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Abstract

Patients with mitral regurgitation (MR) due to mitral valve prolapse operated at the Second Department of Surgery, Okayama University Medical School, between 1976 and 1986 were divided into two groups. The first consisted of 20 patients who had mitral valve replacement (MVR) and the second 15 patients who had mitral annuloplasty (MAP). Long-term results of surgery, cardiac function, hemodynamic status, and surgical findings were compared between the two groups. Before surgery, there were no significant differences in patient's clinical status and cardiac function between the two groups. However, after surgery statistically significant differences emerged between the two groups in ejection fraction (EF), cardiac index (CI) and mean circumferential fiber shortening velocity (mVcf). Left ventricular pumping function and myocardial contractile force tended to decrease after surgery in the MVR group and to remain unchanged or even increase in the MAP group indicating that valve preservation procedures should be selected as often as possible for the patients involved in mitral valve prolapse.

KEYWORDS: mitral valve prolapse, mitral regurgitation, mitral valve replacement, mitral annuloplasty

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Long-Term Results of Surgery for Mitral Regurgitation Due to Mitral Valve Prolapse: A Comparison of Valve Replacement and Annuloplasty

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Patients with mitral regurgitation (MR) due to mitral valve prolapse operated at the Second Department of Surgery, Okayama University Medical School, between 1976 and 1986 were divided into two groups. The first consisted of 20 patients who had mitral valve replacement (MVR) and the second 15 patients who had mitral annuloplasty (MAP). Long-term results of surgery, cardiac function, hemodynamic status, and surgical findings were compared between the two groups. Before surgery, there were no significant differences in patient's clinical status and cardiac function between the two groups. However, after surgery statistically significant differences emerged between the two groups in ejection fraction (EF), cardiac index (CI) and mean circumferential fiber shortening velocity (mVcf). Left ventricular pumping function and myocardial contractile force tended to decrease after surgery in the MVR group and to remain unchanged or even increase in the MAP group indicating that valve preservation procedures should be selected as often as possible for the patients involved in mitral valve prolapse.

Key words : **mitral valve prolapse, mitral regurgitation, mitral valve replacement, mitral annuloplasty.**

Mitral valve prolapse (MVP) has been a recent cardiopathological topic of discussion because of its manifold pathological manifestations, particularly its important role in the pathogenesis of non-rheumatic valvular disease. Surgical procedures to correct mitral regurgitation (MR) caused by MVP include mitral valve replacement (MVR) and mitral annuloplasty (MAP). In order to clarify the issue of indications for these surgical procedures, we compared long-term prognosis and changes in cardiac function in patients with MVR-caused MR who had undergone MVR or MAP at the Second Department of Surgery, Okayama University Medical School.

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Subjects and Methods

Between 1976 and 1986, 53 patients underwent operations for MR due to mitral valve prolapse. This constituted 58% of all patients who underwent open mitral valve operations for MR. Among 18 of the 53 patients who had the complications of tricuspid regurgita-

tion (TR), ventricular septal defect (VSD), atrial septal defect (ASD) and infective endocarditis were excluded from this study. The remaining 35 patients with MVP-caused MR were divided into two groups; 20 patients (11 males, 9 females) who had MVR, and 15 patients (12 males, 3 females) who had MAP. The clinical findings were listed in Table 1. Long-term results of surgery, cardiac function, hemodynamic status, and surgical findings were compared between the two groups.

The following prosthetic valves were used for MVR: Björk-Shiley valve in 11 patients, St. Jude Medical valve in five patients, Hancock valve in two, and Carpentier-Edwards valve in two. The following procedures were applied on MAP: Kay's method in seven patients, Carpentier ring method in five, a combination of McGoon's and DeVega's methods in two, and valvuloplasty using a pericardial patch in one.

Mitral valve prolapse was defined when there was a systolic mitral click and a late systolic murmur or both. Systolic buckling or hammocking of the mitral valve detected by M mode echocardiography or mitral valve prolapse detected by cross-sectional echocardiography also had to be present. Myxomatous degeneration was confirmed by histological findings from resected specimens in the MVR group. In the MAP group, diagnosis of MVP was based on ultrasonic cardiographic (UCG) findings (1), phonocardiographic identification of clicks (2), and mitral valve appearance during surgery. Cardiac function of all patients was measured before and after surgery by means of cardiac catheterization and UCG. On the average, cardiac catheterization was done two months before and one month after surgery. UCG was performed one week before and five years after surgery.

The following were studied: patient's age at the time of surgery, New York Heart Association (NYHA) functional class, cardiac rhythm, MR severity, cardiothoracic ratio (CTR), heart rate, blood pressure, mean pulmonary arterial pressure (PAP), and left ventricular end-diastolic pressure (LVEDP). Based on UCG findings, the following were measured: left atrial diameter (LAD), left ventricular end-diastolic volume index (LVEDVI), left ventricular end-systolic volume index (LVESVI), stroke volume index (SVI), ejection fraction (EF), cardiac index (CI), and mean circumferential fiber shortening velocity (mVcf). Surgical procedure, necessity of repeat surgery, necessity of medication, length of follow-up period, and long-term results were compared between the two groups. NYHA class and CTR were measured an average of one month before and five years after surgery. Before 1979, surgery was performed with the patient under moderate body hypothermia and beating heart to confirm the regurgitation site. Since 1979, topical cooling and cold cardioplegia have been adopted for this surgery.

Analysis of data. The average value of ten cardiac cycles of UCG recording was used. All results were expressed as the mean ± SD. Student's t-test and χ^2 tests were used, and differences were considered significant when $p < 0.05$.

Table 1 Clinical findings in the two groups

	MVR group (n = 20)	MAP group (n = 15)
Mean age (range)	40 (15-64)	44 (24-60)
Sex (male/female)	11/9	12/3
MR severity		
Grade 4/4	15	10
Grade 3/4	5	5
Mitral complex lesions		
Site of prolapse		
Anterior leaflet	7	7
Posterior leaflet	4	5
Both leaflets	9	3
Ruptured chordae tendineae		
Anterior leaflet	6	3
Posterior leaflet	2	4
Both leaflets	2	0
Annular dilatation		
Yes	20	15
No	0	0

MVR: mitral valve replacement, MAP: mitral annuloplasty, MR: mitral regurgitation

Results

MVR group. Patients were between the ages of 15 and 64 (mean = 40) at the time of surgery. Seven patients had atrial fibrillation; the remainder were in sinus rhythm. MR severity was grade 4/4 in 15 patients and grade 3/4 in five. In terms of preoperative clinical status, five patients were NYHA class IV, five class III, and 10 class II (mean = 2.7). After surgery, patient's NYHA functional class improved to 1.5, on the average. CTR improved from 60% before 56% after surgery. Hemodynamic data before and after surgery were listed in Table 2. In this study, the

Table 2 Comparison of hemodynamic data between the two groups in the survivors

		Preoperative data		Postoperative data	
		MVR[a] group (n = 18)	MAP[b] group (n = 14)	MVR group (n = 18)	MAP group (n = 14)
Heart rate		67 ± 7	65 ± 8	78 ± 7	75 ± 6
Blood pressure	(mmHg)	118 ± 12	120 ± 10	130 ± 13	128 ± 12
PAP[c]	(mmHg)	24 ± 10	23 ± 8	14 ± 3[l]	13 ± 4[m]
LVEDP[d]	(mmHg)	10 ± 4	11 ± 5	9 ± 2	6 ± 2[m]
LAD[e]	(mm)	46 ± 10	50 ± 11	42 ± 8	38 ± 6[m]
LVEDVI[f]	(ml/m^2)	138 ± 22	130 ± 28	80 ± 21[l]	72 ± 14[m]
LVESVI[g]	(ml/m^2)	60 ± 14	54 ± 12	39 ± 8[l]	27 ± 6[m]
SVI[h]	(ml/m^2)	78 ± 16	76 ± 12	41 ± 7[l]	45 ± 9[m]
EF[i]	(%)	57 ± 6	58 ± 8	51 ± 8[l]	63 ± 9[n]
CI[j]	(l/min/m^2)	5.2 ± 1.4	5.0 ± 1.2	3.2 ± 0.8[l]	4.4 ± 0.9[n]
mVcf[k]	(circ/sec)	1.60 ± 0.30	1.25 ± 0.20	1.32 ± 0.30	1.90 ± 0.21[m,n]

a: Mitral valve replacement, *b*: Mitral valve annuloplasty, *c*: Mean pulmonary arterial pressure, *d*: Left ventricular end-diastolic pressure, *e*: Left atrial diameter, *f*: Left ventricular end-diastolic volume index, *g*: Left ventricular end-systolic volume index, *h*: Stroke volume index, *i*: Ejection fraction, *j*: Cardiac index, *k*: Mean circumferential fiber shortening velocity. *l*: Significant difference ($p < 0.05$) between the pre- and post-operative data in the MVR group, *m*: Significant difference ($p < 0.05$) between the pre- and post-operative data in the MAP group, *n*: Significant difference ($p < 0.05$) between MVR and MAP groups in the postoperative data.

data of the survivors (18 patients) were compared. There were significant differences between the preoperative and postoperative cardiac function in the following parameters; PAP, LVEDVI, LVESVI, SVI, EF, and CI.

Postoperative perivalvular regurgitation occurred in two patients, one of whom underwent a second surgery and died 13 days later from multiple organ failure resulting from low output syndrome (LOS). The other patient died from endocarditis 51 days after the first operation. The mean follow-up period for the MVR group was eight years. All survivors (18 patients) were medicated with Warfarin, diuretics and digoxin in the long-term follow-up periods.

MAP Group. Patients were between 24 and 60 years old (mean = 44) at the time of surgery. Before surgery, nine patients had atrial fibrillation; the remainders were in sinus rhythm. MR severity was grade 4/4 in 10 patients and grade 3/4 in five. As for preoperative clinical status, one patient was NYHA class IV, nine were class III, and five class II (mean = 2.7). Clinical status improved following surgery to class I in 13 patients. On the average, CTR decreased from 60 % before to 52 % after surgery ($p < 0.05$). Hemodynamic data before and after surgery in 14 survivors were compared in Table 2. There were significant differences in the following parameters; PAP, LVEDP, LAD, LVEDVI, LVESVI, SVI, and mVcf.

Postoperative residual MR was detected in the three patients (20 %), two of whom had grade 1/4 MR and were left untreated. The remaining patient one had grade 2/4 residual MR. There was no improvement in their profiles, so second surgery (MVR) was performed 6 years after the first one. A patient who had MAP with a Carpentier ring died from cerebral embolism 53 days after surgery. Mean follow-up period was nine years. Five patients (33 %) were treated with digoxin, and the remaining nine patients had no medication long after surgery.

Comparison of MVR and MAP groups.

Before surgery, there were no significant differences in the patient's clinical status, hemodynamic profiles, cardiac function, and CTR between the MVR and MAP groups. However, following surgery statistically significant differences emerged between the two groups in EF, CI and mVcf. On the whole, EF, mVcf, and CI tended to decrease after surgery in the MVR group and to remain unchanged or even increase in the MAP group. In other words, in the MVR group, although cardiac volume decreased significantly after surgery, left ventricular pumping function and myocardial contractile force tended to decrease late in the postoperative course. Postoperative low output syndrome was more frequent in the MVR group than in the MAP group: three patients (15 %) to one (7 %).

Discussion

Surgical procedures for MVR-caused pure MR can be widely classified into valve replacement and valvuloplasty. As there is currently no perfect substitute for the natural mitral valve, cardiac surgeons are constantly establishing procedures and striving to preserve patient's valves. However, though there are various procedures for valvuloplasty, the effectiveness varies and well-defined criteria for the indication of valvuloplasty are lacking. For these reasons, valve replacement remains the inevitable treatment of choice in some MR patients. Thus, selection of surgical procedures for MR is a subject that is still much discussed, even in light of today's advanced cardiac surgery.

In this study, we compared MVR and MAP based on changes in cardiac function before and after surgery and long-term surgical results in patients with MVP-caused MR to determine effects on cardiac function, problems, and indications.

Surgical correction of MR causes a definite rapid increase in left ventricular afterload. Therefore, regardless of whether MVR or MAP is selected, left ventricular afterload increases immediately after surgery in direct proportion to the amount of regurgitation before surgery. However, little is known about the long-term effects of MVR and MAP on the left ventricle in mitral valve prolapse syndrome, and definite conclusions have not yet been made. In our current study, we observed a significant decrease in left ventricular volume shortly after MVR in both the diastolic and systolic phases. However, the ejection fraction (index of left ventricular pumping function) and mVcf (index of left ventricular contractile force) both decreased late in postoperative course. Although left ventricular volume also decreased after MAP, a relatively high stroke volume was maintained. Interestingly, both the ejection fraction and mVcf tended to increase after MAP. The cardiac index of the MVR group decreased significantly after surgery, but few changes were noted in the MAP group.

Wong *et al.* (3) reported a decrease in the ejection fraction after MVR was performed for pure MR, and theorized that the postoperative increase in afterload was responsible for the change. We obtained similar results with MVR. However, long-term MAP results indicate that cardiac function was not diminished, despite the increased afterload. Comparison of the MVR and MAP groups revealed no differences in clinical symptoms and cardiac function before surgery. There were no great differences either in the surgeons or methods used for myocardial protection between the two groups. Thus, the differences observed in long-term left ventricular response in the MVR and MAP groups can probably be attributed to differences in surgical procedure.

We perform MVR when central regurgitation is caused by prolapse and rupture of chordae tendineae involving both anterior and posterior leaflets or in the presence of mitral valve vegetation. In contrast, we perform MAP when the area of prolapse and tearing of the chordae tendineae is small, localized to either the anterior or posterior commissure, or confined to a segment

of the posterior leaflet. When conducting MAP, we select the procedure appropriate to the individual patient. Recently, Lessana *et al.* (4) reported a new technique of treatment for ruptured or elongated anterior mitral valve chordae by partial transposition of the posterior leaflet. Vetter *et al.* (5) reported an another technique with good results using expanded polytetrafluoroethylene suture replacing the ruptured chordae tendineae. Sixty-six percent of the MR patients at our hospital underwent MVR and 34 % did MAP. There are no well-defined criteria for selecting a surgical procedure (MVR or MAP) for pure MR. Moreover, MAP requires special skills and cannot be done as easily as MVR. As a result, the percentage of patients undergoing MAP for mitral valve prolapse varies considerably with the institution, ranging from 20 % to 85 % in some reports (6).

In this study, we performed MAP using the Carpentier ring, Kay, McGoon, and DeVega methods either alone or in combination. Although no deaths were directly associated with MAP, postoperative regurgitation was detected in three patients (20 %), one of whom required second surgery. However, patients in whom MR completely disappeared and who were of postoperative regurgitation grade 1/4 showed improved cardiac function after surgery, with increases in EF and mVcf. In these patients, both left ventricular volume and inner diameter decreased significantly and quickly after MAP (about one month). However, decrease in left ventricular volume in patients with postoperative regurgitation grade 2/4 tends to be delayed.

Although there was no difference in mortality between the MVR and MAP groups, two patients in the MVR group developed perivalvular leakage. In MR caused by myxomatous degeneration, the entire mitral complex is fragile. This may be one of the causes of perivalvular leakage after MVR. For this reason, some surgeons think that MVR without resecting the mitral cusps is advantageous for preventing postoperative perivalvular regurgitation (7).

One factor we cannot ignore for maintaining better cardiac function late in the postoperative course of the MAP group is the tethering effect of the chordae tendineae and papillary muscle on the left ventricular wall. Rushmer (8) pointed out that continuity of the left ventricular wall and mitral annulus is very important for maintaining left cardiac function. Through experiments he proved that the mitral complex (cusps, chordae tendineae, and papillary muscle) greatly influences the pattern of left ventricular contraction. Lillehei *et al.* (9) applied Rushmer's findings to clinical practice, reporting that MVR in which the mitral valve was preserved (particularly the posterior leaflet) along with the attached chordae tendineae and papillary muscle reduced both mortality and the incidence of postoperative LOS. In fact, recent reports (10-12) indicate that transplanting a prosthetic valve without resecting the cusps, chordae tendineae, and papillary muscle improved not only clinical symptoms but also cardiac function. These reports support our hypothesis.

Comparing MVR and MAP, we found that patients in the MAP group achieved a greater improvement in cardiac function and this result contributed to reduce the numbers of patients on medication. This suggests that valve-preserving procedures should be selected as often as possible for treating MR. Even if MVR seems to be the only alternative when the characteristics and anatomical findings of the mitral valve are examined, we believe that valve replacement procedures that allow papillary-annular continuity to be preserved in the left ventricular wall is therapeutically advantageous. Thus, we plan to adopt such procedures as often as possible.

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