Outcomes and Long-Term Survival for Patients Undergoing Mitral Valve Repair Versus Replacement: Effect of Age and Concomitant Coronary Artery Bypass Grafting

Vinod H. Thourani, MD; William S. Weintraub, MD; Robert A. Guyton, MD; Ellis L. Jones, MD; Willis H. Williams, MD; Sharif Elkabbani, MD; Joseph M. Craver, MD

Background—A paucity of literature is available on the effects of age and coronary artery bypass grafting (CABG) on the outcomes of patients undergoing mitral valve (MV) repair versus replacement.

Methods and Results—A matched study was performed using prospectively collected data from the Emory cardiovascular database from 1984 to 1997 comparing 625 MV repair patients with 625 MV replacement patients. Mean age was significantly higher in the replacement group (56.1 ± 14 versus 55.1 ± 14 years). Preoperative demographics and postoperative outcomes were similar between groups. Length of stay (LOS) was significantly less in the repair group (9.5 ± 9.4 versus 12.3 ± 13.1 days). In-hospital mortality was significantly less in the repair group (4.3% versus 6.9%), and overall 10-year survival was significantly higher in the repair group (62% versus 46%). Ten-year survival of patients < 60 years of age was significantly higher in repair patients (81% versus 55%) but similar in patients ≥ 60 years of age (33% versus 36%, respectively). Ten-year survival of MV repair without CABG was significantly higher compared with MV replacement patients (74% versus 51%) but similar to patients with concomitant CABG (28% versus 34%, respectively). Independent predictors of long-term mortality included increasing age, urgent/emergent status, female sex, diabetes mellitus, increasing weight, heart failure, decreasing ejection fraction, concomitant CABG, and MV replacement.

Conclusions—Mitral valve repair has reduced LOS and improved in-hospital and 10-year survival. However, in the present series, MV repair does not provide significant long-term survival benefit over MV replacement in patients older than 60 years of age or those requiring concomitant CABG. (Circulation. 2003;108:298-304.)

Key Words: mitral valve surgery coronary disease bypass

The use of mitral valve (MV) repair to correct mitral regurgitation using techniques developed by Carpentier to overcome the disadvantages of mitral valve replacement are increasing.1–4 Patients undergoing mitral valve repair may have reduced incidence of thromboembolism and reduced necessity for anticoagulation compared with those patients undergoing mitral valve replacement.5 Furthermore, it is possible that the repair of a valve may lead to improved functional durability compared with that achieved with a bioprosthesis or mechanical valve, ultimately leading to improved long-term results.5,7 Because preservation of the intrinsic mitral valve apparatus has been shown to improve postoperative ventricular function, mitral valve repair, instead of replacement, may lead to a reduced long-term incidence for recurrent postoperative mitral regurgitation.4–7

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Over the past decade, there has been an increase in the performance of mitral valve repair, such that it is the standard therapy for most patients with mitral regurgitation in some institutions.8 Although there is vast literature on both mitral valve replacement and repair, a limited number of studies have directly compared these 2 common techniques.4–7 Furthermore, there are limited data on the interaction of either older age or concomitant coronary artery bypass grafting (CABG) on survival of patients undergoing mitral valve surgery.

Methods

A matched case-control study was performed using prospectively collected data from the Emory cardiovascular clinical database. Of 698 consecutive patients undergoing mitral valve repair for mitral regurgitation at Emory University Hospitals from 1984 to 1997, 625 of these patients were matched for age, sex, acuteness of surgery, and concomitant CABG to 625 patients undergoing mitral valve replacement. The control patients (those undergoing MV replacement) were obtained from the database by computer-matching algorithms from the same time interval. The replacement patients all had an operation within 5 years of the MV repair patients (study patients), were within
6 years of age of the repair patients at the time of the operation, were the same sex, and had the same number (or within 1) of coronary bypass grafts placed.

Standard cardiopulmonary bypass techniques for intracardiac valve operations were used in all patients. Prosthetic ring mitral valve repair based on the Carpentier techniques was used.9 Mitral valve operations were used in all patients. Prosthetic ring mitral valve replacement included a series of techniques including quadrangular resection of areas of prolapsed leaflet, trench, sliding and cylindrical chordoplasty, and placement of annuloplasty ring.9 Implantation of a prosthetic annuloplasty ring was performed in all patients undergoing mitral valve repair. Complex repairs with multiple techniques were frequent owing to the high incidence of degenerative tissue disease. Mitral valve replacement was performed using a variety of techniques for bioprosthetic and mechanical valves.

Intraoperative evaluation of the adequacy of the valve repair was made by direct visual inspection of leaflet coaptation by observing any regurgitation when the ventricular chamber was filled. The ventricle was filled by the bulb-flush technique or by production of temporary aortic valve insufficiency. Once available, intraoperative transesophageal Doppler echocardiography became the standard method of repair valve evaluation. Long-term anticoagulation with warfarin was used in all mechanical valves but only in the presence of chronic atrial fibrillation with a large left atrium in patients who received a bioprosthetic valve or a valve repair.

Clinical data were recorded prospectively on standardized forms and entered into a computerized database. Definitions for variables studied include the following: urgent procedure, a procedure judged by the attending cardiac surgeon to be required within 24 hours from presentation; emergent procedure, a procedure performed in the setting of acute ischemia, infarction, or hemodynamic compromise; postoperative myocardial infarction, development of significant new Q waves on ECG; neurological event, new focal neurological findings that were either permanent or that resolved; and related variables defined from the patient’s history and physical examination, hypertension, diabetes mellitus, severity of angina, and previous myocardial infarction. The Canadian Cardiovascular Society Classification was used to define the severity of angina and the New York Heart Association criteria to define the severity of heart failure.

Follow-up information was obtained from medical records or by telephone or letter from the patient, family, attending physicians, or a combination. Additional information on patients who died was obtained from the state bureau of records. Follow-up data were available for 1181 of the 1250 patients (94%); the mean follow-up time for survivors was 5.4±3.2 years (median, 5.1 years; range, 0.42 to 10 years). All follow-up information was recorded on standardized forms and entered into the computerized database.

### Statistical Analysis

The data are expressed as proportions or as mean±SD. Differences in categorical variables were analyzed by the McNemar Test of Symmetry, and differences in continuous variables were analyzed by paired t test. Results are considered significant if P<0.05. Overall survival (cardiac- and noncardiac-related deaths) was determined by the Kaplan-Meier method. Multivariate correlates of in-hospital survival were determined by logistic regression and correlates of long-term survival by Cox model. Missing data were imputed by the method of Harrel.10 Discrimination of the multivariate analyses were examined using the C index. Validation and calibration of models were tested by the method of Harrel.10 Potential nonlinear effects of each of the continuous predictor variables were checked using restricted cubic splines. Interaction terms were examined. Statistical modeling and testing were performed in S-Plus.

### Results

The demographics and operative characteristics of the 1250 patients undergoing mitral valve repair or replacement are shown in Table 1. Mean age of patients was slightly higher in the MV replacement group. The proportion of female patients, height, history of prior myocardial infarction (MI), diabetes, hypertension, and angina class II–IV were not significantly different between groups. The proportion of patients with preoperative heart failure was higher in the replacement group compared with the repair group (56% versus 50%, respectively, P=0.024). The most common

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**TABLE 1. Patient Characteristics**

<table>
<thead>
<tr>
<th>Mitral Valve Replacement (n=625)</th>
<th>Mitral Valve Repair (n=625)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>56±14</td>
<td>55±15</td>
</tr>
<tr>
<td>40 to 49</td>
<td>198 (31.7)</td>
<td>222 (35.5)</td>
</tr>
<tr>
<td>50 to 59</td>
<td>135 (21.6)</td>
<td>134 (21.4)</td>
</tr>
<tr>
<td>60 to 69</td>
<td>181 (29.0)</td>
<td>160 (25.6)</td>
</tr>
<tr>
<td>70 to 79</td>
<td>111 (17.8)</td>
<td>109 (17.4)</td>
</tr>
<tr>
<td>Female sex</td>
<td>345 (55.2)</td>
<td>345 (55.2)</td>
</tr>
<tr>
<td>Height, cm</td>
<td>169±16</td>
<td>168±17</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>69±15</td>
<td>72±17</td>
</tr>
<tr>
<td>Hypertension</td>
<td>166 of 617 (26.9)</td>
<td>180 of 620 (29.0)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>60 of 617 (9.7)</td>
<td>50 of 620 (8.1)</td>
</tr>
<tr>
<td>Previous MI</td>
<td>83 of 616 (13.5)</td>
<td>69 of 620 (11.1)</td>
</tr>
<tr>
<td>Class II–IV angina</td>
<td>142 of 607 (23.4)</td>
<td>134 of 613 (21.9)</td>
</tr>
<tr>
<td>Class II–IV heart failure</td>
<td>346 of 615 (56.3)</td>
<td>308 of 618 (49.8)</td>
</tr>
<tr>
<td>Valve dysfunction etiology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Myxomatous</td>
<td>232 of 590 (39.3)</td>
<td>280 of 609 (46.0)</td>
</tr>
<tr>
<td>Ischemic</td>
<td>55 of 590 (8.3)</td>
<td>72 of 609 (11.8)</td>
</tr>
<tr>
<td>Rheumatic</td>
<td>139 of 590 (23.6)</td>
<td>173 of 609 (28.4)</td>
</tr>
<tr>
<td>Other</td>
<td>164 of 590 (27.8)</td>
<td>84 of 609 (13.8)</td>
</tr>
</tbody>
</table>

Values are mean±SD or number of patients (%). MI indicates myocardial infarction.
etiology for valve dysfunction in both groups was myxomatous valve disease.

The severity of disease and acuteness of the patients are shown in Table 2. Most operations were performed electively (96.8%). Twenty-five percent in each group underwent concomitant CABG, with a similar number of grafts.

Crossover from repair to replacement during the index hospitalization was unusual (Table 3). No difference between groups was noted for postoperative neurologic events or MI. Length of stay was reduced by 3 days in those patients undergoing mitral valve repair (9.5 vs 9.4 days) compared with replacement (12.3 vs 13.1 days, P<0.0001). In-hospital mortality was lower in repair patients (4.3%) than in replacement patients (6.9%, P=0.049).

Multivariate predictors for in-hospital mortality (Table 4) included increasing age (OR 1.53 per 10-year increments in age), urgent operations (OR 3.03), and emergent status (OR 9.18), and mitral valve replacement (OR 1.72). The adjusted c index and validated c index for in-hospital mortality were 0.736 and 0.719, respectively.

Intermediate- and long-term mortality curves for all patients are shown in Figure 1. At 5 years, the survival of patients who underwent mitral valve repair was 82% compared with 72% for those who underwent valve replacement. The divergence in survival curves continues to grow after year 5, such that at 10 years, survival for patients who underwent mitral valve repair was 62% versus 46% in mitral valve replacement patients (P<0.0001).

The effect of age on long-term mortality for repair and replacement patients is shown in Figure 2. At 5 years, the survival of patients younger than 60 years of age who underwent mitral repair was 90% compared with 79% for those who underwent valve replacement. The curves for these patients continued to diverge, such that at 10 years, survival for patients undergoing mitral repair was 81% compared with 55% in mitral replacement (P<0.0001). This differentiation in mortality between mitral valve repair and replacement was not evident in patients older than 60 years (P=0.34).

The effect of concomitant CABG on long-term mortality for repair and replacement patients is shown in Figure 3. At 5 years, the survival of patients undergoing MV repair without concomitant CABG was 89% compared with 77% for those who underwent MV replacement. The curves for these patients continued to diverge such that at 10 years, survival for patients undergoing MV repair without concomitant CABG was 74% compared with 51% in MV replacement patients (P<0.0001). When concomitant CABG was performed with the mitral valve operation, this differentiation in mortality was not evident (P=0.74).

A divergence in freedom from subsequent mitral valve replacement for all patients undergoing MV repair or replacement (Figure 4) was not evident until 6 years of follow-up. At 5 years of follow-up, MV replacement patients had a 96% freedom from additional MV replacement compared with 94% in patients undergoing MV repair. However, at the end of 10 years, freedom from subsequent mitral valve replacement was significantly higher in mitral repair patients (78%) compared with mitral replacement patients (66%, P<0.0001).

Multivariate correlates of long-term mortality are shown in Table 5. There was an interaction between age and choice of surgery. The correlates included age (per 10-year increase, hazard ratio [HR] 1.67 in repair patients and 1.19 in replacement patients), urgent operations (HR 1.43), emergent operations (HR 2.06), congestive heart failure (HR 1.49), female sex (HR 1.43), diabetes mellitus (HR 1.6), ejection fraction (per 10% increase, HR 0.79), concomitant coronary artery bypass grafting (HR 1.30), and mitral replacement (HR 3.10; 95% CI, 1.90 to 5.04 at age 40 years; decreasing to HR 0.93; 95% CI, 0.67 to 1.28 at age 75 years). Thus, the significant univariate interaction between age and type of surgery was confirmed on multivariate analysis. The adjusted c index and

### Table 2. Severity of Disease and Acuteness

<table>
<thead>
<tr>
<th></th>
<th>Mitral Valve Replacement (n=625)</th>
<th>Mitral Valve Repair (n=625)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elective status</td>
<td>605 (96.8)</td>
<td>605 (96.8)</td>
<td>1</td>
</tr>
<tr>
<td>Ejection fraction</td>
<td>57±13 (n=572)</td>
<td>56±12 (n=586)</td>
<td>0.28</td>
</tr>
<tr>
<td>Concomitant CABG</td>
<td>155 (25)</td>
<td>155 (25)</td>
<td>1</td>
</tr>
<tr>
<td>No. of grafts (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No CABG</td>
<td>470 (75.2)</td>
<td>470 (75.2)</td>
<td>0.75</td>
</tr>
<tr>
<td>1 graft</td>
<td>48 (7.7)</td>
<td>44 (7.0)</td>
<td></td>
</tr>
<tr>
<td>2 grafts</td>
<td>41 (6.6)</td>
<td>45 (7.2)</td>
<td></td>
</tr>
<tr>
<td>3 grafts</td>
<td>35 (5.6)</td>
<td>43 (6.9)</td>
<td></td>
</tr>
<tr>
<td>4 grafts</td>
<td>25 (4.0)</td>
<td>17 (2.7)</td>
<td></td>
</tr>
<tr>
<td>5 or 6 grafts</td>
<td>6 (1.0)</td>
<td>6 (1.0)</td>
<td></td>
</tr>
</tbody>
</table>

Values are mean±SD or number of patients (%).

### Table 4. Multivariate Correlates of In-Hospital Mortality

<table>
<thead>
<tr>
<th></th>
<th>OR</th>
<th>95% CI</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per 10-year increase)</td>
<td>1.53</td>
<td>1.24 to 1.90</td>
<td>0.0001</td>
</tr>
<tr>
<td>Surgical status vs elective</td>
<td></td>
<td></td>
<td>0.0004</td>
</tr>
<tr>
<td>Urgent</td>
<td>3.03</td>
<td>1.64 to 5.59</td>
<td></td>
</tr>
<tr>
<td>Emergent</td>
<td>9.18</td>
<td>2.69 to 31.26</td>
<td></td>
</tr>
<tr>
<td>EF &lt;50% (per 10% increase)</td>
<td>0.50</td>
<td>0.36 to 0.70</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>EF &gt;50% (per 10% increase)</td>
<td>0.94</td>
<td>0.67 to 1.34</td>
<td>0.0362</td>
</tr>
<tr>
<td>Mitral valve replacement</td>
<td>1.72</td>
<td>1.02 to 2.89</td>
<td>0.0414</td>
</tr>
</tbody>
</table>

EF indicates ejection fraction. ROC=0.736; corrected ROC=0.719.
validated c index for long-term mortality were 0.723 and 0.711, respectively.

**Discussion**

**Mitral Valve Repair Versus Mitral Valve Replacement**

A limited number of studies in large patient populations have directly compared mitral valve repair with replacement.⁴⁻⁷ In one of the earliest first case-matched comparative studies, Craver et al⁴ evaluated a consecutive, case-matched series of 65 pairs of patients with MV repair versus replacement. Hospital mortality was 1.5% for repair and 4.6% for replacement patients (P<0.001). Survival at 4 years was 84% for repair and 82% for replacement patients (P=NS). Freedom from reoperation to replace the mitral valve at 4 years was 62 of 65 patients in the repair group and 64 of 65 patients in the replacement group (P=NS). The authors felt that although no differences in outcome over the 4-year follow-up were noted, the benefits of maintaining the native valve with chordal and papillary muscle structure intact and avoidance of prosthetic valve implantation might become apparent with longer follow-up. In another early study comparing mitral valve repair to replacement, Cohn¹¹ noted an operative mortality in 3 of 75 patients (4%) in the repair group, all with CABG, versus 2 of 65 patients (3%) in the replacement group, 1 with CABG. Survival at 30 months was 85±6% for the replacement group and 94±4% for the repair group. Akins et al⁶ evaluated outcomes of patients undergoing MV repair (133

![Figure 1](image1.png) **Figure 1.** Survival, mitral valve repair versus replacement, all patients.

![Figure 2](image2.png) **Figure 2.** Survival, mitral valve repair versus replacement, below and above age 60 years.
patients) or replacement (130 patients). The median postoperative stay was shorter in repair (10 versus 12 days; P=0.02). Hospital mortality was 3% in the repair group versus 12% in the replacement group (P=0.01).

Enriquez-Sarano et al.12 evaluated outcomes in 195 patients with MV repair and 214 with replacement. They noted an operative mortality of 2.6% in MV repair patients versus 10.3% in replacement patients (P=0.0002). Survival at 10 years was 68±6% with repair versus 52±4% with replacement (P=0.0004). Multivariate analysis indicated an independent beneficial effect of valve repair on overall survival (HR 0.39; P=0.00001), operative mortality (OR 0.27; P=0.026), and late survival (HR 0.44; P=0.001). The present series comparing MV repair with replacement is in concordance with the short- and long-term mortalities from these previously published series. However, it is imperative that studies evaluating the differences in mortality of patients undergoing MV surgery extend beyond 5 to 6 years, because the divergence in mortality curves may occur after a 5-year period.

Although the present series did not investigate the mechanisms of the improved survival in patients undergoing MV repair, we agree with the present literature that preservation of myocardial function by retaining the subvalvular apparatus, annulus, and mitral leaflets allows improvement of ventricular function after MV repair, reducing postoperative cardiac deaths. Furthermore, the lower incidence of thromboembolic events and lower reoperation rates may account for the improved late survival for MV repair patients.12–15

Figure 3. Survival, mitral valve repair versus replacement, with and without CABG.

Figure 4. Freedom from future mitral valve replacement, mitral valve repair versus replacement.
Concomitant CABG and Mitral Valve Surgery

From Emory University, Thourani et al. reported that catheterization-proven coronary artery disease has increased from 30% in that institution’s population undergoing MV replacement in 1988 to 43% in 1997, necessitating an increase in concurrent CABG from 18% to 28% in patients undergoing mitral valve surgery. Expanding on their original study, Cohn et al. reported no increase in in-hospital mortality for 120 patients undergoing MV replacement with concomitant CABG (4.2%) compared with 190 patients undergoing MV replacement without concomitant CABG (4.7%). In contrast, Jamieson et al. reported that in 13,936 isolated mitral replacements in the Society of Thoracic Surgeons database, the overall operative mortality rate was 6.4%. This mortality increased to 15.3% for the 8,788 patients undergoing combined MV replacement and CABG. More recently, Thourani et al. reported the in-hospital mortality for 1,332 patients undergoing MV replacement without concomitant CABG was 5.9% compared with 14% for 360 patients undergoing MV replacement and CABG (P < 0.05). They added that concomitant CABG was a more important multivariate predictor of in-hospital (OR 2.06) than long-term mortality (OR 1.44).

Although there are numerous studies evaluating outcomes of MV replacement and CABG, few studies have evaluated the long-term effects of concomitant CABG on MV repair. Cohn et al. noted no statistically significant difference in operative mortality for those patients undergoing MV repair of the floppy valve with (1.6% in 63 patients) or without (2.6% in 156 patients) CABG. More recently, Cohn noted an approximately 4-fold increase in in-hospital mortality of 181 patients undergoing MV repair and concurrent CABG (6.6%) compared with 264 patients undergoing MV repair without concurrent CABG (1.5%).

Enriquez-Sarano et al. compared the impact of CABG on overall survival for those undergoing MV surgery, finding that MV repair was better than MV replacement when stratified in patients with (at 6 years, 74±6% and 34±8%; P = 0.0002) and without (at 10 years, 73±7% and 61±5%; P = 0.006) CABG. In contrast, Akins et al. have noted no statistically significant difference in 6-year survival for those patients undergoing mitral replacement or repair with or without concomitant CABG. Similar to Enriquez-Sarano et al., the present series reports a significant benefit in long-term survival in performing mitral valve repair without CABG compared with MV replacement. In contrast to Enriquez-Sarano et al. and similar to Akins et al., we do not show a significant long-term benefit in those patients undergoing MV repair with concomitant CABG compared with MV replacement with concomitant CABG. Of interest in the present series is not that the repair patients had improved survival over the replacement patients but the margin of survival advantage in patients without concomitant CABG and no survival benefit between the groups with concomitant CABG.

Concomitant CABG and Mitral Valve Repair Versus Replacement

In a series of patients older than 80 years of age, Tsai et al. reported on 42 patients undergoing MV replacement with or without CABG and 31 patients undergoing MV repair and CABG. In-hospital and 30-day mortality for all patients undergoing MV replacement was 28.6%, compared with 22.6% for MV repair. Actuarial survival at 5 years was 37% for the MV replacement patients, compared with 19% for the repair patients. Meanwhile, Fremes et al. reported a 1.6% operative mortality for 311 patients undergoing MV repair and 7.4% for 888 patients undergoing MV replacement at younger than 70 years of age (P < 0.01). For patients older than 70 years of age, they noted a 14.7% operative mortality in 34 patients undergoing MV repair and 16.2% in 154 patients undergoing replacement (P < 0.01). In contrast, Goldsmith et al. noted no significant 30-day mortality advantage in 22 patients undergoing MV repair (mortality, 22.7%; median age, 78 years) and 21 patients undergoing MV replacement (mortality, 38.0%; median age, 77 years, P = 0.2). Unlike the present series, none of the aforementioned studies investigated the long-term mortality effects of age on MV replacement versus repair.

Study Limitations

The limitations of the present study include the inherent confines of retrospective, nonrandomized data collection. Although case matching and multivariate analysis can help to account for some differences in the groups, the effect of unmeasured variables affecting selection of therapy may confound the analysis. Moreover, the study period was over a long period of time and therefore the length of stay for patients may be affected by this variable. It is possible that more bioprosthetic valves were placed in the initial portion of...
this study, which we would expect to fail at approximately 10 years, leading to the possible reduced freedom of MV replacement in those patients. Without a large time interval, we would be unable to compare large cohorts of patients required to make definitive clinical analysis.

Conclusions
Similar to our previous report on midterm results of MV repair versus replacement, we advocate MV repair when feasible. From the present study, MV repair has reduced LOS and improved short- and long-term survival. However, in the present series, the survival benefit of MV repair is confined to patients younger than 60 years of age and patients not having concomitant CABG.

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References
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