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Mitral Valve Repair with Artificial Chordae for Posterior Leaflet Disease

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Abstract

Background: Recently, the concept of "Respect rather than resect" has been proposed in an attempt to restore mitral valve function. We investigated the results of mitral valve repair for posterior leaflet disease. **Methods:** Between April 2008 and July 2017, mitral valve repair was performed in 78 cases at our facility. Among them, 37 cases were analyzed. We divided patients into three groups according to the repair techniques used: artificial chordae technique, which uses the anchoring-technique and measured tube technique (Group A, 23 cases), resection and suture technique (Group R, 10 cases), and artificial chordae together with resection and suture technique (Group AR, 4 cases), and compared their postoperative outcomes. **Results:** Residual postoperative mitral regurgitation (MR) grade in groups A, R and AR at discharge were 0.3 ± 0.4, 0.8 ± 0.9 and 0.0 ± 0.0 ($p = 0.07$), respectively. Mitral valve areas (cm^2) in groups A, R and AR were 3.2 ± 0.6, 2.9 ± 0.6 and 3.0 ± 0.6 ($p = 0.47$), respectively. Freedom from severe MR at 5 years postoperatively was seen in 91.7%, 90% and 100% ($p = 0.92$) in groups A, R and AR, respectively. **Conclusions:** There was no significant difference in postoperative outcomes, as assessed echocardiographically, between the artificial chordae technique and resection and suture technique. The results of all repair techniques were satisfactory.

Keywords

Mitral Valve Regurgitation, Mitral Valve Repair, Artificial Chordae, Heart Valve Diseases

1. Introduction

Currently, mitral valve repair is the standard procedure for mitral valve regurgi-

tation (MR), because it is superior to mitral valve replacement in terms of restoration of cardiac systolic function and does not require postoperative anticoagulant therapy. Several techniques are used for mitral valve repair. Among them, the French correction advocated by Carpentier [1], which involves repair using resection and suture of the mitral valve, and the American correction advocated by Lawrie [2], which uses artificial chordae, are popular basic techniques for mitral valve repair. For posterior mitral leaflet disease, although the resection and suture technique is considered the standard, it is associated with certain problems, such as change in valve geometry following resection and with scarring during healing followed by thickened or stiffened. Hence, Perier advocated the "Respect Rather than Resect" approach [3] [4]. Perier's repair concept involves sparing the mitral valve without performing resection. The mitral valve repair technique has matured in recent years, such that mitral valve repair using the artificial chordae technique is currently relatively easily performed. Hence, we treat posterior mitral leaflet prolapsing using the modified artificial chordae technique. Furthermore, Choi, *et al.* suggest that artificial chordae repair is superior to resection and suture technique in terms of leaflet mobility and coaptation evaluated by their virtual mitral valve repair simulation [5]. So, we compared the results of this artificial chordae technique for posterior mitral leaflet diseases with those of the resection and suture technique in this study.

2. Material and Methods

From April 2008 to July 2017, we performed 78 cases of mitral valve repair. Among them, 44 procedures were performed for repair of posterior mitral valve disease (active endocarditis and repair of only anterior mitral valve disease were eliminated). Of those, 37 cases without 7 cases (edge to edge repair: 2, unsuccessful repair: 5) were analyzed. We divided the 37 patients into three groups according to the repair technique used, as follows artificial chordae technique group (Group A, 23 cases), resection and suture technique group (Group R, 10 cases) and both artificial chordae technique and resection and suture technique used group (Group AR, 4 cases). The study was approved by the institutional review board.

2.1. Surgical Procedure

Following establishment of cardiopulmonary bypass via a full median sternotomy, the ascending aorta and superior and inferior vena cava were directly cannulated, the ascending aorta was cross-clamped, and antegrade and retrograde cardioplegic solution was injected. The mitral valve was exposed via a conventional left atriotomy.

After placing sutures (2-0 polyester) along the mitral annulus, the mitral valve configuration and the prolapse site were assessed using saline injection to the left ventricle. Then, the mitral valve was repaired by one of the following techniques. And then, ring annuloplasty was performed with a semi-rigid full ring of the

same size as the anterior leaflet height. Valve reconstruction was evaluated using the saline test to determine the appropriateness of the resultant valve morphology and position of the closure line.

2.2. Artificial Chordae Technique (Figure 1)

An anchor consisting of a CV-2 ePTFE (Gore-Tex) suture with pledget (Gore-Tex; W.L. Gore & Associates, Flagstaff, AZ, USA) was attached to the top of papillary muscle. A CV-5 Gore-Tex suture was then passed through the anchor (anchoring technique). Next, the CV-5 Gore-Tex suture was passed through a cut 12 Frazier suction tube (Nipro Corporation, Osaka, Japan) and attached to the edge of the prolapsed mitral valve leaflet. The length of the cut tube was determined by measuring the length of near healthy native chordae as a reference. This method constitutes the measured tube technique [6]. With the aid of the cut tube, the proper length of the chordae was fixed when the suture was tied. Finally, the tube was carefully removed. In this technique, if additional artificial chordae are required, they can be easily attached using the CV-2 anchor.

2.3. Resection and Suture Technique

We used triangular or quadrangular resection, depending on the size of the prolapsed area. If the prolapse area was small, triangular resection was performed.

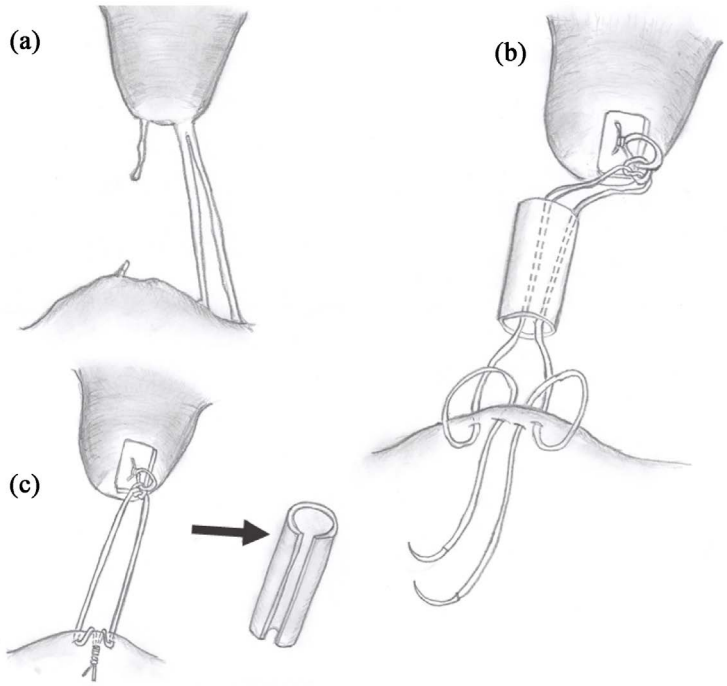

Figure 1. Mitral valve repair with insertion of artificial chordae. (a) The basal chordae of the posterior mitral leaflet was ruptured; (b) Anchoring technique with the measured tube technique. A CV-2 Gore-Tex suture was attached as an anchor to the papillary muscle. After a CV-5 Gore-Tex suture was inserted through the anchor and the cut tube, it was attached to the prolapsing posterior leaflet; (c) The CV-5 Gore-Tex suture was tied and fixed to the prolapsing leaflet, following which the tube was removed (Gray arrow).

After resecting the prolapsed leaflet, it was repaired using interrupted with 5-0 polypropylene suture. If there was extensive prolapse, quadrangular resection with annular plication using 2-0 polyester sutures was performed.

2.4. Artificial Chordae Together with the Resection and Suture Technique

We sometimes added artificial chordae when the resection and suture was not enough to repair. We also additionally performed resection and suturing if a minor residual prolapse existed at a separate location from the region of attachment of the artificial chordae.

2.5. Echocardiography

We performed echocardiographic evaluations at discharge, 3, 6 and 12 months postoperatively, and every year thereafter. Mitral valve area (MVA) was calculated using the pressure half-time (PHT) method. Mean transmitral pressure gradient (MPG) was determined using continuous wave Doppler echocardiography. The severity of MR was classified as none or trivial (MR area ≤ 2.0 cm^2; grade 0), mild (MR area > 2.0, ≤ 4.0 cm^2; grade 1), moderate (MR area > 4.0, ≤ 6.0 cm^2; grade 2), moderately severe (MR area >6.0, ≤8.0 cm^2; grade 3) and severe (MR area > 8.0 cm^2; grade 4).

2.6. Statistical Analysis

All values are expressed as means ± standard deviation. Between groups comparisons were analyzed using one-way ANOVA, χ^2 test and Kaplan Meier analysis. $P < 0.05$ was considered statistically significant.

3. Results

The characteristics of patients in groups A, R and AR are shown in Table 1. There were no significant differences in baseline characteristics between groups. The patients' operative data is shown in Table 2. The sizes of the artificial rings (mm) in groups A, R and AR were 31.4 ± 2.0, 30.0 ± 3.3 and 32.0 ± 1.6 ($p = 0.24$), respectively. There were no significant differences in terms of the concomitant procedures performed in the three groups. Regarding the prolapse site of the posterior mitral leaflet, P2 and P3 were the most common sites of prolapse in all groups. In group A, one patient died because of low output syndrome in the perioperative period. In group R, two patients required permanent pacemaker implantations because of bradycardia with atrial fibrillation. Postoperative bleeding occurred in one patient each in groups R and AR. Bleeding in the patient in group AR resulted in post-resuscitation encephalopathy. Mediastinitis and pneumonia did not occur in any of the patients. More than half of the patients underwent surgery without blood transfusion.

The MR grade at discharge in groups A, R and AR were 0.3 ± 0.4, 0.8 ± 0.9 and 0.0 ± 0.0 ($p = 0.07$), respectively (Table 3). The MVA at discharge in groups A, R and AR were 3.2 ± 0.6, 2.9 ± 0.6 and 3.0 ± 0.6 cm^2 ($p = 0.47$), respectively.

Table 1. Patient characteristics.

	Group A (n = 23)	Group R (n = 10)	Group AR (n = 4)	p-value
Gender (Male)	19	7	2	0.33
Age (years)	65.9 ± 12.6	68.4 ± 7.9	63.3 ± 14.3	0.74
BSA (m^2)	1.62 ± 0.18	1.62 ± 0.12	1.61 ± 0.12	1.00
NYHA	2.1 ± 0.5	2.0 ± 0	1.8 ± 0.5	0.37
MR grade	3.9 ± 0.3	3.7 ± 0.5	4.0 ± 0	0.26
LVEF (%)	61.5 ± 9.1	64.6 ± 9.4	69.2 ± 1.7	0.24
HT	11	6	3	0.55
CAD	2	4	0	0.05
CVD	2	1	0	0.81
PAD	1	1	0	0.71
CKD	7	4	1	0.82
Respiratory dysfunction	7	1	0	0.23
PAF	4	1	0	0.60
CAF	6	4	1	0.71

BSA: body surface area, NYHA: New York Heart Association classification, MR: Mitral regurgitation, LVEF: left ventricular ejection fraction, HT: Hypertension, CAD: Coronary artery disease, CVD: cerebrovascular disease, PAD: Peripheral artery disease, CKD: Chronic kidney disease, PAF: paroxysmal atrium fibrillation, CAF: chronic atrium fibrillation.

Table 2. Operative data.

	Group A (n = 23)	Group R (n = 10)	Group AR (n = 4)	p-value
Artificial ring	23	10	4	-
Physio II	9	8	2	-
MEMO3D	13	2	2	-
Cosgrove	1	0	0	-
Average ring size (mm)	31.4 ± 2.0	30.0 ± 3.3	32.0 ± 1.6	0.24
Average number of artificial chordae	2.0 ± 0.8	0	1.5 ± 0.6	-
Anterior mitral leaflet disease	12	4	2	0.81
Concomitant procedure	18	8	2	0.45
AVR	2	1	1	-
TAP	18	8	2	-
Maze procedure	8	2	1	-
CABG	2	4	0	
Ascending aorta replacement	1	1	0	-

AVR: Aortic valve replacement, TAP: Tricuspid annuloplasty, CABG: Coronary artery bypass grafting.

The MPGs at discharge were 3.1 ± 1.8 mmHg, 3.3 ± 1.1 mmHg, and 2.0 ± 1.0 mmHg (p = 0.43) in groups A, R and AR, respectively. MR grade, MVA and MPG did not significantly differ between the three groups. At one year postoperatively, as well, echocardiography data on MR grade, MVA and MPG did not

Table 3. Echocardiography data after the operation.

	Group A	Group R	Group AR	p-value
MR grade At discharge	0.3 ± 0.4	0.8 ± 0.9	0.0 ± 0.0	0.07
After 1 year	0.7 ± 1.1	0.7 ± 0.5	0.8 ± 0.3	0.98
MVA (cm^2) At discharge	3.2 ± 0.6	2.9 ± 0.6	3.0 ± 0.6	0.47
After 1 year	2.6 ± 0.4	2.7 ± 0.6	2.4 ± 0.7	0.60
MPG (mmHg) At discharge	3.1 ± 1.8	3.3 ± 1.1	2.0 ± 1.0	0.43
After 1 year	3.5 ± 1.6	4.2 ± 2.4	4.8 ± 4.0	0.55

MR: mitral regurgitation, MVA: mitral valve area, MPG: mean transmitral pressure gradient.

significantly differ between the three groups. Overall survival rate at 5 years postoperatively in groups A, R and AR were 95.7%, 100% and 75% (p = 0.32), respectively. Cardiac disease-related death did not occur in any of the groups. Freedom from severe MR at 5 years postoperatively was seen in 91.7%, 90% and 100% of patients in groups A, R and AR, respectively (**Figure 2**), indicating no statistically significant difference between the three groups (p = 0.92). In terms of MR recurrence, one case in group A experienced recurrence due to new degenerative changes in the anterior mitral leaflet, while dehiscence of the suture line occurred in one case in group R. Both cases were treated with mitral valve replacement.

4. Discussion

The resection and suture technique based on the French correction advocated by Carpentier [1] is widely performed for surgical repair of posterior mitral leaflet prolapse. In this procedure, quadrangular resection of the prolapse area is performed and the edge of the cut leaflet is sutured with annular plication. If the height of the remnant is excessively tall, a sliding technique should be added [7]. Although a high degree of surgical skill is required, butterfly resection [8] [9] and hourglass resection [10] do not require annular compression sutures. Hence, their procedures may expect good hemodynamic results of the mitral valve [11]. If the prolapse area is small, triangular resection is used without annular plication [12]. Since the above techniques involve resection and suturing of the mitral valve leaflet, they carry the risk of future mitral valve stenosis. Dehiscence or thickening of the suture line is also a concern. Hence, the concept of "respect rather than resect", which involves restoring the leaflet as much as possible, has been recently advocated. By restoring the valve leaflet, its anatomical structure is maintained, so that a large mitral valve area and good hemodynamics are expected. This technique requires the use of artificial Gore-Tex chordae as the neochordae. The usefulness and durability of artificial Gore-Tex chordae in mitral valve repair for anterior mitral leaflet disease has already been demonstrated [13] [14].

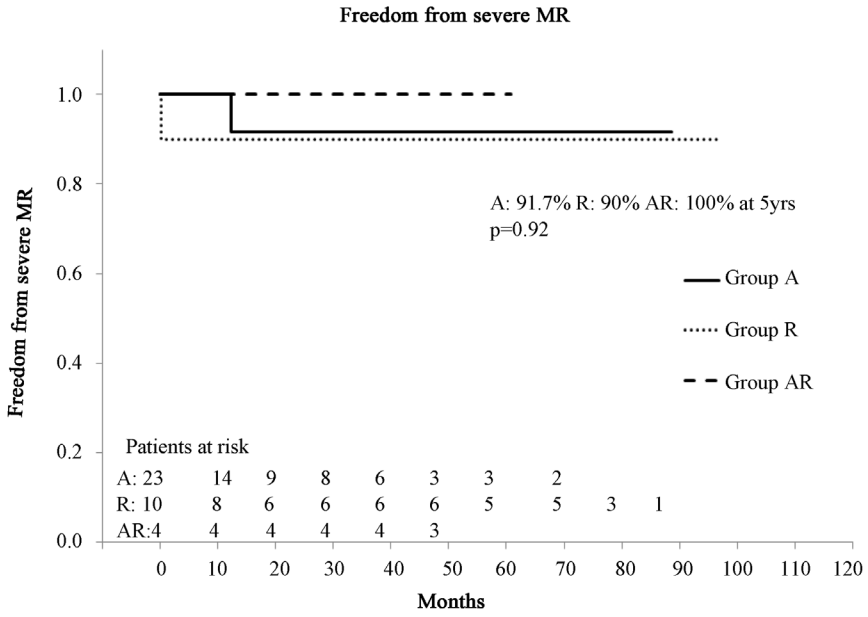

Figure 2. Freedom from severe MR. Resultant freedom from severe mitral valve regurgitation (MR) in the three groups. No significant differences were seen in the three groups at the 5-year follow up, with freedom from severe MR being seen in 91.7%, 90% and 100% of patients in Groups A, R and AR, respectively (p = 0.92).

Although adjustment of the appropriate artificial chordae length is reportedly difficult, the new anchoring technique and measured tube technique [6] make mitral valve repair using artificial chordae easier. The merit of the anchoring technique is that by anchoring CV-2 Gore-Tex sutures to the papillary muscle, multiple artificial chordae (CV-5 Gore-Tex sutures) can be easily attached to the mitral valve leaflet via the anchor. The benefit of the measured tube technique is that the use of a 12 Frazier suction tube cut to the same length as healthy native chordae prevents knot slippage and allows keeping the appropriate length of the chordae. Re-establishment of the artificial chordae is also easy because this technique does not involve resection of the valve leaflet. Currently, mitral valve repair has become the standard procedure for MR, which should, thus, be mastered by all cardiac surgeons. We consider the anchoring technique and measured tube technique as being safe, reliable and an easily reproducible technique. At present, we preferentially use this technique for repair of posterior leaflet disease.

Our study showed that there was no significant difference in postoperative echocardiographic data between the artificial chordae group and the resection and suture group. However, since the artificial chordae technique does not require resection of the valve leaflet, the repaired leaflet is expected to maintain its flexibility and a large mitral valve area. The report of Takai, *et al.* supports this theory [15]. Future studies should be performed to confirm the superiority of artificial chordae. On the other hand, the resection and suture technique, which was routinely performed at our hospital before introduction of the artificial

chordae technique, also has good long-term results (such as durability). Further, in some cases, such as those with leaflet destruction due to infective endocarditis, or cases with excessive tissue such as with Barlow's disease, leaflet resection is a necessity. Hence, the resection and suture technique is also a clinically useful procedure.

5. Conclusion

Both the artificial chordae technique and resection and suture technique produce equally favorable results following mitral valve repair for posterior leaflet disease. Further long-term analyses of these techniques are needed to confirm their utility.

6. Study Limitation

The study cohort was small, because mitral valve prolapse is not a very common condition. Further, echocardiography could not successfully assess all the relevant parameters in our study cohort.

Disclosure Statement

The Authors declare that there is no conflict of interest.

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