Evaluation of the Relation between Anterior Mitral Valve Leaflet Motion based on Height-to-Length Ratio and the Immediate Outcome of Percutaneous Balloon Mitral Valvuloplasty

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Abstract

Aims- The purpose of this study was to investigate whether there is any relation between mitral leaflet motion based on height-to-length ratio of the anterior mitral valve leaflet doming in diastole and the immediate outcome of balloon mitral valvuloplasty,.

Methods- The study population consisted of 49 patients (47 women, mean age: 43.7±13.35 years) with symptomatic rheumatic mitral stenosis who underwent balloon valvuloplasty. Complete transthoracic and transesophageal studies were performed in all the patients before valvuloplasty, and transthoracic study was repeated 24-48 hours after valvuloplasty. The severity of the restriction of the mitral valve leaflet motion was classified based on the height-to-length ratio of the anterior mitral valve leaflet doming. Mitral valve thickness, calcification, subvalvular thickening, and mobility were scored according to the Wilkins system. Optimal immediate outcome of balloon mitral valvuloplasty was defined as a valve area improvement of 50% or more or a final mitral valve area of ≥1.5 cm^2 and mitral regurgitation Sellers' grade ≤ 2.

Results- There was a significant relation between the total mitral valve score and its thickness with the optimal immediate post-balloon mitral valvuloplasty results (*p* value=0.03 and 0.04, respectively), but no relation was found between the Wilkins score and its components with the anterior mitral valve leaflet height-to-length ratio. There was no significant relationship between the amount of increase in the mitral valve area, decrease in trans-mitral pressure gradients, decrease in pulmonary artery pressure, and anterior mitral leaflet height-to-length ratio (all *p* values > 0.05; all the correlation coefficients < 0.2).

Conclusions- Our study showed that post-balloon mitral valvuloplasty results are mainly affected by valve thickness and the total Wilkins score. In addition, the severity of mitral leaflet motion restriction in terms of the height-to-length ratio of the anterior mitral valve leaflet has no significant relation with the immediate result of balloon mitral valvuloplasty ***(Iranian Heart Journal 2010; 11 (2):30-38).***

Keywords: Mitral valve ■ Mitral stenosis ■ Balloon dilatation ■ Echocardiography

Rheumatic mitral stenosis (MS) is a common form of acquired heart disease, characterized by chronic restriction of diastolic left ventricular filling.[1]

Percutaneous balloon mitral valvuloplasty (BMV) produces major increases in mitral valve area (MVA) and relieves symptoms in patients with severe MS.[2,3]

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Two-dimensional echocardiographic total scoring methods have been proposed for the analysis of the mitral valve morphology before BMV.[4] However, such methods rely on total scores for leaflet motion, leaflet thickness, subvalvular disease, and valvular calcification, without assessing the relative contribution of each variable. [2]

The relief of symptoms and improvement of hemodynamic parameters produced by BMV persists at mid and long-term follow-up. It has been suggested that the best long-term results are seen in patients with echocardiographic scores of 8 or less, as described by Abascal and colleagues.[5] When BMV produces a good immediate outcome in this group of patients, restenosis is unlikely to occur at 3-month follow-up. Although BMV can confer a good outcome in patients with echocardiographic scores greater than 8, hemodynamic and echocardiographic restenosis is frequently observed. [6]

The aim of this study was to determine whether there is any association between mitral leaflet motion based on height-to-length (H/L) ratio of anterior mitral valve leaflet (AMVL) doming in diastole and mitral valve mobility, thickening, calcification, subvalvular thickening, and immediate results and outcome of patients with symptomatic mitral valve stenosis after BMV.

Methods

The study included 49 symptomatic patients (46 women, mean age: 43.7 ± 13.35 years, range: 14-69 years) with rheumatic MS with MVA ≤ 1.5 cm^2, Wilkins' score ≤ 10, isolated mitral stenosis or with ≤ grade 2 mitral regurgitation. Exclusion criteria were patients with poor echocardiographic window, left atrial thrombus, recent thromboembolic event of less than 3 months' duration, associated coronary artery disease, and other valve lesions that needed surgical correction.

The study was approved by our faculty ethical committee, and informed consent to the procedure was obtained from all the patients.

Valvuloplasty procedure

After diagnostic left and right heart catheterization, trans-septal puncture for the Inoue balloon was done. BMV was performed using an appropriate size Inoue balloon catheter (Toray Industries, Japan). Balloon size was selected according to the body surface area (26mm if 1.5 m^2, 28mm if 1.5 to 1.7 m^2, and 30mm if more than 1.7 m^2), modulated by anatomy (1 to 2 mm smaller in unfavorable cases), and reached after several stepwise inflations.

After each dilation, the left atrial and left ventricular pressures were determined to assess the transmitral valve gradient before proceeding to the next dilation. Left ventriculography was performed before and after the last balloon inflation.

Echocardiography

Transthoracic echocardiography (TTE) was done the day before and 24–48 hours after BMV (before discharge), using real time ultrasound imaging system (GE Medical Systems, Vivid 3) equipped with a phased array 2.5 MHz transducer.

The standard echocardiographic measurements were done and averaged in 4 cardiac cycles. These measurements were taken while the patient was in the supine and left lateral decubitus positions. MVA was calculated by planimetry and pressure half-time (PHT) method from the parasternal short-axis view and apical 4-chamber view, respectively.

The severity of mitral valve mobility restriction, thickening, calcification, and subvalvular thickening was scored by the Wilkins system.[7] In addition, special measurements were taken to assess the valve motion. Mitral valve peak (MVPPG) and mean pressure gradients (MVMPG) were measured using CW Doppler echocardiography. Pulmonary artery pressure (PAP) was estimated by tricuspid regurgitation (TR) gradient.

Height-to-length ratio

To assess leaflet motion, the mitral valve leaflets were imaged in the parasternal long-axis, two-dimensional echocardiographic view during the maximal doming of the anterior leaflet in diastole. The extent of doming of the anterior leaflet was measured by drawing a line [named as length (L)] from the junction of the posterior wall of the aortic root and the anterior mitral valve to the tip of the mitral valve leaflet. From this line, a perpendicular line [named as height (H)] was drawn to the leading edge of the maximal dome of the anterior leaflet of the mitral valve (Fig.1).

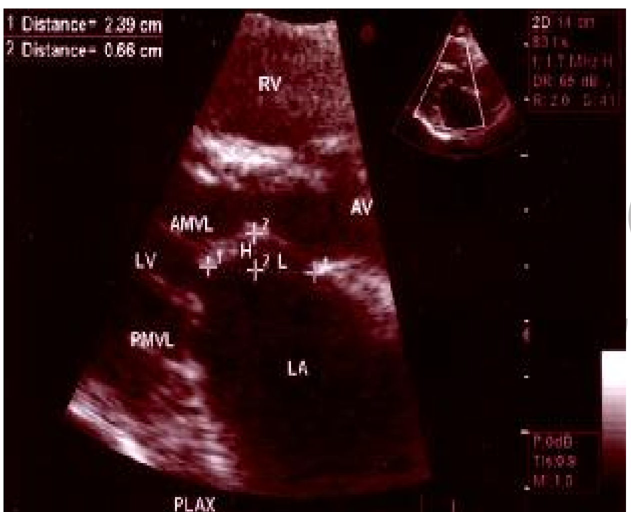

Fig. 1. Parasternal long-axis view, showing maximal doming of the anterior mitral valve leaflet. Height (H : maximal doming of the anterior mitral leaflet, length (L): the distance between the tip and the hinge point of the anterior mitral leaflet with the aortic valve.

Leaflet motion was expressed as the ratio of the height of the doming by the length (H/L ratio). The severity of the restriction of leaflet motion was classified as **1)** mild restriction when H/L ratio was ≥0.45, **2)** moderate restriction when H/L ratio was 0.26- 0.44, and **3)** severe restriction when H/L ratio was ≤0.25.

Definitions

The following definitions were used in our study:

***Optimal valvotomy (group I)*:** a valve area improvement of 50% or more or a final MVA of ≥1.5 cm^2 and mitral regurgitation (MR) Sellers' grade ≤ 2.

***Suboptimal valvotomy (group II)*:** a valve area improvement of less than 50% or a final valve area of <1.5 cm^2 with MR Sellers' grade ≤ 2, or "severe regurgitation" irrespective of post-procedural area.

***Significant post-BMV mitral regurgitation*:** an increase of two or more grades of angiographic regurgitation after the procedure or a final regurgitation grade ≥3. [8]

Statistical Analysis

Mean ± standard deviation and count (%) were used for the description of the interval and categorical data. Independent sample *t*-test (or its non-parametric equivalent, Mann-Whitney U test) and one-way analysis of variance (or its non-parametric equivalent, (Kruskal-Wallis test) were used to compare the data between the sub-groups of the study. Repeated measure analysis of variance models was conducted to investigate the changes in the interval data before and after the procedure, the difference between groups, and their statistical interactions. The Wilcoxon signed-rank test was also utilized for comparison between ordinal paired data. Pearson's *r* and Spearman's *rho* correlation coefficients and simple linear regression models were fitted to investigate the relations between the interval variables. A *p* value of <0.05 was considered statistically significant. Statistical analysis was performed by SPSS 15 for Windows (SPSS Corp., Chicago, Illinois).

Results

Baseline Data

Patients' mean ± SD age was 44 ± 13.4 years, and most of them were female (46 out of 49). The mean area of the mitral valve was 0.87± 0.16 before treatment, and the Wilkins score had an average of 8.4 ± 1.31. The mean mitral valve mean gradient was 11±6.6 mmHg.

Twenty-eight (57.1%) patients had some degrees of MR. The mean anterior mitral leaflet height-to-length ratio (AMVL - H/L) was 0.33 ± 0.05 (Table I).

Table I. Study participants' baseline data

Age (years)	44 ± 13.4
Female Gender (%)	46 (93.8%)
MVA(cm^2)	0.8 7 ± 0.16
Wilkins Score	
Mitral valve mobility	2.0 ± 0.14
Mitral valve thickness	2.2 ± 0.57
Mitral valve calcification	2.0 ± 0.38
Sub-valvular thickening	2.5 ± 0.50
Total score	8.4 ± 1.31
Age (years)	44 ± 13.4
H/L ratio	0.33 ± 0.05
MVPPG (mmHg)	17.64 ± 8.63
MVMPG (mmHg)	11 ± 6.6
MR	28 (57.1%)
PAH: ***Mild (30–49 mmHg)***	27 (55.1%)
Moderate (50–69 mmHg)	16 (32.65%)
Severe ≥ (70 mmHg)	6 (12.24%)

MVA: mitral valve area; MVPPG: mitral valve peak pressure gradient; MVMPG: mitral valve mean pressure gradient; PAH, pulmonary arterial hypertension

Relations between height-to-length ratio of anterior mitral valve leaflet and treatment outcomes

For investigating the relationships between the outcomes of BMV and AMVL- H/L, we used Pearson's *r* and Spearman's *rho* correlation coefficients. No linear correlation was observed between AMVL- H/L and the regarded outcomes (Table II). Statistical associations were determined by using linear regression models. As it is shown, no significant associations were found between the data.

Table II. Relationships between height-to-length ratio of anterior mitral valve leaflet and the outcomes of balloon mitral valvuloplasty

	Regression Coefficient (β)	P value	Correlation coefficient
MVA(cm^2)	0.51 ± 0.17	0.32	0.170*
MVPPG (mmHg)	0.69 ± 4.83	0.88	0.122†
MVMPG (mmHg)	-0.99 ± 4.28	0.82	0.042†
PAP (mmHg)	0.17 ± 2.10	0.93	0.089†
MR ***mild worsening***	0.03 ± 0.02	0.14	0.133†
moderate worsening	-0.03 ± 0.03	0.26	

MVA: mitral valve area; MVPPG: mitral valve peak pressure gradient; MVMPG: mitral valve mean pressure gradient; PAP: pulmonary artery pressure; MR: mitral regurgitation.
* *Pearson's r* correlation coefficient
† *Spearman's rho* correlation coefficient

Relationships between height-to-length ratio of anterior mitral valve leaflet and Wilkins score

There was no correlation between the Wilkins score and the AMVL-H/L ratio (Spearman's rho = - 0.179). The associations between AMVL- H/L ratio and the contributing components of the Wilkins score are presented in Table III. It was observed that none of the patients had a score of 4. No significant association existed between the AMVL- H/L ratio and mitral valve thickness, calcification, mobility, and sub-valvular thickening. Also, no correlation was found between the above-mentioned variables and the AMVL- H/L ratio.

Table III. Relationships between height-to-length ratio of anterior mitral valve leaflet and the components of Wilkins score

	Score			P value	Spearman's rho
	1	2	3		
Thickness	0.36 ± 0.05	0.33 ± 0.05	0.32 ± 0.05	0.44	-0.151
Calcification	0.38 ± 0.07	0.33 ± 0.05	0.31 ± 0.04	0.27	-0.228
Mobility	0.42	0.33 ± 0.05	-	0.12	-0.225
Sub-valvular thickening	0.34 ± 0.05	0.32 ± 0.04	-	0.57	-0.081

Comparison of treatment outcomes in patients with optimal and suboptimal results

The anatomic and hemodynamic parameters were compared before and after the treatment procedure (Table IV, column 5). Also, these parameters were compared between the patients with optimal results of valvuloplasty and patients with suboptimal results (Table IV, column 6).

Table IV. Morphologic and hemodynamic changes before and after BMV according to the results

	Optimal Results (n = 22)		Suboptimal Results (n = 27)		P value		
	Before BMV *(1)*	**After BMV** *(2)*	**Before BMV** *(3)*	**After BMV** *(4)*	***1 versus 2***	***3 versus 4***	***2 versus 4†***
MVA (cm^2)	0.79 ± 0.16	1.29 ± 0.17	0.94 ± 0.12	1.22 ± 0.12	**< 0.001**	0.22	**< 0.001**
MVPPG (mmHg)	21.3 ±9.5	11.1 ± 2.6	14.8 ± 6.9	13.1 ± 7.7	**< 0.001**	0.21	**< 0.001**
MVMPG (mmHg)	13.7 ± 7.1	6.3 ± 2.1	8.7 ± 5.2	7.5 ± 6.6	**< 0.001**	0.18	**< 0.001**
PAP (mmHg)	53.8 ± 19.9	40.7 ± 12.0	45.7 ± 9.9	39.4 ± 14.4	**< 0.001**	0.17	0.14
MR (%)					**0.004**	0.10	
No MR	8 (34.8%)	7 (30.4%)	13 (48.1%)	12 (44.4%)			
Mild MR	14 (60.9%)	9 (39.1%)	13 (48.1%)	11 (40.8%)			
Moderate MR	1 (4.3%)	7 (30.4%)	1 (3.8%)	2 (7.4%)			
Severe MR	0	0	0	2 (7.4%)			

BMV: balloon mitral valvuloplasty; MVA: mitral valve area; MVPPG: mitral valve peak pressure gradient; MVMPG: mitral valve mean pressure gradient; PAP: pulmonary artery pressure; MR: mitral regurgitation.
† Interaction between BMV and optimal results in patients according to repeated measure ANOVA models

For MAV, MVPPG, MVMPG, and PAP, the interaction between the changes before and after the procedure and optimal results of treatment was determined by repeated measure ANOVA models (Table IV, column 7).

The mean difference between MVA before and after BMV was about 0.4 ± 0.02 cm^2. This increase in MVA seems statistically significant (p value < 0.001). On the other hand, the mean MVA had no significance difference between the patients with and without optimal results (p value = 0.22). However, it was found that the increase in the MVA was much more prominent in the patients with optimal, rather than those with suboptimal results (p value < 0.001). It means that there was an interaction between the changes in the MVA and the patient's group (Fig. 2).

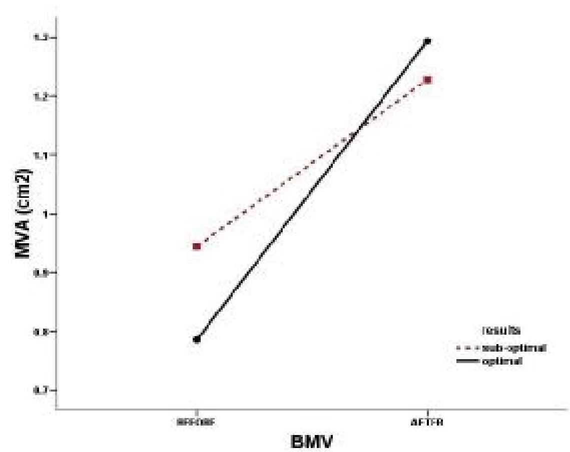

Fig. 2. Comparison of mitral valve area before and after balloon mitral valvuloplasty between the two groups

Both peak and mean gradients had a significant decrease after BMA (p values < 0.001). These decreases were more obvious in the patients with optimal results of the procedure (p values < 0.001; Figs. 3, 4).

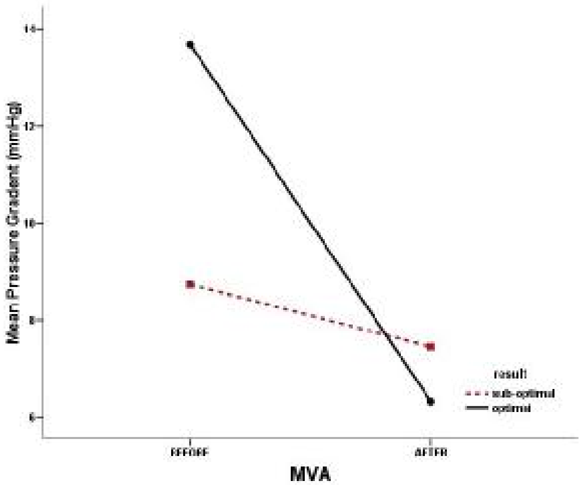

Fig. 3. Correlation between the mitral valve area and mean pressure gradient between the two groups before and after balloon mitral valvuloplasty.

There were no significant differences between the overall mean of MVPPG and MVNPG in the two groups of patients.

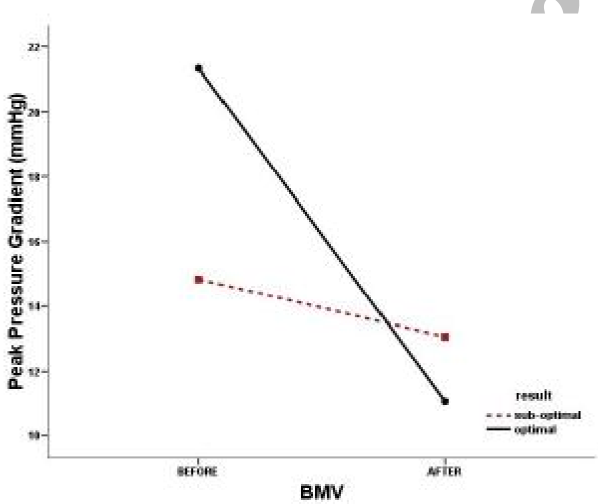

Fig. 4. Comparison of the peak pressure gradient between the two groups before and after balloon mitral valvuloplasty

The mean difference of PAP, before and after the procedure, was about 9.6 mmHg. This decrease was statistically significant (p value < 0.001). No difference between the two groups of patients and no interaction were observed (Fig. 5).

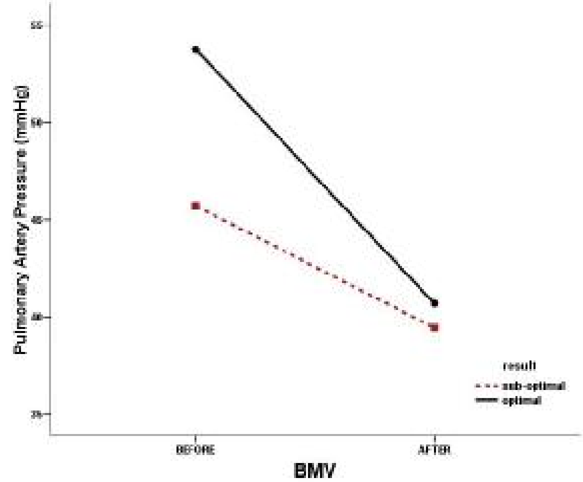

Fig. 5. Comparison of pulmonary artery pressure before and after balloon mitral valvuloplasty between the two groups

Data suggested that the severity of MR was increased after BMV, especially in moderate severity condition (p value = 0.004). No difference was detected between the two groups of patients.

We also investigated the associations between the Wilkins score and its components with the result of BMV (Table V).

Table V. Wilkins score in patients with and without optimal results of valvuloplasty

	Result of BMV		P value
	Optimal (n = 22)	Suboptimal (n = 27)	
Total score	7.9 ± 1.34	8.7 ± 1.20	**0.03**
Thickness	2.0 ± 0.54	2.3 ± 0.56	**0.04**
Calcification	2.0 ± 0.38	2.1 ± 0.39	0.27
Mobility	2.0 ± 0.21	2.0 ± 0.00	0.27
Sub-valvular Thickening	2.5 ± 0.51	2.5 ± 0.51	0.85
Height-to-length ratio	0.34 ± 0.04	0.33±0.05	0.497

Mean score was 7.9 ± 1.34 in the patients with optimal results and 8.7 ± 1.20 in those with suboptimal results (*p* value = 0.03). Maybe this difference was attributed to the difference in the mean of the mitral valve thickness between the two groups; however, its clinical importance is under question.

Discussion

Rheumatic heart disease induces varying degrees of fusion of the mitral commissures, calcification and fibrosis of the valve leaflets, shortening and fusion of the chordae tendinea.[9] Therefore, the consequential morphology of the valve influences the selection of the therapeutic intervention and the result of the procedure applied.

Kaplan's[10] and McKay's[11] groups showed in their postmortem studies that after successful BMV, improvements in the mitral valve area and leaflet mobility were primarily due to the splitting of the commissures and fracturing of the calcific and fibrotic tissues of the leaflets.

Because the mechanism of the increase in the mitral valve area by balloon commissurotomy is splitting of the commissures, it may be assumed that the morphology of the mitral valve apparatus influences the results of the procedure. Total echocardiographic scoring systems that have their basis in leaflet morphology have been proposed as a guide to the selection of patients for BMV.[5]

The echocardiographic scoring system of Wilkins and associates takes into consideration leaflet rigidity, leaflet thickening, leaflet calcification, and subvalvular thickening, all of which can affect the early results and the restenosis rate after BMV. Wilkins scored each of these variables from 0 to 4.[7]

Using the Wilkins system, Palacios and coworkers [6] reported that BMV produced excellent immediate and follow-up results in patients with total echocardiographic scores of 8 or less; suboptimal results immediately after BMV and hemodynamic restenosis were more likely to occur in patients who had scores of more than 8.

Herrmann and colleagues[4] showed that echocardiographic evaluations of mitral leaflet thickening and mobility and of subvalvular thickening and calcification might be useful in predicting the immediate hemodynamic effects of BMV.

However, Reid and associates[12] reported that the total morphology score (sum of the four variables) showed a weak relationship to MVA immediately after BMV (r = 0.24), which was persistent at 6 months after BMV (r = -0.25). Also, they reported that no two-dimensional echocardiographic feature predicted which patients would experience an early reduction in MVA three months after BMV.

The National Heart, Lung, and Blood Institute Balloon Valvuloplasty Registry Participants reported that increase in the mitral valve area was weakly related to the mitral valve morphology as assessed by an echo score (r = -0.15) . [13]

Sutaria and coworkwers[14] showed that the transesophageal echocardiographic assessment of commissural morphology predicts MVA and outcome after BMV, adding significantly to the Wilkins score. Also, they reported that commissural calcification as assessed by transthoracic echocardiography was a useful predictor of outcome in patients with otherwise "good" valves (echo score < 8). Calcification of one or more commissure(s) predicts a less than 50% probability of achieving a valve area above 1.50 cm^2 and is an indication for valve replacement in those who are suitable for surgery.[15]

In this study, we found a significant relation between the mean total mitral valve Wilkins echo score and valvular thickness with results of BMV (7.9 ± 1.34 vs. 8.7 ± 1.20, *p* value = 0.03 and 2.0 ± 0.54 vs. 2.3 ± 0.56, *p* value=0.04, respectively). Our results were similar to the ones reported by Palacios[6] and Herrmann.[4]

Also in our investigation, there was no significant association between the H/L ratio of the AMVL doming and the amount of increase in the MVA immediately after BMV (0.34 ± 0.04 vs. 0.33±0.05, *p* value=0.497). Although Akin and coworkers[5] showed that neither mitral leaflet motion nor leaflet thickness index score influenced MVA immediately after balloon valvuloplasty, they found that higher (more severe) leaflet motion index scores were associated with reductions in the MVA at 3 months.

Study limitations

We did not perform MVA measurement 3-6 months after BMV for an evaluation of early restenosis in patients with good immediate results and this point needs further clarification.

Conclusions

Although BMV is a safe and effective procedure for patients with MS, all echo scoring systems such as quantitative assessment of the mitral leaflet motion restriction severity and the total mitral valve Wilkins' echo score have limited predictive value for immediate outcome and final valve area after BMV. Patients with optimal results obtain better valve area and hemodynamic improvement, but those with a suboptimal result may still have sustained hemodynamic and symptomatic relief.

Conflict of Interest

No conflicts of interest have been claimed by the authors.

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