Repair versus replacement for degenerative mitral valve disease with coexisting ischemic heart disease

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Objective: We sought to compare mitral valve repair and replacement as treatments for degenerative mitral valve disease with coexisting ischemic heart disease. Specifically, we sought to (1) identify differences between patients undergoing repair and replacement, (2) determine whether the choice of mitral valve procedure affected survival after adjusting for those differences, and (3) discover which patients were predicted to benefit from mitral valve repair and which from replacement.

Methods: From 1973 to 1999, 679 patients (mean age, 67 ± 9.1 years; 73% men) with degenerative mitral valve and ischemic heart diseases underwent combined coronary artery bypass grafting and either mitral valve repair (66%) or replacement (34%). Factors associated with repair and replacement were used for multivariable propensity matching. Risk factors for death were identified by means of multivariable, multiphase hazard-function analysis.

Results: Patients more likely to undergo repair had isolated posterior chordal rupture ($P < .0001$) or more recent date of operation ($P < .0001$); those more likely to undergo replacement were older ($P = .0003$) or had bileaflet prolapse ($P < .0001$). Unadjusted survival at 30 days and 1, 5, and 10 years was 97%, 92%, 79%, and 59% after repair and 94%, 88%, 70%, and 37% after replacement. After adjusting for comorbid factors, the extent and effect of ischemic heart disease, and propensity score, the survival benefit of repair became evident after 2 years ($P = .01$). Eighty-nine percent of patients were predicted to benefit from repair.

Conclusions: In patients with degenerative mitral valve and ischemic heart diseases, mitral valve repair confers a survival advantage over replacement that becomes evident about 2 years after the operation.

With current surgical techniques, most degenerative mitral valves can be repaired.¹⁻⁴ Purported advantages of mitral valve repair over replacement include greater freedom from reoperation and endocarditis, better preservation of left ventricular function, and improved survival.¹⁻⁹ These advantages have been investigated when degenerative mitral valve disease exists in isolation.¹ However, particularly in aging populations with a limited life expectancy, it often coexists with ischemic heart disease. When a prolonged combined coronary artery and valve operation is contemplated, the appropriate valvular surgical strategy (mitral valve repair vs expeditious replacement) is unclear.

Therefore we have compared long-term survival in patients with ischemic heart disease undergoing coronary artery bypass grafting (CABG) with either mitral valve repair or replacement for degenerative disease. Because selection of the valve repair or replacement procedure was not randomized, comparison required (1) identifying patient characteristics that were more likely to lead to repair than replacement at this center, (2) determining whether survival was better after repair or replacement once those characteristics were taken into account, and (3) discovering which patients were predicted to benefit from repair and which from replacement.

Patients and Methods

Patients

Definitions. Classification of degenerative mitral valve disease was based on standard criteria extracted from review of pathology reports, echocardiograms, and direct surgical inspection.^{1,10} If microscopic pathologic examination revealed myxomatous degeneration, the valve was classified as degenerative (although we recognize that myxoid material might represent a final common pathway for possible diverse causes). When pathology reports were unavailable, valves were classified as degenerative if on echocardiography or inspection they had typical findings of leaflet prolapse caused by chordal elongation or rupture and thick floppy leaflets. Finally, those rare patients with annular dilatation and thick billowing leaflets but without frank leaflet prolapse were judged to have degenerative mitral valve disease.

Particular care was taken to exclude patients with ischemic mitral regurgitation. In the setting of ischemic heart disease, mitral valve regurgitation is caused by ischemic heart disease in about half of patients and coexists with it in the other half.¹¹ Ischemic mitral regurgitation is caused by papillary muscle infarction and elongation, papillary muscle rupture, or failure of leaflet coaptation caused by leaflet restriction after myocardial infarction.¹² Patients in the latter group, who have functional ischemic mitral regurgitation, are distinguished from patients with degenerative disease by the presence of leaflet restriction after myocardial infarction and lack of excess leaflet tissue.

Patient identification. By using these definitions, potential patients operated on from 1973 to 1999 were identified for this study by query of the Cardiovascular Information Registry. This registry contains detailed demographic, clinical, pathologic, operative, and outcome variables on all patients having cardiac surgery at The Cleveland Clinic Foundation abstracted from clinical records concurrently with patient care. Data from this registry has been approved for use in research by The Cleveland Clinic Foundation's Institutional Review Board. Because definitions of valve cause have evolved and because of the need to clearly separate degenerative disease from ischemic disease, search criteria were intentionally broad to cast a wide net that we believed would capture all instances of degenerative disease and CABG. Medical records of the 1500 patients so identified were reviewed to verify valve cause, and this netted 679 patients.

Among these 679 patients, the mitral valve was repaired in 447 and replaced in 232. All had at least 2+ (moderate) mitral regur-

gitation. Patients undergoing tricuspid valve repair were included, but those undergoing aortic valve or Maze procedures were not.

The mean age of patients undergoing mitral valve repair was 67 ± 9.1 years, which was similar to that of patients undergoing mitral valve replacement (67 ± 9.4 years, $P = .4$). Patient characteristics overall and according to whether repair or replacement was performed are given in Tables 1 and 2.

Surgical Details

The decision to perform mitral valve surgery and the choice of procedure were made by the cardiologist and surgeon. The most common mitral valve repair technique was annuloplasty, which was used in 396 patients (89%, Table 3); 70% had leaflet resection. Among patients undergoing mitral valve replacement, 69% received bioprostheses, and 31% received mechanical valves.

All patients had concomitant CABG (Table 4). The mean number of distal anastomoses was 2.2 ± 1.2 in patients having mitral valve repair and 2.1 ± 1.1 in patients having mitral valve replacement ($P = .2$). An internal thoracic artery (ITA) graft was used for 62% of patients who underwent repair and 25% of those who underwent replacement ($P < .001$).

Aortic clamp time was 88 ± 31 minutes (median, 82 minutes) in the mitral valve repair group and 84 ± 33 minutes (median, 74 minutes) in the mitral valve replacement group ($P = .06$).

Tricuspid valve repair was performed in 15 (3%) patients having mitral valve repair and 10 (4%) having mitral valve replacement.

Follow-up

Patients were followed systematically at 2-year intervals with a mailed questionnaire, a telephone interview, or examination at the Cleveland Clinic. Mean follow-up among survivors was 5.2 ± 3.6 years, with 25% followed for more than 6 years and 10% for more than 10 years; 3568 patient-years of information were available for analysis. Nonparametric survival estimates were considered reliable to 11 years.¹³

Data Analysis

Overview. The primary challenge in comparing long-term survival after CABG and either mitral valve repair or replacement is that selection of repair or replacement was not allocated on the basis of a randomized process. Thus data analysis first addressed the following question: "Were characteristics of patients undergoing mitral valve repair similar to those of patients undergoing replacement?" Lack of similarity necessitated use of methods specific for nonrandomized comparisons. We then asked, "Is long-term survival better after mitral valve repair than after replacement?" A simple comparison was not possible, and therefore both risk adjustment and adjustment for nonrandom treatment assignment were used. Finally, we asked, "Which patients benefit from which procedure?" Multivariable simulation was used to answer this question.

Were characteristics of patients undergoing mitral valve repair similar to those of patients undergoing replacement? Multivariable logistic regression analysis was used to identify factors associated with valve repair rather than replacement. In this analysis demographic characteristics, symptoms and clinical status, mitral valve pathology, cardiac comorbidity, noncardiac comor-

TABLE 1. Patient characteristics

Characteristics	Total (n = 679), No. (%)	Mitral repair (n = 447), No. (%)	Mitral replacement (n = 232), No. (%)	P value
Demography				
Age (y)				.8*
<50	32 (5)	23 (5)	9 (4)	
≥50-60	106 (16)	56 (13)	50 (22)	
≥60-70	252 (37)	179 (40)	73 (31)	
≥70-80	250 (37)	169 (38)	81 (35)	
≥80	39 (6)	20 (4)	19 (8)	
Male	496 (73)	336 (75)	160 (69)	.08
Cardiac comorbidity				
NYHA functional class				.002*
I	33 (5)	25 (6)	8 (3)	
II	386 (57)	264 (59)	122 (53)	
III	213 (31)	136 (31)	77 (33)	
IV	45 (7)	20 (4)	25 (11)	
Atrial fibrillation	153 (22)	94 (21)	59 (25)	.2
Coronary artery disease†				
Left main	58 (9)	41 (9)	17 (7)	.4
LAD system	502 (74)	326 (73)	176 (76)	.4
LCX system	395 (59)	260 (59)	135 (59)	.9
RCA system	434 (64)	280 (63)	154 (67)	.3
No. of diseased systems				.3*
0	25 (5)	20 (6)‡	5 (3)§	
1	205 (30)	139 (31)	66 (29)	
2	199 (29)	123 (28)	76 (33)	
3	245 (36)	162 (36)	83 (36)	
Left ventricular dysfunction				.002*
None	376 (56)	263 (59)	113 (49)	
Mild	164 (24)	105 (24)	59 (26)	
Moderate	94 (14)	59 (13)	35 (15)	
Severe	39 (6)	17 (4)	22 (10)	
Previous cardiac surgery	44 (6)	29 (6)	15 (6)	.9
History of MI	217 (32)	127 (28)	90 (39)	.006
Noncardiac comorbidity				
Hypertension	307 (56)	226 (55)	81 (58)	.6
COPD	67 (10)	49 (11)	18 (8)	.2
Diabetes (oral or insulin treated)	73 (12)	43 (10)	30 (14)	.15
Renal disease	15 (2)	9 (2)	6 (3)	.6
Experience				
Year of operation				<.001
Before 1990	267 (39)	122 (27)	145 (62)	
1990-1995	215 (32)	160 (36)	55 (24)	
After 1995	197 (29)	165 (37)	32 (14)	

LAD, Left anterior descending coronary artery; LCX, lateral circumflex; RCA, right coronary artery; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.

*Logistic test for trend.

†Fifty percent or greater diameter stenosis.

‡Six had left main disease only, 1 had an atypical left main lesion, 12 had coronary lesions reported on cineangiography as less than 50% stenosis, and 1 had electrocardiographic changes of ischemia.

§Two had left main disease only, and 3 had coronary lesions reported on cineangiography as less than 50% stenosis.

bidity, operative details, and experience were considered (Appendix Table 1).

The process of identifying these factors was similar in all multivariable analyses. Initial screening of variables was performed to ensure that at least 5 events were associated with each factor considered. Continuous and ordinal variables were exam-

ined by means of decile analysis to discover possible linearizing transformations of scale that best met model assumptions. Noninformative imputation of sporadic missing values was used.

Selection of risk factors used bootstrap bagging, with automated analysis of 1000 random data sets by using a *P* value of .05 or less as the criterion for retention of factors in each model. This

TABLE 2. Mitral valve pathology

Pathophysiology	Total (n = 679), No. (%)	Mitral repair (n = 447), No. (%)	Mitral replacement (n = 232), No. (%)	P value
Mitral regurgitation grade				
2	56 (8)	37 (8)	19 (8)	.4
3	232 (34)	147 (33)	85 (37)	
4	388 (57)	262 (59)	126 (54)	
Not stated	3	1	2	
Prolapsed leaflet				
Any	661 (97)	439 (98)	222 (96)	.05
Posterior only	340 (50)	280 (63)	60 (26)	<.001
Anterior only	132 (20)	83 (19)	49 (21)	<.4
Bileaflet	157 (23)	68 (15)	89 (39)	<.001
Location not stated	32	8	24	
None*	18 (3)	8 (2)	10 (4)	
Ruptured chordae				
Any	422 (63)	308 (69)	114 (50)	<.001
Posterior only	314 (47)	259 (58)	55 (24)	<.001
Anterior only	63 (9)	32 (7)	31 (14)	.007
Bileaflet	31 (5)	10 (2)	21 (9)	<.001
Location not stated	14	7	7	
Elongated chordae	206 (31)	121 (27)	85 (37)	.008

*Isolated dilatation (see text for definitions).

was followed by tabulation of the frequency of occurrence at a *P* value of .05 or less of both single factors and closely related clusters of factors.^{14,15} In the final model only factors occurring in at least 50% of the analyses were considered statistically significant for the parsimonious model.

This parsimonious model was amplified into a propensity model by adding factors from each class of variables not already represented (see Appendix Table 1 for these classes).^{16,17} The propensity model was solved to generate a propensity score for each patient, representing the probability of undergoing repair. It was used in 3 ways in this study: (1) to stratify patients by quintiles to demonstrate differential survival between repair and replacement^{17,18}; (2) to form propensity-matched pairs by means of greedy matching for comparison¹⁹; and (3) to adjust the multivariable time-related comparison for not only risk factors but also selection bias.^{20,21} Results of all 3 types of propensity matching were similar, and only the results of method 3 are presented.

Is long-term survival better after mitral valve repair than after replacement? Overall nonparametric estimates of survival were obtained by using the Kaplan-Meier method.²² A parametric method was used to resolve the number of phases of instantaneous risk of death (hazard function) and to estimate its shaping parameters.^{23*} Thereafter, multivariable analysis was performed in the hazard-function domain by using the strategies discussed above.

In all analyses we forced in the variable “mitral valve repair versus mitral valve replacement” and the propensity score to obtain an overall estimate of the benefit of repair versus that of replacement. This was followed by an intense investigation of factors interacting with type of operation to discover modulating factors.

*For additional details, see <http://www.clevelandclinic.org/heartcenter/hazard>.

TABLE 3. Mitral valve surgical procedure (n = 679)

Procedure	No.	%
Mitral valve replacement (n = 232)		
Mechanical	72	31
Bioprosthetic	160	69
Mitral valve repair (n = 447)		
Annuloplasty	396	89
Annuloplasty type (n = 396)		
Carpentier-Edwards ring	94	24
Cosgrove ring	206	52
Bovine pericardial	80	20
Autologous pericardium	9	2
Suture	4	1
Other (Gergod, Duran)	2	0.5
Type not stated	1	0.2
Leaflet resection	314	70
Sliding repair	48	11
Chordal transfer	60	13
Chordal shortening	51	11

Which patients benefit from which procedure? The overall multivariable survival equation was solved twice for each patient, once as though the patient's mitral valve had been replaced and once as though a repair had been performed (simulation). The difference between predicted survivals for these 2 strategies at 10 years was compared. A positive difference was interpreted as a repair benefit and a negative difference as a replacement benefit.

Multiple linear regression of the 10-year survival differences was performed by using the strategies discussed above. From this, an algorithm for predicting the strategy for mitral valve repair versus that for replacement was devised.

TABLE 4. CABG surgical procedure

Procedure	Total (n = 679), No. (%)	Mitral Repair (n = 447), No. (%)	Mitral Replacement (n = 232), No. (%)	P value
ITA grafting	333 (49)	276 (62)	57 (25)	<.001
LITA used	236 (35)	201 (45)	35 (15)	<.001
Complete revascularization	495 (73)	344 (77)	151 (66)	.001
No. of grafts				.15
1	245 (36)	162 (36)	83 (36)	
2	181 (27)	106 (24)	75 (32)	
3	175 (26)	121 (27)	54 (23)	
≥4	78 (11)	58 (13)	20 (9)	

LITA, Left ITA.

TABLE 5. Factors associated with mitral valve repair versus replacement

Factor	Logistic coefficient ± SE	P value
Demography		
Younger age*	−0.59 ± 0.16	.0003
Valve pathology		
Isolated posterior chordal rupture	1.22 ± 0.22	<.0001
Bileaflet prolapse†	−1.24 ± 0.24	<.0001
Retracted leaflet‡	−1.28 ± 0.50	.01
Noncardiac comorbidity		
Peripheral vascular disease†	−0.61 ± 0.26	.02
Experience		
Previous cardiac surgery†	−1.02 ± 0.38	.008
Date of operation‡		
Recent	0.49 ± 0.07	<.0001
Earlier§	−1.15 ± 0.25	<.0001
Intercept	−3.09	

C = 0.86.

*exp(age/50) Exponential transformation.

†Negative sign indicates increased chances of mitral valve replacement.

‡Complex relation shown in Figure 1.

§(opyears/15)³ Cubic transformation.

||Twenty-four patients had regional posterior leaflet prolapse and, at a different portion of the posterior leaflet, an abnormal chordal mesh, causing leaflet retraction.

Presentation

Mortality and survival estimates are accompanied by an asymmetric 68% confidence interval, which is comparable to ± 1 SE. Throughout, model coefficients are given with their SEs rather than either odds ratios (logistic) or hazard ratios (time-related analyses). This is because hazard ratios lose simple meaning in the setting of transformations of scale of continuous variables to obtain appropriate calibration and a time-related events model that is one of nonproportional hazards.

Both logistic regression and hazard-function models were solved for specific sets of values for variables to illustrate the results in a risk-adjusted fashion.

Results

Were Characteristics of Patients Undergoing Mitral Valve Repair Similar to Those of Patients Undergoing Replacement?

The answer to the question of whether characteristics of patients undergoing mitral valve repair are similar to those of patients undergoing replacement is no (Tables 1 and 2). Factors associated multivariably with a greater likelihood of repair included isolated posterior chordal rupture, more recent date of operation, and younger age. Factors associated multivariably with replacement were bileaflet prolapse and previous cardiac surgery (Table 5). There was a striking increase in the prevalence of mitral valve repair in more recent experience (Figure 1, A). Increasing prevalence of repair in recent years corresponds to the era during which ITA grafting became increasingly routine (Figure 1, B); this explains the higher ITA use among patients undergoing repair (Table 4). Figure 2 shows the relationship of age and probability of repair in patients with and without isolated posterior chordal rupture.

Is Survival Better After Mitral Valve Repair Than After Replacement?

The answer to the question of whether survival is better after mitral valve repair than after replacement is not simple. It depends on patient characteristics.

Non-risk-adjusted survival comparison: early mortality. Thirty (4.4%; confidence limit [CL], 3.6%-5.4%) patients died in the hospital: 16 (3.6%; CL, 2.7%-4.7%) after mitral valve repair and 14 (6.0%; CL, 4.4%-8.1%) after mitral valve replacement ($P = .14$). Thirty-day mortality was 3.1% after mitral valve repair and 5.6% after replacement ($P = .12$), and operative mortality (hospital mortality and patients dying within 30 days) was 4.0% and 6.5% ($P = .16$), respectively.

Non-risk-adjusted survival comparison: time-related survival. For the entire group, unadjusted survival was 76% at 5 years and 46% at 10 years. For the repair group,

Figure 1. Trends in prevalences of procedures by calendar year. Each symbol represents the actual proportion of patients in each calendar year who underwent the procedure indicated. Solid lines with 68% CLs are estimated trend lines. A, Prevalence of mitral valve repair versus replacement; B, prevalence of use of ITA grafting in patients undergoing repair or replacement.

survival was 79% and 59% at 5 and 10 years, and for the replacement group, it was 70% and 37%, respectively (Figure 3, A). The unadjusted survival curves diverged at about 4 years because of earlier divergence (less than 2 years) of the late rising phase of the hazard (Figure 3, B), with patients undergoing mitral valve replacement having a marked increase in mortality risk compared with those undergoing repair.

Propensity and risk-adjusted comparison. The nonproportional hazards model resulted in 3 phases of instantaneous risk of death in the overall study group. After using the propensity score to adjust for dissimilarities in patient characteristics between those undergoing mitral valve repair versus re-

placement and other variables for risk adjustment, replacement was identified as a risk factor for death in the late hazard phase, beginning about 2 years after the operation (Table 6). During the early hazard phase (operation to 6 months), survival was similar after repair and replacement; in the constant hazard phase (6 months to 3.5 years) there was possibly improved survival in patients undergoing repair, but this varied with age.

Which Patients Benefit From Which Procedure?

Simulation with the multivariable equation (Table 6) indicated that 89% of patients would have better 10-year survival after repair compared with after replacement of the

Figure 2. Relationship between age and probability of mitral valve repair in patients with and without isolated posterior chordal rupture.

mitral valve (Figure 4). Linear regression produced a clinical algorithm useful for suggesting whether repair or replacement should be used in a patient (Appendix 2). For example, Figure 5, A, shows predicted time-related survival in a 70-year-old patient coming to operation in New York Heart Association (NYHA) class II, with no other cardiac or noncardiac risk factors. Such a profile is typical of patients referred in the current era. Predicted survival after mitral valve repair and replacement diverges at about 4 years, with better survival after repair. In contrast, Figure 5, B, shows predicted survival in a 70-year-old diabetic patient in NYHA class IV with severe left ventricular dysfunction from previous myocardial infarcts. Survival is limited after a mitral valve operation and concomitant CABG, with no advantage of either strategy for managing the mitral valve.

Discussion

Key Findings

In our institution the choice of valve procedure in patients with degenerative mitral valve and ischemic heart diseases depended on patient characteristics, valve pathophysiology, and surgical era. After accounting for these differences, the survival benefit of mitral valve repair became evident after about 2 years. Eighty-nine percent of patients with degenerative mitral valve and ischemic heart diseases were predicted to benefit from repair versus replacement, and these patients can be identified with an algorithm that predicts the effect of mitral valve procedure in individual patients.

Implications of Differences Among Patients

Undergoing Mitral Valve Repair Versus Replacement

Patients who underwent mitral valve repair differed in important respects from many patients who underwent replacement. As a group, elderly patients have more advanced degenerative disease with more prolapse than do younger patients with isolated mitral valve degeneration.¹ In the analysis of mitral valve repair versus replacement, we approached the potential confounding of outcome from these differences by using propensity score adjustment.¹⁶⁻¹⁸

In our institution patients with complex mitral valve pathology, such as bileaflet prolapse, were more likely to have their valves replaced. Other investigators have noted a similar experience.^{5,6,8,9} Although repair of anterior or bileaflet prolapse is challenging, multiple surgical techniques can provide reliable and durable results.¹⁻⁴ With current surgical techniques, most patients with anterior leaflet prolapse can be offered durable valve repair.^{1,10}

Mitral Valve Repair Versus Replacement

In elderly patients with ischemic heart disease, surgeons might be tempted to replace rather than repair the mitral valve, presuming that the choice of procedure will have little or no effect on survival. In addition, valve replacement is easily and reliably completed, generally requiring less time than repair.

We documented several risk factors for early and late death after surgical treatment of degenerative mitral valve and ischemic heart diseases. These included general factors, such as older age, advanced NYHA functional class, severe

Figure 3. Time-related survival after CABG and either mitral valve repair or replacement. **A**, Each symbol represents a death according to the Kaplan-Meier estimator. Vertical bars enclose asymmetric 68% CLs. Solid lines represent parametric survival estimates; these are enclosed between dashed 68% CLs. Numbers in parentheses are numbers of patients traced beyond that point. **B**, Hazard functions (instantaneous risk) for death after CABG and mitral valve repair or replacement.

left ventricular dysfunction, preoperative atrial fibrillation, and renal dysfunction. Mitral valve replacement emerged as a risk factor for late death after adjustment for these factors and the propensity score.

It is generally accepted that mitral valve repair rather than replacement confers a survival advantage. Although Akins and colleagues⁷ and Enriquez-Sarano and associates⁹ found that repair was associated with reduced hospital mortality, we and others^{5,24} did not. Sand and coworkers⁵ found

that mitral valve replacement might be a risk factor for late death. In a study limited to patients with degenerative disease, Lee and colleagues⁶ concluded that surgical procedure (mitral valve repair, replacement with subvalvular preservation, or replacement without subvalvular preservation) did not affect 6-year survival.

The previously mentioned studies suffer from small numbers of patients^{5,6} and populations that include multiple causes for mitral valve dysfunction.^{5,7-9} It is particularly

Figure 4. Cumulative distribution of differences in 10-year survival between mitral valve repair and replacement. Patients to the right of 0 difference are predicted to benefit from repair and those to the left from replacement.

TABLE 6. Incremental risk factors for death

Risk factor	Coefficient $\pm$ SE	P value
Early hazard phase		
Mitral valve replacement	-0.005 ± 0.45	.9
Propensity adjustment*	-0.59 ± 0.70	.4
Older age†	1.03 ± 0.25	<.0001
Elongated chordae	1.00 ± 0.37	.007
Bilirubin	0.43 ± 0.17	.01
LITA graft	-1.12 ± 0.57	.05
Constant hazard phase		
Mitral valve replacement‡	3.8 ± 2.5	.13
Propensity adjustment	-0.29 ± 1.01	.8
Older age†	0.49 ± 0.26	.06
Younger age in patients undergoing replacement§	-1.43 ± 0.65	.03
Higher NYHA functional class	0.69 ± 0.25	.006
Moderate or severe LV dysfunction	1.03 ± 0.33	.002
Preoperative atrial fibrillation	0.76 ± 0.33	.02
Preoperative BUN level	0.048 ± 0.011	<.0001
Late hazard phase		
Mitral valve replacement	1.24 ± 0.51	.01
Propensity adjustment	-0.71 ± 0.48	.13
Older age†	0.89 ± 0.19	<.0001
Diabetes	0.88 ± 0.30	.003
Smoking history	0.88 ± 0.24	.0002

LITA, Left internal thoracic artery; LV, left ventricular; BUN, blood urea nitrogen.

*Probability of receiving mitral valve repair.

†exp(age/50) Exponential transformation.

‡Represents increment to intercept for patients undergoing mitral valve repair.

§Interaction term.

important to distinguish patients with ischemic mitral regurgitation from those with concomitant degenerative mitral valve and ischemic heart diseases. Patients with ischemic mitral regurgitation have a poor prognosis.¹²

Which Patients Benefit From Repair?

Eighty-nine percent of patients with degenerative mitral valve and ischemic heart diseases were projected to derive a survival benefit from mitral valve repair versus replacement. Even in elderly patients with ischemic heart disease, repair is desirable. However, patients in NYHA class IV with extreme left ventricular dysfunction have poor survival, regardless of mitral valve procedure, and present a contemporary surgical challenge.

Limitations

This was a nonrandomized clinical study. By using the propensity score, we attempted to adjust the multivariable analyses of outcomes for nonrandom selection bias related to the choice of valvular procedure.

The end point of this study was death.²⁵ We did not analyze other valve-related complications, all of which have been thoroughly documented in the literature on mitral valve repair and replacement. For similar reasons, we did not examine valve durability or reoperation.^{1,10,26}

We were unable to determine from review of the operative reports which patients with mitral valve replacement had preservation of all or part of the subvalvular apparatus. Thus we could not analyze the effect of this surgical technique directly. However, because the procedure became

Figure 5. Nomograms representing solutions of the multivariable survival equation in Table 6 for specific patient characteristics. The equation has been solved twice, once for mitral valve repair and again for replacement. **A**, Survival predicted for a patient who is 70 years old, in NYHA class II, has normal left ventricular function, does not have chordal elongation, does not have atrial fibrillation, does not have diabetes, never smoked, has a blood urea nitrogen value of 21 mL/dL, and had a left ITA used in bypass grafting. **B**, Survival predicted for a patient similar to the patient in Figure 5, **A**, except that he is in NYHA class IV, has severe left ventricular dysfunction, and is diabetic and a smoker.

standard practice at the Clinic in 1988, we analyzed the interaction between the date of operation and valve replacement as a surrogate and did not identify a statistically significant relationship.

Clinical Inferences and Decision Making

Choice of surgical procedure affects late survival in patients with degenerative mitral valve disease coexisting with ischemic heart disease. Most patients benefit from mitral valve repair.

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Appendix 1

Variables considered in risk analyses

Demographic characteristics

Age (years)

Body size: height (centimeters), weight (kilograms), body mass index, body surface area (square meters)

Sex

Symptoms and clinical status

NYHA class, emergency surgery

Mitral valve pathology

Prolapse of the anterior leaflet, prolapse of the posterior leaflet, elongated chordae to the anterior leaflet, elongated chordae to the posterior leaflet, rupture of the anterior chordae, rupture of the posterior chordae, dilated annulus, leaflet retraction

Cardiac comorbidity

Previous cardiac surgery, family history of coronary artery disease, preoperative atrial fibrillation, left ventricular dysfunction (graded as none, mild, moderate, or severe), history of myocardial infarction, coronary artery disease (maximum stenosis in left main trunk, left anterior descending, circumflex, and right coronary trunk systems), number of coronary systems with greater than 50% stenosis (0-3)

Noncardiac comorbidity

Blood urea nitrogen, creatinine, renal disease, cholesterol, bilirubin, treated diabetes, smoking, hypertension, chronic obstructive pulmonary disease, peripheral vascular disease

Operative details

Mitral valve replacement versus repair

Mitral prosthesis: bioprosthesis, mechanical

Mitral repair: site of repair (annulus, posterior leaflet, anterior leaflet); use of annuloplasty (type of ring: Carpentier-Edwards, Cosgrove, Edwards; bovine pericardial annuloplasty); leaflet resection (partial or complete, sliding or not); chordal resection; chordal shortening or transfer

CABG: ITA grafting, single versus bilateral ITA grafting; number of grafts; complete revascularization

Experience

Date of operation expressed on a continuous scale as years from January 1, 1973.

Appendix 2. Algorithm to choose mitral valve strategy

Analysis of 10-year survival difference for mitral valve repair versus replacement yields an algorithm that aids in deciding which strategy to pursue. Estimating the 10-year survival difference is a 4-step process. First, select one value for each of the 3 continuous variables from the columns below. Enter these values into the table on the following page.

Age	Value	BUN	Value	Bilirubin	Value
35	2.2	10	16.6	0.3	−0.43
40	2.9	12	16.1	0.4	−0.57
45	3.7	14	15.2	0.5	−0.71
50	4.5	16	14.2	0.6	−0.85
55	5.5	18	13.0	0.7	−0.99
60	6.5	20	11.9	0.8	−1.14

continued

Appendix 2. Continued

Age	Value	BUN	Value	Bilirubin	Value
65	7.7	22	10.7	0.9	−1.28
70	8.9	24	9.6	1.0	−1.42
75	10.2	26	8.5	1.1	−1.56
80	11.6	28	7.5	1.2	−1.71
85	13.1	30	6.5	1.4	−1.99
		35	4.1	1.8	−2.55
		40	1.9	2.2	−3.12

BUN, Blood urea nitrogen.

Variable	Value	Value chosen
Age	See above	
BUN	See above	
Bilirubin	See above	
NYHA class		
II	−3.7	
III	−9.6	
IV	−18.3	
LV dysfunction*	−11.9	
Atrial fibrillation	−8.5	
Chordal rupture†	−1.2	
Ever smoked	11.7	
Diabetes§	9.7	
Ventricular arrhythmias	1.7	
Total		

BUN, Blood urea nitrogen; LV, left ventricular.

*Grade 3 (moderately severe) or 4 (severe) left ventricular dysfunction.

†Only those of the posterior leaflet.

§Pharmacologically treated (real hypoglycemic agents or insulin).

Third, sum all the numbers in the column marked “Value chosen.”

Fourth, interpret the total. The total is the estimated 10-year survival difference in percentage. If the sum is positive, repair is favored; if negative, replacement is recommended. Approximate error of the survival difference is 5.5%.

Example: The patient is 70 years old (8.9) in sinus rhythm (0 for atrial fibrillation) without ventricular ectopy (0) but with only posterior chordal rupture and leaflet prolapse (−1.2) in NYHA class III (−9.6) with 3-system coronary artery disease and well-preserved left ventricular function (0) who has never smoked (0), has no history of diabetes (0), has a blood urea nitrogen value of 18 (13.0), and has a bilirubin value of 0.8 (−1.14). The total score is 9.96 ± 5.5 , meaning mitral valve repair is recommended.

Discussion

Dr Tirone E. David (Toronto, Ontario, Canada). I would like to congratulate Dr Faber and his colleagues from the Cleveland Clinic for having attempted to demonstrate the relative values of mitral valve repair and mitral valve replacement in patients with mitral regurgitation caused by myxomatous degeneration and associated coronary artery disease. I have to confess that I do not understand the statistical methods he used to adjust for the differences in the patients’ clinical profile, but I trust Eugene Blackstone so much that I have to accept their conclusions.

What is evident to me, however, is that your patients who had mitral valve replacement were operated on much earlier in your experience than those who had mitral valve repair. Actually, 62%

of your patients who had mitral valve replacement were operated on before 1990, and 73 of those who had mitral valve repair were operated on after 1990. This alone suggests to me a change in approach at your institution, that the surgeons who are facing the problem decided to change the way they manage their problem. In addition, patients who had mitral valve replacement were much older, they are much more symptomatic, and they had worse ventricular function than patients who had mitral valve repair.

There was no mention in your presentation or your manuscript that I reviewed, thanks to you, as to whether the papillary muscles and chordae tendineae were preserved during mitral valve replacement. Years ago we published an article showing that mitral valve repair or replacement with the preservation of the chordae tendineae had similar 10-year survival if the patients had isolated mitral valve regurgitation caused by myxomatous disease.

I have a couple of questions for you, Dr Faber. Were the papillary muscles preserved in any of your patients, and if they were, was the result the same?

The second question is related to the ITA. We have shown over and over that revascularization of the internal descending artery with the left ITA enhances life span. Forty-five percent of your mitral valve repairs used the ITA, whereas this was the case in only 15% of the replacements. Could this difference alone account for most of the difference found in survival?

Finally, there must be a number of patients in whom, even after 1990, when your surgeons were more experienced in mitral valve repair, your surgeons attempted to repair the mitral valve, and then, after a while, 30 minutes or an hour, they abandoned the procedure and replaced the valve. Those patients, if they were lumped together with the elective mitral valve replacements, had a much worse prognosis than those who had mitral valve replacement to start with.

Dr Faber. Dr David, thank you very much for your kind comments, and those are very important issues that you pointed out. I would like to say that we did not have the information about the preservation of the subvalvular apparatus on the operative reports of the patients, so we could not say which ones we preserved and which ones we did not preserve. I know about the results of your article, and I agree with them, but we could not analyze that data, and that probably could be accounting for some of the differences that we saw.

Dr David. I am sorry to dwell on this issue. Did you take a look at temporal response of mitral valve replacement as well? In other words, of the patients who were operated on after 1990 and had mitral valve replacement, did those patients do better than those operated on in 1973?

Dr Faber. I do not know the answer for this. We did not look into that. The only thing we know is that after we gained more experience with repair, we started doing more and more of those, but we did not look specifically at the time frame of those. Therefore I could not answer this question for you.

About the ITA differences in survival, yes, I agree with that, and it has been shown that there is a difference in survival. Still, this, in the beginning of our experience, was based on the decision of the surgeon. Therefore I could not say why they used that. But I agree with your comments, and lately, that is what we use for the revascularization of the LAD.

What was your last question?

ACD