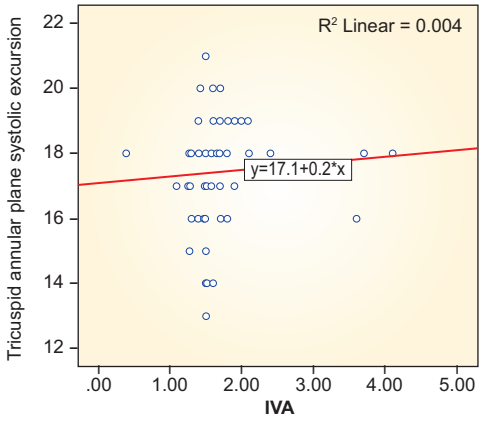

Fig.-5: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with TAPSE*
IVA = Isovolumic myocardial acceleration
TAPSE= Tricuspid annular plane systolic excursion
IVA vs RVFAC; r = + .567 p < .001

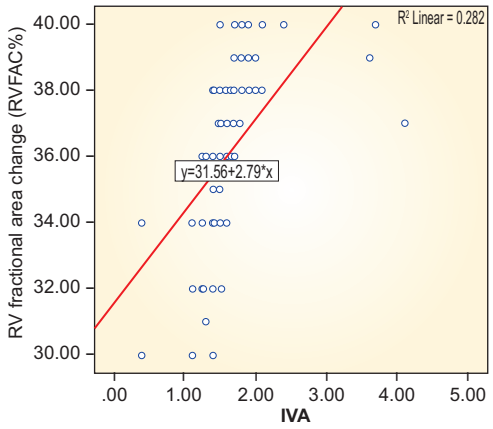

Fig.-6: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with RVFAC*
IVA = Isovolumic myocardial acceleration
RVFAC = Righr ventricular fractional area change
IVA vs MVA
R = .441 p <.001

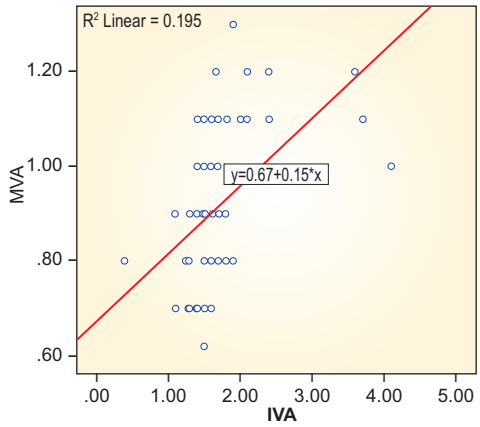

Fig.-7: *Scatter diagram showing correlation between IVA and MVA*
IVA = Isovolumic myocardial acceleration
MVA= Mitral valve area
IVA vs PASP
r = .517 P .001

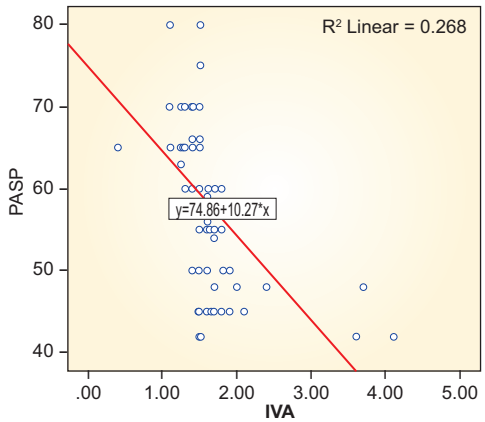

Fig.-8: *Scatter diagram showing correlation of isovolumic myocardial acceleration (IVA) with PASP*
IVA = Isovolumic myocardial acceleration
PASP = Pulmonary artery systolic pressure

Discussion:

Our study revealed that TDI-derived RV IVA had a good correlation with right ventricular systolic dysfunction in patients with MS. IVA had a significant negative correlation with the conventional parameters of PASP, RVAWT, LA diameter and RV myocardial performance index.

Mitral stenosis has a physio pathologic process which results in RV failure.[4]

Vogel et al[14] showed that TDI-derived index of myocardial acceleration during isovolumic contraction (IVA) has been validated to be a reliable and relatively load independent measure of RV systolic functions.

Tayyareci et al[19] investigated the IVA of RV in prediction of the degree of MS and demonstrated that Sa, IVV and IVA significantly decreased in patients with MS compared to the control group, however, they found that only RV dysfunction and IVA can predict the degree of MS.

Our study also revealed that IVA of RV was also decreased in patients with MS. Mean RV IVA of our study was lower than previous study[19] which may be due to the fact that our study includes only the patient of severe mitral stenosis.

Other TDI-derived parameters of RV systolic function such as peak myocardial velocity during isovolumic contraction (IVV) peak systolic velocity during ejection period (Sa) were significantly decreased in patients with MS.

In our study IVA showed significant positive correlation with IVV which is similar to previous study.[19]

In previous study[19] showed no correlation between IVA and peak systolic velocity during ejection period (Sa). In our study IVA showed weak positive correlation with peak systolic velocity during ejection period (Sa) which may be due to the fact that we studied only the patient of severe mitral stenosis.

Previous study Tayyareci et al[19] showed no correlation between peak myocardial velocity during isovolumic contraction (IVV) and peak systolic velocity during ejection period (Sa).

Bharathi et al[20] investigated the efficacy of isovolumic acceleration (IVA) in assessing right ventricular function in pulmonary hypertension by comparing with control group. They showed that RV IVA had significant negative correlation with TDI derived myocardial performance index (MPI) in patients with pulmonary hypertension.

Tayyareci et al[19] also showed that IVA can detect early RV systolic dysfunction in patients with mitral stenosis

and it shows significant negative correlation with MPI . Our study also revealed significant negative correlation between IVA and MPI in patients with mitral stenosis which is similar to previous study.

Bharathi et al[20] showed that isovolumic acceleration has good significant positive correlation with right ventricular fractional area change (RVFAC) in patients with pulmonary hypertension which is similar to our study.

'Two-dimensional assessment of right ventricular function: an echocardiographic-MRI correlative study 'which is done by Anavekar et al[21] showed that RVFAC measured by echocardiography correlated best with MRI derived RVEF.

So American Society of Echocardiography Guidelines (2010: 23) recommended the RVFAC as a quantitative measure of RV function.

Tayyareci et al[19] showed that there is no relation between RV IVA and TAPSE in patient with mitral stenosis which is similar to our study.

Anavekar et al[21] showed that there was no correlation between MRI derived RVEF and tricuspid annular motion (TAM) but Bharathi et al (2014: 5) showed weak correlation between IVA and TAPSE. So we suggest further study to establish a correlation between RV IVA and TAPSE.

Tayyareci et al[19] showed that RV IVA shows significant negative correlation with pulmonary artery pressure in patients with MS which is similar to our study.

Tayyareci et al[19] showed that RV IVA shows significant negative correlation with mitral valve area (MVA) in patients with MS which is similar to our study.

Tayyareci et al[19] also showed that RV IVA shows significant negative correlation with left atrial (LA) diameter in patients with MS which is similar to our study.

Tayyareci et al[19] showed that RV IVA shows weakly negative correlation with right ventricular anterior wall thickness (RVAWT) which is similar to our study.

Tayyareci et al[19] showed that RV IVA shows moderately positive correlation with pulmonary acceleration time (Pat) which is similar to our study.

In this study it was observed that majority of patients were female which was similar to the previous study.[19] In their study female patients were 70.5% and in our study it is about 70% also.

In our study mean age of the MS patients were 29.454.83 years which is obviously different from other study.[19] In their study mean age of MS patients were 51.63years. It may be due to high prevalence of rheumatic fever in the developing world.[1]

Rheumatic heart disease causes 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.[22]

. In the western world mitral stenosis takes many years to develop and is mostly a disease of adult life, this is in striking contrast to the developing countries where mitral stenosis can develop rapidly and therefore often affects adolescents and even children as young as 5 years of age- "Juvenile mitral stenosis.[23]

In Previous study[19] mean BMI was 23 and our study mean BMI was 20.02 1.03 kg/m2. This comparatively low BMI may be due to the low socioeconomic status of our population. Besides this mean body weight of the Asian population is lower than that of European.

Conclusion:

TDI-derived right ventricular IVA may be used as an adjunctive, reliable, noninvasive parameter for the early detection of right ventricular systolic dysfunction in patients with MS but without signs of systemic venous congestion. RV IVA negatively correlate with RV MPI, Positively correlate with IVV and Sa.

RV IVA shows positive correlation with RVFAC and negative correlation with PAP, LA size. IVA shows no correlation with TAPSE.

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