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Original Article

Chordae Tendineae Sparing during Mitral Valve Replacement: A Comparative Study

Ahmed M Abdelazim, Ashraf Mostafa Elnahas, Yousry Elsaid Rizk, Hany Mohammed Elrakhawy, Mahmoud Mohammed Abdel Azeem Mubarak, Mahmoud Ahmed Al-Shafiey

Department of Cardiothoracic Surgery, Banha University Hospital, Banha, Egypt

Abstract

Background: Mitral valve replacement (MVR) with chordal sparing could improve ventricular function in patients with mitral regurgitation. This study aimed to compare the outcomes of prosthetic MVR with and without chordae tendineae sparing.

Methods: This prospective, single-blinded, randomized study was executed on 60 patients undergoing prosthetic MVR with or without chordae tendineae sparing. Patients were divided into two equal groups: Group A (n= 30) included patients who underwent MVR with complete chordae tendineae sparing, and Group B (n= 30) included patients who underwent mitral valve replacement without chordae tendineae sparing.

Results: Patients who underwent chordae tendineae sparing demonstrated significantly lower total bypass time (median = 67 vs. 110 min, P < 0.001), total cross-clamp time (median = 40 vs. 80 min, P < 0.001), inotropic support (30% vs. 96.7%, P < 0.001), and arrhythmia (6.7% vs. 86.7%, P < 0.001) than those who did not undergo chordal sparing. Additionally, patients who underwent sparing demonstrated a significantly lower 6-month left ventricle end-systolic diameter (3 ±0.8 vs. 3.9 ±0.5 cm, P < 0.001), 6-month left ventricle end-diastolic diameter (4.4 ±0.7 vs. 5.3 ±0.5 cm, P < 0.001), 3-month left atrium diameter (4.5 ±0.8 vs. 5.1 ±0.6 cm, P < 0.001), and 6-month left atrium diameter (4.3 ±0.8 vs. 5.4 ±0.6 cm, P < 0.001).

Conclusion: This technique of MVR might enhance cardiac function and structural parameters and lower the end-diastolic and systolic diameters and the end-systolic and diastolic volumes up to the sixth month of follow-up.

KEYWORDS
Chordae Tendineae; Sparing; Mitral valve replacement; MVR

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Introduction

Mitral valve replacement (MVR) is a commonly performed cardiac procedure. The mortality rate remains substantially high despite advancing surgical techniques and mitral valve prostheses, and cardiac failure is the most frequent cause of death after MVR [1,2].

In earlier studies, the preservation of the papillary muscles, chordae tendineae, and atrioventricular rings in the mitral leaflets and

Corresponding author: Mahmoud Mohammed Abdel Azeem Mubarak modoobassha@yahoo.com

their potential impact on left ventricular (LV) function have all been proposed [3]. This preservation was suggested to improve ventricular function and reduce mortality compared to conventional MVR. Further reports showed the beneficial effects of maintaining the mitral apparatus in MVR for mitral regurgitation on postoperative LV performance. In contrast, others demonstrated that the surgical resection of the mitral apparatus could lead to LV function deterioration regardless of whether there was a preexisting mitral regurgitation [4]. Removing the mitral valve and replacing it with a prosthesis is detrimental to LV function [5].

The papillary muscles and valve leaflets are joined by robust, fibrous structures called chordae tendineae (CT). These keep the cusps from swinging back into the atrial cavity during systole and are connected to the leaflets on the ventricular side. The CT is a crucial part of the atrioventricular (AV) valve complex. The link between CT and the cusp pillars must be understood to comprehend the functional architecture of the mitral valve. The chordae are categorized depending on their function in ventricular dynamics [6].

CT sparing during MVR involves the meticulous preservation or selective sparing of the native chordal structures while replacing the diseased valve. This technique aims to maintain the integrity of the subvalvular apparatus, allowing for improved conservation of ventricular geometry, more physiological coaptation of prosthetic valves, and improved hemodynamics. The risk of complications associated with conventional MVR is reduced after sparing the chordae tendineae [7]. This technique is promising, and its impact on patient outcomes and long-term follow-up remains an area of exploration [8]. Therefore, this study aims to compare the outcomes of prosthetic MVR with and without CT sparing.

Patients and Methods

From July 2020 to June 2022, this prospective, single-blinded, randomized study was performed on 60 patients who underwent prosthetic MVR with or without CT sparing.

The patients were divided into two equal groups: Group A (n= 30) included patients who underwent MVR with complete CT sparing, while Group B included patients who underwent MVR without CT sparing (n= 30).

The inclusion criteria were patients of both sexes with ejection fraction (EF) > 50% and New York Heart Association (NYHA) class up to grade III who had mitral valve lesions requiring elective replacement. Tricuspid valve repair was performed in most patients who underwent mitral valve replacement with moderate to severe tricuspid regurgitation. The exclusion criteria were redo or emergency surgeries and concurrent coronary artery bypass surgery patients.

Preoperative evaluation

The preoperative patient assessment included complete history taking and investigations. Laboratory investigations included complete blood count (CBC), liver function tests (LFTs), renal function tests (RFTs), and international normalized ratio (INR). Other investigations included a plain chest X-ray, an electrocardiogram (ECG), and echocardiography. Echocardiography detailed the severity of mitral valve lesions, ejection fraction, fraction shortening, left ventricular function, geometry, and left ventricular and atrial dimensions. Cardiac catheterization was conducted in patients above 40 years old.

Intraoperative details

The intraoperative details were as follows: (A) general anesthesia was conducted; (B) a median sternotomy incision was made; and (C) an arterial cannula was placed in the femoral artery or ascending aorta for cardiopulmonary bypass (CPB). The femoral vein or superior and inferior vena cavae were used for bicaval cannulation to obtain venous drainage; (D) cardioplegic arrest was brought on while receiving CPB and an aortic cross-clamp. The cardioplegic solution, Custodiol, was used for 5-7 minutes at a 50-70 mmHg pressure. In Group A, the core of the anterior mitral leaflet (AML) was incised after being cut away from the annulus. The anterior and posterior commissures were incised to the annulus. Excessive cuspal tissue and fibrous and calcific nodules were excised. The two newly formed

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Table 1: General clinical characteristics and preoperative laboratory and echocardiographic findings. Data are presented as the mean ± standard deviation (SD), frequency (%)

	Group A (n = 30)	Group B (n = 30)	P value
Age at surgery (years)	42 ±8	46 ±13	0.205
Gender			
Males	7 (23.3)	10 (33.3)	0.390
Females	23 (76.7)	20 (66.7)	
Body mass index (kg/m2)	24.08 ±4.09	25.37 ±4.83	0.268
Body surface area (m2)	1.65 ±0.19	1.71 ±0.18	0.207
Smoking			
Current	0 (0)	2 (6.7)	0.173
Ex-smoker	2 (6.7)	5 (16.7)	
Clinical characteristics			
Diabetes mellitus	1 (3.3)	4 (13.3)	0.353
Hypertension	1 (3.3)	3 (10)	0.612
Prior catheterization	6 (20)	11 (36.7)	0.152
NYHA class			
I	24 (80)	18 (60)	
II	4 (13.3)	6 (20)	0.196
III	2 (6.7)	6 (20)	
Angina symptoms status			
Stable	30 (100)	30 (100)	-
Preop arrhythmia	9 (30)	15 (50)	0.114
Preoperative laboratory and echo finding			
Baseline hemoglobin (gm/dl)	12.5 ±1.5	12.6 ±1.2	0.604
Baseline creatinine (mg/L)	0.8 ±0.2	0.9 ±0.2	0.154
Ejection fraction (%)	57 ±5	59 ±4	0.183
Fractional shortening (%)	26 ±5	27 ±4	0.379
LVEDD (mm)	4.7 ±0.7	4.7 ±0.7	0.902
LVESD (mm)	3.3 ±0.8	3.2 ±0.5	0.363
Tricuspid regurgitation			
No	7 (23.3)	2 (6.7)	
Mild	2 (6.7)	6 (20)	0.128
Moderate	8 (26.7)	12 (40)	
Severe	13 (43.3)	10 (33.3)	
Pulmonary artery pressure	50 ±5	45 ±12	0.069

NYHA: New York Heart Association; LVEDD: left ventricular end-diastolic diameter; LVESD: left ventricular end-systolic diameter

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chordal segments were then stitched to the corresponding anterolateral and posteromedial commissures. Using Miki's technique, the posterior mitral leaflet (PML) was divided, and the prosthetic valve was stitched into place while plicating the AML and chordae. In Group B, resection of both the anterior and posterior mitral leaflets was performed, and continuity between the PM and mitral annulus was restored using 2 4-0 PTFE mattress sutures: the anterior PM was placed at the 9 to 10 o'clock position on the mitral ring, and the posterior PM was placed at the 5 to 6 o'clock position.

Assessment of the outcomes

The primary postoperative outcomes included echocardiography with a detailed assessment of prosthetic mitral valve function, ejection fraction, fraction shortening, left ventricular function and geometry, and left ventricular and atrial dimensions. In contrast, the secondary postoperative outcomes included the duration of mechanical ventilation, mean arterial blood pressure, central venous pressure, ECG, cardiac enzymes, ICU stay, hospital stay, complications such as arrhythmias, renal, hepatic or neurological manifestations, bleeding, and wound infection.

All patients were followed up after three and six months for assessment of dyspnea, NYHA grading, and orthopnea, in addition to plain chest X-ray and echocardiography.

Statistical analysis:

SPSS version 28 was used for data entry and statistical analysis (IBM, Armonk, New York, United States). The Shapiro–Wilk test and methods for direct data visualization were employed to determine the normality of quantitative data. Quantitative data were summarized using medians, ranges, means, and standard deviations according to normality. Numbers and percentages served as a summary for categorical data. Depending on whether the quantitative data were normally distributed, the independent t test or Mann–Whitney U test was employed to compare the quantitative data between the groups. The chi-square or Fisher's exact test was employed to compare categorical data. Significant P values were defined as those less than 0.05.

Results

The two groups were comparable regarding age (P = 0.205), sex (P = 0.390), body mass index (BMI) (P = 0.268), body surface area (BSA) (P = 0.207), smoking (P = 0.173), diabetes (P = 0.353), hypertension (P = 0.612), prior catheterization (P = 0.152), NYHA class (P = 0.196), angina symptoms, and preoperative arrhythmia (P = 0.114). Additionally, no significant differences were observed regarding preoperative laboratory and echo findings, including baseline hemoglobin (P = 0.604), creatinine (P = 0.154), ejection fraction (P = 0.183), fractional shortening (P = 0.379), left ventricular end-diastolic diameter (LVEDD) (P = 0.902), left ventricular end-systolic diameter (LVESD) (P = 0.363), TVR (P = 0.128), and pulmonary artery pressure (P = 0.069). (Table 1)

Regarding intraoperative findings, all patients underwent cardiopulmonary bypass. Patients who underwent CT sparing demonstrated significantly lower total bypass time (median = 67 vs. 110 min, P < 0.001), total cross-clamp time (median = 40 vs. 80 min, P < 0.001), inotropic support (30% vs. 96.7%, P < 0.001), troublesome coming off bypass (3.3% vs. 40%, P < 0.001), arrhythmia (6.7% vs. 86.7%, P < 0.001), DC shock (3.3% vs. 90%, P < 0.001), and DeVega tricuspid repair (26.7% vs. 36.7%, P < 0.001) than those who did not undergo sparing. No significant difference was observed regarding ring size (P = 0.064) (Table 2).

Table 2: Intraoperative findings in the studied groups. Data are presented as the mean ± standard deviation (SD), frequency (%), or median (range)

	Group A (n = 30)	Group B (n = 30)	P value
Cardiopulmonary bypass	30 (100)	30 (100)	-
Valve suturing			
Continuous	1 (3.3)	0 (0)	>0.99
Interrupted with Teflon	29 (96.7)	30 (100)	
Ring Size	28 ±2	27 ±1	0.064
Total bypass time (min)	67 (40 - 120)	110 (60 - 300)	<0.001
Total cross-clamp time (min)	40 (20 - 84)	80 (35 - 210)	<0.001
Inotropic support	9 (30)	29 (96.7)	<0.001
Coming off bypass			
Smooth	29 (96.7)	18 (60)	<0.001
Troublesome	1 (3.3)	12 (40)	
Arrhythmia	2 (6.7)	26 (86.7)	<0.001
Use of DC	1 (3.3)	27 (90)	<0.001
Tricuspid repair			
DeVega	8 (26.7)	11 (36.7)	0.014
Pericardial patch	13 (43.3)	3 (10)	

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Table 3: Postoperative findings in the studied groups. Data are presented as frequency (%), median (range)

	Group A (n = 30)	Group B † (n = 28)	P value
Immediate postop complications	0 (0)	5 (17.9)	0.021
Arrhythmias	2 (6.7)	11 (39.3)	0.003
Ventilation duration (hours)	8 (4 - 14)	12 (5 - 168)	<0.001
Pulmonary complications	0 (0)	1 (3.6)	
Neurological complications	0 (0)	0 (0)	0.483
Renal complications	0 (0)	3 (10.7)	0.106
Bleeding	0 (0)	2 (7.1)	0.229
Wound infection	0 (0)	9 (32.1)	<0.001
ICU stays (days)	3 (3 - 4)	6 (3 - 14)	<0.001
Hospital stay (days)	9 (6 - 14)	15 (7 - 26)	<0.001
Central venous pressure (mmHg)	6 (4 - 8)	8 (6 - 13)	<0.001
Urine output (Normal)	30 (100)	28 (100)	-

† Two patients died intraoperatively in group B, so percentages were calculated based on 28 patients

Regarding postoperative findings, patients who underwent chordal sparing demonstrated significantly lower immediate postoperative complications (0% vs. 17.9%, P = 0-.021), arrhythmias (6.7% vs. 39.3%, P = 0.003), hours of ventilation (median = 8 vs. 12 hours, P < 0.001), wound infection (0% vs. 9%, P < 0.001), ICU stay (median = 3 vs. 6 days, P < 0.001), hospital stay (median = 9 vs. 15 days, P < 0.001), and CVP (median = 6 vs. 8 mmHg, P < 0.001). The two groups did not significantly differ in terms of neurological complications (P = 0.229), renal complications (P = 0.106), bleeding (P = 0.229), or mortality (P = 0.112). All patients had normal urine output (Table 3).

Table 4: Follow-up findings of the studied groups. Data are presented as the mean ± standard deviation (SD), frequency (%)

	Group A (n = 30)	Group B † (n = 26)	P value
Sinus rhythm			
At 6 months	28 (93.3)	7 (26.9)	<0.001
EF			
At 3 months	55 ±3	52 ±5	0.012
At 6 months	58 ±3	47 ±5	<0.001
LVESD			
At 3 months	3.2 ±0.8	3.5 ±0.5	0.149
At 6 months	3 ±0.8	3.9 ±0.5	<0.001
LVEDD			
At 3 months	4.7 ±0.7	4.9 ±0.5	0.076
At 6 months	4.4 ±0.7	5.3 ±0.5	<0.001
LA			
At 3 months	4.5 ±0.8	5.1 ±0.6	0.004
At 6 months	4.3 ±0.8	5.4 ±0.6	<0.001
All mortality			
At 6 months	0 (0)	4 (13.3)	0.112

† Two patients died intraoperatively, and two died during follow-up in group B, so the percentage of sinus rhythm at six months was calculated based on a total of 26 patients

EF: Ejection fraction LVESD: Left ventricular end-systolic volume; LVEDD: Left ventricular end-diastolic volume; LA: Left atrial

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Regarding follow-up findings, patients who underwent chordae tendineae sparing demonstrated significantly higher sinus rhythm at 3 months (93.3% vs. 26.9%, P < 0.001) and ejection fraction at 3 months (55 ±3% vs. 52 ±5, P = 0.012) and 6 months (58 ±3 vs. 52 ±5, P < 0.001) than those who did not undergo sparing (Table 4). Additionally, patients who underwent sparing demonstrated significantly lower 6-month LVESD (3 ±0.8 vs. 3.9 ±0.5 cm, P < 0.001), 6-month LVEDD (4.4 ±0.7 vs. 5.3 ±0.5 cm, P < 0.001), 3-month LA (4.5 ±0.8 vs. 5.1 ±0.6 cm, P < 0.001), and 6-month LA (4.3 ±0.8 vs. 5.4 ±0.6 cm, P < 0.001) (Table 4, Figure 1).

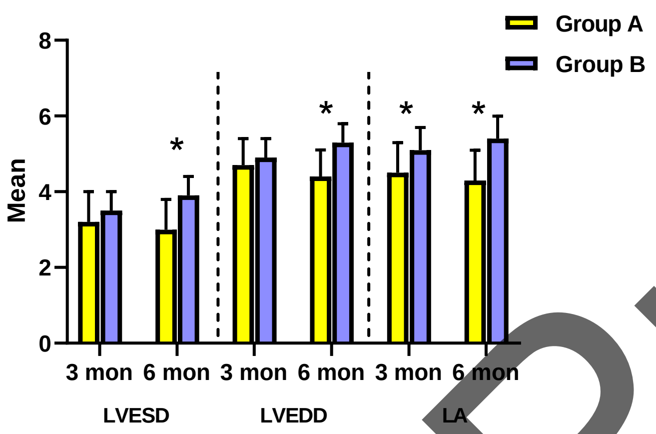

Figure 1: Follow-up echo findings of the studied groups at 3 and 6 months

Discussion

In the present study, patients who underwent chordae tendineae sparing demonstrated significantly higher sinus rhythm at three months (93.3% vs. 26.9%, P < 0.001) and ejection fraction at three months (55 ±3% vs. 52 ±5, P = 0.012) and six months (58 ±3 vs. 52 ±5, P < 0.001) than those who did not undergo sparing. Additionally, patients who underwent sparing demonstrated significantly lower 6-month LVESD (3 ±0.8 vs. 3.9 ±0.5 cm, P < 0.001), 6-month LVEDD (4.4 ±0.7 vs. 5.3 ±0.5 cm, P < 0.001), 3-month LA (4.5 ±0.8 vs. 5.1 ±0.6 cm, P < 0.001), and 6-month LA (4.3 ±0.8 vs. 5.4 ±0.6 cm, P < 0.001).

Chowdhury et al. reported an initial decline in the EF of the chordal preservation group, but the decline continued in the nonchordal preservation group [9]. Alsaddique reported that EF was maintained during immediate follow-up in patients who underwent MVR while preserving CT [4]. Straub et al. reported that the EF was unchanged in the chordal preservation group seven days after surgery but increased three months postoperatively. In contrast, the EF in the conventional group decreased seven days postoperatively and recovered three months later [10].

Consistent with these findings, Rozich et al. included seven patients who underwent MVR with chordal resection and eight with chordal preservation. The resection group demonstrated no postoperative alteration in LV end-diastolic volume, a significant increase in LV end-systolic volume, a substantial rise in end-systolic stress, and a significant reduction in ejection fraction. In contrast, the preservation group demonstrated significant reductions in LV end-diastolic and end-systolic volumes, with the ejection fraction unchanged [11]. Yun et al. reported an initial decline in the end-diastolic volume in both groups. However, only patients who underwent chordal sparing continued to experience a decline. They also observed that end-systolic volume declined with complete chordal preservation. Furthermore, in patients who underwent partial chordal-sparing procedures, the ejection fraction decreased and did not improve after a year. In contrast, in patients with complete chordal sparing, the ejection fraction increased initially before returning to its preoperative level [12].

It has been established that the most accurate measure of LV function is LVEDD. A decline in LVEDD correlated favorably with clinical improvement following valve surgery [13,14]. Kayagioglu et al. reported that although the effects were statistically insignificant, the LVEDD and LVESD decreased in the preservation group but increased in the conventional group postoperatively. Additionally, the EF slightly declined in individuals with preserved chordae, while in those who underwent conventional MVR, it dramatically decreased [15]. Gaiotto et al. reported that patients with end-stage cardiomyopathy who underwent MVR with preservation of the CT experienced a decrease in the LVEDD and LVESD [16].

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In line with the current findings, Straub et al. reported a decline in postoperative arrhythmias due to preserving the mitral subvalvular structures [10]. Other studies reported a lower cross-clamp time in the preservation group, with one of them reporting a cross-clamp time of 46 ± 12 min, which is very close to our estimate [16]. In contrast, Hennein et al. reported a cross-clamp time of 45 ± 10 min in the conventional group and 47 ± 11 in the preservation group [17].

According to Chowdhury et al., 75.8% of the patients in the conventional group required postoperative inotropic support compared to 22.5% of patients in the preservation group ($P < 0.05$). This could be explained by the shorter bypass time in the preservation group [9].

Patients who underwent sparing in the current study demonstrated significantly lower immediate postoperative complications (0% vs. 17.9%, $P = 0.021$), arrhythmias (6.7% vs. 39.3%, $P = 0.003$), ICU stay (Median = 3 vs. 6 days, $P < 0.001$), and hospital stay (Median = 9 vs. 15, $P < 0.001$). Additionally, Hennein et al. reported four deaths in patients whose chordae were surgically removed [17]. The mortality rate at six months was 0% in Group A and 13.3% in Group B. Previous studies reported no mortalities in patients who underwent MVR with chordal preservation [15, 18, 19]. Interestingly, Muthialu et al. reported that patients with partial or complete leaflet preservation experienced increased 5-year survival (92% vs. 80%, $P < 0.001$) [20].

In the current study, all patients in both groups underwent cardiopulmonary bypass. Patients who underwent CT sparing demonstrated significantly lower total bypass time (median = 67 vs. 110 min, $P < 0.001$), total cross-clamp time (median = 40 vs. 80 min, $P < 0.001$), inotropic support (30% vs. 96.7%, $P < 0.001$), and arrhythmia (6.7% vs. 86.7%, $P < 0.001$) than those who did not undergo CT sparing.

Limitations

This study has some limitations, including the relatively small sample size and the short follow-up of six months. Therefore, further randomized trials with larger sample sizes and longer follow-ups are needed to provide more information about the value of chordae tendineae sparing MVR.

Conclusion

Sparing the chordae tendineae could improve intraoperative characteristics, including shorter bypass and cross-clamp times, decreased demand for inotropic support, and lower incidence of complications, such as arrhythmias and troublesome coming off bypass. Postoperatively, it is associated with fewer complications, shorter ventilation durations, and decreased hospital and ICU stays. Additionally, it was associated with higher sinus rhythm, improved ejection fraction, and reduced end-diastolic and systolic diameters and end-systolic and diastolic volumes. Subsequently, MVR with CT preservation might enhance postoperative left ventricular function in patients with mitral stenosis.

Conflict of interest: Authors declare no conflict of interest.

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