Research Article

International Journal of Cardiology Research & Reviews

Benefits in Simplicity of Folding Plasty for Mitral Valve Repair

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Received Date: 21 March 2024

Revised Date: 18 April 2024

Accepted Date: 28 April 2024

Publication Date: 04 May 2024

Abstract

Objectives: Although leaflet resection suture (RS) is the standard mitral valve (MV) repair in patients with degenerative MV regurgitation, folding plasty is an alternative method of MV repair. In this study, feasibility, reproducibility and postoperative mitral valve (MV) regurgitation were compared between leaflet resection suture (RS) and folding plasty (FP).

Methods: Seventy-nine patients with degenerative MV disease of posterior (PL) and commissure lesion (CL) were reviewed. Two techniques were compared in; (1) feasibility of MV repair, (2) how to control residual MV regurgitation found by saline test, and (3) postoperative MV regurgitation area (MRA).

Results: In PL, all patients in both groups underwent MV repair, and in CL, 8/9 (92%) in RS and 15/16 (94%) in FP underwent MV repair (p=0.667). In PL, 2/19 (11%) in RS required additional procedure (artificial chordae (2)), and 0/35 (0%) required additional procedure in FP (p=0.051). In CL, 6/8 (75%) in RS required additional procedure (artificial chordae (2), edge-to-edge (4)), and 0/15 (0%) required additional suture in FP (p<0.001). Redo-suture was not performed in RS, however, adjustment of the coaptation was dealt with redo-suture (posterior:57%, commissure: 56%) in FP. There were no differences in postoperative MRA. Ischemic time was shorter in FP than RS group (RS:103±24 min vs. 87±24 min, p=0.015).

Conclusions: Leaflet resection is a standard operative procedure, however, folding plasty is an effective alternative which has advantages in reproducibility, easiness in redo-suture when coaptation re-adjustment is required, and these advantages were significantly shown in CL.

Keywords

Mitral valve repair, Folding plasty.

INTRODUCTION

Since the introduction of French Correction by Alan Carpentier [1], quadrangular or triangular resection suture (RS) has been the standard surgical technique for mitral valve repair (MVP). RS had also been our routine technique for posterior leaflet and/or commissure region, however, we have experienced some technical difficulties: when residual regurgitation is found by saline test, coaptation was adjusted by additional surgical procedures such as edge-to-edge suture [2] or artificial chordae, and repetitive repair, i.e., redo suture was uneasy to perform, especially when excessive leaflet was resected.

In 1998, Grossi and colleagues reported 145 patients who underwent folding plasty (FP) for the posterior leaflet repair, including 3 patients with extending lesion of commissure leaflet [3]. Thereafter, many variations this technique have evolved and published [4-6]. Since October 2015, we have changed our surgical strategy of MVP from RS to FP. The purpose of this study was to compare between RS and FP in MV repair for posterior and commissure leaflet in feasibility, reproducibility, and control of postoperative MV regurgitation.

SUBJECTS AND METHODS

This study complies with the Declaration of Helsinki, and was approved by the Institutional Review Board of Showa University, school of medicine (IRB No.3123, approved on 2022.5.7). Patients have been given an opt-out information regarding this study. In this retrospective study, we reviewed 212 patients who underwent mitral valve surgery between October 2012 and July 2022. We had performed MV repair mainly by RS until October 2015, and FP was our preferred operative technique thereafter. In RS, quadrant leaflet resection with annuloplasty using 2-0 TiCron sutures was our standard procedure (Figure 1). In FP, the margin of the prolapsed leaflet was decided by inspection or saline test,

Citation: Tadashi Omoto, Atsushi Aoki, Kazuto Maruta, Akitoshi Takazawa, Tomoaki Masuda. Benefits in Simplicity of Folding Plasty for Mitral Valve Repair. Int J Cardiol Res Rev. 2024;1(1):1-4. DOI: 10.52106/3066-3431.1001.

and 5-0 prolene suture was placed on the normal leaflet adjunct with prolapsed segment. Then, the prolapsed leaflet is inverted underneath towards the left ventricular side, and sutured by double layers (Figure 2). In both technique, leaflet anatomy was evaluated by saline test at this point and redo suture or additional procedure was considered if leaflet coaptation seemed to be unsatisfactory. After appropriate leaflet coaptation was achieved, Cosgrove Edwards semi-rigid ring (Edwards Lifesciences, Irvine, Calif.) was implanted in both RS and FP. Ring size was selected according to the inter-trigonal distance after all annular sutures were placed.

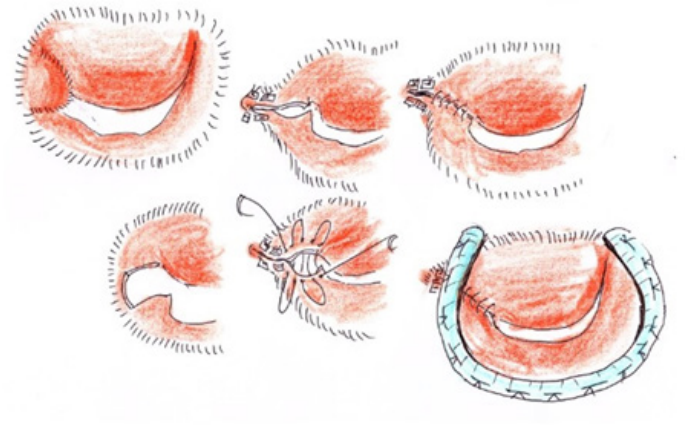

Figure 1: Resection suture in commissure lesion was composed of; annular plication by pledgeted 2-0 TiCron sutures, 5-0 prolene by double layers, and ring annuloplasty.

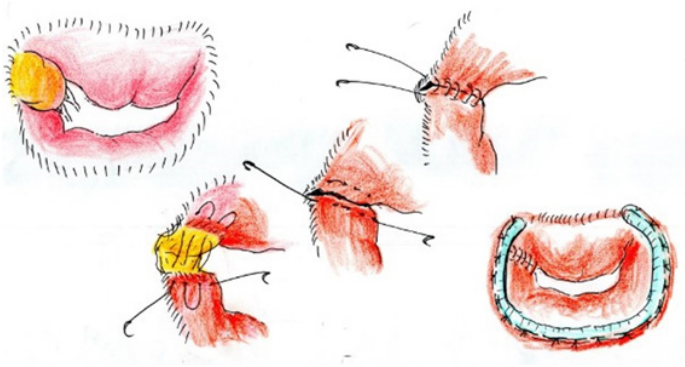

Figure 2: Folding plasty for commissure lesion; prolapsed lesion is inverted to the left ventricular side by the first layer of 5-0 prolene, and anastomosis was secured by the second layer. Annuloplasty ring (Cosgrove-Edwards) was always used.

Of reviewed 212 patients, there were 92 patients with degenerative mitral valve disease, and patients with infective endocarditis (n=28), mitral valve insufficiency secondary to atrial fibrillation (n=27), ischemic heart disease (n=11), aortic valve disease (n=17), calcified mitral valve including rheumatic disease (n=27), and cardiomyopathy (n=10) were excluded from this study. After excluding patients with anterior leaflet lesion (n=10) and bi-leaflet lesion (n=3), 79 patients with posterior and commissure lesion were enrolled in this study. Posterior lesion including commissure leaflet was categorized into commissure lesion. Following subjects were compared between patients who underwent RS (n=28) and FP (m=51) regarding following subjects;

1. Patient profiles
2. Feasibility of MV repair
3. How to control residual MV regurgitation found by saline test, i.e., whether redo suture after taking down the first anastomosis was performed, or additional procedure like edge to edge repair or artificial chordae was performed.
4. Postoperative MV regurgitation area (MRA), and MV morphology.
5. Used annuloplasty ring size in posterior and commissure repair

STS score [7] was used as predictive value of operative mortality. In order to assess the complexity of prolapse lesion for MV repair, "complexity score" was used. Complexity score, first advocated by Mount Sinai Hospital, assigns a score to each valve based on the following: prolapsing segments (weight 1 for each posterior segment; weight 2 for each anterior and commissural segment); presence of valve restriction (weight 2); presence of calcification (weight 3 if the annulus is involved; otherwise, weight 2); and prior mitral valve repair (weight 3) [8]. Postoperative MV regurgitation area (MRA) and MV morphology was evaluated by transthoracic echocardiogram, which performed 7-10 days after the surgery. MRA was measured by computerized planimetry in the frame the maximal jet area was seen by the parasternal long-axis view [9]. MV morphology was evaluated by MV orifice area (MOA), coaptation depth (CD) and tenting height (TH). MOA was calculated from pressure half-time obtained by continuous-wave Doppler. MOA index was calculated from MOA divided by the body surface area. CD was defined as the distance of overlap between the anterior and posterior mitral leaflet during systole, and TH was defined as the distance between the mitral annular plane and the most atrial margin of the coaptation zone [10]

Statistical analysis was performed using JMP Pro 13 (SAS Inc., NC, USA), and the demographic and clinical data were expressed as mean ± standard deviation or number (%). Baseline differences in categorical variables were tested using the Pearson χ^2 test, while analysis of variance was used for comparing differences in means among the groups. Fisher's exact test was used for comparisons of frequencies between the groups. Frequency of Values of $p<0.05$ were considered statistically significant.

RESULTS

The frequency of posterior lesion was 68% in both RS and FP group. There were no differences in patient profiles including operative risk and complexity of MV repair (Table 1). There were no differences in frequency of concomitant procedure between two groups, (Table 2). There were 13 patients in RS and 12 patients in FP who underwent only simple MV repair without any concomitant operation. and aortic cross-clamp time in simple MV repair was shorter in FP than RS (Table 2). In comparison of posterior repair (FP 8, RS 8), ischemic time was shorter in FP in RS (87±17 min. vs. 68±8, p=0.020). Due to small number (FP 4, RS 5), comparison of commissure repair could not effectively be performed; ischemic time was 52±36 min, and 107±34min, respectively.

Table 1: Patient's profile.

	RS (n=28)	FP (n=51)	P-value
Age (year)	66.5±12.9	69.1±10.2	0.383
Female	11 (39%)	20 (39%)	0.995
Height(cm)	161.0±9.8	161.4±10.5	0.931
Weight (kg)	56.4±11.8	59.1±12.3	0.378
BSA	1.6±0.2	1.6±0.3	0.403
STS Score	2.4±3.9	1.8±2.6	0.322
EF(%)	65±6	62±8	0.100
Complexity Score	2.4±1.5	2.0±1.4	0.274
Lesion			
Posterior	19 (68%)	35 (68%)	0.944
Commissure	9 (32%)	16 (32%)	0.944

BSA: body surface area, EF: left ventricular ejection fraction.

Table 2: Operative findings.

	RS (n=28)	FP (n=51)	P-value
Comcomitant Procedure	15(53%)	34 (67%)	0.251
CABG	1 (4%)	4 (8%)	0.456
AVR	1 (4%)	2 (4%)	0.938
TAP	13 (46%)	28 (55%)	0.471
MAZE	11 (39%)	17 (33%)	0.597
Procedure Time			
Ope Time	270±68	243±46	0.232
TPT	134±35	119±30	0.110
ACC	103±24	87±24	0.015
MVP only	13	12	
Ope Time	242±56	216±47	0.220
TPT	112±28	93±19	0.077
ACC	94±26	62±21	0.001

CABG: coronary artery bypass graft, AVR: aortic valve replacement, TAP: tricuspid valve annuloplasty, MAZE: Cox-maze IV procedure, Ope Time: operative time, TPT: total perfusion time, ACC: aortic cross-clamp time, MVP: mitral valve plasty.

In posterior, the used ring size was significantly different between RS and FP, and 28mm was most frequently used in FP, and 26mm in RS (Table 3). There were no significant differences in MOA index between RS and FS with ring of 26mm and 28mm (26mm: 1.7±0.3 vs. 1.8±0.2; p=0.905, 28mm: 1.7±0.5 vs.1.9±0.7; 0.815, respectively), and also there were no significant differences in MOA index between ring of 26mm and 28mm in RS and FP (p=0.905 and p=0.815, respectively).

Table 3: Mitral valve repair for posterior lesion. MVP: mitral valve repair, ring size: implanted Cosgrove-Edwards annuloplasty ring size.

Posterior Lesion

	RS (n=19)	FP(n=35)	P-value
MVP performed	19/19 (100%)	35/35(100%)	0.000
RS or FP only	17/19 (89%)	35/35(100%)	0.051
Additional Procedure	2/19 (11%)	0/33 (0%)	0.051
	Artificial chordae (2)		
Ring size			0.035
26	11/19 (58%)	9/35 (26%)	
28	5/19 (26%)	22/35 (62%)	
30	2/19 (11%)	3/35 (9%)	
32	1/19 (5%)	1/35 (3%)	

Table 4: Mitral valve repair for commissure lesion. MVP: mitral valve repair, ring size: implanted Cosgrove-Edwards annuloplasty ring size.

Commissure Lesion

	RS (n=9)	FP(n=16)	P-value
MVP performed	8/9 (92%)	15/16(94%)	0.667
RS or FP only	2/8 (25%)	15/15(100%)	<0.001
Additional Procedure	6/8	0/15	<0.001
	Edge to edge (4)		
	Artificial chordae (2)		
Ring size			0.353
26	2/8 (25%)	7/15(47%)	
28	4/8 (50%)	7/15(47%)	
30	2/8 (25%)	1/15 (7%)	

In posterior lesion (Table 3), all patients underwent MV repair (RS 19/19, vs FP 35/35). Two cases in RS (2/19, 11%) required additional artificial chordae implantation after saline test, however, there was no cases (0/35, 0%) in FP who required additional procedure (p=0.051). Redo-suture which performed after saline test was performed only in FP (20/35 (57%)). There were no differences between the two repair techniques in postoperative MRA, however, the frequency of MRA>1cm^2 was higher in RS than FP (32% vs. 6%; p=0.011). There were no differences in MV morphology in the two groups.

Table 5: Postoperative mitral valve regurgitation, morphology and function.

	RS	FP	P-value
Posterior Leaflet	n=19	n=33	
Coaptation Depth(mm)	0.90±0.17	0.90±0.16	0.399
Tenting Height(mm)	0.91±0.16	0.90±0.16	0.807
MRA (cm^2)	0.59±0.92	0.17±0.46	0.065
MRA >1cm^2	6/19 (32%)	2/33 (6%)	0.011
MOA (cm^2)	2.69±0.55	2.93±0.89	0.622
MOA Index	1.70±0.25	1.64±0.57	0.951
Commissure Leaflet	n=8	n=15	
Coaptation Depth(mm)	0.92±0.15	0.87±0.12	0.232
Tenting Height(mm)	0.90±0.19	0.82±0.19	0.245
MRA (cm^2)	1.6±2.2	0.5±0.9	0.354
MRA >1cm^2	4/8 (50%)	3/15 (20%)	0.136
MOA (cm^2)	2.8±0.4	2.8±0.5	0.852
MOAI	1.64±0.39	1.72±0.51	0.698

MRA: mitral regurgitation area, MOA: mitral valve orifice area.

In commissure lesion (Table 5), there was no difference in feasibility of MV repair (RS 8/9, 92% vs. FP 15/16, 94%; p=0.667). However, additional procedure was more frequently required in RS (6/8, 75%, edge to edge repair (6), artificial chordae (2)) than FP (0/15, 100%). Redo-suture which performed after saline test was performed only in FP (9/16 (56%)). Also, there were no differences between the two repair techniques in MV morphology, postoperative MRA and the frequency of MRA>1cm^2.

COMMENTS

Although leaflet resection has been the standard for surgical treatment of MV repair, FP has introduced and developed in some institutes, with technical modifications [3-6,11,12]. "Because it is fast and reproducible", FP is also applied to robotic MV plasty [13]. We have changed our surgical strategy from RS to FP because redo-suture became quite easier and safer by FP. If resected leaflet is not enough, the coaptation can be adjusted by redo-resection and suture, however, if too much leaflet was resected, it is unable to suture again.

Our study clearly showed the advantage of FP in feasibility of redo-suture. And this advantage was quite obvious in commissure leaflet repair. In RS, additional repair technique was often required, however, FP did not require additional procedure, and repaired simply only by FP.

RS for the posterior leaflet has been a standard MV repair technique in high repetitiveness, or uniformity, however, RS for the commissure lesion might not have been achieved similar technical effect. Anyanwu and colleagues studied the feasibility of MV repair in 667 patients according a complexity scoring scale, which demonstrated that commissure leaflet repair was demonstrated as more complex procedure than the simple posterior lesion [14]. For successful commissure leaflet repair, great caution should be taken in order not to cause anastomotic dehiscence between the anterior and

posterior leaflet because leaflet resection in commissure lesion often accompanies length differences between the cut edges. Additional repair technique, which was necessary in 70% in our series, should be appropriately performed. By RS techniques, if residual regurgitation from suture line was found by water test, whether artificial chordae on the edge of the anterior leaflet, or edge to edge suture between the anterior and posterior leaflet, should be concerned to reduce regurgitation (Figure 1). By FP techniques, if residual regurgitation was found, suture would be cut without any hesitation, and coaptation could be adjusted by redo suture based on the first-time suture (Figure 2). Additionally, ischemic time became shorter by changing repair strategy from RS to FP.

There were no differences in postoperative MV function or morphology between two repair techniques for commissure lesion. On the other hand, better control of residual MV regurgitation was demonstrated in FP for posterior lesion. Although it is unclear, there are two possibilities to explain the mechanism. First, it may be associated with high frequency of coaptation adjustment by redo-suture in FP group. In cases with FP, redo-suture can be repeatedly performed without hesitation, until optimal leaflet coaptation has been achieved. Second, the effects of annular ring might have differed between the two repair techniques. Annular plication is necessary in cases with RS, which might have altered mitral annular geometry and caused strain in the annulus after ring implantation. Also, the difference in annular geometry between the two operative techniques might be associated with the ring selection between the two groups; use of small size annular ring (26mm) was used less in FP than in RS. And, this phenomenon was not significant in commissure leaflet repair, possibly because RS in commissure repair usually required less plication length compared with RS in posterior repair. Theoretically, larger ring selection should have resulted in better MV function, however, there were no differences between the two groups in MOA or MOA index. The reason is unclear; it might be due to small sample size of this study, or it might be because MOA is associated with multiple factors including leaflet area or stiffness.

Technical uniformity is a great advantage in FP. In RS, incisional line of leaflet and annular basement may be varied according to the surgeons, and inadequate or excessive resection may occur even by experienced surgeon. However, surgical technique of FP can be similarly applied both to posterior and commissure lesion; pull the prolapsed lesion in order to define the suture line, invert the prolapsed lesion on the first layer and check whether the suture was appropriate or not. Higher technical uniformity resulted in reduced ischemic time, widened application of MV repair for various type of prolapse, additionally, easiness to learn for inexperienced surgeons. Redo-suture plasty for adjusting coaptation was safely performed in FP and ischemic time was reduced because of its technical simplicity which means potential benefit in minimally invasive surgery including robotic surgery.

CONCLUSIONS

For degenerative mitral valve regurgitation whether it is caused by posterior or commissural leaflet prolapse, folding plasty can be simply, uniformly applied, and highly feasible in redo-suture.

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