Worsening of left ventricular twist mechanics in isolated rheumatic mitral stenosis immediately after balloon mitral valvuloplasty

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Abstract  Background: Reportedly, left ventricular (LV) mechanics are worsened in patients with mitral stenosis (MS) compared to controls. The immediate effect of balloon mitral valvuloplasty (BMV) on LV mechanics is, however, not known.

Aim: To assess the immediate effect of balloon mitral valvuloplasty on the left ventricular twist mechanics.

Methods and results: We studied 39 candidates for BMV. Pressures were measured invasively before and after BMV. Speckle tracking echocardiography (STE) was done for twist mechanics (basal rotation, apical rotation, and torsion) before and immediately after BMV. Twist mechanics were also measured by STE in 15 normal subjects as control group. Mean age was 30.4 ± 7.2 years, mean BMI was 24.7 ± 3.1 and 28 patients (72%) were females. All twist mechanics apical rotation and torsion were lower post-BMV compared to pre-BMV. Left ventricular end diastolic pressure was significantly higher post compared to pre-BMV while left atrial pressure (LAP) was similar between both groups. Importantly, patients who showed an increased LVEDP post compared to pre-BMV had worse LV twist mechanics than those whose LVEDP post-BMV was similar to or lower than pre-BMV.

Conclusion: LV twist mechanics are worsened in MS with a further worsening, immediately after BMV probably because of failure of the LV to adapt to the sudden increased preload.

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1. Introduction

Mitral stenosis (MS) is the most common valve lesion seen in chronic rheumatic heart disease, and results from the inflammatory. As a result of the decreased valve area, LV preload decreased significantly and thus LV systolic performance
in patients with MS is controversial.\textsuperscript{2,3} Reportedly, LV systolic dysfunction occurs in patients with rheumatic MS, probably because reduced preload in these patients results in adverse LV remodeling, or due to the extension of inflammatory process from the mitral valve apparatus into the adjacent myocardium.\textsuperscript{3,5}

LV systolic dysfunction in MS is difficult to be appreciated using the conventional methods such as LV ejection fraction (LV-EF), which decreases only with significant myocardial damage. With the recent introduction of speckle tracking echocardiography technique (STE), the appreciation of LV systolic dysfunction before they manifest as a decrease in LV-EF became possible.\textsuperscript{6,7}

Mechanically, the myocardial fibers deform in the form of longitudinal and circumferential shortening and radial thickening, in addition to the opposite rotations of the LV apex and base that result in a wringing motion, i.e. LV twist or torsion.\textsuperscript{8} All deformational behaviors of the myocardium can be appreciated by STE. LV torsion is of particular importance for systolic ejection and recoil of torsional forces (untwist) creates negative suction pressures and thus is important for diastolic filling.\textsuperscript{9} LV torsion is load dependent and, with constant afterload, LV torsion increases with increasing preload and vise versa.\textsuperscript{9}

Despite that some reports suggested that STE derived LV mechanics are worsened in MS compared to controls,\textsuperscript{3,10,11} little is known about the immediate effect of balloon mitral valvuloplasty (BMV) in patients with MS on the systolic performance of the LV.

As would be expected from the volume dependency of LV twist mechanics in a normal LV, torsion should increase immediately after BMV, because BMV increases LV preload back to relatively normal values; however, this concept is not yet studied.

Therefore, the aim of the present study was to assess the immediate effect of balloon mitral valvuloplasty on the left ventricular twist mechanics.

2. Patients and methods

2.1. Study population

In the period between August 2013 and June 2014, 39 consecutive patients with rheumatic MS referred to our echocardiography laboratory for pre-balloon mitral valvuloplasty (BMV) assessment, were recruited. In addition, 15 age, sex, and LV function matched controls were also recruited. The study protocol was approved by the research committee of our institution, and all patients gave informed consent consistent with this protocol.

2.2. Echocardiography

Echocardiographic examinations were done within 1 h before and within 6 h after BMV. All echocardiographic studies were acquired with a commercially available echocardiography system using a 2.5 MHz multi-frequency phased array transducer (Vivid 5 or 7; GE Vingmed Ultrasound AS, Horten, Norway). The LV-EF was assessed using the biplane Simpson’s method with manual tracing of the digital images. The mean trans-valvular pressure gradient (PG) was calculated by manual tracing of the Doppler derived transmitral flow envelope.

From the parasternal LV short-axis view at the mitral valve level, the smallest orifice of the mitral valve was identified by scanning from the left atrium in the direction of the LV apex. The gain settings were adjusted until the lowest level was determined, at which the circumference of the mitral orifice was still visible. After identification of the frame with the mitral valve orifice at its maximal opening in early diastole, MVA was measured by planimetry of its contours. The anatomic severity of MS was defined as mild if MVA was > 1.5 cm\textsuperscript{2}, moderate if MVA was > 1.0 and ≤ 1.5 cm\textsuperscript{2}, and severe if MVA was ≤ 1.0 cm\textsuperscript{2}.\textsuperscript{12}

BMV procedural success was defined as post-procedural MVA > 1.5 cm\textsuperscript{2} with ≥ 25% gain in mitral valve area and mitral regurgitation ≤ 2.\textsuperscript{13}

2.3. Speckle tracking echocardiography (STE)

Short-axis images at the mitral valve and apical level were obtained with a frame rate > 50 frames/s. The LV endocardial border was manually traced at the LV basal and apical levels and the speckle-tracking region of interest was automatically selected, the width of which was adjusted as necessary to accommodate the thickness of the LV wall. Stable objects were automatically tracked in each frame throughout the cardiac cycle and LV basal and apical rotation curves were generated, as previously described.\textsuperscript{14}

LV torsion was defined as the difference between the peak rotations at the apical and mitral valve level (torsion = peak apical rotation – peak basal rotation).\textsuperscript{14}

2.4. Statistical analysis

Nominal data were expressed as number (%). Continuous data were expressed as mean ± SD and were compared between groups using Student t-test. Correlation analyses were performed using linear regression and expressed as Pearson correlation coefficients. p-value ≤ 0.05 was considered statistically significant. All the analyses were performed with commercially available software (SPSS version 21.0, SPSS, Inc., Chicago, IL, USA). The authors had full access to the data and take full responsibility for their integrity.

3. Results

The study included 39 patients with mitral stenosis, all were in sinus rhythm and were candidates for balloon mitral valvuloplasty (BMV). The mean age was 30.4 ± 7.2 years, mean BMI was 24.7 ± 3.1 and 28 patients (72%) were females. Basic demographic, clinical and echocardiographic data of the study group are listed in Table 1.

3.1. Comparisons between patients and controls

In our study, 15 control subjects were studied. The mean age of controls was 32.7 ± 5.1 years, 8 (60%) were females, and the mean left ventricular ejection fraction was 64.6 ± 6%. There was no significant difference between patients and controls regarding age (p = 0.261), sex (p = 0.646), and basal left ventricular ejection fraction (p = 0.121).
Two-dimensional speckle tracking echocardiographic (2D-STETC) derived apical rotation and LV torsion were significantly lower in patients with MS compared to controls, while basal rotation was not different (Table 2). Interestingly, it was found that post-BMV, apical rotation and torsion further decreased compared to the corresponding values before BMV and compared to controls (Table 2).

3.2. Comparisons before and after BMV (Table 3)

According to the definition of procedural success, BMV was successful in all patients. MVA increased significantly, while mean Doppler pressure gradient, LAP, mPAP, and RVsP decreased significantly after compared to before BMV (Table 3). Surprisingly, LVEDP increased significantly after BMV compared to before BMV (14 ± 3.3 vs. 11.3 ± 3.7 mmHg, p = 0.006, Table 3).

Interestingly, all left ventricular rotational values were lower after compared to before BMV, with a significant decrease in apical rotation (5.1 ± 1.5 vs. 6.5 ± 2.8 deg, p = 0.007, Table 3), insignificant decrease in basal rotation (−4.9 ± 2.4 vs. −5.7 ± 2.4 deg, p = 0.133, Table 3), and a significant decrease in torsion (11.6 ± 2.7 vs. 9.99 ± 2.03 deg, p < 0.001, Table 3).

3.3. Comparison according to post-procedural LVEDP (Table 4)

Patients were then classified into 11 patients for whom LVEDP did not change or decreased after BMV (delta-LVEDP = −2.5 ± 2.9 mmHg), and 28 patients who showed an increase in post-BMV LVEDP compared to pre-BMV LVEDP (delta-LVEDP = 4.7 ± 3.6 mmHg). It was noticed that for the group that showed no increase in post-BMV LVEDP, the basal LV rotational measurements were significantly higher than the group of patients whose LVEDP increased after LVEDP (16.7 ± 3.9 vs. 10.1 ± 2.8 mmHg, p < 0.001). This might be related to the finding that there was a trend toward more basal moderate MR in those patients [6(55%) vs. 7(25%) patients, p = 0.07], causing worsening of basal LVEDP.

Although MVA, mean PG, LAP, and apical rotation, and torsion were not significantly different between both groups before BMV, apical rotation and LV torsion were significantly lower after BMV in patients who showed an increase in LVEDP, despite that they had a significantly larger post-BMV MVA (Table 4). Importantly, despite that the difference between post and pre-BMV LVEDP (delta-LVEDP) was significantly larger and higher in patients with increased post-BMV LVEDP, the difference between post and pre-BMV LAP (delta-LAP) was not significantly different.

3.4. Correlations with left ventricular rotation mechanics

Apical rotation, basal rotation, or LV torsion did not correlate with MVA before BMV (r = −0.173, −0.044, −0.122, p = 0.291, 0.792, 0.466, respectively, Fig. 1A–C); however, it was found that, apical rotation, basal rotation and LV torsion after BMV correlated significantly with MVA after BMV (r = −0.391, 0.39, −0.593, p = 0.014, 0.014, < 0.001, respectively, Fig. 1A–C).

Importantly, a significant correlation was found between the changes between delta-LVEDP and post-BMV apical rotation and torsion (r = −0.409, −0.41, p = 0.01, p = 0.009). Another weaker correlation was also found between delta-LVEDP and delta-torsion (r = −0.32, p = 0.048).

4. Discussion

In our study we found that compared to controls, patients with mitral stenosis had worse left ventricular twist mechanics, and that further worsening occurs in those patients immediately post-balloon mitral valvuloplasty. LV rotational mechanics were also related to the change in LVEDP and MVA after BMV.
4.1. LV systolic mechanics in patients with MS before and after BMV

Whether LV systolic function is affected in patients with MS remains controversial.3–5 The left ventricle is not expected to be significantly affected in patients with MS because there is no significant changes in LV preload and afterload. It has been reported, however, that abnormal LV mechanics may occur in MS,15–17 and that global longitudinal strain and strain rate may be reduced in MS patients.3,18 In the present study, we found that LV twist mechanics are also affected in patients with MS compared to controls.

As expected from an increase in the afterload caused by dilating the mitral valve and thus treating the stenosis, LV mechanical properties may recover to their normal values after BMV. In our study, however, we found that LV rotational mechanics are worsened immediately after compared to before BMV. This finding was associated with larger MVA and higher LVEDP that increased post-BMV. These observations may make it possible to deduce that the worse twist mechanics can be caused by failure of the left ventricle to adapt to the sudden increase in preload produced by successful dilatation.

4.2. Comparison with previous studies

Pamir et al., reported that LV diastolic performance is impaired, LVEDP is increased, and LV-EF is not changed after successful BMV.19 In our study, the finding that LVEDP might increase immediately after BMV was reproduced. Tomai et al. also reported that a transient lack of LV adaptation to the increased LV preload occurs after successful BMV.20 These findings seem to go along with the findings of our study.

Sengupta et al., on the other hand, reported that BMV results in rapid recovery of LV systolic function in MS patients through improvement in LV diastolic loading.11 We think that our findings do not go against the later report, as in our study we depended on the concept of stunning of LV toward the sudden increase in preload as a possible mechanism for the immediate worsening of LV twist mechanics. A normal LV, however, is expected to regain function rapidly after BMV by compensation to this sudden increase in preload. In the later report, LV mechanics were studied 72 h post-BMV, a period during which the LV might have already adapted to the increased preload and thus the normalization of LV mechanics.

4.3. Study limitations

Unfortunately, the study suffered some important limitations. First, the study included a small number of patients and further studies should be done on a larger sample size to confirm the study findings. Second, the study hypothesis depended on that the left ventricular dysfunction is only a transient one; however, there was no follow-up for patients to prove the recovery of LV functions after the transient decrease. Further studies should consider this issue. Third, left ventricular functions were only studied in terms of LV rotational mechanics, traditional echocardiographic variables such as volumes and ejection fraction and other LV deformation indices including longitudinal and circumferential LV strain were not studied. Further studies should be done to study the immediate effect of BMV on all deformation indices. Fourth, patients who did not have significant increase in their post-procedural BMV had a significantly higher basal LVEDP, which might be related to the fact that there was a trend that these patients had worse MR; thus, the basal status of their LV functions might differ from patients who showed a post-procedural increase in LVEDP, and might be another factor that influences post-procedural twist mechanics. Other factors that might cause this observation are volume status and the use of diuretic therapy, which were not investigated, in the current study. Because MR worsening did not occur in the study patients, the better post-procedural mechanics noticed in these patients despite worse basal LVEDP may be related to that their LV was more subjected to a higher preload.
due to the worse basal MR, thus may not be as stunned to the sudden increase in preload; however, further investigation of this hypothesis should be done taking into account all other factors that may influence LV hemodynamics before firm conclusions are made. Finally, we used MVA measurements by planimetry and not by Doppler pressure halftime, because of known inconsistencies in the Doppler measurements, especially post-BMV. However, it is important to take into consideration that all methods used to measure MVA immediately after BMV may have some inaccuracies because of the prompt change in loading conditions and valve elastic recoil.

5. Conclusion

LV twist mechanics are decreased in patients with MS because of decreased preload. A further decrease in LV twist performance was found to occur immediately after BMV probably because of failure of the LV to adapt to the sudden increased preload.

Conflict of interest

None.

References


