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Original Article

Effect of balloon mitral valvotomy on left ventricular function in rheumatic mitral stenosis

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ABSTRACT

Aim: Mitral stenosis (MS) is found to produce left ventricular (LV) dysfunction in some studies. We sought to study the left ventricular function in patients with rheumatic MS undergoing balloon mitral valvotomy (BMV). Ours is the first study to analyze effect of BMV on mitral annular plane systolic excursion (MAPSE), and to quantify prevalence of longitudinal left ventricular dysfunction in rheumatic MS.

Methods: In this prospective cohort study, we included 43 patients with severe rheumatic mitral stenosis undergoing BMV. They were compared to twenty controls whose distribution of age and gender were similar to that of patients. The parameters compared were LV ejection fraction (EF) by modified Simpson's method, mitral annular systolic velocity (MASV), MAPSE, mitral annular early diastolic velocity (E′), and myocardial performance index (MPI). These parameters were reassessed immediately following BMV and after 3 months of procedure.

Results: MASV, MAPSE, E′, and EF were significantly lower and MPI was higher in mitral stenosis group compared to controls. Impaired longitudinal LV function was present in 77% of study group. MAPSE and EF did not show significant change after BMV while MPI, MASV, and E′ improved significantly. MASV and E′ showed improvement immediately after BMV, while MPI decreased only at 3 months follow-up.

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Abbreviations: MS, mitral stenosis; BMV, balloon mitral valvotomy; LV, left ventricle; EF, ejection fraction; MAPSE, mitral annular plane systolic excursion; MASV, mitral annular systolic velocity; E′, early diastolic mitral annular velocity; MPI, myocardial performance index; TDE, tissue Doppler echocardiography; RHD, rheumatic heart disease; AF, atrial fibrillation; ROC, receiver–operating characteristics; IVCT, isovolumic contraction time; IVRT, isovolumic relaxation time.

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Conclusions: There were significantly lower mitral annular motion parameters including MAPSE in patients with rheumatic mitral stenosis. Those with atrial fibrillation had higher MPI. Immediately after BMV, there was improvement in LV long axis function with a gradual improvement in global LV function. There was no significant change of MAPSE after BMV.

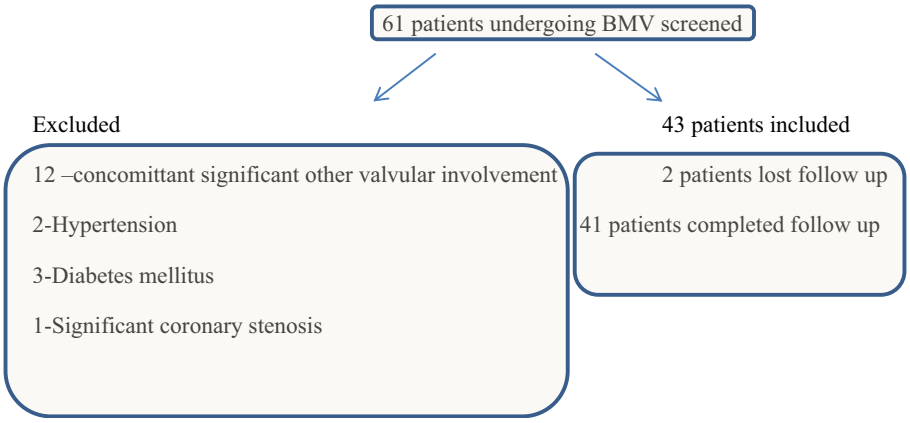
1. Introduction

Left ventricular (LV) dysfunction has been described in mitral stenosis (MS),[1–4] which may be a due to change in interaction between right and left ventricles, myocardial fibrosis or a chronic decrease in preload.[5] Even with normal ejection fraction (EF) (indicating preserved global left ventricular function), there can be impairment in long-axis function (measured by tissue Doppler echocardiography).[6,7] Altered LV long-axis movement has been shown to be a sensitive indicator of early myocardial dysfunction. Atrial fibrillation has shown to cause impairment of LV function. Pulsed-wave Doppler tissue velocities have been proven to be a good tool for assessment of long-axis ventricular shortening and lengthening. There are no previous studies on mitral annular plane systolic excursion (MAPSE) in mitral stenosis and the effect of balloon mitral valvotomy (BMV) on it. The previous studies have utilized myocardial performance index (MPI), mitral annular systolic velocity (MASV), and early mitral annular diastolic velocity (E′). Previous studies have not quantified the prevalence of longitudinal LV dysfunction in rheumatic MS. We sought to study the various echo parameters of LV function in rheumatic mitral stenosis and effect of BMV on these indices.

2. Methods

2.1. Study population

In a prospective cohort study conducted at a tertiary care hospital in Kerala, the southernmost state of India, patients of severe MS undergoing BMV from August 2013 to March 2014 were screened. Patients with more than mild stenosis or regurgitation of other valves, evidence of coronary artery disease (symptomatic, electrocardiographic or angiographic), hypertension and diabetes mellitus were excluded. Of a total of 61 patients screened, 2 had hypertension, 3 had diabetes mellitus, 1 had significant coronary artery disease (underwent PTCA to LAD), and 12 patients were excluded due to more than mild concomitant valve involvement. 20 controls, whose distribution of age and gender was similar to that of patients, were chosen from healthy controls with no cardiac symptoms, good effort tolerance, normal ECG and no structural heart disease undergoing echocardiography. Data were collected after getting informed consent from the patients and institutional ethics committee approval. Study conforms to widely accepted ethical principles guiding human research.



2.2. Echocardiography

Echocardiography was done by Philips HD11 XE system, using probe frequency range of 2–4 MHz. A single investigator did all the echocardiographic evaluation (except for assessing inter-observer variability, where 2 investigators were involved). All echocardiographic measurements were taken as mean of 3 consecutive cycles in those in sinus rhythm and 5 consecutive cycles in AF. Modified Simpson's method was used to assess ejection fraction (after measuring end diastolic and end systolic volumes). Mitral valve area was calculated by planimetry (measurement obtained by direct tracing of the mitral orifice at the leaflet tip, on a parasternal short-axis

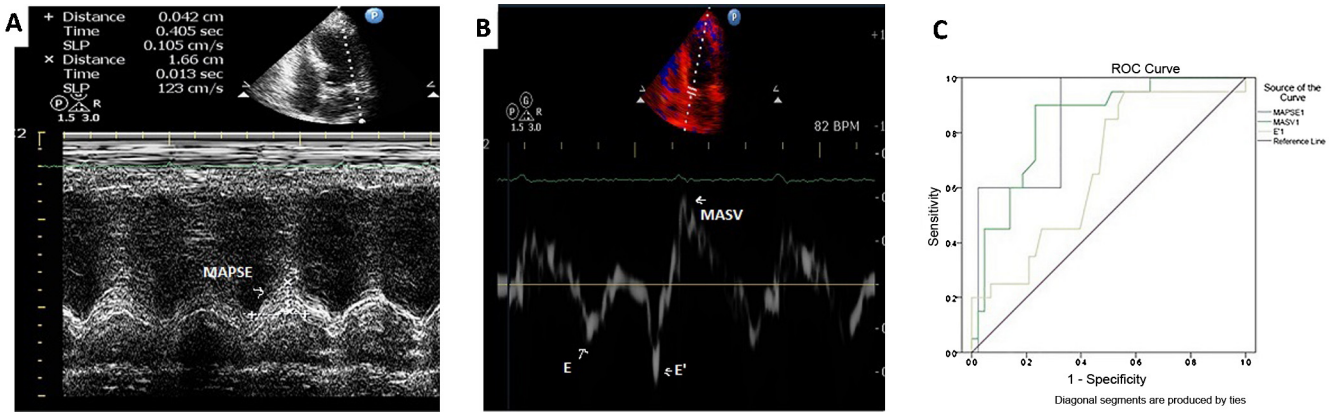


Fig. 1 – (A) Measurement of mitral annular plane systolic excursion: The systolic excursion of mitral annulus was measured from the lowest point at end-diastole to aortic valve closure (end of the T-wave on the electrocardiogram). (B) Measurement of myocardial performance index: in the apical 4-chamber view, TDE cursor was placed at the septal and lateral side of the mitral annulus. In the apical 2-chamber view, the TDE cursor was placed at the anterior and inferior sides of the mitral annulus in the same manner. Myocardial performance index was calculated by dividing the sum of IVCT and IVRT by ejection time. (C) ROC curve.

view). From the apical window maximum and mean transmitral pressure gradients were obtained by continuous wave Doppler. The systolic pulmonary artery pressure was derived from the tricuspid regurgitant jet velocity by means of the modified Bernoulli equation. MAPSE was measured by M-mode images obtained at the LV septal, lateral, anterior, and posterior borders of the mitral ring in the apical 2-chamber and 4-chamber views, and an average MAPSE value was calculated[8] (Fig. 1A). In the apical four-chamber view, the tricuspid annular plane systolic excursion was measured by the level of systolic excursion of the lateral tricuspid valve annulus towards the apex.[9]

Sweep speed of 100 mm/s was used to assess pulsed wave tissue Doppler tracings. In the apical 4-chamber view, TDE cursor was placed at the septal and lateral sides of the mitral annulus. In the apical 2-chamber view, the TDE cursor was placed at the anterior and inferior sides of the mitral annulus. Myocardial performance index was calculated by dividing the sum of IVCT and IVRT by ejection time. Peak velocities during systole (S′) and early diastole (E') were measured. Average value from four sites was obtained (Fig. 1B).

An experienced team performed BMV monitoring of conventional hemodynamic parameters. Balloon size was chosen according to height.[10] Percutaneous BMV was regarded as successful if the mitral valve area post-percutaneous BMV was $>1.5\ cm^2$ or the gain was >50% of baseline with no significant mitral regurgitation.[11]

2.3. *Follow-up*

Follow-up was done within 24 h after BMV, and 3 months after discharge. Though most of the previous studies have follow-up analysis at 48–72 h post BMV, we chose to do it within 24 h as it was an institution policy to discharge uncomplicated successful BMV patients after 24 h. As parameters were assessed within 24 h, we did not analyze MVA by pressure halftime, as it may be inaccurate during this period. Patients were evaluated with echocardiogram and various indices of LV function were reassessed.

2.4. *Statistical analysis*

Statistical analysis was performed with SPSS software version 18 (SPSS Inc., Chicago, IL). Qualitative variables, expressed as numbers and percentages were compared by the Chi-square test. Quantitative variables among study group and control group were compared by Mann–Whitney *U* test and those at three different time intervals were done with repeated measure ANOVA. Receiver operating characteristics curve was plotted to get the best cut off predictor for defining longitudinal LV dysfunction (Fig. 1C). Multivariate analysis was done to identify the various factors affecting left ventricular function. P value less than 0.05 was considered significant.

3. Results

3.1. *Baseline*

There were 43 patients (25 in sinus rhythm) in the study group and 20 subjects in control group. Majority were females with no significant gender difference in either group (79.1% vs. 75%, $p = 0.718$). Heart rates were also similar ($p = 0.084$). The baseline characteristics of the study and control population are depicted in Table 1. Intra-class coefficient was analyzed for assessing inter and intra-observer variabilities. For intra-observer variability, intra-class coefficients were MASV – 0.95, MPI – 0.86, E′ – 0.91, and MAPSE – 0.97. For inter-observer variability, intra-class coefficients were MASV – 0.92, MPI – 0.84, E′ – 0.89, and MAPSE – 0.96. All the parameters had intra-class coefficient more than 0.7 (acceptable range 0.7–1). Maximum intra and inter-observer variabilities were for MPI.

Table 1 – Baseline characteristics.

Parameter	Mitral stenosis	Controls	*p* value
Age (years)	40.05 (12.59)	43.30 (8.23)	0.174
Duration (years)	6.16 (0.456)	NA	–
Heart rate (bpm)	82.60 (17.18)	76.00 (8.89)	0.084
2D MVA (cm^2)	0.85 (0.10)	NA	–
Mean MVG (mm Hg)	14.31 (5.97)	NA	–
TAPSE (mm)	18.67 (1.50)	18.82 (1.40)	0.778
EF (%)	58.38 (4.70)	63.18 (3.85)	<0.001
EDVI (ml/m^2)	58.41 (17.95)	52.20 (8.79)	0.149
MAPSE (mm)	11.35 (4.72)	13.07 (1.44)	<0.001
MASV (cm/s)	7.28 (1.26)	8.57 (0.67)	<0.001
E′ (cm/s)	7.68 (1.46)	8.55 (1.54)	0.033
MPI	0.59 (0.12)	0.46 (0.06)	<0.001

All values are given as mean (SD).
MVA, mitral valve area; MVG, mitral valve gradient; TAPSE, tricuspid annular plane systolic excursion; EF–ejection fraction, EDVI, end diastolic volume index; MAPSE, mitral annular plane systolic excursion; E′, early mitral annular diastolic velocity; MPI, myocardial performance index.

3.1.1. *Comparison of LV Function in sinus rhythm vs. AF*

There were 25 patients in sinus rhythm, while 18 had AF. They were comparable with respect to age, gender, and duration of symptoms. Ejection fraction was not significantly different between two groups. Of the other baseline LV parameters, only MPI ($p = 0.04$) was significantly higher in the AF group. The various parameters are compared in Table 2. Patients with atrial fibrillation were noted to have better improvement in MPI at 3 months follow-up post BMV as compared to those in sinus rhythm ($p = 0.006$). All other parameters of LV function including MPI immediate post BMV were not significantly different in atrial fibrillation and sinus rhythm group.

Table 2 – Comparison of characteristics of patients with sinus rhythm vs. atrial fibrillation at baseline.

Parameter	Sinus rhythm	AF	*p* value
Age (years)	37.56 (12.01)	43.50 (12.89)	0.146
Duration (years)	6.64 (4.54)	5.50 (4.64)	0.12
Heart rate (bpm)	79.40 (14.09)	87.06 (20.33)	0.112
2D MVA (cm^2)	0.85 (0.11)	0.84 (0.09)	0.76
Mean MVG (mm Hg)	15.85 (6.89)	12.17 (3.59)	0.156
TAPSE (mm)	18.92 (1.47)	18.31 (1.51)	0.401
EF (%)	59.06 (5.47)	57.43 (3.27)	0.506
EDVI (ml/m^2)	60.89 (19.94)	55.24 (14.99)	0.323
MAPSE (mm)	11.62 (6.07)	10.98 (1.67)	0.247
MASV (cm/s)	7.66 (0.77)	6.75 (1.59)	0.09
E′ (cm/s)	7.75 (1.32)	7.57 (1.68)	0.931
MPI	0.55 (0.11)	0.64 (0.12)	0.04

All values are given as mean (standard deviation).
MVA, mitral valve area; MVG, mitral valve gradient; TAPSE, tricuspid annular plane systolic excursion; EDVI, end diastolic volume index; MAPSE, mitral annular plane systolic excursion; MASV, mitral annular systolic velocity; E′, early mitral annular diastolic velocity; MPI, myocardial performance index; AF, atrial fibrillation.

Table 3 – Comparison of pre BMV and post BMV parameters.

Parameter	Pre BMV (group 1)		Post BMV (group 2)		3-month follow-up (group 3)	
	Mean	SD	Mean	SD	Mean	SD
MPI	0.587	0.020	0.582	0.028	0.488	0.012
MASV (cm/s)	7.274	0.201	7.951	0.195	8.015	0.187
E′ (cm/s)	7.677	0.234	8.015	0.226	8.331	0.229

p values-MASV, E′-group 2 to group 1 = <0.001, 0.04, respectively. MPI, E′ group 3 to group 2 = 0.002, <0.001, respectively.

3.2. *Follow-up*

Mean post-BMV 2D MVA was 1.47 cm^2 (SD 0.11) and average mitral valve mean gradient was 3.97 mm Hg (SD 1.12). EF and MAPSE did not show significant change immediate post BMV or at 3-month follow-up (*p* value = 0.524, 0.830, respectively). MASV showed immediate increase after BMV, but did not show further improvement at 3-month follow-up. E′ improvement was seen immediately after BMV, and further significant improvement was noted at 3-month follow-up. MPI failed to show any change immediate post BMV but decreased significantly at 3-month follow-up (Table 3).

There was no significant difference in left ventricular systolic and diastolic volumes either immediately or 3 months after BMV.

Receiver–operating characteristic (ROC) curve (Fig. 1C) was plotted with the 3 parameters of longitudinal LV function-MASV, MAPSE, and E′. Based on that, MASV with a cut of value of 8.1 cm/s was selected as the best parameter to classify the study group into those with normal LV longitudinal function and with reduced LV longitudinal axis function (MASV < 8.1 cm/s). 77% of those in study group had LV longitudinal dysfunction, which decreased to 27% at 3-month follow-up. Thus BMV improved LV long axis function ($p < 0.01$).

3.2.1. *Predictors of improvement in LV function*

Magnitude of improvement in left ventricular longitudinal function was correlated with age, duration of symptoms and degree of baseline dysfunction. Only those indices that showed a significant change after BMV were taken for this analysis. On multivariate analysis, improvement in LV function indices did not show any correlation to age, duration of symptoms, or to baseline TAPSE. Magnitude of change in MPI post-BMV showed inverse correlation to baseline MPI. Findings are summarized in Table 4. Patients with atrial fibrillation were noted to have better improvement in MPI at 3 months follow-up post BMV as compared to those in sinus rhythm ($p = 0.006$).

The improvement in various parameters of LV function was independent of change in LV volumes. There was no correlation between NYHA functional class and longitudinal LV function both before and after BMV ($p = 0.372$, 0.642, respectively). There was no statistical correlation between longitudinal LV function and Wilkins echo score ($p = 0.21$).

Table 4 – Change in LV function parameters correlated to age, gender, duration of symptoms, improvement in mitral valve area and baseline parameter value.

Variable	MASV		E′		MPI	
	β	p value	β	p value	β	p value
Age	−0.057	0.76	−0.36	0.03	0.02	0.8
Gender	−0.056	0.75	−0.16	0.27	0.04	0.6
Duration of symptoms	0.125	0.47	0.027	0.86	0.05	0.63
Baseline same parameter value	−0.38	0.035	−0.39	0.02	−0.7	0.001

MASV, mitral annular systolic velocity; E′, early mitral annular diastolic velocity; MPI, myocardial performance index; MVA, 2D mitral valve area; r, coefficient of correlation; β, beta coefficient.

4. Discussion

4.1. *Left ventricular dysfunction in rheumatic mitral stenosis*

In patients with MS, varying degrees of deterioration in LV function has been reported. The data on the prevalence of longitudinal left ventricular dysfunction in rheumatic mitral stenosis are not enough. Our study showed lower MAPSE, MASV, and E′, with higher MPI in mitral stenosis patients compared to controls. In our study, 77% of study group had evidence of LV longitudinal dysfunction. The higher prevalence of longitudinal LV dysfunction in our group may be due to the fact that we have taken only patients with severe MS. Other factors that may have contributed to this are the delay to medical care from onset of symptoms, as well as earlier onset of valvular disease in Indian population. The study by Ozdemir et al.[6] showed that MS affects long axis left-ventricular performance. The myocardial velocities of the left ventricle indicating left-ventricular function were found to be significantly lower in patients with pure MS. Ozer et al.[7] examined left ventricular long-axis function of patients with pure MS. There was no significant difference in global systolic function, but tissue Doppler systolic velocities were significantly lower in patients with mitral stenosis than in controls. Our study showed lower indices of LV function (MPI) in AF subset, though EF difference was non-significant between the groups. In patients with MS and AF, the causative mechanisms of LV dysfunction are not well known.

4.2. *Improvement of longitudinal function after BMV*

In our study, EF and MAPSE did not show significant change with BMV. Mitral annular systolic velocity and E′ showed improvement immediate post-BMV, while MPI showed a decrease only at 3-month follow-up. The immediate improvement of LV long axis parameters may be due to mechanical effect of BMV, while improvement of MPI (indicating global LV function) took longer time. Another possible explanation for lack of MPI change immediate post BMV could be due to the fact that MPI, though averaged for 5 cycles in AF patients, could produce significant intra observer variability. In a study by Lee and colleagues,[12] most patients with impaired LV ejection fraction showed improvement after mitral valvuloplasty. Study by Sengupta et al.[13] showed that after BMV, MASV and E′ showed significant improvement, which is similar to our outcome. A study by Nurcan et al.[14] which included 76 consecutive patients, who underwent BMV for isolated rheumatic mitral stenosis, showed improvement in MASV and E′ post-BMV. Left ventricular global function by MPI did not improve significantly 48 h and three months after BMV. This is in contrast to results of our study, which showed a decrease in MPI at 3 months following BMV. Thus serial evaluation of changes in mitral annular velocities by Doppler tissue imaging aids clinical assessment of immediate improvement in left ventricular function after BMV.

4.3. *Predictors of improvement of LV longitudinal function*

Our study showed that magnitude of change in MPI post-BMV had inverse correlation to baseline MPI. The improvement of global LV function after BMV is thus inversely correlated to baseline global LV function. Hence, it may be assumed that performance of early BMV, before significant worsening of global LV function may yield better long-term outcomes, and needs to be assessed by future studies with larger sample size.

5. Conclusions

There was a significant reduction in left ventricular function parameters in severe rheumatic mitral stenosis. Impaired LV long axis function was present in 77% of study group. Those with atrial fibrillation had higher MPI compared to those in sinus rhythm (indicating a worse global LV function). Immediately after BMV, there was an improvement in LV long axis function. There was a gradual improvement in global left ventricular function post-BMV.

Conflicts of interest

The authors have none to declare.

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