Current Results of Operation for Mitral Stenosis
Clinical and Hemodynamic Assessments in 124 Consecutive Patients Treated by Closed Commissurotomy, Open Commissurotomy, or Valve Replacement

By Edward M. Mullin, Jr., M.D., D. Luke Glancy, M.D., Lawrence M. Higgs, M.D., Stephen E. Epstein, M.D., and Andrew G. Morrow, M.D.

SUMMARY
Among 124 consecutive patients undergoing operation for pure or predominant mitral stenosis between 1964 and 1969, closed commissurotomy was carried out in 53 (43%). There were no early or late deaths, and the hemodynamic and symptomatic results of operation were excellent. In 51 (41%) of the patients, valvular anatomy was such that valve replacement proved necessary. As a group, these patients were more severely symptomatic preoperatively and had worse hemodynamics than patients in the closed-commissurotomy group. With replacement, operative (24%) and late (12%) mortality were high, but surviving patients enjoyed hemodynamic and symptomatic benefits comparable to those of the patients undergoing closed commissurotomy. In 20 patients whose preoperative clinical and hemodynamic characteristics were intermediate between those of the closed-commissurotomy and valve-replacement groups, open commissurotomy was performed. Early (10%) and late (5%) mortality were less than with mitral replacement, but in general hemodynamic and symptomatic benefits were modest.

Additional Indexing Words:
Prior mitral valvotomy Starr-Edwards prosthesis Kay-Shiley prosthesis
Left heart catheterization Mitral calcium Atrial fibrillation
Systemic emboli NYHA functional class Residual mitral stenosis

Many studies have described the results of specific operative procedures for mitral valve disease, but no recent assessment has been made of the results of operative treatment in a consecutive series of patients with mitral stenosis. In the 6-year period between January 1964 and December 1969, 124 patients underwent operation for pure or predominant mitral stenosis at the National Heart and Lung Institute. This report describes the clinical and hemodynamic results in these patients.

Methods
Of the 124 patients with mitral stenosis, 53 were treated by closed mitral commissurotomy, 20 by open mitral commissurotomy, and 51 by mitral valve replacement. Concomitant tricuspid valvuloplasty was performed in two patients undergoing open mitral commissurotomy and in one whose mitral valve was replaced. Patients with mitral stenosis who had tricuspid disease requiring valve replacement or who had aortic valve disease severe enough to require any type of operative treatment were excluded from consideration. The operative methods of mitral commissurotomy,1 including the use of the transventricular dilator, and of valve replacement2 have been.

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Received February 3, 1972; revision accepted for publication March 20, 1972.
described previously. In the present study, an early death was defined as one occurring within 30 days of operation.

Of the 124 patients, 122 underwent cardiac catheterization before operation, and 58 patients were catheterized postoperatively, usually 6 months after operation. Right heart, transseptal left heart, and retrograde arterial catheterization technics were employed preoperatively, and after operation left ventricular pressure ordinarily was obtained by percutaneous puncture of this chamber. Pressures were measured with Statham P23Db strain gauges set at midchest level. The mean diastolic pressure gradient between left atrium (or pulmonary arterial wedge) and left ventricle was determined by planimetry using equisensitive, phasic pressure tracings. Cardiac output was measured by the indicator (indocyanine green) dilution technic, and effective mitral orifice area was calculated using the Gorlin formula. Statistical significance was determined by a t test using paired data where appropriate.

### Results

#### Preoperative Clinical Findings

The pertinent preoperative clinical findings in all 124 patients are summarized in table 1. In an earlier study at this institution, young women in sinus rhythm who had mobile, noncalcified valves were found to be the patients most likely to obtain hemodynamic benefit from closed commissurotomy, and in the present study patients with such favorable characteristics usually were treated by this method. Compared to them, patients undergoing valve replacement were older and were more likely to be male, to be in atrial fibrillation, to have fluoroscopically detectable mitral valvular calcium, to have had a previous mitral commissurotomy, and to be more severely symptomatic. The clinical profile of patients undergoing open mitral commissurotomy had some of the characteristics of the closed-commissurotomy group and some of the valve-replacement group. The prevalence of preoperative systemic embolization did not differ significantly among the three groups.

#### Preoperative Hemodynamic Findings

Pulmonary arterial systolic pressure was abnormally elevated (>29 mm Hg) in 93% of the patients in whom it was measured (fig. 1), and left atrial mean pressure exceeded the upper limit of normal (12 mm Hg) in 96% (fig. 2). The mean diastolic gradient between left atrium and left ventricle was at least 5 mm Hg in all patients, and in 78% of them the gradient was 10 mm Hg or more (fig. 3). The cardiac index was abnormally low (<2.5 liters/min/m²) in 60% of patients (fig. 4). The calculated effective mitral orifice area was less than 1.7 cm² in 95% of patients and less than 1.2 cm² in 67% (fig. 5).

Pulmonary arterial pressure, left atrial pressure, and the left atrial-left ventricular diastolic pressure gradient were higher in

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**Table 1**

<table>
<thead>
<tr>
<th>Group</th>
<th>Closed commissurotomy</th>
<th>Open commissurotomy</th>
<th>Mitral valve replacement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total patients</td>
<td>53</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td>Women</td>
<td>43</td>
<td>81</td>
<td>16</td>
</tr>
<tr>
<td>With Sinus rhythm</td>
<td>37</td>
<td>70</td>
<td>3</td>
</tr>
<tr>
<td>With mitral valvular calcium fluoroscopically</td>
<td>12</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>With preoperative systemic emboli</td>
<td>12</td>
<td>23</td>
<td>4</td>
</tr>
<tr>
<td>With previous mitral commissurotomy</td>
<td>5</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>In NYHA functional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class II</td>
<td>15</td>
<td>28</td>
<td>4</td>
</tr>
<tr>
<td>Class III</td>
<td>37</td>
<td>70</td>
<td>12</td>
</tr>
<tr>
<td>Class IV</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Average age (range)</td>
<td>37 (19-57)</td>
<td>43 (26-57)</td>
<td>47 (22-64)</td>
</tr>
</tbody>
</table>

*Preoperative Clinical Findings in 124 Consecutive Patients Operated upon for Mitral Stenosis*
patients undergoing mitral valve replacement than in those undergoing closed commissurotomy, and the cardiac index and mitral valve area were lower in the valve-replacement group (table 2). The hemodynamic values in patients undergoing open commissurotomy were intermediate between those of the other two groups.

Operative Findings, Procedures, and Early Deaths

Closed mitral commissurotomy was attempted in 69 patients and was completed in 53 (77%) of them. All 53 survived. In nine patients a closed commissurotomy was converted to an open commissurotomy because left atrial thrombus was suspected when the atrium was examined externally at operation, and in seven of the nine atriotomy revealed thrombus. All nine survived operation. In seven other patients the mitral valve was not amenable to either closed or open commissurotomy and was replaced. Preoperatively, each of the seven had had fluoroscopically visible valvular calcium or mitral regurgitation, or both, and only two of them, both men, were under 40 years old. Thus, none of these
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Figure 2

Left atrial (LA) mean pressure pre- and postoperatively. (See figure 1 for explanation of symbols.)

seven patients was an ideal candidate for closed commissurotomy. One of the seven died in the early postoperative period.

Because left atrial thrombus was suspected, or because the findings at an earlier commissurotomy indicated valvular anatomy unfavorable for transventricular dilatation, commissurotomy was planned as an open procedure in 21 patients and was completed in 11 (52%) of them. There were two operative deaths. One patient suffered cerebral emboli on the day of operation and died 11 days later. A second patient died in the operating room of aortic dissection during cardiopulmonary bypass. Since in nine other patients a commissurotomy planned as a closed procedure was performed as an open one with no deaths, the operative mortality among the 20 patients undergoing open commissurotomy was 10%. In 10 patients the valve was not amenable to open commissurotomy and was replaced. Seven of the ten had fluoroscopically visible mitral valvular calcium, and eight had some degree of mitral regurgitation. Half of them were over 50 years old, and only three were in sinus rhythm. Thus, the possibility of valve replacement in these patients was clearly apparent preoperatively. One of the 10 died in the early postoperative period.

In 34 patients preoperative findings, usually large amounts of fluoroscopically visible valvular calcium, indicated that the mitral valve could not be repaired adequately and should be replaced. In 17 additional patients, the decision to replace the valve was made at operation. Starr-Edwards prostheses (models 6000, 6120, 6300, and 6310) were employed in 44 patients, but in seven others the left ventricular cavity appeared to be too small to accommodate a caged-ball prosthesis. In six of
them a Kay-Shiley valve was used, and in one patient a Kay-Suzuki valve was employed. Of the 51 patients undergoing mitral valve replacement, 12 (24%) died in the early postoperative period. Two patients died in the operating room. In one the right ventricle was inadvertently torn at the site of cannulation for cardiopulmonary bypass. Open commissurotomy with debridement of mitral valvular calcium was attempted in the other patient before the valve was replaced, and this may have been responsible for his death. He developed intractable ventricular fibrillation coming off cardiopulmonary bypass and was found to have several calcific emboli in his coronary arteries at necropsy. Five patients died with signs of low cardiac output, and in three of them this apparently was the result of prosthetic dysfunction due to the left ventricular cavity being too small to adequately accommodate the mitral prosthesis. In each of the three a large, fresh, left atrial thrombus was found at necropsy. One patient died of each of the following: multiple cerebral emboli, bronchopneumonia, recurrent ventricular arrhythmias and cardiac arrests, multiple coronary and pulmonary thromboemboli, and uncorrected aortic regurgitation complicated by an acute myocardial infarct and a calcific cerebral embolus. No specific type or model of prosthesis was associated with a disproportionate number of fatalities.

Left atrial thrombi were found in 13 patients undergoing commissurotomy and in 12 undergoing valve replacement. Each of these 25 patients was in atrial fibrillation.
Results of operation for MS Cardiac index (L/min./m²)

There was no significant correlation between the presence of left atrial thrombus at operation and either preoperative or postoperative systemic emboli.

Postoperative Hemodynamic Assessment

Preoperative and postoperative hemodynamic values are compared in figures 1–5. Both after closed mitral commissurotomy and after valve replacement, pulmonary arterial and left atrial pressures, and the left atrial-left ventricular diastolic pressure gradient fell significantly. The cardiac output and mitral orifice area also increased in both groups, but the increase in cardiac output in the closed-commisurotomy group (which preoperatively had a higher output than the other two groups) was significant only at the 10% level. Among patients undergoing open mitral commissurotomy, cardiac output and mitral orifice area increased significantly postoperatively, but the pressures in pulmonary artery and left atrium and the pressure gradient across the mitral valve were essentially unchanged. Thus, the hemodynamic results of operation were similar, and in general excellent, in patients who survived closed commissurotomy or valve replacement, and were less satisfactory in those who underwent open commissurotomy.

Eleven of the postoperative studies included in figures 1–5 were in patients with model 6300 Starr-Edwards prostheses (10 size 2M, one size 3M). These prostheses previously have been shown to have inadequate primary orifices. Among patients in the present review, those with model 6300 prostheses had larger left atrial-left ventricular mean diastolic pressure gradients (7.5 vs 4.7 mm Hg, \( P < 0.02 \)) and smaller mitral orifice areas (1.76 vs 2.74 cm, \( P < 0.01 \)) postoperatively than did patients with other model prostheses.
Late Postoperative Deaths and Complications

All of the patients who underwent closed commissurotomy are alive. One patient who had an open mitral commissurotomy and a concomitant tricuspid valvuloplasty died in Greece 9 months after operation; the cause of her death is unknown. Six patients with prostheses have died after discharge from the hospital. Two of the six died of cerebrovascular accidents: cerebral hemorrhage 14 months after operation in one; cerebral emboli 3 months postoperatively in the other. Both were receiving warfarin. Two patients died of infective endocarditis 4 and 16 months after operation, respectively. One patient died of chronic congestive failure 34 months postoperatively, and the final patient died of unknown cause 4 months after operation.

Of the 53 patients who underwent closed commissurotomy, four (8%) have had a subsequent operation on the mitral valve. Each survived. In one patient, catheterization 15 months after the initial commissurotomy revealed that the left atrial mean pressure had fallen from 19 to 13 mm Hg and that the calculated mitral orifice area had increased from 1.1 to 2.1 cm². The patient, however, continued to have symptoms, and she underwent a second closed commissurotomy 23 months after the first one. Eight months later her pulmonary arterial wedge mean pressure was 10 mm Hg. The second patient, a 49-year-old man, was known to have moderately heavy mitral valvular calcification. He nevertheless obtained a good result from commissurotomy, as judged by intraoperative pressure measurements. He returned 5 years later...
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markedly symptomatic from a severely stenotic and heavily calcified mitral valve, which was then replaced. The other two patients, both of whom had mild mitral regurgitation and aortic valve disease before their mitral commissurotomies, underwent mitral and aortic valve fluoroscopically visible mitral valvular calcification. They underwent mitral and aortic valve replacement 5 and 6 years later respectively, after closed mitral commissurotomy.

Table 2

Preoperative Hemodynamic Findings in 124 Consecutive Patients Operated upon for Mitral Stenosis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CMC</th>
<th>OMC</th>
<th>MVR</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SEM</td>
<td>Mean ± SEM</td>
<td>Mean ± SEM</td>
<td></td>
</tr>
<tr>
<td>Pulmonary arterial systolic pressure</td>
<td>44.7 ± 2.6</td>
<td>55.5 ± 5.2</td>
<td>60.2 ± 3.0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>(mm Hg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left atrial mean pressure (mm Hg)</td>
<td>18.2 ± 0.7</td>
<td>20.0 ± 1.0</td>
<td>23.7 ± 0.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Left atroventricular mean gradient (mm Hg)</td>
<td>12.2 ± 0.6</td>
<td>11.1 ± 0.7</td>
<td>15.4 ± 0.8</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cardiac index (liters/min/m²)</td>
<td>2.58 ± 0.08</td>
<td>2.16 ± 0.10</td>
<td>2.20 ± 0.08</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Mitral valve area (cm²)</td>
<td>1.17 ± 0.05</td>
<td>0.92 ± 0.07</td>
<td>0.93 ± 0.06</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Abbreviations: CMC = closed mitral commissurotomy; OMC = open mitral commissurotomy; MVR = mitral valve replacement; NS = not significant = P > 0.05.

Preoperative Findings Affecting Mortality

Both for patients undergoing open commissurotomy and for those having mitral valve replacement, mortality after operation was in general associated with the more severe replacement mortality after operation was in three of the 53 survivors of closed commissurotomy, and in five of the 33 survivors of mitral valve replacement. Systemic emboli have occurred in the late postoperative period in two of the 35 patients of closed commissurotomy.
derangements in preoperative hemodynamic values. A high pulmonary arterial pressure, a high diastolic pressure gradient across the mitral valve, and a small mitral valve area each had a statistically significant \( P < 0.05 \) adverse influence on mortality. Prognosis also tended to be poor among patients in functional class IV preoperatively (fig. 6).

**Current Clinical Status**

Of the 103 surviving patients, four have not returned to the National Heart and Lung Institute. For the other 99 patients, the duration of postoperative follow-up has averaged 3.4 years (range 0.5–7.0), and clinical status at the most recent follow-up is shown in figure 6. The symptomatic results both of closed commissurotomy and valve replacement have been excellent. Although most patients improved after open commissurotomy, at last follow-up five of the 16 were in New York Heart Association functional class III or IV.

**Discussion**

In the present group of 124 patients with mitral stenosis, the best operative results were obtained in the 53 patients treated by closed mitral commissurotomy. There were no early or late deaths, and excellent hemodynamic improvement was noted postoperatively. After follow-up periods ranging up to 7 years, only four patients have required reoperation, and 96% of the patients are in class I or II.

Undoubtedly the excellent results with closed commissurotomy are due in part to patient selection. The ideal candidate for this procedure is a young woman with a loud first heart sound and opening snap, sinus rhythm, no mitral regurgitation, and no fluoroscopically visible intracardiac calcium. Hemodynamically significant mitral regurgitation and large amounts of valvular calcium are particularly strong contraindications to commissurotomy.3,5 Although patients with

### Figure 6

*New York Heart Association functional classification preoperatively and at the most recent postoperative examination.*
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these unfavorable findings sometimes experience symptomatic benefit,\textsuperscript{5,7} which may occasionally be prolonged, the hemodynamic result is usually unsatisfactory.\textsuperscript{5} Calcification of the left atrial wall is a contraindication to a closed procedure, since patients with this fluoroscopic finding virtually always have left atrial thrombus. Although previous commissurotomy is not in itself a contraindication to a closed procedure, most of our 32 patients with prior operations had other contraindications, and only five of them proved suitable for a closed commissurotomy (table 1).

Of the 69 patients in whom closed commissurotomy was planned, seven (10\%) underwent mitral replacement instead. However, each of the seven had at least two characteristics known to be relative contraindications to closed commissurotomy. Thus, although any operation on the mitral valve may culminate in valve replacement, this is highly unlikely when the patient fulfills all of the preoperative criteria favorable for successful closed commissurotomy. Because of this, and because in these ideal candidates closed commissurotomy usually confers striking hemodynamic\textsuperscript{1,3,7,8} and prolonged symptomatic\textsuperscript{6,7} benefit, we have recommended this operation to a number of such patients who were only in functional class II. Valve replacement, on the other hand, is almost always deferred until the patient is in class III.

The less satisfactory results with open commissurotomy in the present series are largely due to the selection of the more favorable patients for closed procedures. Patients with mobile and favorable valves are treated by open operation in many centers, and in some of them the mortality rate for open commissurotomy is approximately 1%.\textsuperscript{9–11} Although the risk of cardiopulmonary bypass is small, it is not negligible, and one of our two operative deaths in the open-commis-surotomy group was due to aortic dissection induced by cannulation for bypass. Consequently, closed commissurotomy is preferred where feasible.

In this study the early mortality rate among patients undergoing valve replacement for mitral stenosis was high (24\%) and exceeded the mortality rate (17\% initially\textsuperscript{2} and 14\% recently) for all patients undergoing isolated mitral replacement at the National Heart and Lung Institute. The difference probably results from the difficulties associated with insertion of a prosthesis into a left ventricle of normal size. Smaller prostheses often produce residual stenosis,\textsuperscript{12} whereas larger prostheses at times malfunction.\textsuperscript{13} Either of these situations may lead to death in the early postoperative period. A recent study of combined mitral and aortic valve disease reported a 52\% operative mortality among 40 patients in whom both valves were stenotic, and the left ventricular cavity consequently of small or normal size, whereas the mortality rate was only 15\% among 84 patients in whom one or both valves were predominantly regurgitant.\textsuperscript{14} At the National Heart and Lung Institute, porcine heterograft aortic valves mounted on flexible stents recently have been used, with a low mortality rate, to replace the mitral valve in patients with small left ventricles.\textsuperscript{15}

Late postoperative deaths have occurred in six patients who underwent valve replacement. In addition, the hemodynamic results of valve replacement were no better than those of closed commissurotomy. Thus, like commissurotomy, valve replacement is a palliative rather than a curative operation. Since following successful commissurotomy the incidence of late postoperative death and of mitral restenosis is low,\textsuperscript{5} closed commissurotomy may well afford more satisfactory palliation than valve replacement in those patients with favorable valves. The availability of valve replacement for patients with severely deformed valves has improved the selection of patients for, and thus the overall results of, mitral commissurotomy. However, the early and late mortality after valve replacement remains the primary reason for attempting valvuloplasty in patients with less than ideal valves, such as many of the present patients who underwent open commissurotomy. Unfortunately, the hemodynamic results of valvuloplasty in such patients are often disappointing.
Although mortality was high, the hemodynamic results of mitral valve replacement in general were good, and among patients with model 6120 or 6310 prostheses were excellent. In addition, among the surviving patients, who have been followed for periods up to 7 years, all but one have been improved symptomatically (fig. 6).

Acknowledgment

The authors wish to thank Miss Ginny King for the illustrations and Mr. Morton S. Raff, Biometrics Research Branch, National Heart and Lung Institute, for aid in the statistical analysis of the data.

References

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_Circulation_. 1972;46:298-308
doi: 10.1161/01.CIR.46.2.298

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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