Surgery in Severe Rheumatic Mitral Valve Disease

— Recognition of Severity and Risk Factors —

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The postoperative course of 294 patients with rheumatic mitral valve disease, who underwent mitral valve surgery during a period from July, 1978 to June, 1981, was studied by comparing the influences of the following clinical parameters: a low left ventricular ejection fraction (LVEF), a high pulmonary arterial systolic pressure (PASP), a high pulmonary vascular resistance (PVR), tricuspid regurgitation (TR), a high right ventricular end-diastolic pressure (RVEDP) and a giant left atrium (GLA). The patients with a functional capacity of class III or IV according to the New York Heart Association were classified into 3 groups (improved, unimproved and died), and from this data we calculated the improvement ratio and the mortality rate. The improvement ratios were 73% in patients with a low LVEF, 70% with a high PASP, 78% with a high PVR, 66% with TR, 11% with a high RVEDP and 77% with a GLA; the mortality rates were 19, 14, 17, 24, 78 and 19%, respectively. As compared with the case of deteriorated left ventricular performance and pulmonary hypertension, deteriorated right ventricular performance, especially high RVEDP, was accompanied by a comparatively poorer surgical prognosis. It is concluded that mitral valve surgery should be performed during the period in which the right ventricular function is still preserved.

IN selecting candidates for mitral valve surgery, morphological and functional abnormalities of patients must be recognized precisely, and moreover, how their prognosis will be improved by surgical therapy must be estimated. Many investigators have described the relationships between the results of cardiac surgery and preoperative clinical features.¹⁻⁶ Advances in cardiac surgery, however, especially myocardial protection using cardioplegia, have increased the number of surgical candidates for severe valvular heart disease, and it seems that the risk factors in cardiac surgery have been changed in recent

years. For these reasons, we undertook a 3 year-review of our experiences with rheumatic mitral valve disease at the Heart Institute of Japan, Tokyo Women's Medical College, with the aim of identifying the severity of the disease and the preoperative risk factors related to the final outcome.

SUBJECTS AND METHODS

Patient Population and Surgical Mortality

Three-hundred and eighty patients with rheumatic mitral valve disease underwent cardiac catheterization and quantitative angiographic measurements between July, 1978 to June, 1981. Two hundred and ninety-four of these patients (77%) were considered to be candidates for cardiac surgery by both cardiologists and

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Fig.1. Assessment of tricuspid regurgitation. Mild: There is a regurgitant jet with mild to moderate opacification of the right atrium (RA) which tends to clear rapidly. Moderate: RA is opacified as intensely as the right ventricle (RV), and contrast medium was washed out slowly from the RA. Severe: the RA is more densely opacified than the RV. The RA remains intensely opacified through the entire series of films.

TABLE I SURGICAL PROCEDURE AND MORTALITY

Surgical procedure	No. of cases	No. of hospital death
MVR	132	11 (8.3%)
+ TAP	37	7 (18.9%)
+ TVR	1	0
OMC	57	0
+ TAP	4	0
MVR + AVR or AVP	85	11 (12.9%)
+ TAP	28	4 (14.3%)
+ TVR	1	0
OMC + AVR or AVP	20	0
+ TAP	1	0
Total	294	22 (7.5%)

Abbreviations: MVR = mitral valve replacement; OMC = open mitral commissurotomy; AVR = aortic valve replacement; AVP = aortic valve plasty; TAP = tricuspid annuloplasty; TVR = tricuspid valve replacement

TABLE II NYHA FUNCTIONAL CLASS AND MORTALITY

Functional class	No. of cases	No. of hospital death
II	64	3 (4.6%)
III	193	13 (6.7%)
IV	37	6 (16.2%)
Total	294	22 (7.5%)

Abbreviation: NYHA = New York Heart Association

cardiovascular surgeons. There were 182 cases with mitral stenosis (MS), 64 with mitral regurgitation (MR) and 48 with combined mitral and aortic valve disease (M + A). They were 116 men and 178 women, ranging in age from 18 to 65 with an average age of 42.5. Tables I and II show surgical procedures, preoperative functional capacity according to the New York Heart Association (NYHA) and the mortality rate. The overall surgical mortality rate (hospital death) was 7.5%.

Laboratory Evaluations

All patients received medical treatment, such

TABLE III RISK FACTORS FOR MITRAL VALVE SURGERY

1) Left ventricular ejection fraction (LVEF)	below 0.4
2) Pulmonary arterial systolic pressure (PASP)	over 60 mmHg
3) Pulmonary vascular resistance (PVR)	over 10 unit·m ²
4) Tricuspid regurgitation (TR)	more than a moderate degree
5) Right ventricular end-diastolic pressure (RVEDP)	over 15 mmHg
6) Left atrial dimension by echocardiography	over 60 mm

as bed rest, salt and water restriction, administrations of digitalis, diuretics, vasodilators and catecholamines, according to the clinical features in each patient before cardiac catheterization. Right- and left-sided cardiac catheterization was performed using standard techniques, and the patients with severely impaired hemodynamic data underwent a second catheterization study after intensive medical therapy. In patients having more than one set of catheterization data, the best set of data was used in this study. Left ventricular volumes were obtained using Kasser's method.⁷ Angiographic assessment of mitral regurgitation and aortic regurgitation were done according to Sellers' classification.⁸ Patients with plus 3 or 4 mitral regurgitation by left ventriculography were classified into the MR (MR dominant) group, and patients with more than plus 3 aortic regurgitation by aortography or with a aortic valvular systolic pressure gradient of more than 50 mmHg were categorized as M + A. For the assessment of tricuspid regurgitation we performed right ventriculography using a special catheter modified in order to minimize artificial tricuspid regurgitation (Fig. 1).

Follow-up Study

The patients were followed up after surgery and their clinical courses were studied by analyzing medical records and by giving a questionnaire to each patient in February, 1982. The mean follow-up period was 2.1 ± 1.1 years, ranging from 0.5 to 2.6 years. There were no late deaths after cardiac surgery.

Evaluation of the Surgical Prognosis

Six hemodynamic variables listed in Table III

Fig. 2. The relationship between the left ventricular end-diastolic volume (LVEDV) and the left ventricular stroke volume (LVSU) in mitral stenosis (MS). The dotted area indicates a left ventricular ejection fraction (LVEF) of below 0.4. Cases who died are shown by solid circles.

Fig. 3. The relationship between the LVEDV and the LVSU in mitral regurgitation (MR). A LVEF of below 0.4 is indicated by the dotted area. Cases who died are shown by solid circles.

were evaluated in order to predict the surgical prognosis. A left ventricular ejection fraction (LVEF) of below 0.4, a pulmonary arterial systolic pressure (PASP) of over 60 mmHg, a pulmonary vascular resistance (PVR) of over 10 unit·m², tricuspid regurgitation (TR) of more than a moderate degree, a right ventricular end-diastolic pressure (RVEDP) of over 15 mmHg and an echocardiographically obtained left atrial dimension of over 60 mm were considered

TABLE IV SURGICAL RESULTS OF THE CLASS III OR IV PATIENTS WITH A LOW LEFT VENTRICULAR EJECTION FRACTION (LVEF BELOW 0.4) GROUP

	No. of cases	Improved	Unimproved	Died
MS	15	11	1	3
MR	6	3	1	2
M + A	5	5	0	0
Total	26	19	2	5

Improvement ratio = 73%; mortality rate = 19%.

Abbreviations: MS = mitral stenosis; MR = mitral regurgitation; M + A = combined mitral and aortic valve disease

TABLE V SURGICAL RESULTS OF THE CLASS III OR IV PATIENTS WITH A PULMONARY HYPERTENSION (PULMONARY ARTERIAL SYSTOLIC PRESSURE OVER 60 mmHg)

	No. of cases	Improved	Unimproved	Died
MS	33	23	6	4
MR	6	3	1	2
MR + A	5	5	0	0
Total	44	31	7	6

Improvement ratio = 70%; mortality rate = 14%.

Abbreviations are the same as in Table IV.

indications of severe impairment of cardiac function, and we defined these variables as the risk factors for mitral valve surgery (Table III). Postoperative cardiac catheterization study was carried out in 222 patients and hemodynamic variables obtained were compared with those of the preoperative catheterization study. In order to evaluate the degree of postoperative symptomatic improvement during the follow-up period, we classified the patients with a preoperative functional class of III or IV according to the NYHA into following 3 groups:

- 1) Improved group:
postoperative NYHA class of I or II.
- 2) Unimproved group:
postoperative NYHA class of III or IV.
- 3) Death group.

Using this classification, the surgical improvement ratio and the mortality rate of patients with class III or IV were calculated as follows:

Improvement ratio (%) = number of the improved cases/number of total patients $\times$ 100 in class III or IV

Mortality rate (%) = number of deaths/number of total patients $\times$ 100 in class III or IV

The overall improvement ratio of the patients with class III or IV was 86% (197 out of 230

Fig.4. Changes of pulmonary arterial systolic pressure (PASP) in patients with pulmonary hypertension (a PASP of over 60 mmHg) after surgery. MS = mitral stenosis; MR = mitral regurgitation

patients) and the mortality rate was 8.3% (19 out of 230 patients).

RESULTS

Left Ventricular Performance

Figures 2 and 3 show the relationship of the

TABLE VI SURGICAL RESULTS OF THE CLASS III OR IV PATIENTS WITH A HIGH PULMONARY VASCULAR RESISTANCE OF OVER 10 unit·m²

	No. of cases	Improved	Unimproved	Died
MS	9	6	1	2
MR	4	3	0	1
M + A	5	5	0	0
Total	18	14	1	3

Improvement ratio = 78%; mortality rate = 17%.
Abbreviations are the same as in Table IV.

TABLE VII SURGICAL RESULTS OF THE CLASS III OR IV PATIENTS WITH TRICUSPID REGURGITATION OF MORE THAN A MODERATE DEGREE

	No. of cases	Improved	Unimproved	Died
MS	25	14	3	8
MR	28	17	5	6
M + A	5	5	0	0
Total	58	36	8	14

Improvement ratio = 62%; mortality rate = 24%.
Abbreviations are the same as in Table IV.

TABLE VIII SURGICAL RESULTS OF THE CLASS III OR IV PATIENTS WITH A GIANT LEFT ATRIUM (LEFT ATRIAL DIMENSION OF OVER 60 mm)

	No. of cases	Improved	Unimproved	Died
MS	17	13	0	4
MR	25	19	2	4
M + A	5	4	0	1
Total	47	36	2	9

Improvement ratio = 77%; mortality rate = 19%.
Abbreviations are the same as in Table IV.

left ventricular end-diastolic volume (LVEDV) and the left ventricular stroke volume (LVSV) in MS and MR. As seen in these figures surgical deaths did not necessarily occur in those patients with low left ventricular performance expressed by a large LVEDV and/or a low LVEF. There were 35 patients with a low LVEF (LVEF below 0.4) and 26 patients were in class III or IV. The surgical results of the class III or IV patients with a low LVEF are summarized in Table IV. The improvement ratio was 73% (11 out of 15 patients) in MS, 50% (3 out of 6) in MR, 100% (5 out of 5) in M + A and 73% (19 out of 26) as a whole. There were 2 unimproved patients and the postoperative LVEF still remained below 0.4

in one patient with MR. The mortality rate as a whole was 19%.

Pulmonary Arterial Systolic Pressure

A high pulmonary arterial systolic pressure (PASP) of over 60 mmHg was observed in 56 patients, and 44 patients were in class III or IV. There occurred 6 deaths, but all patients who died from low output syndrome had tricuspid regurgitation (TR) and a high right ventricular end-diastolic pressure (RVEDP). Post-operative cardiac catheterization was performed on 32 patients with a high PASP, which decreased in almost all patients, as shown in Fig. 4 (from 74 ± 12 to 41 ± 9.4 mmHg in MS and from

Fig.5. Relationship between right ventricular end-diastolic pressure (RVEDP) and the right ventricular stroke work index (RVSWI). O: patients without TR, Δ : patients with TR, $\bullet$, $\blacktriangle$: patients who died. MS = mitral stenosis; MR = mitral regurgitation, $\text{RVSWI (g}\cdot\text{m/M}^2\text{/beat)} = \text{cardiac index/heart rate} \times (\text{mean pulmonary artery pressure} - \text{RVEDP}) \times 0.0136$, LOS = low output syndrome

84 ± 12 to 44 ± 7.1 mmHg in MR). One patient developed mitral regurgitation after open mitral commissurotomy, and her PASP did not decrease postoperatively. In the high-PASP group, the improvement ratio was 70% and the mortality rate was 14% (Table V).

Pulmonary Vascular Resistance

A high pulmonary vascular resistance (PVR) of over $10 \text{ unit}\cdot\text{m}^2$ was found in 18 patients, and all these patients were in class III or IV. There was one unimproved patient and 3 patients died, as shown in Table VI, but all these patients had TR and/or a high RVEDP. In the high PVR group, the improvement ratio was 78% and the mortality rate was 17%.

Tricuspid Regurgitation

Tricuspid regurgitation of more than a moderate degree was observed in 80 patients and tricuspid valve surgery was performed on 70 of these. Although some patients also had slight organic tricuspid valvular changes, TR occurred mainly due to a dilatation of the tricuspid annulus. Table VII shows the surgical results of the TR group. Fifty-eight of the 80 patients were in class III or IV, and the improvement ratio was

62%. There were 14 deaths with a mortality rate of 24%, and all fatal cases with low output syndrome (13 patients) had TR.

Right Ventricular End-diastolic Pressure

Right ventricular end-diastolic pressure was elevated more than 15 mmHg in 4 patients with MS and 5 with MR. The functional capacity according to the NYHA was more than class III, and TR of more than a moderate degree was found in all these patients. Figure 5 shows the relationship between RVEDP and the right ventricular stroke work index (RVSWI) in patients with MS and MR. Surgical deaths frequently occurred in the high-RVEDP and the low-RVSWI group. Surgical results were very poor, 7 deaths occurred among 9 patients (a mortality rate of 78%) and the improvement ratio was 11%.

Giant Left Atrium

A giant left atrium (left atrial dimension > 60 mm) was observed in 54 patients. Most of them also had other risk factors and 40 patients (74%) had TR. A low LVEF and a high PASP were observed in 13 (24%) and 16 (30%) of these patients, respectively. Forty-seven out of the 54 patients were in class III or IV with an im-

provement ratio of 77% (Table VIII).

DISCUSSION

Our results showed that the presence of any risk factor used in this study was associated with an increased surgical mortality and a decreased symptomatic improvement after surgery. Although surgical results were not clearly different according to the type of predominant valvular lesions, there was a distinct difference in the influence of each risk factor on the results of the mitral valve surgery.

Left Ventricular Function

Previous studies have suggested that the LVEF is the single most useful measure of left ventricular function, having both a diagnostic and a prognostic value.⁹⁻¹¹ In this study, however, we found that a low LVEF does not necessarily indicate unfavorable surgical results as compared with the other risk factors. Patients with a low LVEF showed markedly deteriorated hemodynamics during the early postoperative period, but most of these patients were able to pass through their low output state by careful management using catecholamines, vasodilators and intraaortic balloon pumping. Moreover, there was only one patient, in whom no postoperative improvement was seen, and this condition was considered to be mainly attributable to impaired left ventricular performance before surgery. Consequently, a low LVEF alone is not considered to be a limiting factor of cardiac surgery for mitral valve disease.

Pulmonary Hypertension

Pulmonary arterial systolic pressure was decreased after surgery in almost all patients with pulmonary hypertension. Six deaths occurred in patients with pulmonary hypertension, but most of these patients had tricuspid regurgitation and high right ventricular end-diastolic pressure. Therefore, pulmonary hypertension is not the main risk factor for mitral valve surgery. Despite a decrease in PASP after surgery, there occurred no symptomatic improvement in 4 patients. In the present study hemodynamic variables were obtained only in the resting state, but hemodynamic response to exercise must be evaluated in such patients, especially in those who undergo reconstructive mitral valve surgery.¹²

Right Ventricular Performance

Our results demonstrated that a high right

ventricular end-diastolic pressure is the most hazardous factor for mitral valve surgery. As shown in Fig. 5, surgical death from low output syndrome frequently occurred in patients with low right ventricular performance. It is well known that severe long standing systolic overload to the right ventricle may result in right ventricular failure with edema, ascites, hepatomegaly and venous distension. All patients with a high RVEDP showed these signs of right ventricular failure and TR was demonstrated angiographically. Moreover, although right-sided pressure variables are highly influenced by the state of congestion, the pressure values used in this study were the best ones obtained after intensive medical therapy for congestive heart failure. Therefore, we must take into consideration the fact that surgery has a high risk in patients with markedly elevated RVDEP, and in this condition a high RVEDP is considered to be an indicator of deteriorated right ventricular performance.¹³ Although several investigators have described the clinical and hemodynamic status of the right ventricle in mitral valve disease,¹⁴⁻¹⁶ little is known about the contractile state of this chamber under the pressure load which is induced by mitral valve disease. In addition, a quantitative estimation of TR has not been established as yet. Further clinical investigations are needed on right ventricular function, and it is likely that cardiac surgery should be performed promptly when obvious TR appears.

Giant Left Atrium

Extreme enlargement of the left atrium as a complication of mitral valve disease is well known,^{17,18} but the exact cause and the hemodynamic influences of a giant left atrium are still obscure. Most patients with a giant left atrium have other risk factors, which may indicate the main surgical risk for these patients.

In summary, the presence of any highly abnormal hemodynamic variables in patients undergoing mitral valve surgery is associated with an increased surgical mortality and a decreased symptomatic improvement after surgery. Among these variables, deteriorated right ventricular performance indicated by a high RVEDP is associated with a considerable increase of surgical mortality. Further investigations to evaluate right ventricular function in mitral valve disease are necessary, and mitral valve surgery should be performed while the right ventricular function is still preserved.

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Discussion on Valvular Heart Disease

Dr. TAKEZAWA (Chairman): Due to the hesitation for undergoing surgical repair, either from patient's and/or from doctor's side, there are still many cases with far-advanced valvular heart disease who have failed to receive surgical therapy. I would like to show one slide of a case with a marked dilatation of the left atrium resulting in an enormously increased cardiothoracic ratio of 100%. This case has been suffering from mitral valvular disease for the past 15 years with 3 episodes of congestive heart failure and progressive deterioration of general condition, thus leading to cardiac cachexia. On the last occasion of heart failure he developed CO₂ narcosis following a 100% oxygen inhalation, which suggested compression of the lungs or of the main bronchus, resulting in alveolar hypoventilation. Dr. Takahashi, you have shown a high surgical risk in 300 patients with mitral valvular disease, and you postulated the significance of tricuspid regurgitation and elevated right ventricular end-diastolic pressure. Have you any comments on the surgical risk of a giant left atrium?

Dr. TAKAHASHI (Medicine, Tokyo Women's Medical College): The giant left atrium in our series usually coexisted with tricuspid regurgitation, although not necessarily associated with an elevation of RVEDP. The giant LA without an elevation of RVEDP is less surgical risk.

Dr. WANIBUCHI (Surgery, Mitsui Memorial Hospital): Higher risk was found in cases with a giant LA together with a TVR or in cases with a giant LA complicated with jaundice. Less risk was present in cases with a giant LA alone, with no restriction of the routine daily physical activity, i.e., in cases in class 1 to 2 according to the NYHA.

Dr. TAKEZAWA: Dr. Furuta, have you any comments on cases with alveolar hypoventilation due to compression of the lungs or the main bronchi caused by an extremely large LA?

Dr. FURUTA (Chairman): It seems to be necessary to define giant LA clinically, especially from the surgical point of view. The case shown in the slide had a huge LA, directly measured 2000 ml during surgery. After surgery, the patient suffered from CO₂ narcosis and decanulation was difficult. For the past 15 years, surgical

intervention has been recommended for this case, but, unfortunately, we could not obtain the patient's consent until recently. The cardiothoracic ratio was 100% during this period, and in the past 5 years, when he became incapacitated, his cardiac silhouette had begun to expand upwards. In cases with a giant LA, severity of the clinical symptoms depends not only on the LA size itself but also on the effects of compression of neighboring organs to larger extent, causing symptoms such as hypoventilation. From the point of view of surgical technique, plication of the LA should be attempted as much as possible.

Dr. KOYANAGI (Surgery, Tokyo Women's Medical College): A giant LA appears to be an outcome of a long-standing, high-degree filling disturbance from the LA to the LV, which functionally indicates a situation not covered by Starling's mechanism. An establishment of the principal methods of LA plication is desired.

Dr. NAITO (Surgery, National Cardiovascular Center): We are performing left atrial plication as much as possible according to the degree of compression of neighboring organs. For example, for cases with a compression of the LV, causing paradoxical contraction, adequate peri- and supra-annular LA plication is important, and for cases with bronchial compression enough plication so as to decompress the postero-superior aspects of the LA are valuable.

Dr. TAKAHASHI: I would like to reemphasize the importance of the decision to perform surgery before the serious elevation of RVEDP and the occurrence of TR.

Dr. BAN (Surgery, Kokura Memorial Hospital): As one of the risk factors, I would like to emphasize the importance of the liver function, such as higher bilirubin, lower choline esterase and cholesterol, suggesting the progression of liver cirrhosis. These patients have the clinical features of "cardiac cachexia". Results of the operation are usually poor.

Dr. TAKAHASHI: Elevation of RVEDP and the occurrence of TR, as I have stressed before, should adequately be taken into account as warning signs for the threatening progression of congestive liver cirrhosis.