Follow-up of Patients Undergoing Percutaneous Mitral Balloon Valvotomy
Analysis of Factors Determining Restenosis

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This study reports the clinical follow-up (13±1 months) of 100 consecutive patients who underwent percutaneous mitral balloon valvotomy (PMV). Echocardiographic (n=32) and cardiac catheterization (n=37) data from this group are also included. Patients were divided into two groups by an echocardiographic score. PMV resulted in a good hemodynamic result (post-PMV mitral valve area, ≥1.5 cm²) in 88% of patients with a score of 8 or less and 44% of patients with a score of more than 8. Eighty-eight percent of patients with a score of 8 or less (n=57) were New York Heart Association (NYHA) functional Classes III and IV before PMV; at follow-up, 81% were NYHA Class I and 12% were NYHA Class II. There were no deaths; three patients underwent mitral valve replacement (MVR). Ninety-eight percent of patients with a score of more than 8 (n=43) were NYHA Classes III and IV before PMV; at follow-up, 58% were NYHA Classes I and II. Seven patients who did not improve and were not surgical candidates died 3.8±1.2 months after PMV. Nine patients who were surgical candidates underwent elective MVR at 4±0.9 months after PMV. Repeat cardiac catheterization demonstrated restenosis in only one of 27 patients (4%) with a score of 8 or less. Mitral valve area after PMV was 1.9±0.1 cm² and at follow-up was 2±0.1 cm² (NS). In contrast, in patients with a score of more than 8 (n=10), mitral valve area decreased from 1.8±0.1 cm² (after PMV) to 1.1±0.1 cm² at follow-up (p<0.01). Restenosis was demonstrated in seven of 10 patients (70%) with a score of more than 8. Multivariate analysis showed echocardiographic score and the presence of atrial fibrillation as predictors of restenosis. At ventriculography, the severity of mitral regurgitation after PMV decreased by one grade in 53% of patients. Thus, PMV produces excellent immediate and follow-up results in patients with a score of 8 or less; suboptimal results immediately after PMV, and hemodynamic restenosis are more likely to occur in patients with a score of more than 8. (Circulation 1989;79:573–579)

Percutaneous mitral balloon valvotomy (PMV) is an alternative to surgical mitral commissurotomy for patients with mitral stenosis.1–6 We have previously demonstrated that age, the presence of atrial fibrillation, fluoroscopic calcium, severity of symptoms, and the effective balloon dilating area all affect the immediate hemodynamic results.1,7,8 But the best predictor of immediate results is an echocardiographic “score” based on the severity of mitral valve morphologic abnormalities.7,8 Although PMV produces immediate hemodynamic improvement in most patients with mitral stenosis, complications of the procedure and the long-term outcome of PMV will be the best measure of its usefulness. This study assesses the immediate results and clinical follow-up of 100 consecutive patients who underwent PMV at the Massachusetts General Hospital. In addition, follow-up echocardiographic (n=32) and catheterization (n=37) findings are presented. We also identify factors that appear to influence mitral valve restenosis.

Materials and Methods

Patient Population

This study reports 100 consecutive patients who underwent PMV at the Massachusetts General Hospital between July 1985 and October 1987. There were 83 women and 17 men (mean age, 55±5 years; range, 14–87 years). Fifty-one patients were in normal sinus rhythm, and 49 patients in atrial fibril-
tion. Before PMV, 25 patients were in New York Heart Association (NYHA) functional Class IV, 67 in Class III, and eight in Class II.

Patients were followed for a mean period of 13 ± 1 months (range, 2 weeks to 28 months). An end point was reached if a patient died, had mitral valve replacement, or could be evaluated clinically by May 1988. An early end point was reached in 19 patients (seven deaths; 12 mitral valve replacements). The functional status of the patients was determined at a follow-up visit by the authors or by telephone interview. If patients could not be contacted, their local physician was called to determine their clinical status. Symptoms before PMV and at follow-up are reported according to the NYHA classification of heart failure. In addition, mitral valve area at follow-up was determined by cardiac catheterization in 37 patients and by two-dimensional echocardiography in 32 additional patients.

Analysis of Data

Patients were divided into two groups according to an echocardiographic score system described previously.7,8 Leaflet rigidity, leaflet thickening, leaflet calcification, and subvalvaral thickening were each scored from 0 to 4 (least to most). A high score was tallied by patients with more severe disease (thickened, rigid, and calcified valve leaflets associated with thickening of the subvalvaral apparatus). Fifty-seven patients had echocardiographic scores of 8 or less, and 43 patients had scores of more than 8. The Table shows the demographic characteristics of these two groups. Patients with echocardiographic scores of more than 8 were older, had a higher frequency of atrial fibrillation, and had more fluoroscopic calcium than those with echocardiographic scores of 8 or less.

Procedures

Percutaneous mitral balloon valvotomy. Written informed consent approved by the Human Studies Committee of the Massachusetts General Hospital was obtained from each patient before PMV. PMV was performed as previously described.1,6–8 All patients were anticoagulated with coumadin before and after PMV if they were in atrial fibrillation, had a history of paroxysmal atrial fibrillation, or had a previous embolus. All patients were given intravenous heparin (100 units/kg) immediately after achiev-

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<th>TABLE. Demographic Characteristics of 100 Patients Undergoing Percutaneous Mitral Valvotomy</th>
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* p < 0.0001. † p < 0.01.
Statistical analysis. Comparison of variables before PMV, immediately after PMV, and at follow-up was performed with analysis of variance and the Newman-Keuls multiple comparison test. Comparison of variables between patients with echocardiographic scores of 8 or less and those with an echocardiographic score of more than 8 was performed using the unpaired Student’s t test. Changes were considered significant when \( p < 0.05 \).

To identify factors associated with immediate outcome of PMV, univariate and stepwise multiple regression analyses of 16 demographic and hemodynamic variables were performed in the 100 patients. The variables included age, sex, EBDA, EBDA/BSA, the number of balloons used (single versus double balloon technique), fluoroscopic presence of calcium, degree of mitral regurgitation, echocardiographic score, rhythm, NYHA functional Class before PMV, and the hemodynamic determinations before PMV (mitral gradient, cardiac output, mitral valve area, pulmonary artery pressure, left atrial pressure, and pulmonary vascular resistance).

In an attempt to identify factors associated with restenosis, univariate and stepwise multiple regression analyses of 10 variables were performed in the 37 patients who underwent repeat cardiac catheterization. The variables included age, sex, EBDA, EBDA/BSA, fluoroscopic presence of calcium, echocardiographic score, rhythm, NYHA functional class before PMV, and the mitral valve area before and after PMV.

All statistical testing was performed with BMDP statistical software on a Digital Vax 11-780 computer (Digital Equipment Corp, Marlboro, Massachusetts).

Results

Immediate Results

The hemodynamic results produced by PMV in patients with echocardiographic scores of 8 or less and more than 8 are shown in Figure 1. PMV resulted in a significant decrease in mitral gradient and a significant increase in cardiac output and mitral valve area in both groups of patients. However, the increase in mitral valve area was greater in patients with echocardiographic scores of 8 or less. In this group, PMV resulted in an increase in mitral valve area from 0.9±0.1 to 1.9±0.1 cm\(^2\) (\( p < 0.01 \)). A “good” hemodynamic result (defined as a post-PMV mitral valve area, \( \geq 1.5 \text{ cm}^2 \)) was observed in 50 of the 57 patients (88%) with echo scores of 8 or less.

In patients with echocardiographic scores of more than 8, PMV resulted in an increase in mitral valve area from 0.9±0.1 to 1.6±0.1 cm\(^2\) (\( p < 0.01 \)). A good hemodynamic result occurred only in 19 of the 43 patients (44%) and a suboptimal result in the other 24 patients (56%) in this group. Comparison of the difference in the increase in mitral valve area produced by PMV in patients with echo scores of 8 or less and more than 8 was statistically significant (\( p < 0.006 \)).

Univariate analysis demonstrated that the increase in mitral valve area with PMV is directly related in EBDA/BSA (\( p = 0.03 \)) and inversely related to the echocardiographic score (\( p = 0.00002 \)), the presence of atrial fibrillation (\( p = 0.0002 \)), fluoroscopic calcium (\( p = 0.0006 \)), and older age (\( p = 0.00007 \)). Multiple stepwise regression analysis demonstrated that the independent predictors of the increase in mitral valve area with PMV are the echocardiographic score (\( p = 0.007 \)), the presence of atrial fibrillation (\( p = 0.005 \)), and mitral regurgitation before PMV (\( p = 0.02 \)).

The immediate outcome of PMV was also related to whether one or two balloons were used for PMV. Mitral valve area increased from 0.8±0.1 to 1.4±0.1 cm\(^2\) in the 22 patients in whom PMV was performed with the single balloon technique (EBDA, 4.3±0.2 cm\(^2\)). In contrast, mitral valve area increased from 0.9±0.1 to 1.9±0.1 cm\(^2\) in the 78 patients in whom PMV was performed using the double balloon technique (EBDA, 7.1±0.1 cm\(^2\)). Comparison of the difference in the increase in mitral valve area produced by PMV in patients treated with single and double balloon technique was statistically significant (\( p = 0.001 \)).

Complications

One patient (1%) died soon after PMV as previously described.\(^1\) Two patients developed transient

**Figure 1.** Bar charts of hemodynamic changes produced by percutaneous mitral valvotomy in patients with echocardiographic scores of 8 or less and more than 8.
(less than 24 hours’ duration) complete atrioventricular block requiring temporary pacing. Two patients developed thromboembolic events, including a stroke in one patient (1%). Severe mitral regurgitation occurred in only one patient (1%). Left-to-right shunt through the interatrial communication was demonstrated by oximetry at the end of the procedure in 20 patients (20%). The pulmonary to systemic flow ratio of the atrial shunt was less than 2:1 in 16 patients and equal or greater than 2:1 in four. Pericardial tamponade occurred in two patients (2%). Both patients were successfully treated in the catheterization laboratory with pericardiocentesis and did not require emergency surgery.

Follow-up Results of Patients With Echocardiographic Scores of 8 or Less

Clinical follow-up. The New York Heart Association functional classification of the 57 patients with echocardiographic scores of 8 or less before PMV, 1 week after PMV, and at follow-up are shown in Figure 2 (left panel). Before PMV, 88% of the patients with echocardiographic scores of 8 or less were NYHA Classes III and IV. At follow-up, 81% were Class I and 12% were Class II. There were no deaths in this group of patients. Three of the four patients in Class III after PMV underwent elective mitral valve replacement at 5.3±1.6 months after PMV because of mitral regurgitation and heart failure. Their mitral valve areas after PMV were 2.1, 2.0, and 1.7 cm²; two patients had 2+ and one patient had 3+ mitral regurgitation.

Follow-up cardiac catheterization. Figure 3 (left panel) shows the mitral valve areas before PMV, immediately after PMV, and at follow-up cardiac catheterization of 29 patients with echocardiographic scores of 8 or less. There was no significant difference in the mean calculated mitral valve area at follow-up catheterization compared with that immediately after PMV. Mitral valve area at follow-up catheterization was 2.0±0.1 cm² compared with 1.9±0.1 cm² immediately after PMV. Restenosis was present in only one patient (4%) in this group of patients.

Follow-up echocardiography. Sixteen additional patients with an echocardiographic score of 8 or less who did not have follow-up cardiac catheterization had evaluation of their mitral valve areas at follow-up by two-dimensional and Doppler echocardiography. In this group of patients, the mean mitral valve area at follow-up was 1.6±0.1 cm² compared with 1.6±0.1 cm² immediately after PMV. Restenosis by echocardiography was demonstrated in only one of these 16 patients (6%).

Follow-up Results of Patients With Echocardiographic Scores of More Than 8

Clinical follow-up. The New York Heart Association functional classification of the 43 patients with echocardiographic scores of more than 8 before PMV, 1 week after PMV, and at follow-up is shown in Figure 2 (right panel). Before PMV, 98% of the patients with echocardiographic scores of more than 8 were in NYHA Classes III and IV. At follow-up, 58% of the patients in this group were Classes I and II. Eighteen of the 24 patients in whom PMV resulted in a suboptimal result remained in NYHA Classes III and IV after PMV. Seven of these patients who were considered nonsurgical candidates because of advanced age and associated major medical problems in addition to end-stage
mitral stenosis died at 3.8 ± 1.2 months after PMV. All died from congestive heart failure, including one patient who was readmitted 2 weeks after PMV with sepsis secondary to a dental abscess. Nine of the remaining 11 Class III and Class IV patients who had a suboptimal result with PMV and were surgical candidates underwent mitral valve replacement at 4 ± 0.9 months after PMV.

**Follow-up cardiac catheterization.** Figure 3 (right panel) shows the mitral valve areas of 10 patients with echocardiographic scores of more than 8 before PMV, immediately after PMV, and at follow-up cardiac catheterization.

Patients with echocardiographic score of more than 8 had a significant decrease in mitral valve area at follow-up when compared with immediate post-PMV results. Mean mitral valve area had decreased from 1.8 ± 0.1 cm² immediately after PMV to 1.1 ± 0.1 cm² at follow-up catheterization (p < 0.01). Restenosis was present in seven patients (70%) of this group.

**Follow-up echocardiography.** Sixteen additional patients with echocardiographic scores of more than 8 who did not have follow-up cardiac catheterization had evaluation of their mitral valve area at follow-up by two-dimensional and Doppler echocardiography. In this group of patients, the mean mitral valve area at follow-up was 1.5 ± 0.1 cm² compared with 1.6 ± 0.2 cm² immediately after PMV. Restenosis was demonstrated in four of these 16 patients (25%).

Univariate analysis demonstrated that the decrease in mitral valve area at follow-up was directly related to older age (p = 0.01), higher echocardiographic score (p = 0.0004), and the presence of fluoroscopic calcium (p = 0.005) and inversely related to EBDA/BSA (p = 0.05). Multiple stepwise regression analysis identified echocardiographic score (p = 0.0004), F = 15.16) as the only independent predictor of restenosis (Δ mitral valve area, 0.136843 × echocardiographic score + 0.953064).

**Mitral Regurgitation**

**Immediate results.** Fifty-three percent of patients undergoing PMV had an increase in mitral regurgitation of one grade or more immediately after PMV. Severe mitral regurgitation (4+) was present in only 1 patient (1%). There was no need for emergency mitral valve replacement.

**Follow-up results.** Figure 4 shows the changes in the degree of mitral regurgitation before and after PMV and at follow-up in 36 of the 37 patients who underwent repeat cardiac catheterization.

PMV resulted in an increase in the severity of mitral regurgitation compared with pre-PMV status in 19 of the 36 patients (53%). At follow-up ventriculography, the severity of mitral regurgitation decreased by one grade in 10 of these 19 patients (53%) and increased by one grade in one patient.

**Left to Right Shunting**

**Immediate results.** A significant step up (≥7% increase) in oxygen saturation was demonstrated in 20% of the patients undergoing PMV. The pulmonary to systemic flow ratio of the shunt was 1.6:1 or less in 11 patients, between 1.7:1 and 2:1 in five patients, and more than 2:1 in four patients.

**Follow-up results.** Seventeen of the 20 patients with post-PMV left-to-right shunt had evaluation of the atrial septal defect at 10 ± 1 months after PMV by either cardiac catheterization, color flow Doppler echocardiography, or cardiac surgery. The other three patients died before follow-up evaluation of the atrial defect. Follow-up evaluation showed no evidence of atrial communication in 11 of these 17 patients (65%).

Of the 37 patients who had follow-up right heart and transseptal left heart catheterization, there were five patients who had evidence of left-to-right shunting immediately after PMV, yet evidence of shunting at follow-up catheterization was demonstrated in only one patient. In most of these patients, repeat transseptal puncture was necessary at the time of follow-up catheterization, which indicates that the atrial septal puncture done at PMV had closed. Of four additional patients who had right heart catheterization with diagnostic oxygen run, a left-to-right shunt was demonstrated in two patients. In each, the pulmonary to systemic flow ratio of the shunt was 1.7:1. Three patients did not have cardiac catheterization but were evaluated by color flow Doppler echocardiography. Left-to-right shunt was demonstrated in one. Finally, among the 12 patients who underwent elective mitral valve replacement, there were five patients who had evidence of left-to-right shunting immediately after PMV. However, at surgery, an iatrogenic atrial septal defect was seen and closed in only two of these five patients.

**Discussion**

Our study shows that the symptomatic and hemodynamic improvement produced by PMV persists as patients are followed up for more than 2 years.
This study also demonstrates that the echocardiographic score, balloon size, age and the presence of atrial fibrillation, fluoroscopic calcium, and mitral regurgitation are the more important predictors of the increase of mitral valve area with PMV.

The best immediate results of PMV are in patients with echocardiographic scores of 8 or less whose mitral valves are mobile, thin, and minimally or not calcified and who have little or no subvalvular fibrosis.\(^7\)\(^8\) Our study shows that a good hemodynamic outcome of PMV (defined as post-PMV mitral valve area, \(\geq 1.5\) cm\(^2\)) is obtained in 88% of these patients. The best long-term functional, echocardiographic, and hemodynamic results are also seen in patients with a score of 8 or less. When PMV produces good hemodynamic results in these patients, restenosis by echocardiographic or cardiac catheterization or both is unlikely to occur at follow-up.

In contrast, patients with echocardiographic scores of more than 8 whose echocardiograms demonstrate severe subvalvular disease, extensive valvular thickening and calcification, and a rigid mitral valve have a high chance of having a suboptimal hemodynamic result with PMV. In our patients, a good hemodynamic result with PMV occurred in only 44% of patients with echocardiographic scores of more than 8. Eighteen of the 24 patients in this group with a suboptimal result of PMV remained in NYHA Classes III and IV after PMV. Of these 18 patients at an average follow-up of 4 months, nine surgical candidates had mitral valve replacement, and seven nonsurgical candidates died. Even if a good hemodynamic result is produced in patients with echocardiographic scores of more than 8, restenosis can frequently be demonstrated by cardiac catheterization at follow-up. However, it is possible that our 37 patients who underwent follow-up cardiac catheterization may not be representative of our entire population because the selection was not random. Nevertheless, there were no significant differences in the demographic characteristics, and the pre-PMV and post-PMV hemodynamics of this subgroup generally compared with our entire PMV population. Although univariate analysis identified age, echocardiographic score, evidence of calcium at fluoroscopy, and EBDA/BSA as variables predictive of a decrease in mitral valve area at follow-up, multiple stepwise regression analysis identified the echocardiographic score as the single most important factor predictive of restenosis.

Our findings are in agreement with previous reports of surgical mitral commissurotomy.\(^10\)-\(^17\) The best results of surgical mitral commissurotomy occur in patients who have little or no calcium deposition in the mitral valve.\(^10\)-\(^14\) Those studies identified significant mitral calcification and the presence of atrial fibrillation as the most important factors adversely influencing both immediate and long-term results.\(^10\)-\(^14\) Unfortunately, most follow-up studies of surgical mitral commissurotomy have reported only functional results.\(^10\)-\(^15\) Studies that reported follow-up hemodynamic parameters lack immediate postcommissurotomy hemodynamic data.\(^16\)^\(^17\) Our data show that a persistent small increase in mitral valve area produces improvement in clinical symptoms even when some restenosis has occurred. Five of seven patients with echocardiographic score of more than 8 and hemodynamic restenosis but still with a mitral valve area greater than before PMV remained in the improved NYHA functional class that they reached after PMV. An attempt to compare our hemodynamic data with previous surgical results is, therefore, difficult.

The clinical usefulness of PMV can only be assessed by follow-up data and acute complications. Our follow-up data is encouraging. The risks of mortality, thromboembolism, and severe mitral regurgitation are similar for surgical mitral commissurotomy and PMV.\(^10\)-\(^15\) In contrast to surgical commissurotomy, 20% of our patients had evidence of left-to-right shunting through the atrial septum immediately after PMV. In 80% of them, the magnitude of the shunt was small with a pulmonary to systemic flow ratio less than 2:1. We demonstrated evidence of left-to-right shunting by oximetry in only one of the 37 patients who underwent follow-up catheterization. Among these 37 patients, there were five patients with evidence of left-to-right shunting immediately after PMV. In addition, no atrial communication was discovered at surgery in nine of 12 patients undergoing elective mitral valve replacement. In this latter group of patients, a left-to-right shunt had been demonstrated in five patients immediately after PMV. Thus, although the atrial septum has a small tear produced by PMV,\(^18\) it is likely that it closes later in the majority of cases. Left-to-right shunting might persist if the result of PMV is suboptimal. Persistence of a high left atrial pressure and the resultant high pressure gradient between left and right atrium could cause enough flow to keep the defect open. Conversely, a good result of PMV with its attendant decrease in left atrial pressure minimizes the atrial pressure differential and may allow septal closure. Thus, if patients do not have a good result after PMV and mitral valve replacement is done later, surgeons should be aware of the possibility of an atrial septal defect that should be repaired at the time of mitral valve surgery.

Mitral regurgitation may occur after surgical mitral commissurotomy.\(^14\)^\(^15\) Approximately half of the patients undergoing PMV have a small increase in mitral regurgitation.\(^1\)^\(^8\) Severe mitral regurgitation is rare. We have previously reported that an increase in mitral regurgitation cannot be predicted from any features of the valve or subvalvular apparatus, clinical characteristics of the patient, or technical aspects of the procedure.\(^19\) This study also indicates that the increase in the severity of mitral regurgitation that was produced by PMV decreases in more than half of patients at follow-up catheterization. There may be three mechanisms responsible for the
decrease in mitral regurgitation: 1) reversible mitral valve “stretching” by PMV; 2) fibrosis and healing of the end of the commissures, which may diminish mitral regurgitation due to excessive splitting of the commissures to the mitral annulus; and 3) improvement in transient papillary muscle dysfunction caused by balloon trauma to the papillary muscle at the time of PMV. Mitral regurgitation is tolerated well clinically. In our patients, there was no deterioration in NYHA class immediately after PMV.

We conclude that 1) patients who have low echocardiographic scores (8 or less) are the best candidates for percutaneous mitral valvotomy; not only do they have a good immediate result from PMV, but their follow-up shows on-going clinical, echocardiographic, and hemodynamic stability; 2) patients with echocardiographic scores of more than 8 have a 56% chance of having a suboptimal immediate result with PMV; although they could have a good initial result from PMV, our study shows that a high percentage of them have restenosis demonstrated by cardiac catheterization or echocardiography at follow-up; and 3) it is our impression that if the echo score is more than 12, it is unlikely that PMV will produce a good immediate or long-term result. These patients, if they are surgical candidates, are better suited for surgical mitral valve replacement, and PMV should be undertaken only if surgery is not an option. Clearly, patients will fall into a continuum of echocardiographic scores. If the score is 9–12, individual consideration may allow identification of patients who might have the most favorable result from PMV. In this group, we feel that valve thickening, subvalvular fibrosis, and calcification are the factors that adversely influence the outcome of PMV. If there is severe subvalvular apparatus disease, relief of mitral obstruction with PMV may be impossible.

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References

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