Original Article

Echocardiographic Follow-up of Robotic Mitral Valve Repair for Mitral Regurgitation due to Degenerative Disease

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Abstract

Background: Mitral valve (MV) repair can now be carried out through small incisions with the use of robotic assistance. Previous reports have demonstrated the excellent clinical result of robotic MV repair for degenerative mitral regurgitation (MR). However, there has been limited information regarding the echocardiographic follow-up of these patients. The present study was therefore to evaluate the echocardiographic follow-up outcomes after robotic MV repair in patients with MR due to degenerative disease of the MV.

Methods: A retrospective analysis was undertaken using data from the echocardiographic database of our department. Between March 2007 and February 2015, 84 patients with degenerative MR underwent robotic MV repair. The repair techniques included leaflet resection in 67 patients (79.8%), artificial chordae in 20 (23.8%), and ring annuloplasty in 79 (94.1%). Eighty-one (96.4%) of the 84 patients were eligible for echocardiographic follow-up assessment, and no patients were lost to follow-up.

Results: At a median echocardiographic follow-up of 36.0 months (interquartile range 14.3–59.4 months), four patients (4.9%) developed recurrent mild MR, and no patients had more than mild MR. Mean MR grade, left atrial diameter (LAD), left ventricular end-diastolic diameter (LVEDD), and left ventricular ejection fraction (LVEF) were significantly decreased when compared with preoperative values. Mean MR grade decreased from 3.96 ± 0.13 to 0.17 ± 0.49 ($Z = -8.456$, $P < 0.001$), LAD from 43.8 ± 5.9 to 35.5 ± 3.8 mm ($t = 15.131$, $P < 0.001$), LVEDD from 51.0 ± 5.0 to 43.3 ± 2.2 mm ($t = 14.481$, $P < 0.001$), and LVEF from 67.3 ± 7.0% to 63.9 ± 5.1% ($t = 4.585$, $P < 0.001$).

Conclusion: Robotic MV repair for MR due to degenerative disease is associated with a low rate of recurrent MR, and a significant improvement in MR grade, LAD, and LVEDD, but a significant decrease in LVEF at echocardiographic follow-up.

Key words: Degenerative Disease; Mitral Regurgitation; Mitral Valve Repair

Introduction

Degenerative disease of the mitral valve (MV) is the most common etiology of mitral regurgitation (MR) requiring surgery.[1] The most common finding in patients with degenerative MV disease is leaflet prolapse due to elongation or rupture of the chordae, resulting in varying degrees of MR.[2] Degenerative MV disease is recognized as an important cause of cardiovascular morbidity and mortality in patients with significant MR.[2]

MV repair is the optimal surgical treatment for patients with severe MR due to degenerative disease.[3] Conventional MV repair has been fulfilled through a median sternotomy under direct vision, which provides generous surgical exposure and allows ample access to all cardiac structures and proximal great vessels. However, it carries the disadvantage of disrupting the integrity of the chest wall and causing significant surgical trauma. Minimally invasive MV surgery continues to evolve as a treatment option. Today, MV repair can be carried out through small incisions with the use of robotic assistance.[4] The main advantages of this approach are represented by better cosmetic results, minimized surgical trauma, reduced postoperative pain, and faster recovery.[5]

Previous reports have demonstrated the excellent clinical result of robotic MV repair for degenerative MR.[6,7]

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However, there has been limited information regarding the echocardiographic follow-up of these patients. The present study was therefore to evaluate the echocardiographic follow-up outcomes after robotic MV repair in patients with MR due to degenerative disease of the MV.

Methods

Patients

A retrospective analysis was undertaken using data from the echocardiographic database of the department of cardiovascular surgery of Chinese People's Liberation Army (PLA) General Hospital. Between March 2007 and February 2015, a total of 112 consecutive patients with MR underwent isolated primary robotic MV repair at Chinese PLA General Hospital. Patients with MR of etiologies other than degenerative (rheumatic in 3 patients, congenital in 11, and infective in 14) were excluded from the study. The remaining 84 patients with robotic MV repair for degenerative MR formed the study cohort of this analysis. Seventy-seven patients (91.7%) of the 84 patients had severe MR. Coronary angiography was conducted in the patients older than 40 years to rule out the significant coronary disease. Computed tomography of the aorta and ultrasound of the femoral and carotid vessels were conducted routinely in all patients to rule out significant arteriosclerosis. We retrospectively analyzed all relevant medical record and echocardiographic data gathered prospectively for the cohort of interest. The study was approved by the Ethics Committee, and written informed consent was obtained from all patients.

Surgical procedure

All procedures were carried out with peripheral cardiopulmonary bypass (CPB), transthoracic aortic cross-clamp, and antegrade cardioplegia utilizing the da Vinci Si Surgical System (Intuitive Surgical, Inc., Sunnyvale, CA, USA) by an experienced surgeon (Gao). Peripheral CPB was established using femoral arterial inflow and kinetic venous drainage using the femoral vein and right internal jugular vein. The MV morphology was analyzed by the surgeon with CPB and cardioplegic arrest, according to Carpentier's pathophysiological triad (etiology, lesions, and dysfunctions) and segmental valve analysis.[8,9] Valve repair was done according to Carpentier's techniques.[10] The repair techniques varied according to morphologic findings of the surgeon at the time of operation. All patients received warfarin sodium postoperatively during the first 3 months if in sinus rhythm and permanently if in atrial fibrillation or flutter.

Echocardiographic examinations and follow-up

Serial echocardiographic examinations and follow-up were accomplished by the same echocardiographer (Wang) using the same commercially available GE Vivid 7 Dimension Imaging System (GE Healthcare, Horten, Norway) equipped with M3S and 6T transducers (before December, 2009) or the Philips iE33 Ultrasound System (Philips Medical Systems, Andover, MA, USA) equipped with S5-1 and X7-2t matrix array transducers (after January, 2010). Preoperative transthoracic echocardiography (TTE) was achieved within 1 week prior to robotic MV repair. The MV morphology was analyzed by TTE according to the same criteria as by the surgery. The severity of MR, left atrium dimension (LAD), left ventricular end-diastolic dimension (LVEDD), and left ventricular ejection fraction (LVEF) was evaluated according to published guidelines.[11,12] Intraoperative transesophageal echocardiography (TEE) was done during the operation. Before CPB, TEE was used to reassess MV, and after weaning from CPB, to assess the competency of valve repair, determine the mechanism and severity of any residual MR, and to exclude clinically significant mitral stenosis, systolic anterior motion (SAM) of the MV or other procedure-related complications.[13] Predischarge TTE was used within 1 week after surgery to reassess the competency of valve repair. Echocardiographic follow-up was conducted at 6 and 12 months after the procedure through direct contact with patients in our outpatient clinic, where TTE was done together with clinical assessment. Subsequent echocardiographic follow-up was done every 1–2 years or when clinically indicated. Whenever the report from an outside hospital indicated the presence of MR, the study was repeated in our outpatient clinic. The severity of MR, LAD, LVEDD, and LVEF was evaluated by follow-up TTE according to the same criteria as by preoperative TTE. All echocardiographic data were entered prospectively into the echocardiographic database of our department. Echocardiographic follow-up data (defined as > or = 6 months) were analyzed on the basis of the records. The follow-up for this study was closed on August 31, 2015.

Statistical analysis

Data were expressed as mean ± standard deviation (SD) for continuous normally distributed variables as median (interquartile range) for continuous nonnormally distributed data and as frequencies and/or percentages for categorical data. Analysis of normality was made with the Kolmogorov-Smirnov. The severity of MR by follow-up TTE was compared with that by preoperative TTE using Wilcoxon signed rank test. Patient's LAD, LVEDD, and LVEF were compared with baseline preoperative measurements by the paired Student's *t*-test. $P < 0.05$ was considered significant. All analyses were made using the SPSS for Windows version 18.0.1 (SPSS, Inc., Chicago, IL, USA).

Results

Baseline characteristics

The baseline characteristics of participants are summarized in Table 1. Of the 84 patients undergoing robotic MV repair for MR due to degenerative disease of the MV, there were 60 (71.4%) men and 24 (28.6%) women. Age ranged from 21 to 70 years (mean 47.8 ± 11.9 years). Body surface area 1.41–2.39 m^2 (mean 1.81 ± 0.20 m^2). Twelve patients (14.4%) had preoperative atrial fibrillation. On preoperative TTE, the severity of MR was graded as severe in 77 patients (91.7%).

Procedural outcomes

The MV morphology analysis by echocardiography or by surgical inspection during the operation is summarized in Table 2. Valve analysis showed that the etiology of MR was degenerative in the 84 patients, the type of valve dysfunction and the corresponding valvular lesions were Type II dysfunction (leaflet prolapse) in all 84 patients (55 owing to chordae rupture, 28 chordae elongation, and 1 chordae rupture plus elongation). The leaflet prolapse involved the posterior leaflet in 66 patients (78.6%), the anterior leaflet in 11 (13.1%), and both leaflets in 7 (8.3%).

The operative procedures carried out are summarized in Table 3. Of the 84 patients, there were no intraoperative conversions to a sternotomy. The repair techniques included leaflet resection in 67 patients (79.8%), artificial chordae in 20 (23.8%), and ring annuloplasty in 79 (94.1%). Annuloplasty types included Cosgrove-Edwards annuloplasty band (n = 46, 54.8%) (Edwards Lifesciences LLC, Irvine, CA, USA), and SJM tailor annuloplasty ring (n = 33, 39.3%) (St. Jude Medical, St. Paul, Minnesota, USA). Median annuloplasty size was 30 mm (range: 26–34 mm) for Cosgrove bands and 31 mm (range: 25–31 mm) for Carpentier's rings. Five patients (5.9%) did not receive an annuloplasty ring because they were no perceived annular dilatation. Ring choice was at the surgeon's discretion.

Table 1: Baseline clinical characteristics of the patients undergoing robotic MV repair (n = 84)

Characteristic	Value
Age (years)	47.8 ± 11.9 (21–70)
Gender, n (%)	
Male	60 (71.4)
Female	24 (28.6)
Body surface area (m^2)	1.81 ± 0.20 (1.41–2.39)
Moderate to severe MR (%)	7 (8.3)
Severe MR, n (%)	77 (91.7)
Coronary artery disease (older than 40 years)	0 (0)
Preoperative atrial fibrillation, n (%)	12 (14.4)

Data are expressed mean ± SD (range) or frequency (percentage). MR: Mitral regurgitation; MV: Mitral valve; SD: Standard deviation.

Table 2: The MV analysis of the patients undergoing robotic MV repair by echocardiography or by surgical inspection (n = 84), n (%)

Characteristic	Value
Etiology of MR	
Degenerative	84 (100)
Types of dysfunction and valvular lesions	
Type II (leaflet prolapse)	84 (100)
Chordae rupture	56 (66.7)
Chordae elongation	28 (33.3)
Localization of prolapse leaflet	
Single P1	4 (4.8)
Single P2	44 (52.4)
Single P3	17 (20.2)
Single A1	0 (0)
Single A2	2 (2.4)
Single A3	8 (9.5)
A >1 (>1 segment involved)	1 (1.2)
P >1 (>1 segment involved)	1 (1.2)
A + P	7 (8.3)

A: Anterior leaflet; A1, A2, and A3: Lateral, middle, and medial third of the anterior leaflet; MV: Mitral valve; MR: Mitral regurgitation; P: Posterior leaflet; P1, P2, and P3: Lateral, middle, and medial scallops of the posterior leaflet.

Of the 84 patients, one patient died within the first 30 days. The patient suffered from severe pneumonia of unknown cause leading to fatal multiple organ failure. Repeated postoperative TTE demonstrated that the patient had normal MV function without residual regurgitation or stenosis of the MV. Two patients experienced perioperative complications related to the MV. One of the two patients developed a paraprosthetic leak and hemolytic anemia. The patient was reoperated on 13 days postoperatively and underwent a bioprosthetic MV replacement through a median sternotomy. The other patient developed SAM of the anterior leaflet of the MV with resultant dynamic left ventricular outflow tract obstruction. The patient received mechanical MV replacement 12 h after the initial operation through a median sternotomy. All the patients survived the reoperations.

Of the 81 patients who ultimately underwent robotic MV repair, intraoperative TEE revealed they were no residual MR after weaning from CPB, and predischarge TTE demonstrated that they were discharged from the hospital with no MR.

Echocardiographic follow-up data

Eighty-one (96.4%) of the 84 patients were eligible for follow-up assessment. Criteria for exclusion were early death (1 patient), early reoperation on the MV (2 patients), or less than 6 months.

Echocardiographic follow-up studies were obtained in all the 81 eligible patients. The follow-up extended from 5.6 to 86.1 months, median of 36.0 months, and interquartile range of 14.3 to 59.4 months. During the follow-up, TTE showed that 4 patients (4.9%) developed recurrent mild MR, 5 (6.2%) had trace MR, and 72 (88.9%) had no MR. The latest (5.6–86.1 months) and the preoperative TTE results in the 81 patients are summarized in Table 4. Compared with preoperative measurements, mean MR grade, LAD, LVEDD, and LVEF were decreased significantly (all $P < 0.001$).

Discussion

The present study shows that robotic MV repair for MR due to degenerative disease is associated with a low rate of recurrent MR, and a significant improvement in MR grade, LAD, and LVEDD.

In our series, 95.1% of patients had no or trace MR, and only 4.9% developed recurrent mild MR after 7 years of echocardiographic follow-up. The previous study

Table 3: Surgical repair techniques of the patients undergoing robotic MV repair (n = 84), n (%)

Characteristic	Value
Posterior leaflet (n = 66)	
Leaflet resection	3 (3.6)
Leaflet resection + annuloplasty ring	56 (66.7)
Artificial chordae	1 (1.2)
Artificial chordae + annuloplasty ring	5 (6.0)
Leaflet resection + artificial chordae + annuloplasty ring	1 (1.2)
Anterior leaflet (n = 11)	
Artificial chordae	1 (1.2)
Artificial chordae + annuloplasty ring	9 (10.7)
Leaflet resection + artificial chordae + annuloplasty ring	1 (1.2)
Bileaflet (n = 7)	
Artificial chordae + annuloplasty ring	1 (1.2)
Leaflet resection + annuloplasty ring	5 (6.0)
Leaflet resection + artificial chordae + annuloplasty ring	1 (1.2)

MV: Mitral valve.

Table 4: Echocardiographic parameters preoperation and at follow-up (5.6–86.1 months) of the patients who ultimately underwent robotic MV repair (n = 81)

Items	Preoperation	At follow-up	Z or t	P
Mean MR grade	3.96 ± 0.13	0.17 ± 0.49	Z = −8.456	<0.001
LAD (mm)	43.8 ± 5.9	35.5 ± 3.8	t = 15.131	<0.001
LVEDD (mm)	51.0 ± 5.0	43.3 ± 2.2	t = 14.481	<0.001
LVEF (%)	67.3 ± 7.0	63.9 ± 5.1	t = 4.585	<0.001

Data are expressed mean ± SD. LAD: Left atrium dimension; LVEDD: Left ventricular end-diastolic dimension; LVEF: Left ventricular ejection fraction; MR: Mitral regurgitation; MV: Mitral valve; SD: Standard deviation. Numerical grading of MR is as follows - 0: None; 1: Trace; 2: Mild; 3: Moderate; 3.5: Moderate to severe; 4: Severe.

reported the rate of recurrence of MR in long-term follow-up after robotic MV repair.[14] Chitwood *et al*.[14] reported at a mean echocardiographic follow-up time of 815 ± 459 days (n = 279) that 68.8% had no or trace MR, 23.6% had mild MR, 5.3% had moderate MR, and 2.2% had severe MR. Our results were better than that reported in the previous study. These differences are likely related to patients' selection. Recurrent MR is a potential problem in patients with degenerative MV disease after initial adequate repair because this disease is progressive and MV repair does not cure the degenerative process.[15] Patients with isolated anterior leaflet prolapse had an increased risk of reoperation when compared with those with posterior leaflet prolapse.[16,17]

In our series, follow-up echocardiography shows that mean MR grade, LAD, and LVEDD were significantly decreased as compared to preoperative values. These findings are in concordance with the previous reports from conventional MV repair.[18-20] Chronic degenerative MR is often associated with volume overload resulting in dilatation (remodeling) of the left atrial and left ventricular.[21] Successful MV repair result in significant reduction of MR grade and has been shown to induce improvement of LAD and LVEDD at follow-up because of correction of the volume overload.[20,22]

The present study shows that the decrease in LVEF was also a statistically significant finding in our serious and is in keeping with previous reports from conventional MV repair.[18,19] Thus, the ability to perform robotic MV repair should regard a potential LV dysfunction. This complication is associated with poor postoperative prognosis[15] and should be taken into account in the clinical decision-making process.

There are several limitations to this study. First, it is a retrospective study. Although all of the echocardiographic data are gathered prospectively, patients had to be retrospectively contacted. Second, this is a single-center observational analysis without comparison with sternotomy experience other than historical data. Most patients were referred specifically for a robotic MV operation, which precluded the option of randomization. Third, all the operations were carried out by an experienced surgeon (Gao) and therefore the results might not be generalizable.

In conclusion, robotic MV repair for MR due to degenerative disease is associated with a low rate of recurrent MR, and a significant improvement in MR grade, LAD, and LVEDD, but a significant decrease in LVEF at echocardiographic follow-up.

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Conflicts of interest

There are no conflicts of interest.

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