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Comparison of Mid-term and Long-Term Effects of Cord Protection Methods on Left Ventricular Function in Mitral Valve Replacement Surgery

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Introduction: The study aimed to determine the effects of cord protection methods applied in Mitral valve replacement (MVR) surgery on left ventricular function.

Materials and Methods: MVR surgery was performed on 634 patients using either single or combined procedures. Of these patients, 358 (56.5%) underwent conventional MVR surgery, 121 (19.1%) underwent total chordal protection, and 155 (24.4%) underwent posterior chordal preservation. All patients were evaluated as class 3 and 4 according to the New York functional classification (NYHA). Left ventricular diastolic end-diameter (SVDSD), left ventricular systolic end-diameter (SVSSD), end-diastolic volume (EDV), end-systolic volume (ESV), and ejection fraction (EF) were compared between groups.

Results: The degree of valve insufficiency was 3 and 4 in mitral insufficiency. The mortality risk undergoing conventional surgical operations was 4.257 times higher (OR:4.25; 95%CI:1.22-14.76). The study showed positive effects of chordal protection on the clinical status and echocardiographic parameters of undergoing MVR ($p<0.01$).

Conclusion: We believe cord protection methods positively affect left ventricular function after MVR. In particular, total chordal protection will positively affect left ventricular function.

Keywords: Mitral valve replacement, total chordal protection, posterior chordal protection

Introduction

The ideal solution for treating valve diseases is to repair or replace the valve before symptoms appear and irreversible damage occurs in the myocardium (1). Valve replacement is the first option in the surgical treatment of valve lesions where repair is impossible (2, 3). Heart valve prostheses, which are used in cardiac surgery for over forty years, reduce symptoms and extend life in suitable patient groups (4, 5).

In conventional mitral valve replacement (MVR), the mitral valve is replaced with a prosthetic valve along with the chordae (6-8). However, it is known that cutting the subvalvular tissues negatively affects the function of the left ventricle and causes segmental wall motion defects (9, 10). Preservation of the subvalvular structure (due to the functional apparatus of the mitral valve consisting of the chordae and

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papillary muscles) positively contributes to left ventricular function in the post-replacement period (11). Our study aims to determine the effects of the surgical techniques of preserving leaflets and chordae on left ventricular function in patients undergoing MVR surgery.

Materials and Methods

Ethical Statement

This study was approved by the Medical Ethics Committee of the Faculty of Medicine at Gaziantep University on June 15th, 2009, with reference number 06-2009/239.

Study Design

The study consisted of patients who underwent surgery in our clinic and was planned as a retrospective study. Patient data were collected from our clinic's web-based database, while control data were obtained from outpatient controls. From May 2002 to June 2010, 634 patients underwent MVR and/or other cardiac procedures (tricuspid valve repair, tricuspid valve replacement, aortic valve replacement, thrombectomy, SIRFA, and coronary surgery) at the Department of Cardiac and Vascular Surgery at Gaziantep University. On these cases, 358 (56.5%) underwent conventional MVR, 121 (19.1%) underwent Total leaflet protection + MVR, and 155 (24.4%) underwent Posterior leaflet protection + MVR. Based on this feature, patients were grouped into Conventional MVR (Group 1), Total leaflet-protected MVR (Group 2), and Posterior leaflet-protected MVR (Group 3). The groups were compared with statistical analyses for medium and long-term results. We analyzed all degrees of left ventricular end-diastolic diameter (LVDSC), left ventricular end-systolic diameter (LVSSC), end-diastolic volume (EDV), end-systolic volume (ESV) and ejection fraction (EF).

Surgical Technique

A membrane oxygenator was used in patients undergoing standard median sternotomy. After cardiac arrest, the left atrium was reached through a classic left atriotomy. The leaflets and

cords were carefully examined in patients who were planned for valve replacement after mitral valve control. All the valves and subvalve apparatus that could be protected were left in place, and the valves were dissected. In cases where protection was impossible, the mitral valve and instrument were examined entirely, single-plicated sutures were placed, and valve replacement was performed. In cases where the anterior and/or posterior leaflets and cords could be protected, plicated and sutures were placed one by one, passing through the annulus

and leaflets, and the valve replacement was performed so that the valve movements did not affect the cords and leaflets.

Statistical Method

NCSS (Number Cruncher Statistical System) 2007 & PASS (Power Analysis and Sample Size) 2008 Statistical Software (Utah, USA) were used for statistical analysis. In evaluating the study data, in addition to descriptive statistics (mean, standard deviation, ratio, frequency), the One-way ANOVA was used for comparing normal distribution parameters between groups, Tukey HSD test was used to identify the group causing the difference, and Paired sample t-test was used for intra-group comparisons. Qualitative data were evaluated using the chi-square test. A p-value < 0.05 was considered significant.

Results

A total of 634 patients who underwent MVR were included in the study. 212 (33.4%) were male, and 422 (66.6%) were female, with an average age of 45.6 ± 14.6 years (12-82). The average follow-up was 35.98 ± 16.8 months, and other demographic data can be seen in Table-1. Upon analyzing the demographic data, concurrent comorbid factors such as CAD were more prevalent in Group-3 ($p=0.01$). In the total 634 surgeries, 615 patients were alive (97%), and 19 died. The average survival time was 65.18 ± 0.4 months. The last death was observed at 65 months, and the cumulative survival rate

at this month was 86.1%, with a standard error of 4.7%. In the conventional surgery group, 346 out of 358 patients were alive (96.6%), and 12 deaths were observed, with an average survival time of 64.85 ± 0.6 months. The last death was observed at 63 months, and the cumulative survival rate at this month was 88.4%, with a standard error of 3.9%.

When evaluating the atrial fibrillation, left atrial thrombus, rhythm surgery, and left atrial thrombectomy among the groups, atrial fibrillation was more frequently associated with Group-1 ($p=0.011$). Similarly, rhythm surgery as a related surgical procedure was more regularly present in the same group ($p=0.011$). The occurrence rate of the left atrial thrombus and

Table 1. Distribution of demographic characteristics by operation types

Variables	Group 1 (n=358)	Group 2 (n=121)	Group 3 (n=155)	P value
Age (years)	47.36 $\pm$ 14	42.23 $\pm$ 15.3	44.22 $\pm$ 15.25	0.002**
Gender Male	109 (%30.4)	44 (%36.4)	59 (%38.1)	0.183
Female	249 (%69.6)	77 (%63.6)	96 (%61.9)	
NYHA 4	222 (%62)	72 (%59.5)	99 (%63.9)	0.76
3	136 (%38)	49 (%40.5)	56 (%36.1)	
COPD	53 (%14.8)	10 (%8.3)	23 (%14.8)	0.167
CAH	45 (%12.6)	20 (%16.5)	36 (%23.2)	0.010*
DM	115 (%32.1)	36 (%29.8)	52 (%33.5)	0.797
HT	135 (%37.7)	37 (%30.6)	58 (%37.4)	0.349
Preoperative Urea-Cr Elevation	78 (%21.8)	22 (%18.2)	29 (%18.7)	0.587
Cerebrovascular Event	22 (%6.1)	4 (%3.3)	9 (%5.8)	0.489
Endocarditis	36 (%10.1)	18 (%14.9)	15 (%9.7)	0.314
Urgent	34 (%9.5)	10 (%8.3)	23 (%14.8)	0.128
REDO	46 (%12.8)	17 (%14)	22 (%14.2)	0.895

Oneway ANOVA test was used in all the analysis except age parameter: * $p<0.05$; ** $p<0.01$

Table 2. Pre-op ECHO Findings by Operation Types

Pre-op Variables	Group 1 (n=358)	Group 2 (n=121)	Group 3 (n=155)	P value
EDV	132.13 $\pm$ 19.38	124.33 $\pm$ 20.24	122.90 $\pm$ 19.73	0.001**
ESV	85.15 $\pm$ 11.8	81.74 $\pm$ 11.23	84.52 $\pm$ 9.21	0.014*
LVDSC	54.35 $\pm$ 6.1	54.45 $\pm$ 7.35	55.94 $\pm$ 8	0.049*
LVSSC	43.05 $\pm$ 4.88	43.74 $\pm$ 5.13	42.46 $\pm$ 5.1	0.105
EF	52.51 $\pm$ 7.67	49.80 $\pm$ 5.31	50.45 $\pm$ 5.16	0.037*

Oneway ANOVA test was used in all the analysis: * $p<0.05$; ** $p<0.01$

Table 3. Post op ECO Findings by Operation Types

Post-op Variables	Group 1 (n=358)	Group 2 (n=121)	Group 3 (n=155)	P value
EDV	125.92 $\pm$ 18.79	113.26 $\pm$ 18.58	114.49 $\pm$ 19.46	0.001*
ESV	77.1 $\pm$ 12.21	70.02 $\pm$ 13.22	72.12 $\pm$ 8.26	0.001*
LVDSC	49.78 $\pm$ 6.83	46.23 $\pm$ 6.76	49.48 $\pm$ 8.45	0.001*
LVSSC	39.14 $\pm$ 5.46	36.5 $\pm$ 5.81	36.87 $\pm$ 5.54	0.001*
EF	55.82 $\pm$ 7.89	60.98 $\pm$ 6.45	56.68 $\pm$ 5.79	0.001*

Oneway ANOVA test was used in all the analysis: * $p<0.05$; ** $p<0.01$

left atrial thrombectomy was higher in Group-2 ($p=0.025$ and $p=0.040$). 87.1% ($n=552$) of the patients did not have complications, while 12.9% ($n=82$) had complications. The post-ventricular rupture was seen in 0.2% (1), bleeding in 3.9% (25), infection in 2.7% (17), stroke in 0.5% (3), valve degeneration in 1.1% (7), struck valve in 1.9% (12), and 7 in 2.7% (17).

The pre-operative EDV in the conventional surgery group was higher than those in the total leaflet protection and posterior leaflet protection groups ($p=0.001$ & $p=0.001$). A decrease in postoperative EDV was observed at 11.07 ± 5.24 in the total leaflet protection group compared to preoperative EDV ($p<0.01$). A decrease in postoperative EDV was observed at 8.41 ± 2.51 in the posterior leaflet protection group compared to preoperative EDV levels ($p<0.01$). The levels of preoperative ESV in the conventional surgical group were higher than those in the total leaflet protection group ($p=0.01$). The levels of postoperative ESV were higher in the total leaflet protection and posterior leaflet protection ($p=0.001$ & $p=0.001$). A decrease of 8.04 ± 3.67 was observed in the postoperative ESV compared to the pre-operative ESV ($p<0.01$). In the total leaflet protection group, a decrease of 11.72 ± 5.76 was observed in the postoperative ESV compared to the preoperative ESV ($p<0.01$). In posterior leaflet protection, a decrease of 12.4 ± 4.91 was observed in the postoperative ESV compared to the preop ESV ($p<0.01$).

The preoperative LVDSC in the posterior leaflet protection group were higher than those in the conventional surgery ($p=0.044$). In conventional surgery, postoperative LVDSC in the posterior leaflet protection group was higher than in the total leaflet protection ($p=0.001$ & $p=0.001$). In the conventional surgical group, a decrease of 4.56 ± 2.82 was observed in postoperative LVDSC compared to the preoperative LVDSC ($p<0.01$). In the total leaflet protection, a significant decrease of

8.22 ± 2.81 was observed in the postoperative LVDSC compared to the preoperative LVDSC ($p<0.01$). In the posterior leaflet protection group, a decrease of 6.45 ± 1.91 was observed in the postoperative LVDSC compared to the preoperative LVDSC ($p<0.01$).

The postoperative LVSSC in the conventional surgical group was higher than those in the total leaflet protection and posterior leaflet protection groups ($p=0.001$ & $p=0.001$). In the conventional surgical group, a decrease of 3.91 ± 3.03 was observed in the postoperative LVSSC compared to the preoperative LVSSC ($p<0.01$). In the total leaflet protection group, a decrease of 7.24 ± 3.09 was observed in the postoperative LVSSC compared to the pre-operative LVSSC ($p<0.01$). In the posterior leaflet protection, a decrease of 5.58 ± 1.85 was observed in the postoperative LVSSC compared to the preoperative LVSSC ($p<0.01$).

The preoperative EF in the conventional surgical group were higher than those in the total leaflet protection and posterior leaflet protection ($p=0.001$ & $p=0.004$). Postoperative EF in the conventional surgical group was lower than in the total leaflet and posterior leaflet protections ($p=0.001$ & $p=0.001$). In the conventional surgical group, an increase of 3.31 ± 3.85 was observed in the postoperative EF compared to the preoperative EF ($p<0.01$). In the total leaflet protection, an increase of 11.17 ± 3.73 in post-operative EF was observed compared to pre-operative EF ($p<0.01$). In the posterior leaflet protection group, an increase of 9.23 ± 3.42 in post-operative EF was observed compared to pre-operative EF ($p<0.01$).

In the total leaflet protection group, 119 out of 121 patients lived (98.3%), 2 were dead, and the average survival time was 64.62 ± 0.53 months. The latest death was observed in the 65th month, and the cumulative survival rate at this month was 73.6, with a standard error of 21.3%. In the posterior leaflet protection group, 150 out of 155 patients lived (96.8%), five deaths

were observed, and the average survival time was 64.72 ± 0.99 months. The latest death was observed in the 61st month, and the cumulative survival rate at this month was 82, with a standard error of 11.3%. When the Log Rank test evaluated survival rates according to the operations, no differences were found in the 6-year survival rates ($p:0.417$). The highest survival was seen where total leaflet protection was performed. The mortality risk for males is 3.557 times higher than for females (OR:3,55; 95% CI: 1,739-9,173). The mortality risk for patients undergoing conventional surgical operations was 4.257 times higher (OR:4,25; 95%CI: 1,228-14,761). The mortality risk was 3.075 times higher in infections (OR:3,07; 95%CI:1,07-8,821).

Discussion

In the present study, total leaflet preservation and, less frequently, posterior leaflet preservation methods in patients who underwent MVR surgery had positive effects on the clinical status of the patients and on left ventricular functions in echocardiographic measurements. Application of left ventricular preservation methods in patients planned for mitral valve surgery leads to significant improvement in left ventricular diameters and ejection fraction rates in medium and long-term follow-up. Preservation methods seriously affect left ventricular functions, especially preservation of chordae and apparatus will have positive effects on left ventricular functions. The protection of appliances that provide all atrioventricular integrity will overlap with cardiac functional integrity and will positively affect the output of the heart.

Since the first successful MVR, over three million individuals have undergone prosthetic valve replacement (12). When performed with appropriate indications, valve replacement can reduce symptoms and improve quality of life while significantly extending life expectancy. However, like any surgery, valve replacement also risks adverse complications (13). Mainly,

posterior ventricular rupture is a fatal complication that can occur after MVR, which is prevented by preserving the posterior leaflet and maintaining continuity between the mitral annulus and papillary muscle (14). Later, the method was reported to affect left ventricular ejection fraction positively. The increase in postoperative left ventricular wall stress was the reason for left ventricular dysfunction after MVR with the removal of the entire natural valve structure (15). Our study found that the age was higher in the group that underwent conventional surgery, and the prevalence of CAD was higher in the group that underwent posterior leaflet-protected surgery.

The main goal of heart valve surgery is to preserve the natural heart valve as much as possible (16). A study by Gürbüz et al. showed no effect on mortality and morbidity from mechanical valve types. Studies conducted by different groups showed that results with mechanical valve-assisted MVR were similar, but complications were most common in conventional MVR (17). The most commonly reported valve-related complication in the literature includes thromboembolism, valve thrombosis, and bleeding due to oral anti-coagulation. According to Debatez, the most common complications in patients undergoing conventional MVR are hemorrhage and thromboembolism (18). In our study, one patient with posterior ventricular rupture underwent conventional MVR surgery, 76% of those who underwent a revision for bleeding complications had conventional MVR, 66.7% of those with valve hemolysis complications had conventional MVR surgery, and 66.7% of those with stroke complications had conventional MVR surgery. Before conventional MVR, the LVSSC was 43 ± 4.8 and decreased to 39.1 ± 5.4 after the operation. In the total leaflet-protected MVR, the LVSSC was 43.7 ± 5.1 before the operation and decreased to 36.4 ± 5.8 after the operation. In the posterior leaflet-protected MVR surgery, the LVSSC was 42.1 ± 5.1 before

the operation and decreased to 36.8 ± 5.5 after the operation. Before conventional MVR, the EF was 52.5 ± 7.6 . This value increased to 55.8 ± 7.8 after operation. In total leaflet-protected MVR, the EF was 49.8 ± 5.3 before and increased to 60.9 ± 6.4 after the operation. In the posterior leaflet-protected MVR, EF was 50.4 ± 5.1 before operation and increased to 59.6 ± 5.7 after the operation. Our results are similar to Debattista et al. Protection techniques positively affect left ventricular remodeling & systolic function (19).

Operative mortality is significantly affected by patients' preoperative characteristics rather than valve performance. In a study by Mavitas et al., the operative mortality rate was 4.7%. Kratz et al. (18) found 3.5%, Arom et al. (19) found 9.9%, and Czer et al. (20) found 11.9%. Our study found an operative mortality rate of 2.99%. David et al. (21) reported a difference in favor of the group in which the mitral valve was protected compared to the group in which a classic MKR. Miki et al. (22) obtained results similar to ours by reporting that there was no change in the preoperative and postoperative left ventricular EF in the group undergoing classic MVR, while there was an increase in the group undergoing protection. Yutaka et al. (23) also reported in their radionuclide study on patients with mitral insufficiency that the left ventricular EF was better in the group undergoing protection compared to the group undergoing classic MKR.

Conclusion

Left ventricular protection methods in patients planned for MVR surgery significantly improve left ventricular diameters and ejection fraction rates in mid & long-term follow-up. We believe that protection methods positively impact left ventricular function, especially the preservation of cordae and apparatus, which positively affects left ventricular function. Preservation of all apparatus that ensure atrioventricular integrity positively influences cardiac functional integrity, positively affecting the heart's output.

In this regard, we think preserving all structures that can be preserved or preserving posterior leaflets and cordae in case it cannot be done will be beneficial in increasing EF.

Conflict of Interest

The authors declare no conflict of interest for the present study.

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