Immediate and Long-term Outcome of Percutaneous Mitral Valvotomy in Patients 65 Years and Older

E. Murat Tuzcu, MD; Peter C. Block, MD; Brian P. Griffin, MD; John B. Newell, PhD; and Igor F. Palacios, MD

Background. We analyzed the immediate and long-term outcome of percutaneous balloon mitral valvotomy (PMV) in 99 patients who were ≥65 years of age (81 women and 18 men; mean±SEM age, 72±0.5 years).

Methods and Results. There were 84 patients in New York Heart Association (NYHA) class III or IV; 26 patients had previous surgical commissurotomy; 64 had one or more comorbidities; 73 had fluoroscopically visible mitral valve (MV) calcification; and 63 had echocardiographic score >8 (mean±SEM score, 9.2±0.2). There were three procedural deaths, all occurring in our early experience. Pericardial tamponade occurred in five patients, thromboembolism in three, and transient atrioventricular block in one. After PMV, MV area was ≥1 cm² in 86 patients and ≥1.5 cm² in 56. A successful outcome (defined as MV area ≥1.5 cm² without a ≥2-grade increase in mitral regurgitation and without left-to-right shunt with a pulmonary-to-systemic flow ratio of ≥1.5:1) was achieved in 46 patients. The best multivariate predictor of success was the combination of echocardiographic score, NYHA functional class, and inverse of MV area. Mean follow-up was 16±1 months. Actuarial survival (79±7% versus 62±10%, p=0.04), survival without MV replacement (71±8% versus 41±8%, p=0.002), and survival without MV replacement and NYHA class III or IV (54±12% versus 38±8%, p=0.01) at 3 years were significantly better in the successful group of 46 patients than in the unsuccessful group of 53 patients. Low echocardiographic score was the only independent predictor of survival. Lack of MV calcification and low NYHA class, low mean left atrial pressure, and low pulmonary artery pressure were the independent predictors of event-free survival.

Conclusions. PMV can be performed safely in selected patients ≥65 years old with good immediate and long-term results. In addition to clinical examination, echocardiographic evaluation of the mitral valve and fluoroscopic screening for valvular calcification are the most important steps in patient selection for successful outcome. (Circulation 1992;85:963–971)

Key Words • mitral stenoses • aging • valvuloplasty • valves

Patients with symptomatic mitral stenosis requiring intervention are generally in their fourth or fifth decade. In published reports of the treatment of mitral stenosis, the mean age of the patients ranges from 15 to 56 years.1–4 Many patients with symptomatic mitral stenosis are older, however, particularly in developed countries. In our institution, one third of the patients who undergo percutaneous mitral valvotomy (PMV) are ≥65 years old. There are no reports of the outcome of PMV in the elderly population except some preliminary communications.5–6 To design a management strategy for elderly patients with symptomatic mitral stenosis, we analyzed the immediate and long-term outcome of PMV in 99 consecutive patients ≥65 years old.

Methods

Patient Population

Clinical pre-PMV and post-PMV hemodynamic measurements of all patients who underwent PMV at the Massachusetts General Hospital were entered prospectively into a computerized data base. Between August 1986 and September 1989, of the 329 consecutive patients who had PMV, 99 (30%) were ≥65 years old. These 99 patients constitute our study population. Age was 72±1 years (mean±SEM; range, 65–87 years). There were 81 women and 18 men.

Pre-PMV Clinical and Laboratory Evaluation

All patients were evaluated clinically and also had two-dimensional and Doppler echocardiography. Transesophageal echocardiography was performed when the quality of the transthoracic study was inadequate, evidence of left atrial thrombus was equivocal, or there was a history of previous embolic event. Patients with left atrial thrombus, atrial fibrillation, and previous thromboembolic episodes were anticagulated with warfarin for 2–3 months before reevaluation for PMV. Patients underwent right and left heart catheterization, coronary arteriography, and left ventriculography either in our hospital or at the referring institution. Of the 99 patients, seven did not have pre-PMV cine left ventriculography. Assessment of the presence and degree of pre-PMV mitral regurgitation was made by Doppler echocardiography in five patients. In the remaining two...
patients, pre-PMV mitral regurgitation was assessed by physical examination. Records and cineangiograms were available for our review in all cases.

**Procedure**

In our early experience, in 13 patients PMV was performed by the single-balloon technique. The double-balloon technique was used in the remaining 83 patients. At that time, balloons were selected according to the dimension of the mitral valve annulus obtained from two-dimensional echocardiography. After January 1988, balloons were selected according to body surface area. Various combinations of balloons with diameters ranging from 15 to 20 mm were used. Right and left heart pressure measurements, simultaneous left atrial and left ventricular pressure recordings, oxygen saturation, and cardiac output measurements were made before and immediately after PMV. Cardiac output was measured by thermodilution technique. Blood samples were obtained from superior vena cava, pulmonary artery, and aorta before and after the procedure in all patients. Significant tricuspid regurgitation was diagnosed by clinical, Doppler echocardiographic, and hemodynamic findings. A diagnosis of left-to-right shunting through the created atrial communication was made when there was a ≥7% step-up between superior vena cava and pulmonary artery blood oxygen saturation in repeated samples. In patients with severe tricuspid regurgitation and left-to-right shunt, cardiac output was measured by the Fick principle. Oxygen consumption was measured with an MRM-2 oxygen consumption monitor (Waters Instrument Inc., Rochester, Minn.). In patients who were unable to cooperate, however, an assumed oxygen consumption value was used. When assumed oxygen consumption value was used for the calculation of cardiac output after mitral valvotomy, the same assumed oxygen consumption value was used for the calculation of the prevalvotomy cardiac output. Because large discrepancies could exist between the direct and assumed measurement of oxygen consumption values, an assumed oxygen consumption represents a limiting factor in the calculation of the mitral valve area of the 15 patients in the present study in whom this assumption was made. A left ventriculogram was performed immediately after PMV in a 45° right anterior oblique projection to assess the presence and severity of mitral regurgitation.

**Data Collection**

Information obtained from history, physical examination, ECG, echocardiogram, and catheterization together with pre-PMV and post-PMV hemodynamic findings, complications, and outcome of the procedure were prospectively entered into an RS/1 table on a micro VAX 3600 computer (Digital Equipment Corp., Maynard, Mass.) data storage system.

**Follow-up**

Patients were followed at 6-month intervals by telephone interviews. Local physicians were contacted and records of examinations were obtained whenever necessary. Follow-up information included survivorship, cause of death, mitral valve replacement, and clinical status. From this information, a New York Heart Association (NYHA) functional class was assigned to every patient. The mean follow-up period for all patients was 16±1 months, and for patients who had a completed PMV and survived hospitalization, it was 17±1 months.

**Method of Analysis**

Successful outcome was defined as a final mitral valve area of ≥1.5 cm² without a ≥2-grade increase in mitral regurgitation and without a left-to-right shunt with a pulmonary-to-systemic flow ratio of ≥1.5:1 after PMV. Major procedure-related complications included death, pericardial tamponade, thromboembolic event, and high-grade atrioventricular block.

Patients were divided into two groups according to outcome. Forty-six patients had a successful outcome, and 53 had an unsuccessful outcome. Univariate analysis of the baseline variables was done for the two groups. A multiple stepwise logistic regression analysis was performed to identify the predictors of successful outcome. A value of p<0.05 was used as the minimum value for statistical significance. Values were expressed as mean±SEM.

The baseline variables entered into the univariate and multivariate analyses were 1) demographic variables (age, sex, and body surface area), 2) comorbidities (hypertension, diabetes mellitus, coronary artery disease, associated aortic valvular disease, chronic obstructive lung disease, renal failure, central nervous system disease, chronic liver disease, history of thromboembolism, neoplastic disease, and previous surgical commissurotomy), 3) clinical variables (NYHA functional class and presence of atrial fibrillation) and 4) laboratory variables (echocardiographic score obtained by grading leaflet thickening, mobility, calcification, and subvalvular involvement 0–4). A relatively simple, semiquantitative echocardiographic evaluation for scoring of the mitral valve was used. Although there may be discrepancies between observers, it has been shown previously by our group that interobserver and intraobserver variabilities are acceptably low. Fluoroscopically visible mitral valve calcification was graded from 0 to 4 according to the severity of the calcification (0, no calcium; 1, mild calcification; 4, severe calcification). Mitral regurgitation was graded according to the Sellers grading system by use of left ventriculography. Finally, hemodynamic variables included mean pulmonary artery pressure, mean left atrial pressure, pulmonary vascular resistance, mean mitral valve gradient, cardiac output, and calculated mitral valve area. The reciprocal of pre-PMV mitral valve area and its interactions with NYHA functional class, echocardiographic score, and pre-PMV mean mitral pressure gradient also were entered into the logistic regression.

The time-related events noted during the follow-up were examined by the Kaplan-Meier method. Actuarial survivorship, actuarial survivorship with freedom from mitral valve replacement, and NYHA functional class III or IV were analyzed. Kaplan-Meier curves were constructed for the whole group as well as for patients who had a successful outcome and for those who had an unsuccessful outcome.

Stepwise Cox regression analysis was used for determining the predictors of time-related events (i.e., death, mitral valve replacement, and NYHA functional class III and IV). In addition to the above-listed baseline and hemodynamic variables, procedural and post-PMV
hemodynamic variables included for regression analysis were effective balloon-dilating area, effective balloon-dilating area index, mean pulmonary artery pressure, mean left atrial pressure, pulmonary vascular resistance, cardiac output, mean mitral valve gradient, calculated mitral valve area (and its difference from before PMV), and degree of mitral regurgitation (and its difference from before PMV).

Results

Baseline Characteristics

Baseline clinical characteristics of the patients are shown in Table 1. Of the 99 patients, 27 had at least one, 15 had two, seven had three, and 15 had four or more comorbidities. Most of the patients were severely symptom limited: 85% were in NYHA functional class III or IV, and 74% had atrial fibrillation. The echocardiographic and fluoroscopic evaluations of the mitral valves are shown in Table 2. Echocardiographic score was >8 in 64%; fluoroscopically visible calcium was present in 73%. Pre-PMV hemodynamic findings are shown in Table 3.

Patients who had an unsuccessful outcome from PMV were in a higher NYHA functional class, had higher echocardiographic scores, and had smaller mitral valve areas before PMV than patients who had a successful outcome (Tables 1, 2, and 3).

Complications

There were three procedure-related deaths: one patient who was brought to the catheterization laboratory in cardiogenic shock for emergency PMV died despite a technically successful and uncomplicated procedure, one patient died of left ventricular perforation and cardiac tamponade, and one patient died of intractable right ventricular failure during emergency mitral valve replacement. All deaths occurred in our early experience.

Pericardial tamponade requiring intervention occurred in five patients. All were successfully treated with

<table>
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<th>TABLE 1. Clinical Characteristics</th>
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<tr>
<td>Patients undergoing percutaneous mitral valvotomy</td>
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<tr>
<td>Total (n=99)</td>
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<tr>
<td>Age (years)</td>
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<tr>
<td>Sex (female:male)</td>
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<tr>
<td>NYHA class</td>
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<td>I</td>
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<td>II</td>
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<td>Surg comm</td>
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<td>CAD</td>
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<td>Aortic valve disease</td>
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<td>Liver disease</td>
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<td>Renal disease</td>
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<td>Cancer</td>
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NYHA, New York Heart Association; Surg comm, surgical commissurotomy; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident.

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<th>TABLE 2. Clinical Characteristics</th>
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<td>Patients undergoing percutaneous mitral valvotomy</td>
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<tr>
<td>Total (n=99)</td>
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<tr>
<td>AF (n)</td>
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<tr>
<td>E score</td>
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<tr>
<td>E score &gt;8 (n)</td>
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<td>MV calcium grade</td>
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<td>0</td>
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<tr>
<td>1</td>
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<td>2</td>
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AF, atrial fibrillation; E, echocardiographic; MV, mitral valve.
TABLE 3. Hemodynamic Characteristics

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<th>Patients undergoing percutaneous mitral valvotomy</th>
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<tr>
<td></td>
<td>Total (n=99)</td>
</tr>
<tr>
<td>Pre-PMV PAP (mm Hg)</td>
<td>39±1</td>
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<tr>
<td>Post-PMV PAP (mm Hg)</td>
<td>33±2</td>
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<tr>
<td>Pre-PMV LAP (mm Hg)</td>
<td>23±1</td>
</tr>
<tr>
<td>Post-PMV LAP (mm Hg)</td>
<td>16±1</td>
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<tr>
<td>Pre-PMV MVG (mm Hg)</td>
<td>13.3±0.5</td>
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<tr>
<td>Post-PMV MVG (mm Hg)</td>
<td>5.4±0.3</td>
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<tr>
<td>Pre-PMV CO (l/min)</td>
<td>3.4±0.1</td>
</tr>
<tr>
<td>Post-PMV CO (l/min)</td>
<td>3.9±0.1</td>
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<tr>
<td>Pre-PMV MVA (cm²)</td>
<td>0.8±0.1</td>
</tr>
<tr>
<td>Post-PMV MVA (cm²)</td>
<td>1.7±0.1</td>
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<tr>
<td>Pre-PMV PVR</td>
<td>406±42</td>
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<tr>
<td>Post-PMV PVR</td>
<td>367±27</td>
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PMV, percutaneous mitral valvotomy; PAP, mean pulmonary artery pressure; LAP, mean left atrial pressure; MVG, mean mitral valve gradient; CO, cardiac output; MVA, mitral valve area; PVR, pulmonary vascular resistance (dynes·sec·cm⁻⁵).

Pericardiocentesis in the catheterization laboratory. In two of these five patients, PMV was terminated before the completion of the procedure. In one patient, the procedure was terminated because of inability to pass the valvotomy balloons across the mitral valve.

One patient had complete atrioventricular block, which disappeared within 24 hours. Three patients...
Immediate Outcome

The hemodynamic findings after PMV are shown in Table 3. In 56 of the patients (57%), the final mitral valve area was ≥1.5 cm². Of these 56, five had a ≥2-grade increase of mitral regurgitation, three had left-to-right shunt with a pulmonary-to-systemic flow ratio of ≥1.5:1, and two had both. Thus, of the 99 patients, 46 (46%) had a successful outcome (i.e., final mitral valve area ≥1.5 cm² without post-PMV ≥2-grade increase in mitral regurgitation and left-to-right shunt with pulmonary-to-systemic ratio ≥1.5:1). Post-PMV mitral valve area was <1.5 cm² but ≥1.0 cm² in 29 patients (29%). Mitral valve area increased by at least 50% in 74 patients (75%) and increased by more than 100% in 51 patients (52%).

No single pre-PMV or procedural variable was found to be an independent predictor of successful immediate outcome. Logistic regression analysis showed that the interaction of echocardiographic score and fluoroscopically visible calcium (echocardiographic score <8 and lack of fluoroscopically visible calcium) is a significant predictor of successful outcome. However, this is not a strong effect (p=0.05). The continuous relation between the final mitral valve area and echocardiographic score diminishes the value of this particular combination further.

The best multivariate predictor of success, as determined by stepwise logistic regression, was the combination of the echocardiographic score, the pre-PMV NYHA functional class, and the reciprocal of the pre-PMV mitral valve area (p=0.0016). The larger this combination, the lower the predicted probability of a successful outcome, as shown in the logistic model:

\[ P_{(success)} = \frac{e^{1.4(±0.5)-0.04(±0.01)×NYHA×echo×1/MVA}}{1+e^{1.4(±0.5)-0.04(±0.01)×NYHA×echo×1/MVA}} \]

where \( P_{(success)} \) is the predicted probability of success and standard errors of the coefficients are in parentheses [e.g., (±0.5) is the standard error of the constant coefficient]. If a cutoff of \( P_{(success)} \) is 0.54 in this probability of a successful outcome assigned to optimize predictive accuracy (with a sensitivity of 0.60±0.07, specificity of 0.69±0.06, and predictive accuracy of 0.65±0.05), then this indicates that the quantity (NYHA)×(echocardiographic score)×1/MVA (mitral valve area) should be <31 to expect a successful outcome of the PMV.

Survival

In addition to three procedure-related deaths, there were 18 late deaths—seven in the successful and 11 in the unsuccessful group. The actuarial survival for the entire group at 1, 2, and 3 years was 83±4%, 73±5%, and 70±6%, respectively (Figure 1). Patients who had a successful outcome, defined as final mitral valve area
Mitral Valve Replacement

During the follow-up period, 14 patients underwent mitral valve replacement—three in the successful group and 11 in the unsuccessful group. The operative mortality of these 14 patients was 14%. The actuarial survival with freedom from mitral valve replacement for the entire group at 1, 2, and 3 years was 74±5%, 58±6%, and 55±6%, respectively (Figure 1). Patients who had a successful outcome had a significantly better actuarial survival with freedom from mitral valve replacement at 3 years than those who had an unsuccessful outcome (71±8% versus 41±8%, p=0.002) (Figure 3).

Clinical Status

At the time of last follow-up contact, in patients who were free from mitral valve replacement, 29 were in NYHA functional class I, 27 in class II, five in class III, and one in class IV.

The actuarial survivals with freedom from mitral valve replacement and with freedom from NYHA functional class III or IV for the entire group at 1, 2, and 3 years were 72±5%, 53±6%, and 46±7%, respectively (Figure 1). Patients who had a successful outcome had a significantly better actuarial survival with freedom from mitral valve replacement and with freedom from NYHA functional class III or IV at 3 years than those who had an unsuccessful outcome (54±12% versus 38±8%, p<0.01) (Figure 4).

Two pre-PMV variables—lack of fluoroscopically visible mitral valve calcification (p<0.005) and low NYHA class (p<0.05)—and one post-PMV variable—low mean pulmonary artery pressure (p=0.003)—were the independent predictors of event-free survival (freedom from death and mitral valve replacement and NYHA functional class III and IV).

Discussion

PMV can be performed in patients ≥65 years old with low morbidity and mortality but can provide good immediate and long-term outcome only in about 50% of them. Our study demonstrates that careful patient selection with clinical evaluation together with echocardiographic evaluation of mitral valve morphology and assessment of valvular calcification by fluoroscopy helps to identify those patients who will have the best chance of successful immediate outcome (defined as final mitral valve area ≥1.5 cm² without post-PMV ≥2-grade increase in mitral regurgitation and left-to-right shunt with pulmonary-to-systemic ratio ≥1.5:1) and long-term success. Even if PMV does not result in a mitral valve area of ≥1.5 cm², however, many patients are still clinically improved. Thus, PMV can be offered as an

![Graph of actuarial survival and survival with freedom from mitral valve replacement in 99 patients (≥65 years old) stratified by subgroups of successful and unsuccessful immediate outcome. Dotted lines represent 1 SD.](http://circ.ahajournals.org/content/circulation/85/3/968_F1a)

≥1.5 cm² without post-PMV ≥2-grade increase in mitral regurgitation and left-to-right shunt with pulmonary-to-systemic ratio ≥1.5:1, had a significantly better actuarial survival at 3 years than those who had an unsuccessful outcome (79±7% versus 62±10%, p=0.04) (Figure 2). High echocardiographic score was the only predictor of early death (p=0.0001).
alternative procedure for elderly patients with symptomatic mitral stenosis.

PMV causes a combined mortality and morbidity (cardiac tamponade and thromboembolism) rate of 11%. All three deaths occurred early in our experience when most of our patients were referred to PMV after they were deemed unsuitable candidates for surgery. In our recent experience, we have had no mortality, and with better patient selection and improved technology, our morbidity rate has declined.

The immediate success rate in our elderly patient population is less than that reported for “mixed” series. This low success rate probably reflects the severity and long-standing nature of mitral stenosis in this age group. High NYHA class (III or IV), atrial fibrillation, high echocardiographic score, mitral valve calcification, and disease of other organ systems are more common in the elderly population than in a younger population. These variables have been reported as determinants of unfavorable outcome for both surgical commissurotomy and percutaneous mitral balloon valvotomy. There clearly is a multivariate aspect to the variation of final mitral valve areas. The outcome is better predicted by a multiple-variable combination of predictors than by any single predictor alone. In our study, echocardiographic score per se was not an independent predictor of immediate outcome. A cutoff point of 8 is also not very helpful in this age group, in which two thirds of the patients have an echocardiographic score >8. The fact that post-PMV mitral valve area declines smoothly and continuously as a function of increasing echocardiographic score makes a cutoff point in the range of echocardiographic scores unhelpful. Although the frequency of patients with echocardiographic scores >8 was greater in the unsuccessful group than in the successful group, a successful immediate outcome of PMV could be obtained in these patients, although less frequently than in patients with lower echocardiographic scores. Patient selection can be improved by taking fluoroscopically visible mitral valve calcification into consideration together with echocardiographic score. Echocardiographic score <8 together with absence of valvular calcification is a predictor of successful outcome. This is not a strong effect, however, especially in view of continuous and linear dependence of post-PMV mitral valve area on echocardiographic score. Echocardiographic score and valvular calcification are also predictors of long-term survival and event-free survival. Thus, in selection of patients with mitral stenosis for PMV, in addition to clinical examination, echocardiography and fluoroscopic evaluation together play an important role.

Other determinants of event-free survival were NYHA class I or II before PMV and low post-PMV pulmonary artery pressures. Pulmonary hypertension declines significantly immediately after PMV in the majority of patients and within 24 hours in most of them, although it remains high in some patients. Recording of the right-side pressures after PMV may be helpful to predict later events.

**FIGURE 4.** Graph of actuarial survival and survival with freedom from mitral valve replacement and New York Heart Association functional class III and IV in 99 patients (≥65 years old) stratified by subgroups of successful and unsuccessful immediate outcome. Dotted lines represent 1 SD.
Patients who are not suitable candidates for PMV are usually referred to surgical treatment. In reports of closed surgical commissurotomy in which the mean age of the patients was >50 years, the prevalence of risk factors was high and hospital mortality was 7–8%. However, many patients who are referred for open mitral commissurotomy have mitral valve replacement because of valvular morphology found at surgery to be unsuitable for commissurotomy. Surgical mortality and morbidity are much higher in elderly patients who have mitral valve replacement. The risk of perioperative mortality and premature death with mitral valve replacement increases with age, high NYHA functional class, atrial fibrillation, and comorbidities. Thus, in deciding for PMV or surgery, one should take into consideration not only the factors affecting the outcome of either procedure but also the relative risks. In addition, PMV can be offered to some patients as a palliative measure when the risk of surgery is too high. The fact that PMV increases the mitral valve area by at least 50% in three fourths of our elderly patients supports this suggestion.

We believe that the management strategy for an older patient with mitral stenosis is best made on an individual basis. Valvular morphology and associated risk factors should first be reviewed; outcome can then be predicted. Elderly patients with symptomatic mitral stenosis who have low echocardiographic scores and no fluoroscopically visible valvular calcification are likely to have a successful result and are best served by PMV. Establishment of an adequate mitral valve orifice and reduction in pulmonary hypertension (which can both be measured immediately after PMV in the cardiac catheterization laboratory) strengthen the likelihood of a good long-term outcome. Surgical treatment is a better option for patients who have high echocardiographic scores and calcified valves. If the surgical risk is prohibitively high because of comorbidities (particularly in cases where adequate surgical commissurotomy does not appear to be possible and mitral valve replacement might be needed), PMV may provide palliation.

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