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Papillary Muscle Sandwich Plasty for the Treatment of Functional Mitral Valve Regurgitation

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We evaluated the availability of original ''sandwich plasty'' for the treatment of functional mitral regurgitation (FMR) associated with ischemic heart disease (IHD) and aortic valve disease (AVD). Forty-three patients were reviewed, including 27 IHD patients and 16 AVD patients. Preoperatively severe FMR was detected in 14 patients, moderate FMR in 26, and mild FMR in 3. The papillary muscle heads of anterior leaflets and posterior leaflets were approximated using Teflon-pledgeted 3-0 Ticron sutures at anterolateral and posteromedial commissural portions. After surgery, residual moderate FMR was observed in 1 patient and mild FMR in 3 patients. Tenting height of the mitral valve significantly decreased. FMR free rates 2 years after surgery were 93% among IHD patients and 83% in AVD patients. ''Sandwich plasty'' was simple and effective for the treatment of functional FMR caused by tethering effects due to left ventricular dilatation.

Key words: Mitral valve plasty – Sandwich plasty – Ischemic heart disease – Aortic valve replacement – Transaortic – Surgery

The cause of functional mitral regurgitation (FMR) is complicated because FMR results from a variable combination of annular dilatation and remodeling of the subvalvular apparatus. Various types of mitral valve plasty (MVP) techniques for FMR such as annuloplasty,[1] edge-to-edge technique,[2] and chordal cutting[3,4] have been reported. Although annular dilatation may be treated effectively, methods of addressing subvalvular remodeling have not been standardized. Therefore, new techniques are needed to attain better outcomes for patients with FMR.

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Table 1 Patient characteristics and operative procedures[a]

	Total	Percentage
Number of patients	43	
Male/female	31/12	
Age, y	68 ± 10 (range, 47–84)	
Ischemic/aortic	27/16	
Preoperative mitral regurgitation		
Severe	14	33
Moderate	26	60
Mild	3	7
Approach to mitral valve		
Left atrium	27	63
Aortic annulus	9	21
Left ventricle	7	16
Mitral ring annuloplasty	17	40
Physio-ring (full)	10	
Cosgrove ring (partial)	7	
Size of ring	27.9 ± 2.0 (range, 26–30)	
Other procedures		
No. of CABG grafts (n = 27)	2.7 ± 1.6 (range, 0–5)	
Aortic valve disease (n = 16)		
Stenosis/regurgitation	9/7	
Valve replacement/David surgery	15/1	
Carpentier-Edwards	10	
Stent-less bioprosthesis	5	
Concomitant procedures		
LV volume reduction	7	16
CRT	7	16
Radiofrequency maze	6	14
Tricuspid annuloplasty	5	12
LV outflow myomectomy	2	5
Aortic cross-clamp time, min	192 ± 71 (range, 71–390)	

LV, left ventricle.

[a]Values: mean ± SD.

The importance of papillary muscle displacement due to left ventricular dilatation in FMR has been recognized recently.[5] In 2004, we initiated an original papillary muscle head approximation procedure, often referred to as a ''sandwich plasty,'' for the treatment of FMR.[6] We adopted this procedure initially for the treatment of ischemic mitral regurgitation (IMR) and then for FMR associated with aortic valve disease (AVD), because the cause of FMR was a tethering effect due to dilatation of the left ventricle (which is similar in ischemic cardiomyopathy and AVD).

In this study, we examined early and midterm surgical results of papillary muscle sandwich plasty. Here we discuss the availability of this procedure for the treatment of FMR in patients with ischemic heart disease (IHD) and AVD.

Patients and Methods

Forty-three patients who underwent sandwich plasty were reviewed, including 27 IHD patients and 16 AVD patients (Table 1). Mean patient age was 67 ± 9 years, ranging from 47 to 84 years; 31 males and 12 females were included in the study. Scheduled operation was performed in 37 patients, and 6 patients underwent emergency surgery. The mean number of coronary artery bypass grafts in IHD patients was 2.7 ± 1.6. Predominant aortic valve diseases consisted of regurgitation (AR) in 9 patients and stenosis (AS) in 7 patients. Aortic valve replacement (AVR) was performed in 15 patients and David surgery in 1. A Carpentier-Edwards bioprosthesis was implanted in 10 patients and a stent-less bioprosthesis in 5. The size of the

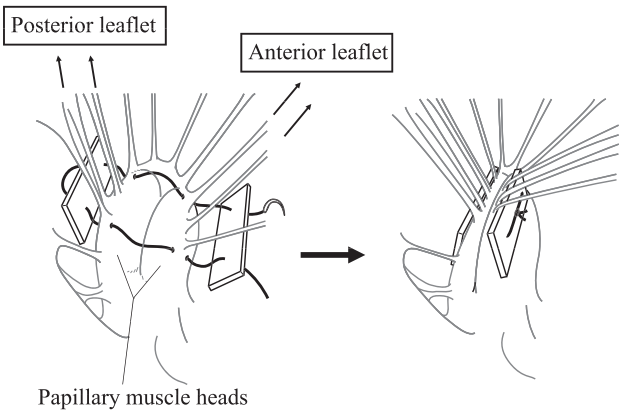

Fig. 1 Schema of transaortic papillary muscle plication. A Teflon-pledgeted 3-0 Ticron suture with a double-armed needle is passed through the papillary muscle head of the posterior leaflet and through the papillary muscle head of the anterior leaflet, reinforced with another Teflon patch.

prosthetic valve was 23 ± 2 mm, ranging from 21 to 28 mm. As concomitant operative procedures, left ventricle volume reduction was performed in 7 patients, cardiac resynchronization therapy (CRT) in 7, radiofrequency Maze procedure in 6, tricuspid annuloplasty in 5, and left ventricle outflow myomectomy in 2 (Table 1). Postoperative early and follow-up results were evaluated. The mean follow-up period was 20 months, ranging from 2 to 39 months.

Technique

Following anesthesia induction and using transesophageal echocardiography (TEE), we reconfirmed that the cause of FMR was a tethering effect due to dilatation of the left ventricle. The mitral valve was approached mainly through a left atrial incision in patients with IHD, and through the aortic valve annulus in patients with AVD. If an annular dilatation of 30 mm or larger was observed with TEE, we selected a left atrial approach for additional mitral ring annuloplasty. A conventional cardiopulmonary bypass was initiated with a left ventricular venting catheter, which was inserted via the right superior pulmonary vein. After aortic cross-clamping, the mitral valve was approached through the left atrium or the aortic incision. By close observation of the mitral valve, papillary muscles and chordae connected to the anterior mitral leaflet and posterior leaflet could be detected. Papillary muscle head approximations of the anterior and posterior mitral valve leaflets were performed to achieve coaptation of the 2 leaflets. At the anterolateral commissural portion, a Teflon-pledgeted 3-0 Ticron suture with a double-armed needle was passed through the papillary muscle head of the posterior leaflet and through the papillary muscle head of the anterior leaflet, then was reinforced with another Teflon patch (Fig. 1). The same approximation suture was made at the posteromedian commissural portion. In patients with mitral valve annular dilatation (n = 20), additional mitral ring annuloplasty was performed.

Statistics

Statistical analysis was conducted with StatView, version 5.0, software (SAS Institute Inc, Cary, North Carolina). Continuous data were expressed as mean ± SD. Student's *t*-test, the χ^2 test, Kaplan-Meier methods, and a log-rank test (Mantel-Cox) were used for statistical analysis. A *P* value less than 0.05 was considered significant.

Results

After surgery, FMR grades significantly ($P < 0.01$) decreased in all patients (Table 2). Residual moderate FMR was observed in a patient, and mild FMR was detected in 3 patients. Tenting height of the mitral valve significantly ($P < 0.01$) decreased from 12.0 ± 2.0 mm to 6.8 ± 1.5 mm. Regarding left ventricle geometry, left ventricle diastolic diameter significantly ($P < 0.05$) decreased from 55 ± 9 mm to 51 ± 10 mm after surgery. No significant changes in left ventricle systolic diameter, fractional shortening, or left ejection fraction were noted (Table 2).

Among patients with IHD, 1 died of heart failure, and the other 3 died of mediastinitis after surgery as the result of methicillin-resistant *Staphylococcus aureus*. All patients with AVD survived surgery with no serious complications. Late results were evaluated in 39 cases, including 23 IHD patients and 16 AVD patients. In the follow-up study, moderate FMR occurred in a patient (5%) with IHD, and 22 patients with IHD were free from prominent FMR. Prominent FMR was observed in 3 patients with AVD, including 1 who required redo mitral valve plasty because of chordae rupture. FMR free rates 2 years after surgery were 93% among IHD patients and 83% in AVD patients, according to Kaplan-Meier methods (Fig. 2).

Comment

The goal of sandwich plasty is reduction of the tethering effect achieved by fixing 2 heads of the

Table 2 Echocardiographic evaluation before and after surgery[a]

	Preoperative	Postoperative	*P*
Mitral regurgitation, n			< 0.01
Severe	14	0	
Moderate	26	1	
Mild	3	3	
Nontrivial	0	39	
Mitral valve geometry			
Annulus, mm	29.4 ± 3.1 (range, 23–~35)	25.9 ± 2.3 (range, 22–~29)	NS
Tenting height, mm	12.0 ± 2.0[b] (range, 11–~15)	6.8 ± 1.5[b] (range, 6–~10)	< 0.01
Left ventricle geometry			
LVDd, mm	55 ± 9[c] (range, 38–~78)	51 ± 10[c] (range, 33–~75)	< 0.05
LVDs, mm	43 ± 9 (range, 26–~63)	41 ± 11 (range, 22–~69)	NS
LVFS, %	24 ± 6 (range, 9–~33)	21 ± 7 (range, 8–~35)	NS
LVEF, %	47 ± 11 (range, 24–~66)	44 ± 12 (range, 22–~61)	NS

LVDd, left ventricle diastolic diameter; LVDs, left ventricle systolic diameter; LVEF, left ventricle ejection fraction; LVFS, left ventricle fractional shortening; NS, not significant.

[a]Values: mean ± SD.

[b]$P < 0.01$ (preoperative versus postoperative).

[c]$P < 0.05$ (preoperative versus postoperative).

papillary muscle connected to the chordae of the anterior and posterior leaflets. Generally, the length of the chordae does not change in FMR; thus approximations of papillary muscle heads achieve recovery of good coaptation of anterior and posterior leaflets. Sandwich plasty is a simple procedure for which no contraindications in terms of left ventricular size, tenting height, or tenting area have been identified. However, strong anatomic variances may obstruct this procedure because the balance of the papillary muscle and the connecting chordae is very important. Ramsheyi *et al*[7] morphologically classified mitral papillary muscles into 4 types.

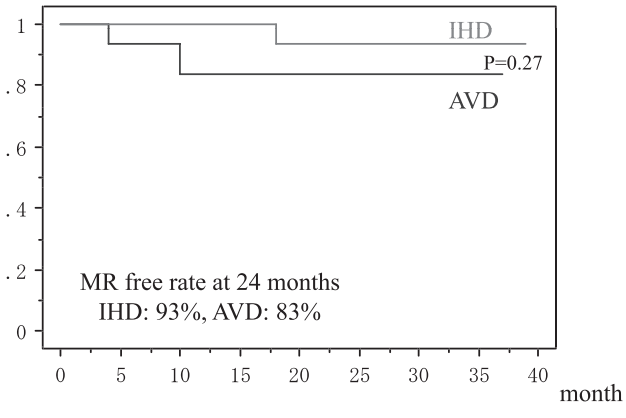

Fig. 2 Free from mitral regurgitation in the follow-up period. Mitral regurgitation free rates 2 years after surgery were 93% in IHD patients and 83% in AVD patients, according to Kaplan-Meier methods.

Among these, a single papillary muscle (type 1) might be a technically challenging target for sandwich plasty, because fixing the huge heads of the papillary muscle might be technically difficult.

Given the importance of papillary muscle displacement in FMR,[5] several procedures for papillary muscle repositioning have been reported. Hvass *et al*[8] reported a simple procedure named the papillary muscle sling method, which created close contact with both papillary muscles using a Gore-Tex tube sling. Menicanti *et al*[9] described the papillary muscle imbrication procedure without mitral ring. Arai *et al*[10] also reported on the efficacy of the mitral complex remodeling procedure, which consists of 3 major components: division and reconstruction of secondary chords, undersized annuloplasty, and bilateral papillary muscle relocation.

The coaptation zone of mitral leaflets increases after fixation of the papillary muscle heads; thus mitral valve leakage usually disappears during intraoperative testing. In the initial period, we did not use the mitral annular ring because we thought sufficient coaptation could be attained with sandwich plasty. We now believe that annular dilatation is not a functional, but a structural, change in the mitral valve, and that mitral valve annular dilatation seems to remain unchanged after surgery. In recent cases with a mitral valve annulus of 30 mm or larger, we performed mitral ring annuloplasty to maintain a sufficient coaptation zone in a beating heart and to prevent continued annular dilatation.

Surgical procedures for coronary artery bypass grafting (CABG) have been almost standardized, including off-pump CABG. The biggest concern at this point is how to manage ischemic cardiomyopathy, which includes treatment for coronary artery disease, mitral valve regurgitation, a dilated heart, and impaired cardiac function. Among these, treatment of IMR is the first valuable step, because IMR is recognized as a common cause of congestive heart failure, caused by the process of myocardial infarction remodeling. Before the induction of sandwich plasty, we used to perform other MVP procedures, such as the Alfieri procedure (edge-to-edge repair) and chordal reconstruction. However, postoperative results were not acceptable. The FMR free rate after sandwich plasty was considered satisfactory in the follow-up study.

Mitral regurgitation (MR) is often clinically present in patients with AVD. According to previous reports, the incidence of MR ranged between 65% and 75% in patients who underwent AVR.[11] Indications for mitral valve surgery in patients undergoing AVR remain controversial. Natural reduction in MR caused by left ventricular recovery after AVR has been reported. However, most previous study populations were limited to patients with AS.[12,13] Ruel *et al*[14] reported on risk factors of heart failure and persistent MR after AVR. In their report, FMR greater than grade 2 and left atrial diameter larger than 5 cm, preoperative peak aortic valve gradient less than 60 mmHg, and atrial fibrillation were risk factors for CHF and persistent mitral regurgitation after AVR in AS patients; FMR greater than grade 2 and left ventricular end-systolic diameter less than 45 mm were risk factors in AR patients. We believe that sandwich plasty is a simple procedure and thus may be indicated in the treatment of patients with the possibility of postoperative heart failure and persistent MR. Besides good surgical results, another advantage of sandwich plasty is reduced operative time due to the transaortic approach used for patients with AVD. Transaortic mitral valve plasty for FMR has not become popular, probably because complicated procedures are difficult to perform through the narrow aortic valve annulus. Simple procedures through aortic root, transaortic edge-to-edge repair (Alfieri stitch),[15,16] the chordal cutting technique,[17] and the posterior mitral annuloplasty method[18] have been reported. However, the best surgical intervention is the topic of ongoing debate.

Ventricular remodeling surgery is reported as an effective procedure for surgical relocation of the posterior papillary muscle tip in the setting of a severely dilated left ventricle.[19] Matsui *et al*[20] reported on the efficacy of overlapping ventriculoplasty combined with papillary muscle plication in patients with a severely dilated heart. Suma *et al*[21] described the selection of a suitable surgical procedure for end-stage cardiomyopathy based on an intraoperative echocardiography evaluation. In combined surgery, selected multiple procedures need to be completed within a limited time. The results of our sandwich plasty were favorable; however, the greatest advantage of this method is the simplicity of the procedure itself.

In conclusion, ''sandwich plasty'' is considered to be a simple and effective procedure for the treatment of FMR associated with IHD and AVD. A transaortic approach should be considered to obviate a separate left atriotomy and to reduce operative time in patients with AVD.

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References

1. McGee EC, Gillinov AM, Blackstone EH, Rajeswaran J, Cohen G, Najam F *et al*. Recurrent mitral regurgitation after annuloplasty for functional ischemic mitral regurgitation. *J Thorac Cardiovasc Surg* 2004;**128**(6):916–924
2. De Bonis M, Lapenna E, La Canna G, Ficarra E, Pagliaro M, Torracca L *et al*. Mitral valve repair for functional mitral regurgitation in end-stage dilated cardiomyopathy: role of the ''edge-to-edge'' technique. *Circulation* 2005;**112** (9 suppl):1402–1408
3. Fayad G, Modine T, Le Tourneau T, Ficarra E, Pagliaro M, Torracca L *et al*. Chordal cutting technique through aortotomy: a new approach to treat chronic ischemic mitral regurgitation. *J Thorac Cardiovasc Surg* 2005;**129**(5):1173–1174
4. Fukuoka M, Nonaka M, Masuyama S, Shimamoto T, Tambara K, Yoshida H *et al*. Chordal ''translocation'' for functional mitral regurgitation with severe valve tenting: an effort to preserve left ventricular structure and function. *Thorac Cardiovasc Surg* 2007;**133**(4):1004–1011
5. Tibayan FA, Rodriguez F, Zasio MK, Bailey L, Liang D, Daughters GT *et al*. Geometric distortions of the mitral valvular-ventricular complex in chronic ischemic mitral regurgitation. *Circulation* 2003;**108**(suppl 1):II-116–II-121
6. Ishikawa S, Ueda K, Kawasaki A, Neya K, Suzuki H. Papillary muscle sandwich plasty for ischemic mitral regurgitation: a

new simple technique. *J Thorac Cardiovasc Surg* 2008;**135**(6): 1384–1386
7. Ramsheyi SA, Pargaonkar S, Lassau JP, Acar C. Morphologic classification of the mitral papillary muscles. *J Heart Valve Dis* 1996;**5**(5):472–476
8. Hvass U, Tapia M, Baron F, Pouzet B, Shafy A. Papillary muscle sling: a new functional approach to mitral repair in patients with ischemic left ventricular dysfunction and functional mitral regurgitation. *Ann Thorac Surg* 2003;**75**(3):809–811
9. Menicanti L, Di Donato M, Frigiola A, Buckberg G, Santambrogio C, Ranucci M *et al*; RESTORE Group. Ischemic mitral regurgitation: intraventricular papillary muscle imbrication without mitral ring during left ventricular restoration. *J Thorac Cardiovasc Surg* 2002;**123**(6):1041–1050
10. Arai H, Itoh F, Someya T, Oi K, Tamura K, Tanaka H. New surgical procedure for ischemic/functional mitral regurgitation: mitral complex remodeling. *Ann Thorac Surg* 2008;**85**(5): 1820–1822
11. Torracca L, Verzini A, De Bonis M, Alfieri O. Influence of concomitant mitral valve dysfunction on survival after aortic valve replacement. *J Cardiovasc Surg (Torino)* 2007;**48**(6):797–800
12. Tassan-Mangina S, Metz D, Nazeyllas P, Torossian F, Pop C, Bertrand J *et al*. Factors determining early improvement in mitral regurgitation after aortic valve replacement for aortic valve stenosis: a transthoracic and transesophageal prospective study. *Clin Cardiol* 2003;**26**(3):127–131
13. Christenson JT, Jordan B, Bloch A, Schmuziger M. Should a regurgitant mitral valve be replaced simultaneously with a stenotic aortic valve? *Tex Heart Inst J* 2000;**27**(4):350–355
14. Ruel M, Kapila V, Price J, Kulik A, Burwash IG, Mesana TG. Natural history and predictors of outcome in patients with concomitant functional mitral regurgitation at the time of aortic valve replacement. *Circulation* 2006;**114**(1 suppl):I-541–I-1546
15. Kavarana MN, Edwards NM, Levinson MM, Oz MC. Transaortic repair of mitral regurgitation. *Heart Surg Forum* 2000;**3**(1):24–28
16. Källner G, van der Linden J, Hadjinikolaou L, Lindblom D. Transaortic approach for the Alfieri stitch. *Ann Thorac Surg* 2001;**71**(1):378–379
17. Fayad G, Modine T, Le Tourneau T, Al-Ruzzeh S, Ennezat PV, Decoene C *et al*. Chordal cutting technique through aortotomy: a new approach to treat chronic ischemic mitral regurgitation. *J Thorac Cardiovasc Surg* 2005;**129**(5):1173–1174
18. Matsumoto H, Sakata R, Kinjo T, Iguro Y. Posterior mitral annuloplasty through the aortic root. *Ann Thorac Cardiovasc Surg* 2005;**11**(4):264–266
19. Kron IL, Green GR, Cope JT. Surgical relocation of the posterior papillary muscle in chronic ischemic mitral regurgitation. *Ann Thorac Surg* 2002;**74**(2):600–601
20. Matsui Y, Fukada Y, Naito Y, Sasaki S. Integrated overlapping ventriculoplasty combined with papillary muscle plication for severely dilated heart failure. *J Thorac Cardiovasc Surg* 2004;**127**(4):1221–1223
21. Suma H, Isomura T, Horii T, Sato T, Kikuchi N, Iwahashi K *et al*. Nontransplant cardiac surgery for end-stage cardiomyopathy. *J Thorac Cardiovasc Surg* 2000;**119**(6):1233–1244