ORIGINAL ARTICLE

CrossMark

Mitral valve repair versus replacement with preservation of the entire subvalvular apparatus

Eiri Kisamori[1] · Satoru Otani[1] · Tsuyoshi Yamamoto[1] · Michiru Nishiki[1] · Yuki Yamada[1] · Taichiro Matsumoto[1]

Abstract

Objective This study aimed to evaluate the outcomes of mitral valve (MV) repair versus MV replacement with preservation of the entire subvalvular apparatus.

Methods We retrospectively searched our dedicated in-hospital database for patients who underwent MV surgery between 2012 and 2017.

Results A total of 82 patients were divided into a group that underwent MV replacement ($n = 35$) and a group that underwent MV repair ($n = 47$). Patients undergoing MV replacement were significantly older ($p < 0.01$). Mortality at 30 days was not significantly different [MV replacement: $n = 1$ (2.9%), MV repair: $n = 0$ (0%); $p = 0.43$]. The single case of 30-day mortality after MV replacement was due to acute aortic dissection. The total cohort did not show significant differences in long-term survival ($p = 0.07$). There were no cardiac-related deaths in this cohort. Postoperative left ventricular end-diastolic diameter (MV replacement: 45.4 ± 6.2 mm, MV repair: 45.6 ± 5.8 mm; $p = 0.89$), left ventricular end-systolic diameter (MV replacement: 29.6 ± 7.1 mm, MV repair: 29.4 ± 5.2 mm; $p = 0.89$), and ejection fraction (MV replacement: 59.2 ± 11.4%, MV repair: 62.0 ± 6.8%; $p = 0.17$) were not significantly different.

Conclusions This study found that MV replacement had operative mortality, long-term survival, and complication rates similar to those of MV repair. There were no cardiac-related deaths in this cohort. MV replacement with preservation of the entire subvalvular apparatus does not seem to be inferior to MV repair.

Keywords Mitral valve repair · Mitral valve replacement · Subvalvular apparatus preservation

Introduction

Mitral regurgitation (MR) is one of the most prevalent valvular diseases in developed countries [1, 2]. Degenerative MR requires surgical correction, which improves prognosis [3] and restores normal life expectancy [4]. Clinical guidelines recommend mitral valve (MV) repair over MV replacement on the basis of comparative studies conducted in the 1980s. A recent study based on a large multicenter database also demonstrated the superiority of MV repair in terms of operative mortality, left ventricular function, valve-related complications, and long-term survival [5].

However, in many studies, the procedure used for subvalvular apparatus preservation was unclear, and only posterior leaflet preservation was commonly performed. MV replacement with subvalvular preservation is associated with postoperative remodeling similar to that after MV repair. Anticoagulation protocols vary among countries [6, 7]. Recently, the designs of artificial valves have improved, and the incidence of thromboembolism is low as long as an optimal range of anticoagulation is maintained. However, some reports have not demonstrated the superiority of MV repair in specific subgroups such as elderly patients, female patients, or patients with ischemic MR.

Therefore, which surgical technique should be used remains unclear. At our hospital, MV replacement with preservation of the entire subvalvular apparatus is performed for degenerative MR. In this study, we investigated the outcomes of MV repair versus MV replacement with preservation of the entire subvalvular apparatus at our institution.

✉ Eiri Kisamori
  e.kisamori@gmail.com

1 Department of Cardiovascular Surgery, National Hospital Organization Iwakuni Clinical Center, 1-1-1 Atagocho, Iwakuni, Yamaguchi 740-8510, Japan

Methods

Patient data

We retrospectively explored our dedicated in-hospital database for patients who underwent MV surgery between 2012 and 2017. Among 129 patients, those who underwent repeat MV surgery or had rheumatic valve pathology, moderate mitral stenosis, or ischemic MR were excluded. In the MV replacement group, 1 patient who underwent anterior leaflet resection because of calcification was excluded. The remaining 82 patients were divided into those who underwent MV replacement ($n = 35$) and those who underwent MV repair ($n = 47$).

Surgical procedure

The decision to perform either MV replacement or MV repair was made through a discussion among the heart team members at our hospital. We considered MV replacement for patients older than 78 years or when successful and durable repair was difficult to accomplish.

Various surgical techniques to repair the MV were used according to the valve anatomy. Resection of leaflets was performed in appropriate cases. In cases with both anterior and posterior leaflet prolapse, insertion of artificial Gore-Tex neochordae to resuspend the prolapsing segments was performed as needed. In some cases, only insertion of neochordae was performed. Commissural annuloplasty or leaflet folding was also performed. Leaflet surgery was always supplemented with remodeling annuloplasty with a ring.

MV replacement was performed with everting mattress sutures. The entire subvalvular apparatus and anterior leaflet were preserved. We did not divide the leaflets or insert leaflets with sutures. The prosthetic valve was placed with thread enclosing the leaflets.

Echocardiography

Echocardiography was performed preoperatively and at follow-up (on average, 2 ± 1.3 years after surgery). Follow-up data were obtained for 80 patients (97.6%). Ejection fraction (EF) was calculated using the biplane modified Simpson method. Left atrial volume index (LAVI) was calculated using the biplane area-length method. Delta EF and LAVI were calculated by subtracting postoperative values from preoperative values.

Anticoagulation

Patients who underwent mechanical valve replacement were taking lifelong warfarin, with a target international normalized ratio of 2.0–2.5. The duration of warfarin therapy was 6 months after prosthetic valve replacement and 3 months after MV repair. Postoperative antiplatelet therapy was continued in patients with coronary artery disease.

Follow-up

Data on events were collected through a direct review of clinical data, patient interviews, and follow-up letters. Causes of death were adjudicated by reviewing death certificates as well as physician and hospital notes.

Outcomes

The primary endpoint was all-cause mortality, and the secondary endpoints were 30-day mortality, reoperation, follow-up echocardiography findings, thromboembolism, and major bleeding.

Statistical analysis

All data were retrospectively analyzed. Data are presented as absolute numbers and percentages for categorical variables and as mean values and standard deviations for continuous variables, unless stated otherwise. Dichotomous variables were compared using Fisher's exact test and the Chi square test, and continuous variables were compared using paired and unpaired t tests, as appropriate. P values were reported without correction for multiple testing. The level of significance was set as a two-tailed p value < 0.05. Kaplan–Meier calculations were performed for survival analyses. All statistical analyses were performed with EZR 1.37 (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria). More precisely, it is a modified version of R commander designed to add statistical functions frequently used in biostatistics.

Results

Baseline characteristics

The baseline characteristics of the overall population are shown in Table 1. In the overall cohort ($N = 82$), patients undergoing MV replacement were significantly older ($p < 0.01$) and were more likely to undergo concomitant

Table 1 Baseline characteristics of the overall patient cohort

Variable	Replace (n = 35)	Repair (n = 47)	p value
Age, mean (SD), years	77.9 (8.3)	61.2 (10.4)	< 0.001
Sex (female, %)	16 (445.7)	20 (42.6)	0.82
NYHA (%) III–IV	7 (20.0)	3 (6.4)	0.08
HTN (%)	13 (37.1)	9 (19.1)	0.13
DL (%)	6 (17.1)	11 (23.4)	0.56
DM (%)	6 (17.1)	3 (6.4)	0.16
COPD (%)	1 (2.9)	1 (2.1)	1
Ischemic heart disease (%)	4 (11.4)	3 (6.4)	0.45
Renal dialysis (%)	1 (2.9)	0 (0.0)	0.43
AF (%)	19 (54.3)	9 (19.1)	0.002
LVEDD, mean, mm, (SD)	50.9 (6.7)	54.3 (6.4)	0.025
LVEDS, mean, mm, (SD)	32.5 (7.6)	33.6 (6.2)	0.47
LVEF, mean, %, (SD)	65.2 (11.1)	66.4 (6.9)	0.55
LAVI, mean, ml/m^2, (SD)	54.2 (17.8)	48.5 (17.73)	0.16
Additional aortic valve surgery (%)	3 (8.6)	0 (0.0)	0.57
Additional tricuspid valve surgery (%)	28 (80.0)	27 (57.4)	0.040
Additional CABG (%)	1 (2.9)	3 (6.4)	0.63
Additional AF procedure (%)	8 (23.4)	11 (23.4)	1
Additional aortic surgery (%)	2 (5.7)	1 (2.1)	0.57

tricuspid valve surgery ($p = 0.04$). Patients undergoing MV replacement more often had a history of atrial fibrillation ($p = 0.002$). Left ventricular end-diastolic diameter (LVEDD) was significantly smaller in MV replacement cases (50.9 ± 6.7 mm versus 54.2 ± 6.4 mm, $p = 0.025$).

Operative and follow-up findings

The aortic cross-clamp time (MV replacement: 76.3 ± 20.2 min, MV repair: 86.9 ± 18.6 min; $p = 0.017$) was significantly different between the 2 groups; however, the cardiopulmonary bypass time (MV replacement: 118.7 ± 35.9 min, MV repair: 120.5 ± 25.4 min; $p = 0.79$) and operative time (MV replacement: 216.4 ± 54.5 min, MV repair: 222.1 ± 43.8 min; $p = 0.60$) were not significantly different.

Mortality at 30 days was not significantly different [MV replacement: $n = 1$ (2.9%), MV repair: $n = 0$ (0%); $p = 0.43$].

The single case of 30-day mortality after MV replacement was due to acute aortic dissection.

In the MV replacement group, more bioprosthetic valves than mechanical valves were implanted [bioprosthetic valve: $n = 29$ (85.3%), mechanical valve: $n = 5$ (14.7%)].

The incidence of stroke during follow-up [MV replacement: $n = 1$ (2.9%), MV repair: $n = 1$ (2.1%); $p = 1$] was not significantly different between the 2 groups. Major bleeding or reoperation did not occur during the follow-up period (Table 2).
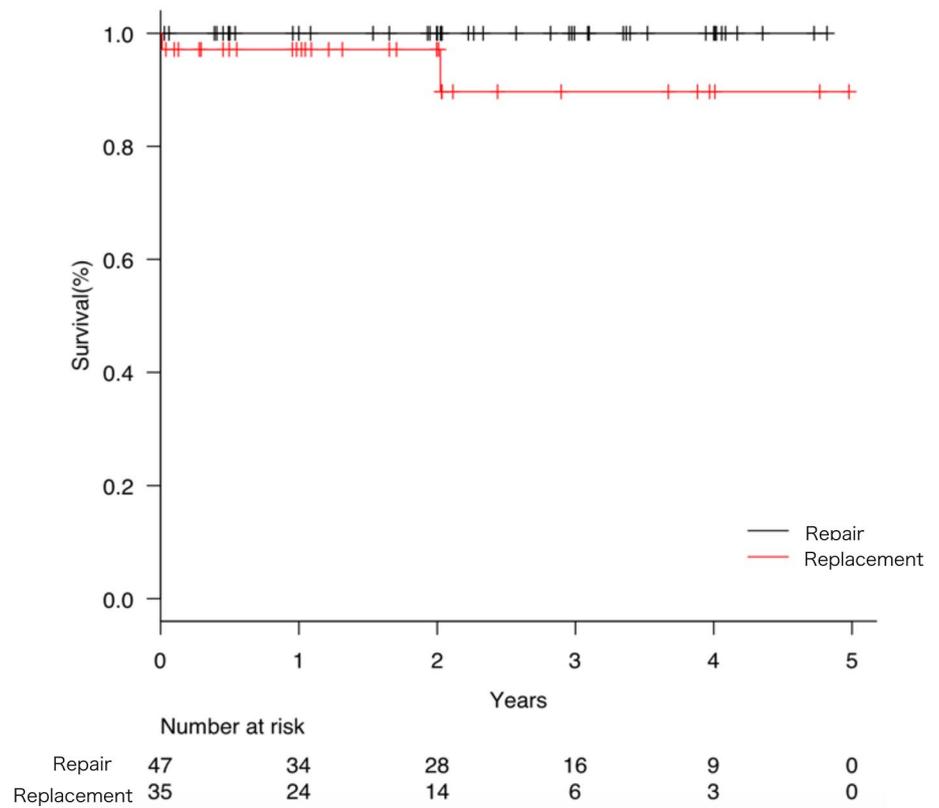
Survival

The median follow-up period was 2 years (734 days) in the overall cohort, 1.8 years (613 days) in the MV replacement group, and 2.2 years (813 days) in the MV repair group. The maximum follow-up period was 5 years (1818 days) in the overall cohort.

Table 2 Acute procedural results and follow-up

Variable	Replace (n = 35)	Repair (n = 47)	p value
30-day mortality (%)	1 (2.9)	0 (0.0)	0.43
Major bleeding (%)	0	0	NA
Stroke (%)	1 (2.9)	1 (2.1)	1
Cross-clamp time, minutes, mean (SD)	76.3 (20.2)	86.9 (18.6)	0.017
Bypass time, minutes, mean (SD)	118.7 (35.9)	120.5 (25.5)	0.79
Operation time, minutes, mean (SD)	216.4 (54.5)	222.1 (43.8)	0.60
Re-admission for HF (%)	2 (5.7)	4 (8.5)	0.69
Reoperation (%)	0 (0)	0 (0)	NA

Fig. 1 Overall survival

On Kaplan–Meier analysis, the total cohort did not show significant differences in long-term survival at 1, 2, and 3 years (MV replacement: 97.2%, 97.2%, and 89.7% versus MV repair: 100%, 100%, and 100%, respectively; $p = 0.07$) (Fig. 1). During follow-up, only 2 patients in the MV replacement group died. One patient died within 30 days after surgery, and the other died of cancer. There were no cardiac-related deaths.

Echocardiography findings

Echocardiographic data were obtained for 80 patients (97.6%), on average at 1.7 ± 1.3 years after MV replacement and 2.2 ± 1.3 years after MV repair ($p = 0.11$). LVEDD (MV replacement: 45.4 ± 6.2 mm, MV repair: 45.6 ± 5.8 mm; $p = 0.89$), left ventricular end-systolic diameter (LVESD) (MV replacement: 29.6 ± 7.1 mm, MV repair: 29.4 ± 5.2 mm; $p = 0.89$), and EF (MV replacement: $59.2 \pm 11.4\%$, MV repair: $62.0 \pm 6.8\%$; $p = 0.17$) were not significantly different. Postoperative LAVI showed a significant difference (MV replacement: 42.5 ± 15.5 ml/m^2, MV repair: 31.0 ± 11.8 ml/m^2; $p < 0.001$). The number of patients with moderate or severe MR was not significantly different [MV replacement: 0 (0%), MV repair: 3 (6.4%); $p = 0.26$] (Table 3).

Table 3 Follow-up echocardiography

Variable	Replace ($n = 35$)	Repair ($n = 47$)	p value
LVEDD, mean, mm, (SD)	45.4 (6.2)	45.6 (5.8)	0.88
LVEDS, mean, mm, (SD)	29.6 (7.1)	29.4 (5.2)	0.89
LVEF, mean, %, (SD)	59.2 (11.4)	62.0 (6.8)	0.17
LAVI, mean, ml/m^2, (SD)	42.5 (15.5)	31 (11.9)	< 0.001
Delta EF, % (SD)	5.6 (10.5)	4.8 (9.3)	0.71
Delta LAVI, % (SD)	11.1 (13.0)	17.5 (11.8)	0.027
Moderate or severe MR (%)	0 (0.0)	3 (6.4)	0.26

Discussion

This study had 3 important findings. First, no cardiac-related deaths occurred in either group during follow-up. Second, there were no differences in left ventricular function between the MV replacement and MV repair groups. Finally, there were no differences in valve-related complications between the 2 groups.

Although no randomized trials comparing MV replacement and MV repair have been conducted in patients with

degenerative MR, the current American Heart Association/American College of Cardiology, European Society of Cardiology, and Japanese Circulation Society guidelines strongly recommend MV repair as the preferred surgical method for the treatment of severe degenerative MR [4, 8]. The evidence supporting these recommendations is based on studies conducted in the 1980s. Moreover, a recent study based on a large multicenter database also demonstrated the superiority of MV repair [5, 9]. However, the procedure used for subvalvular apparatus preservation was unclear and only posterior leaflet preservation was commonly performed [9–11]. Our study is thus unique because we compared MV replacement with MV repair, focusing on the preservation of the entire subvalvular apparatus in patients with degenerative MR and precisely described the subvalvular-sparing procedure. The present analysis indicates that MV replacement has operative mortality, long-term survival, and complication rates similar to those of MV repair. Moreover, no cardiac-related deaths occurred.

In this study EF, LVEDD, and LVESD were not significantly different between before and after the operation. Delta EF was also not significantly different. LVEDD and LVESD returned to the normal ranges after surgery in both groups. This indicated that left ventricular remodeling after surgery is similar after both MV replacement and MV repair. Previous studies have shown the importance of the subvalvular apparatus [10–12]. Preservation of the entire subvalvular apparatus showed an advantage in terms of a reduction in the left ventricular chamber size, systolic afterload, and left ventricular ejection performance when compared with those on partial subvalvular apparatus preservation [13]. We hypothesized that this advantage was because of the preservation of the chordae of the anterior leaflet, which can prevent posterior mitral annular tilt and improve the vortex pattern during diastole, like anterior papillary muscle relocation for ischemic MR [14, 15]. The results of this study are in concordance with those of several previous studies. Preservation of both the anterior and posterior leaflets can explain the non-inferiority of EF in MV replacement, which can result in decreased postoperative mortality because most deaths seen after MV replacement were due to heart failure with low cardiac output syndrome [9].

Although preoperative LAVI showed no significant difference between the 2 groups (MV replacement: 54.2 ± 187.8 ml/m^2, MV repair: 48.5 ± 17.7 ml/m^2; $p = 0.16$), postoperative LAVI showed a significant difference (MV replacement: 42.5 ± 15.5 ml/m^2, MV repair: 31.0 ± 11.8 ml/m^2; $p < 0.001$). Elderly patients tend to have difficulty in left atrial remodeling, and atrial fibrillation could cause left atrial dilation. In this study, the MV replacement group included more elderly patients and those with atrial fibrillation, which can explain the difference in postoperative LAVI.

Further, in this study, there were no significant differences in the incidence of major bleeding or thromboembolism between the groups. Frequent use of bioprosthetic valves may explain the low incidence of valve-related complications. Elderly patients tend to require MV replacement. MV replacement with bioprosthetic valves in elderly patients may not increase the risk of valve-related complications compared with that with MV repair. In this study, the average age of the patients who underwent MV replacement was 77.9 years. The rate of freedom from SVD at 10 years after MVR was reported to be 100% in some studies on patients aged > 70 years [16–18]. According to these data, SVD after operation does not seem to affect the outcome of MVR performed in elderly patients. Therefore, MV replacement may not be inferior to MV repair in elderly patients receiving bioprosthetic valves.

Limitations

Our study has a retrospective design and was conducted at a single center. Consequently, it included a limited number of patients. There is a possibility of beta error in this study. The mean follow-up period was 2.1 ± 1.4 years. Thus, further observation is required to verify our conclusions. In addition to these limitations, the baseline patient characteristics were different between the MV replacement and MV repair groups.

Conclusion

Data from our hospital demonstrated no differences in operative mortality, left ventricular function, valve-related complications, and long-term survival between MV replacement and MV repair. MV replacement with preservation of the entire subvalvular apparatus does not seem to be inferior to MV repair.

Compliance with ethical standards

References

1. Nkomo VT, Gardin JM, Skelton TN, Gottdiener JS, Scott CG, Enriquez-Sarano M. Burden of valvular heart diseases. Lancet. 2006;368:1005–11.
2. Iung B, Baron G, Butchart EG, Delahaye F, Gohlke-Bärwolf C, Levang OW, et al. A prospective survey of patients with valvular heart disease in Europe: the Euro Heart Survey on Valvular Heart Disease. Eur Heart J. 2003;24:1231–43.

3. Enriquez-Sarano M, Avierinos J-F, Messika-Zeitoun D, Detaint D, Capps M, Nkomo V, et al. Quantitative determinants of the outcome of asymptomatic mitral regurgitation. N Engl J Med. 2005;352:875–83.

4. Nishimura RA, Otto CM, Bonow RO, Carabello BA, Erwin JP, Guyton RA, et al. 2014 AHA/ACC guideline for the management of patients with valvular heart disease: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Circulation. 2014;129:e650.

5. Lazam S, Vanoverschelde J-L, Tribouilloy C, Grigioni F, Suri RM, Avierinos J-F, et al. Twenty-year outcome after mitral repair versus replacement for severe degenerative mitral regurgitation: analysis of a large, prospective, multicenter, international registry. Circulation. 2017;135:410–22.

6. Mori T, Asano M, Ohtake H, Bitoh A, Sekiguchi S, Matsuo Y, et al. Anticoagulant therapy after prosthetic valve replacement -optimal PT-INR in Japanese patients-. Ann Thorac Cardiovasc Surg. 2002;8(8):3–7.

7. Uetsuka Y, Hosoda S, Kasanuki H, Aosaki M, Murasaki K, Ooki K, et al. Optimal therapeutic range for oral anticoagulants in Japanese patients with prosthetic heart valves: a preliminary report from a single institution using conversion from thrombotest to PT-INR. Heart Vessels. 2000;15:124–8.

8. Baumgartner H, Falk V, Bax JJ, De Bonis M, Hamm C, Holm PJ, et al. 2017 ESC/EACTS guidelines for the management of valvular heart disease. Eur Heart J. 2017;38:2739–86.

9. Silaschi M, Chaubey S, Aldalati O, Khan H, Uzzaman MM, Singh M, et al. Is mitral valve repair superior to mitral valve replacement in elderly patients? Comparison of short- and long-term outcomes in a propensity-matched cohort. J Am Heart Assoc. 2016: e003605.

10. Natsuaki M, Itoh T, Tomita S, Furukawa K, Yoshikai M, Suda H, et al. Importance of preserving the mitral subvalvular apparatus in mitral valve replacement. Ann Thorac Surg. 1996;61:585–90.

11. Sénéchal M, MacHaalany J, Bertrand OF, O'Connor K, Parenteau J, Dubois-Sénéchal I-N, et al. Predictors of left ventricular remodeling after surgical repair or replacement for pure severe mitral regurgitation caused by leaflet prolapse. Am J Cardiol. 2013;112:567–73.

12. Rozich JD, Carabello BA, Usher BW, Kratz JM, Bell AE, Zile MR. Mitral valve replacement with and without chordal preservation in patients with chronic mitral regurgitation. Mechanisms for differences in postoperative ejection performance. Circulation. 1992;86:1718–26.

13. Yun KL, Sintek CF, Miller DC, Pfeffer TA, Kochamba GS, Khonsari S, et al. Randomized trial comparing partial versus complete chordal-sparing mitral valve replacement: effects on left ventricular volume and function. J Thorac Cardiovasc Surg. 2002;123:707–14.

14. Watanabe T, Arai H, Nagaoka E, Oi K, Hachimaru T, Kuroki H, et al. Influence of procedural differences on mitral valve configuration after surgical repair for functional mitral regurgitation: in which direction should the papillary muscle be relocated? J Cardiothorac Surg. 2014;9:185.

15. Akiyama K, Nakamura N, Itatani K, Naito Y, Kinoshita M, Shimizu M, et al. Flow-dynamics assessment of mitral-valve surgery by intraoperative vector flow mapping. Interact Cardiovasc Thorac Surg. 2017;24:869–75.

16. Jamieson WRE, Burr LH, Janusz MT, Munro AI, Hayden RI, Miyagishima RT, et al. Carpentier-Edwards standard and supraannular porcine bioprostheses: comparison of technology. Ann Thorac Surg. 1999;67:10–7.

17. Neville PH, Aupart MR, Diemont FF, Sirinelli AL, Lemoine EM, Marchand MA. Carpentier-Edwards pericardial bioprosthesis in aortic or mitral position: a 12-year experience. Ann Thorac Surg. 1998; 66; S14307.

18. Marchand MA, Aupart MR, Norton R, Goldsmith IRA, Pelletier LC, Pellerin M, et al. Fifteen-year experience with the mitral Carpentier-Edwards PERIMOUNT pericardial bioprosthesis. Ann Thorac Surg. 2001;71:236–9.