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Surgical Treatment of Mitral Valve Regurgitation in Dilated Cardiomyopathy

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ABSTRACT

Background: Mitral valve (MV) surgery for dilated cardiomyopathy (DCM) was proposed at the beginning of the 1990s, and its effectiveness has been confirmed by many studies. The aim of this study is to evaluate long-term survival and the functional results of our experience with MV surgery for DCM.

Methods: From January 1990 to October 2002, MV surgery for DCM was performed in 91 patients (64 ischemic, 27 idiopathic). DCM was defined as in our previous reports. Patients with organic MV disease, severe right ventricle dilatation with impaired function, or severe renal or hepatic failure were excluded from the study. MV annuloplasty was performed in 64 patients, and 27 patients underwent a MV replacement.

Results: The 30-day mortality rate was 4.4% (4 patients). The probability of being alive at 5 years was 78.4% ± 4.3% and was higher in patients who underwent MV repair (81.4% ± 4.5%) than in patients who underwent replacement operation (66.7% ± 9.1%), even if the *P* value was not statistically significant. After a mean follow-up period of 27 ± 30 months, the New York Heart Association (NYHA) class decreased from 3.5 ± 0.7 to 2.1 ± 0.6 in the 69 survivors ($P < .001$). The probability of being alive 5 years after surgery with an improvement of least 1 NYHA class was 65.9% ± 5.0% and was higher in patients with MV repair (76.6% ± 6.0%) than in patients who underwent valve replacement (51.9% ± 9.6%), even if the *P* value was not statistically significant. Fifty patients were carefully followed with serial evaluations in our echocardiographic laboratory. Volumes did not change, nor did stroke volume or ejection fraction. Some degree of functional mitral regurgitation (FMR) was present in all but 8 of the patients who underwent repair. The analysis of these patients showed that all of the patients who had no residual MR had a mitral valve coaptation depth (MVCD) of 10 mm or less and had a better functional result. Conversely, the MVCD was shorter in patients who had no or mild (1/4) residual MR than in patients who had a residual MR >1/4. NYHA class was lower in patients with no or up to 1/4 residual MR, showing that the purpose of the procedure is the reduction or elimination of FMR, which is the determinant of the clinical result.

Conclusions: Long-term results in our patients are satisfying. FMR can be crucial for achieving a higher effectiveness of a combined strategy to improve the global outcome of these patients.

INTRODUCTION

Mitral valve (MV) surgery for dilated cardiomyopathy (DCM) was proposed at the beginning of the 1990s [Bolling 1995], and different reports [Calafiore 1999, Bishay 2000, Buffolo 2000, Calafiore 2001, Radovanovic 2002] have confirmed the effectiveness of this procedure. The appearance of functional mitral regurgitation (FMR) complicates the natural history of DCM and has a negative impact on survival [Romeo 1989, Blondheim 1991, Junker 1993]. Restoring the MV competence has a direct effect on reducing left ventricle (LV) overload, which in turn has an effect on LV end-diastolic pressure and on stroke volume, which becomes prevalently antegrade, resulting in a positive net effect on cardiac output. Reducing the LV volumes and increasing the ejection fraction (EF) are not purposes of the procedure.

We review our experience with MV surgery for treating DCM to evaluate long-term survival and functional results.

MATERIALS AND METHODS

DCM has been defined in our previous reports [Calafiore 1999]. The patients had ischemic (n = 64) or idiopathic (n = 27) DCM. Ischemic DCM was defined as an impaired contractile performance not explained by the extent of coronary artery disease or ischemic damage. No patients had

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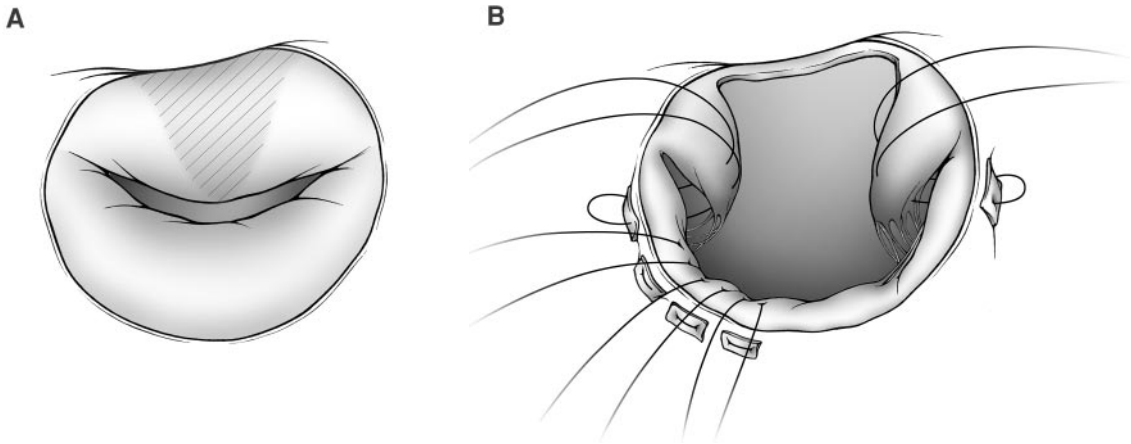

Figure 1. Mitral valve replacement. A small triangle of the anterior leaflet was excised (A), and the papillary muscles were drawn toward the annulus with the prosthetic sutures (B). Reprinted with permission [Calafiore 2003].

evidence of residual ischemia, and coronary bypass grafting, if performed, was done to avoid additional coronary occlusions.

From January 1990 to October 2002, MV surgery for DCM was performed in 91 patients. The cases of some of these patients have previously been reported [Calafiore 2001]. No patients had organic MV disease, and right ventricular function was normal or moderately impaired. Severe right ventricular dilation with poor contractility, as well as severe renal or hepatic failure, was a formal surgical contraindication. MV surgery was indicated if FMR was severe (4/4) or moderate to severe (3/4); however, we do recommend surgery in cases of a moderate FMR (2/4). The definition of moderate FMR is often echocardiographic, and its influence on cardiac output depends on the LV function and on the stroke volume. The lower the EF and the stroke volume are, the higher will be the impact of moderate FMR on cardiac output. Moreover, the MR in DCM, being functional, can change from time to time. For this reason, the result of the echocardiographic evaluation is the key point for the surgical indication, because the echocardiographic MV anatomy does not change, whereas FMR can.

Echocardiographic evaluation has to consider the MV annulus, which is enlarged in DCM, and the degree of displacement of the papillary muscles. This latter aspect can be easily inferred from the depth of the coaptation of the mitral leaflets into the LV (MV coaptation depth [MVCD]) [Calafiore 2001]. This value can easily be obtained by measuring the distance between the plane of the annulus and the coaptation point of the MV leaflets (Figure 1). In the normal MV, the MVCD does not exceed 6 mm (mean ± SD, 4.1 ± 1.6 mm) [Calafiore 2001]. The greater the MVCD is, the more displaced will be the papillary muscles. This value can be a determinant of surgical indication, because a larger MVCD increases the possibility that FMR will severely increase under stress conditions, independently from its basal value. Surgery is indicated in the presence of an enlarged annulus, a deep MVCD, and a 2/4 basal FMR.

Table 1 shows the clinical and hemodynamic preoperative data, and Table 2 presents the echocardiographic data.

Surgical Technique

Myocardial protection was always achieved with intermittent antegrade warm blood cardioplegia [Calafiore 1995]. Both cavae were directly cannulated, because we prefer the transatrial approach for MV exposure.

Mitral valve annuloplasty was performed in 64 patients. In 19 patients, surgery was performed with a posterior double-suture annuloplasty using a 2-0 polyester suture (Ti-cron; Sherwood Medical, St. Louis, MO, USA) adapted to a no. 26

Table 1. Preoperative Clinical and Hemodynamic Data (n = 91)*

Age, y	65.1 ± 9.3
Female sex, n	15 (16.5%)
NYHA class	3.2 ± 0.6
NYHA class III-IV, n	83 (91.2%)
Etiology, n	
Ischemic	64 (70.3%)
Idiopathic	27 (29.7%)
Mean PAP, mm Hg	34 ± 14
Cardiac index, $L \cdot min^{-1} \cdot m^{-2}$	2.05 ± 0.84

*Data are presented as the mean ± SD where appropriate. NYHA indicates New York Heart Association; PAP, pulmonary artery pressure.

Table 2. Preoperative Echocardiographic Data (n = 91)*

End-diastolic volume, mL/m^2	146 ± 52
End-systolic volume, mL/m^2	102 ± 43
Stroke volume, mL/m^2	40 ± 14
Ejection fraction, %	27 ± 7
Mitral annulus, mm/m^2	22.0 ± 3.2
Coaptation depth, mm	10.4 ± 1.7
Mitral regurgitation	3.3 ± 0.7
Sphericity index (diastole)	0.82 ± 0.10

*Data are presented as the mean ± SD.

Table 3. Operative Data (n = 91)*

Mitral valve repair, n	64
Isolated	9
+ CABG	31
+ Tricuspid repair	14
+ CABG + tricuspid repair	10
Mitral valve replacement, n	27
Isolated	4
+ CABG	13
+ Tricuspid repair	6
+ CABG + tricuspid repair	4
CPB time, min	88 ± 38
Ao Xcl time, min	69 ± 28

*Data are presented as the mean ± SD where appropriate. CABG indicates coronary artery bypass grafting; CPB, cardiopulmonary bypass, Ao Xcl, aortic cross-clamping.

sizer. In the remaining patients, a pericardial strip (treated with a solution of 0.625% glutaraldehyde for 15 minutes and then rinsed in saline for 15 minutes) was used to reduce the posterior annulus from commissure to commissure. The strip length was 52 mm (corresponding to a no. 26 sizer) in 12 patients. In the last 33 patients, the length was reduced to 40 mm [Calafiore 2003]. The result was a better undersizing of the MV annulus, with an area between 3.0 and 3.5 cm^2 and a mean gradient of 1 to 3 mm Hg.

When the MV was replaced (n = 27), only a small triangle of the anterior leaflet was excised, and the papillary muscles were drawn toward the annulus with the prosthetic sutures (Figure 1).

The choice of MV repair or replacement depends on the MVCD. If the MVCD is 10 mm or less, MV repair is always possible. If it is greater than 10 mm, the alterations of the subvalvular apparatus are such that FMR is expected to return in a short period of time. MV replacement is then indicated.

Tricuspid annuloplasty was obtained with a double-suture annuloplasty and a 2-0 Ti-cron suture. Coronary bypass grafting was performed when necessary, and atriobiventricular pacing was inserted at the end of the procedure in 4 cases to synchronize both ventricles in the presence of left bundle branch block.

Before the aorta was unclamped, an elective infusion of dobutamine (5 μg/kg per minute) was started. If necessary, stronger support with adrenaline or an intra-aortic balloon pump (IABP) was used. In cases of chronic renal failure, a continuous infusion of dopamine (3 μg/kg per minute) and furosemide (20 mg/h) was always started. In cases of peripheral systemic resistance, sodium nitroprusside (Nipride) or nitroglycerin infusions were freely added.

Postoperative Course

After surgery, all of the patients were admitted to the intensive care unit and subsequently to the surgical and cardiologic wards. All of the patients were followed up in our outpatient clinic at 3, 6, 9, and 12 months postoperatively and every 6 months thereafter. The follow-up is 100% complete.

Statistical Analysis

Results are expressed as the mean ± SD unless otherwise indicated. Statistical analyses of 2 groups were performed with the unpaired 2-tailed Student *t* test for means or with the χ^2 test for categorical variables. Actuarial curves were obtained by the Kaplan-Meier method. Statistical significance was calculated with the log-rank test. SPSS software (Chicago, IL, USA) was used. *P* values ≥.05 were considered not significant.

RESULTS

Early Mortality and Morbidity

Tables 3 and 4 show the perioperative and postoperative data. Four patients (4.4%) died during the first 30 days after surgery. The causes of death were acute myocardial infarction, rupture of the abdominal aorta, respiratory hemorrhage, and rupture of the left atrium–aorta junction. All of the patients had elective inotropic support for 30 ± 32 hours. Seven patients required IABP support, 1 in the operating room and the other 6 in the intensive care unit. Twelve patients required readmission, and all of these patients were redischarged after 36.3 ± 31.5 hours. The total postoperative length of stay (in the surgical and cardiologic wards) was 6.3 ± 2.7 days. Medical treatment for chronic problems included angiotensin-converting enzyme inhibitors, diuretics, and β-blockers such as carvedilol.

Late Survival

After 21 ± 30 months, 18 patients had died, 17 from cardiac causes (16 from heart failure and 1 from sudden death) and 1 from a noncardiac cause (respiratory failure). The actuarial survival curve is shown in Figure 2. The probability of being alive 5 years after surgery was 78.4% ± 4.3% and was higher for the patients who underwent MV repair (81.4% ± 4.5%) than for the patients who underwent replacement (66.7% ± 9.1%), although the *P* value was not significant.

Functional Results

After a mean follow-up period of 27 ± 30 months, the New York Heart Association (NYHA) class decreased from 3.5 ± 0.7 to 2.1 ± 0.6 ($P < .001$) in the group of 69 survivors. The probability of being alive 5 years after surgery with an improvement of at least 1 NYHA class was 65.9% ± 5.0% and

Table 4. Postoperative Data (n = 91)*

Death, n	4 (4.4%)
Acute myocardial infarction, n	0
Cerebrovascular accident, n	1 (1.1%)
Intra-aortic balloon pump, n	6 (6.6%)
Acute renal failure, n	14 (15.4%)
Acute respiratory failure, n	5 (29.7%)
Bleeding, mL/12 h	791 ± 628
Transfused patients, n	34 (37.4%)
Intensive care unit stay, h	33 ± 32
Hospital stay, d	6.3 ± 2.7

*Data are presented as the mean ± SD where appropriate.

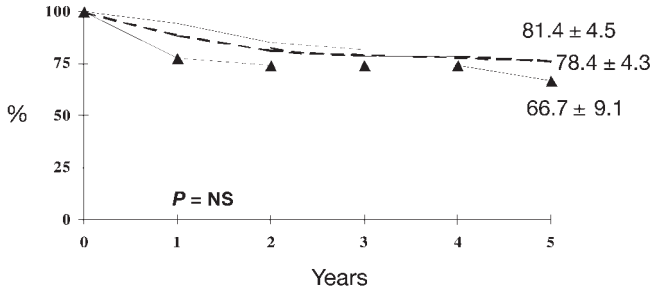

Figure 2. Five-year actuarial survival for all patients (– – –) and for the patients with mitral valve repair (——) and mitral valve replacement (–▲—▲–). NS indicates not significant.

was higher in the patients with MV repair (76.6% ± 6.0%) than in the patients with replacement (51.9% ± 9.6%), although the *P* value was not significant (Figure 3).

Echocardiographic Results

Fifty patients were carefully followed with serial evaluations in our echocardiographic laboratory (Table 5). The results were comparable and were independent of MV repair or replacement, even if the latter patients were the most dilated. Volumes, as well as the stroke volume and EF, were unchanged. However, the NYHA class was significantly lower for both groups. Some degree of MR was present in all but 8 of the patients who underwent MV repair. The analysis of these patients (Table 6) showed that all of the patients who had no residual MR had a MVCD of 10 mm or less and had a better functional result. Conversely, the MVCD was shorter in patients who had no or mild (1/4) residual MR than in patients who had a residual MR >1/4. The NYHA class was lower in patients with no or up to 1/4 residual MR, showing that the purpose of the procedure is the reduction or elimination of FMR, which is the determinant of the clinical result.

DISCUSSION

The Laplace law states that myocardial wall stress is proportional to the radius of the curvature and to the intraventricular pressure and inversely proportional to the thickness of the wall. According to this law, an increase in the radius of the chronic failing heart exposes the myocytes to a higher wall stress. This stress leads to chamber and cellular hypertrophy, which acts in an adaptive process to normalize the wall stress. As the chamber continues to dilate over time and the limits of hypertrophy are reached, the wall stress ultimately increases with a consequent reduction in pump efficiency.

Techniques of volume reduction, such as the Batista operation, mainly address radius reduction and as a consequence reduce the wall stress to increase the efficiency of the systolic pump. However, the limit of every technique that reduces LV volume is the unpredictability of such a volume reduction on the diastolic pump properties. When the LV volume is reduced, diastolic filling can be worsened, because the remaining LV cavity can be stiffer than necessary to receive a volume of blood at a low-end diastolic pressure that is sufficiently reasonable to ensure a normal stroke volume [Zile 2002]. The correction of FMR has less spectacular consequences, because its effects on LV volumes, if any, are minor; however, the FMR correction triggers a mechanism that, in reducing the LV endoventricular pressure, is able to maintain the stroke volume unchanged, thereby increasing the net antegrade flow.

The appearance of FMR has a negative impact on the natural history of DCM in that the degree of heart failure increases and life expectancy decreases [Romeo 1989, Blondheim 1991, Junker 1993]. FMR is related to incomplete MV closure. Displacement of the papillary muscles posterolater-

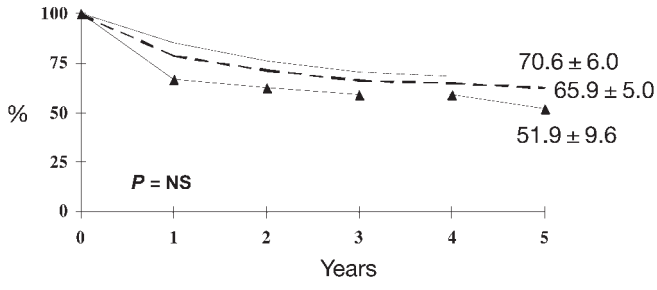

Figure 3. Probability of being alive at 5 years with at an improvement of at least 1 New York Heart Association class for all patients (– – –) and for the patients with mitral valve repair (——) and mitral valve replacement (–▲—▲–). NS indicates not significant.

Table 5. Echocardiographic Results of 50 Patients at Follow-up (21 ± 30 mo)*

	Preoperative	Postoperative	*P*
End-diastolic volume, mL/m^2	144 ± 52	131 ± 38	NS
End-systolic volume, mL/m^2	105 ± 44	90 ± 35	NS
Stroke volume, mL/m^2	40 ± 14	42 ± 16	NS
Ejection fraction, %	27 ± 7	32 ± 12	NS

*Data are presented as the mean ± SD. NS indicates not significant.

Table 6. Echocardiographic Results According to Mitral Valve Coaptation Depth (MVCD) and Postoperative Mitral Regurgitation (MR)*

	MVCD		
	≤10 mm (n = 26)	>10 mm (n = 11)	*P*
No residual MR, n	8	—	
Degree of MR	0.8 ± 0.7	1.6 ± 0.6	.002
	Postoperative MR		
	0-1 (n = 24)	>1 (n = 13)	*P*
MVCD, mm	9.3 ± 1.2	11.6 ± 0.5	<.001
NYHA class	1.6 ± 0.6	2.3 ± 0.9	<.001

*Data are presented as the mean ± SD. NYHA indicates New York Heart Association.

ally and apically increases the distance over which the mitral leaflets are tethered from the papillary muscle to the anterior annular ring and restricts the possibility of their closing at the annular level [Otsuji 1997]. The leaflets take on a tented geometry, and their coaptation depth increases. When FMR starts, the MV annular area increases together with the mitral annulus, and, consequently, the base of the heart increases. This process causes a further increase in FMR.

Surgery has as its purpose the restoration of MV competence to reduce LV endoventricular pressure and to change the stroke volume from antegrade and retrograde to only or primarily antegrade, with the achievement of an immediate increase in cardiac output. Reduction of the LV volume and an increase in the EF are not purposes of the procedure, which remains palliative because the underlying disease is not corrected.

The degree of MR is not the determinant of surgical indication, because the FMR can change with time. Because the echocardiographic anatomy remains unchanged, a careful evaluation of the different aspects of the mechanisms of FMR can allow us not only to indicate surgery but also to understand which kind of procedure has to be performed. In fact, the decision to repair or to replace the MV depends on the degree of displacement of the papillary muscles, which is mirrored by the MVCD. We have found in some cases that MV replacement is the procedure of choice, because MV repair when the MVCD is too great is not as effective as it is when the geometry of papillary muscles is not deeply modified [Calafiore 2001].

The long-term results in our patients are satisfying, and these results are supported by those of other investigators [Bolling 1998, Calafiore 2001, Badhwar 2002, Radovanovic 2002]. The probability of being alive with an improvement of at least 1 NYHA class is definitively higher in the patients who underwent repair, and the difference, although not statistically significant, is clinically significant. However, the patients who underwent MV replacement had hearts that were more enlarged and, globally, more advanced degrees of disease. Volume, stroke volume, and EF did not change significantly; this lack of modification did not influence the late functional result.

How long the palliative effects of the surgical procedure will last is not possible to say. However, the great improvements in medical treatment that today are able to increase life expectancy and to reduce heart failure symptoms in patients with DCM, allow us to conceive of a synergy between cardiologists and surgeons, because eliminating or reducing FMR can be crucial for achieving a higher effectiveness of a combined strategy to improve the global outcome of these patients.

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