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ORIGINAL ARTICLE

Seamless reconstruction of mitral leaflet and chordae with one piece of pericardium

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Abstract

OBJECTIVES: Mitral valve repair is challenging when enough pliable mitral leaflets and chordae are not left intact because of extensive infective endocarditis or chronic sclerotic degeneration. For those cases, we developed a simple method to reconstruct defective leaflets and chordae en bloc with a piece of pericardium, and the mid-term results were evaluated.

METHODS: From January 2009 to November 2013, 25 patients with the mean age of 63 (range 20–88) years underwent this operation. The causes of mitral regurgitation were infective endocarditis in 8, sclerotic degeneration in 8, leaflet dehiscence of previous repair in 2, mitral annular calcification in 3, rheumatic in 2 and congenital in 2. After complete debridement of infected or consolidated tissue, we reconstructed defective mitral leaflets and chordae en bloc with a piece of glutaraldehyde-treated autologous pericardium. To substitute posterior leaflet and chordae, the pericardium was trimmed into a narrow pentagonal shape. The pointed end was attached directly to the corresponding papillary muscle, basal side edges to remnant leaflets on both sides, and the base to the annulus. For anterior leaflet, the pericardium was trimmed into a triangular shape if the lesion was confined in the left or right half or into a double-triangle shape if the lesion involved whole anterior leaflet. The summit of triangle was fixed to corresponding papillary muscle, and the base to remnant anterior leaflet, thus reconstructing coaptation zone and chordae seamlessly.

RESULTS: There was no hospital death, and mitral regurgitation at discharge was none or trivial in all patients. During 1–59 months (mean 12.7) of complete follow-up, death, infection or hemolysis was not observed. In one patient, mitral regurgitation recurred 8 months postoperatively because the fixation suture of the pericardium to the papillary muscle broke. The valve was re-repaired with re-attaching the leg of the pericardium. Regurgitation was less than moderate in all other patients. One patient with rheumatic lesion who underwent anterior leaflet repair and Maze operation suffered minor stroke 1 month postoperatively but fully recovered.

CONCLUSIONS: Seamless reconstruction of leaflets and chordae with pericardium seemed promising to repair extensively destructed mitral valve.

Keywords: Endocarditis • Mitral valve repair • Pericardium

INTRODUCTION

Mitral valve plasty for Carpentier's type II lesion with sufficient pliable leaflet tissue has been almost established using the resection and suture technique, and/or Gore-Tex (W.L Gore & Associates, Newark, DE, USA) artificial chordae [1]. However, in surgery for active infective endocarditis, for example, extensive defect of leaflet and that of corresponding chordae sometimes occur after debridement of infected tissue. Because direct approximation of remnant healthy tissues could lead to undue deformity of mitral valve, supplementation of leaflet tissue and reconstruction of chordae for successful repair are necessary. Glutaraldehyde-treated autologous pericardium (GTAP) has commonly been used for supplementation of leaflets, and its durability is reportedly promising with a very low rate of calcification, shrinkage or disruption [2–4]. Contrary to its well-established position as a substitute for mitral leaflet, GTAP is now rarely used as a substitute for chordae tendineae. However, if GTAP is used as artificial chordae in a sheet shape as it is used as artificial leaflet, it could potentially show durability similar to that in the case of supplementation of leaflet. Therefore, we hypothesized that when reconstruction of mitral leaflet and corresponding chordae is necessary in complex mitral plasty, they could be seamlessly substituted with a piece of GTAP in a very simple way, instead of being reconstructed using two different materials: GTAP for leaflets and Gore-Tex for chordae.

PATIENTS AND METHODS

The Institutional Review Board at our institutions approved this retrospective study. Consent for this study from each patient was

Table 1: Preoperative patient demographics and operative data

Variables	*n* = 25
Age; mean ± SD (range)	63 ± 16.3 (20–88)
Male gender	9
History of cardiac surgery	2
NHHA ≥ III	16
Hemodialysis	1
MR/MSR/MS	23/1/1
Atrial fibrillation	9
Aetiology of mitral lesion	
Endocarditis; active/healed	6/2
Consolidating degeneration	8
Rheumatic	2
Mitral annular calcification	3
Congenital	2
Dehiscence of previous repair	2
Operative data	
Sternotomy/mini thoracotomy	15/10
Aortic cross clamp time (min; mean ± SD)	144 ± 39
Cardiopulmonary bypass time (min; mean ± SD)	187 ± 55
Concomitant Maze/TAP/AVR	8/13/2
Prosthetic ring size; mean(range), *n* = 17	30 (28–32)

MR: mitral regurgitation; MSR: mitral stenosis and regurgitation; MS: mitral stenosis; TAP: tricuspid annuloplasty; AVR: aortic valve replacement.

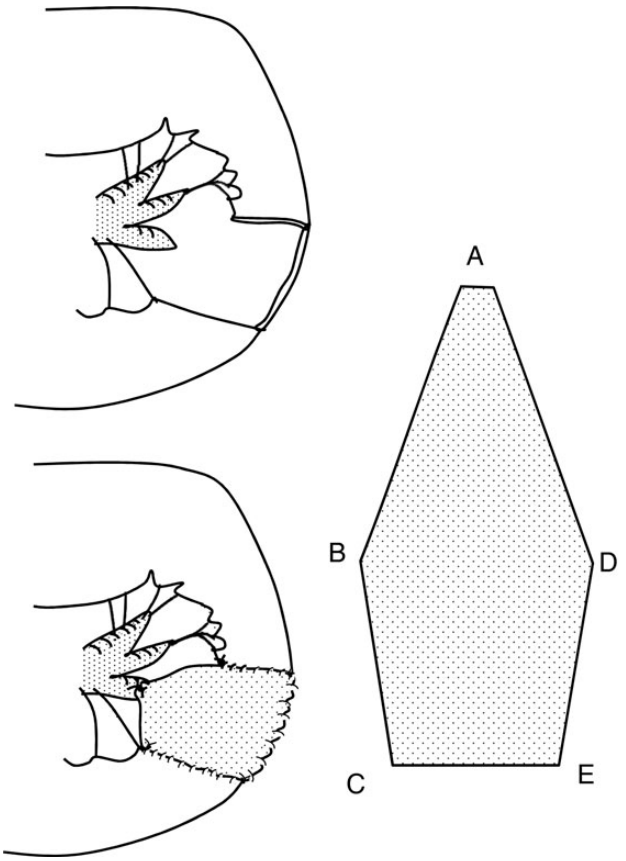

Figure 1: Glutaraldehyde-treated autologous pericardium was trimmed into a narrow pentagon shape. The sharp point (A) was directly attached to either the anterior or posterior papillary muscle according to the location of the defective leaflet. The side edges (BC, DE) and basal edge (CE) were sutured to the remnant leaflets and the annulus.

waived because of the retrospective nature of this study. General informed consent was obtained from each patient prior to surgery. Patients' demographic and operative data are shown in Table 1. The first patient [5], a 20-year-old woman, underwent this procedure as a bail-out technique in urgent surgery for extensive active endocarditis to avoid valve replacement in January 2009. Encouraged by favourable mid-term results in 3 young patients with active endocarditis operated on during 2009, we eventually extended the indication for this procedure to elderly patients and to other mitral lesions. Between January 2009 and November 2013, 305 patients underwent mitral valve plasty at our institutions. Of them, 25 patients underwent this type of surgery. Conventional repair techniques, for example, resection and suture, Gore-Tex artificial chordae and ring annuloplasty, were preferred first, and these techniques were indicated only when valve repair was impossible or seemed very difficult because of loss of enough pliable leaflet tissue and corresponding chordae. Most prevalent indication for this procedure was extensive loss of leaflet and chordae due to endocarditis. Other indications were re-do plasty and Carpentier's type IIIa lesion because of consolidating degeneration, mitral annular calcification extending to the leaflets and congenital mitral disease.

Technique

The mitral valve was approached via a median sternotomy and standard cardio-pulmonary bypass in 15 patients and via a small right thoracotomy and femoro-femoral bypass in 10. Autologous pericardium was harvested and treated with 0.6% glutaraldehyde for 10 min. In one re-do case, bovine pericardium (Edwards Life Science, Irvine, CA, USA) was used instead because adequately sized autologous pericardium could not be obtained. In patients with active endocarditis, infected mitral tissues were completely resected first. Also in patients having calcified or consolidated leaflets and chordae, diseased leaflets and chordae were trimmed off. After debridement of infected or consolidated tissue not appropriate for subsequent reconstruction, this technique was indicated when coaptation zone of the leaflets and corresponding chordae became widely defective in 2 or more mitral segments by Carpentier's classification.

The repair technique was modified according to the location of the lesion: posterior, commissure or anterior leaflet.

Firstly, as the basic technique for reconstruction of posterior leaflet and chordae, harvested pericardium was trimmed into a narrow pentagon shape (Fig. 1). The trapezoidal lower half of the narrow pentagon corresponded to neo-leaflet and the upper triangular part to chordae tendineae. The height of pericardium was adjusted to that of adjacent normal leaflets and chordae when they keep normal structure. When leaflet augmentation was intended to replace consolidated leaflet and chordae, the total height of the pericardium was trimmed about 1–1.5 cm longer than the distance between the mitral annulus and the papillary muscle. As a result, the total height of the pentagonal pericardium became 4-5 cm. The width of the base was adjusted to that of the defective leaflet after placing several annular compression sutures if appropriate. The tip of the pericardium was directly attached to the corresponding papillary muscle with a pledgeted CV4 Gore-Tex or 4–0 polypropylene mattress suture. The side edges were then sutured to the remnant leaflets on both sides with 5-0 polypropylene sutures. The base of the pericardium was sutured to the annulus with 5-0 or 4-0 polypropylene sutures, thus

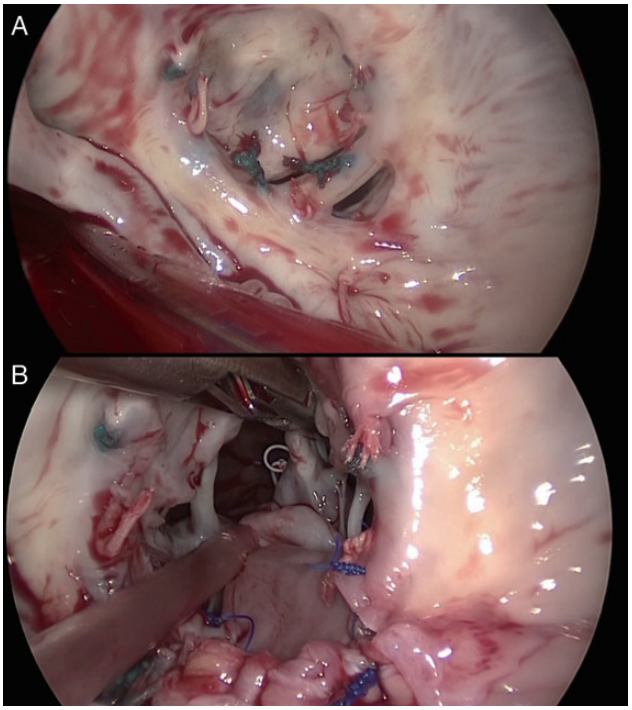

Figure 2: A 40-year-old woman who underwent previous extensive resection and suture repair of P2 and P3 for endocarditis showed dehiscence of posterior leaflet and flexible ring 9 months after initial operation (**A**). A gap in the posterior leaflet was supplemented using pentagon autologous pericardium. The tip of the pericardium was fixed to the dorsal surface of the posterior papillary muscle (**B**).

reconstructing the defective leaflets and chordae en bloc. In two re-do cases for dehiscence of the previous resection and suture repair on the posterior leaflet, a gap between the leaflets was supplemented in the same manner (Fig. 2). To reconstruct wider area of the posterior leaflet, the autologous pericardium was trimmed into the shape of double pentagons joined in parallel (Fig. 3). One head of the pericardium was attached to the anterior papillary muscle and the other to the posterior papillary muscle. The rest of the procedures were completed in the same manner.

Secondly, for extensive commissural lesion because of endocarditis, wide triangle-shaped pericardium was used to supplement the defective area between A3 and P3 across the posterior commissure (Fig. 4). The anterior part of the pericardial patch acted as part of the anterior leaflet and the posterior part acted as part of the posterior leaflet, being naturally folded at the commissure area, as shown on postoperative echocardiography.

Finally for anterior leaflet, this technique was indicated when rough zone and corresponding chordae were lost extensively because of endocarditis. Also for type IIIa lesion with consolidated rough zone and chordal fusion and thickening, this technique was indicated after shaving off consolidated chordae and rough zone.

A basic unit to reconstruct anterior leaflet and chordae was a triangle-shaped pericardium. When the lesion was located in the right or left half of the anterior leaflet, the summit of triangule-shaped pericardium was attached to the corresponding papillary muscle. Then the base of the triangle was sutured to the remnant of the anterior leaflet using interrupted 5–0 polypropylene sutures, thus reconstructing rough zone and chordae seamlessly (Fig. 5). Usually, the height of the triangle was 3–3.5 cm. When whole anterior leaflet and chordae were diffusely affected, the

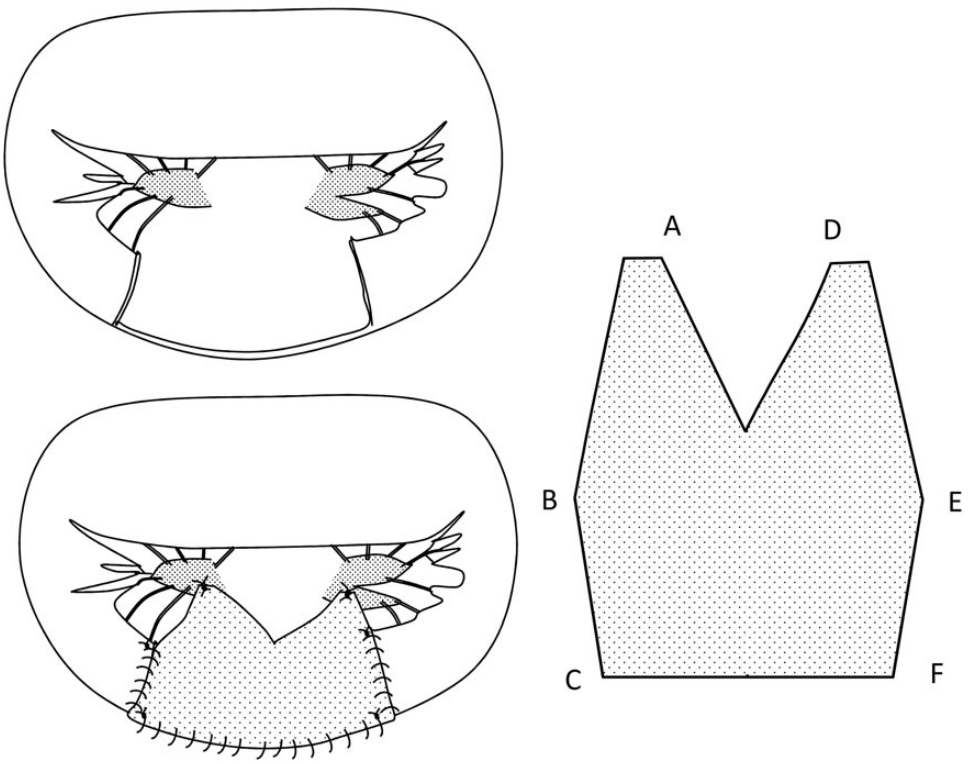

Figure 3: Autologous pericardium was trimmed into a double-pentagon shape. One head (A) was sutured to the anterior papillary muscle and the other (D) was sutured to the posterior papillary muscle.

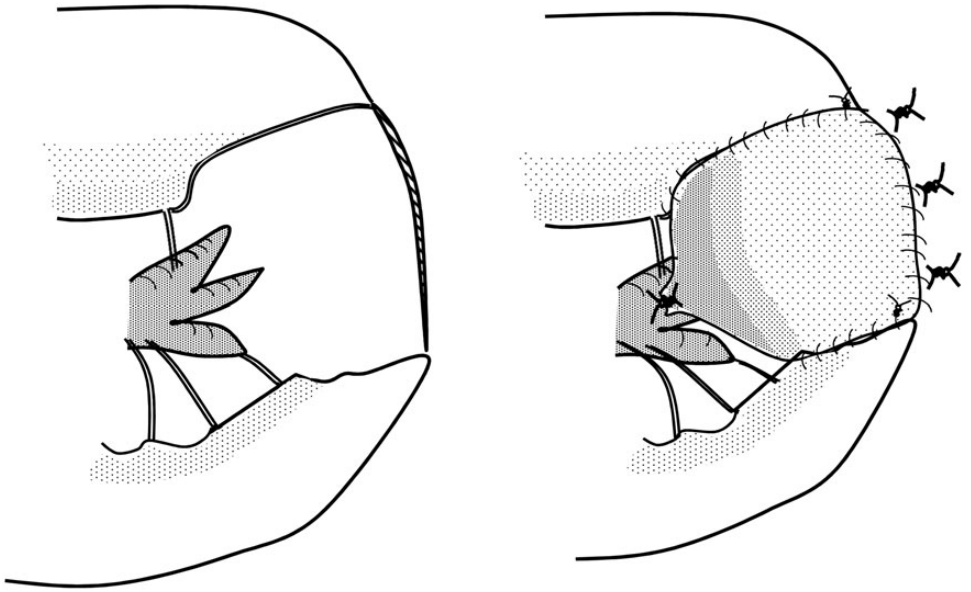

Figure 4: When the leaflet became defective across the commissure area, one piece of wide triangle-shaped pericardium was used to reconstruct the anterior, commissure and posterior leaflets en bloc.

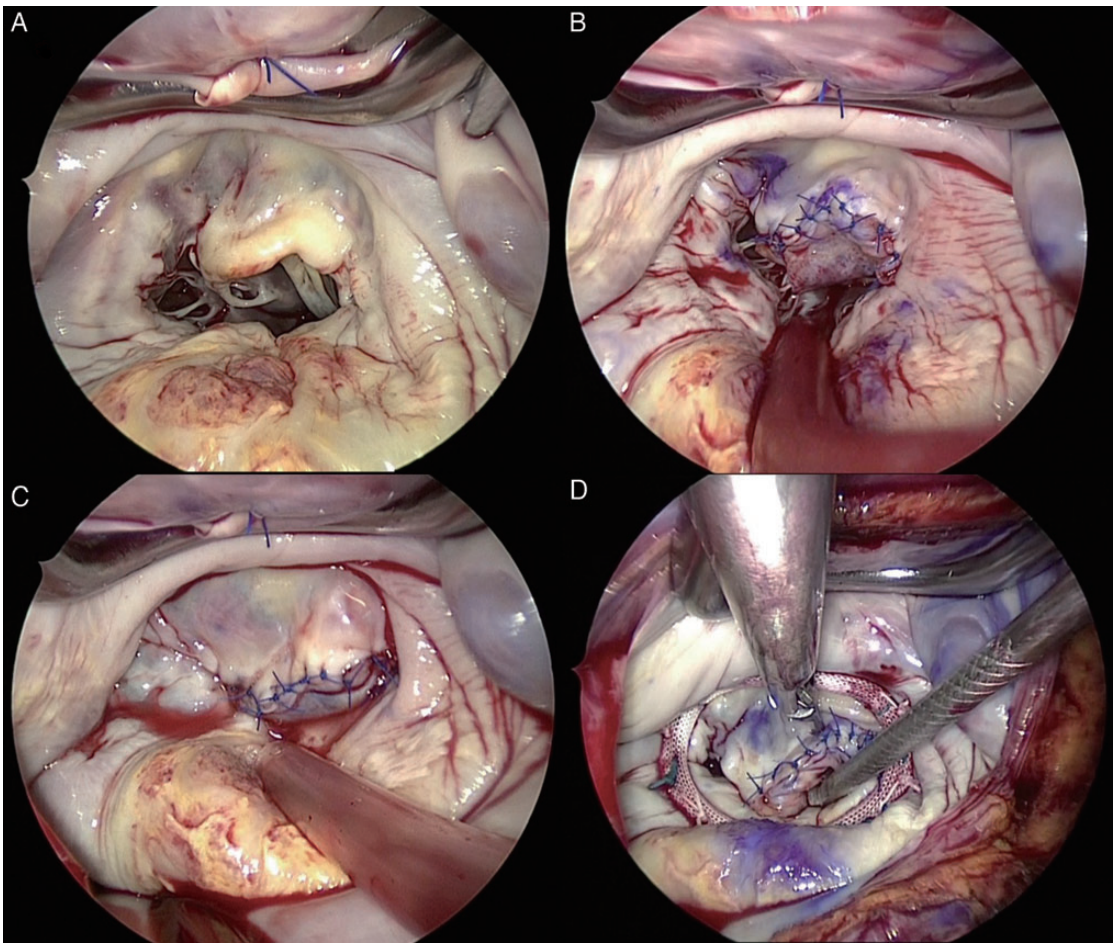

Figure 5: A 63-year-old woman with mitral regurgitation because of treated endocarditis 30 years ago underwent repair of mitral valve through right small thoracotomy. All marginal chordae tendineae arising from the posterior papillary muscle and connected to the anterior leaflet disappeared leaving only one thickened secondary chorda. Thickening and shrinkage of the rough zone of A2 and A3, jet lesion in the opposing posterior leaflet and the posterior atrial wall were observed (**A**). The base of the triangle-shaped pericardium was sutured to the rough zone from A2 to A3 with interrupted 5–0 sutures and the summit to the posterior papillary muscle (**B**). Saline test showed competent valve (**C**). A 30-sized Carpentier Edwards Physio II ring was placed (**D**).

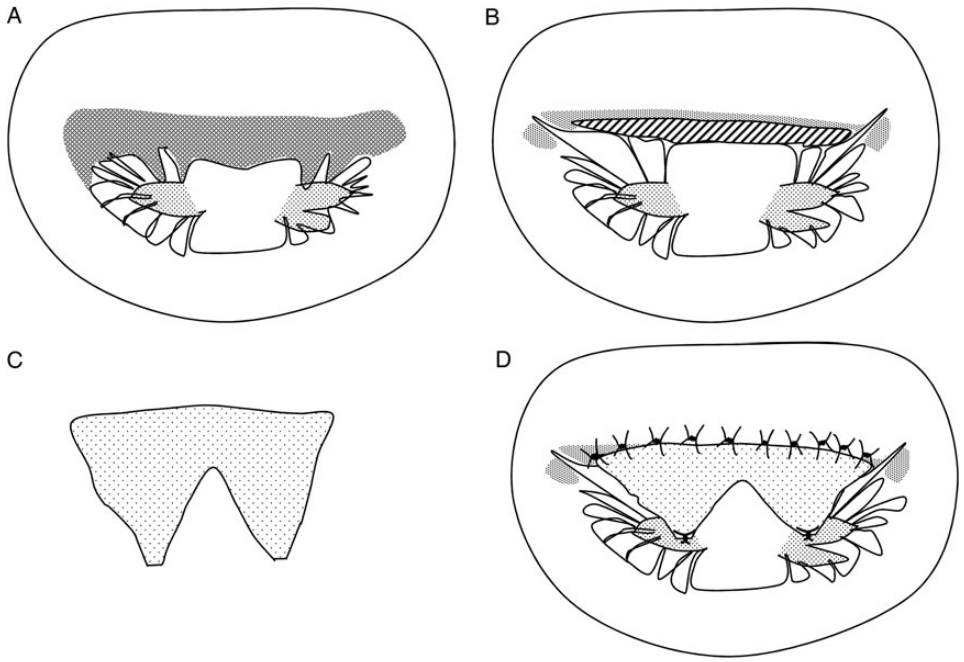

Figure 6: For diffuse type IIIa lesion with thickening and fusion of rough zone and chordae (**A**), diseased chordae were cut and the rough zone was shaved off (**B**). A "W"-pericardium (**C**) was sutured to both papillary muscle and the remnant edge of the anterior leaflet to construct pliable coaptation zone and chordae seamlessly (**D**).

pericardium was trimmed into a "W" shape joining two triangles in parallel. Each summit of the double triangle-shaped pericardium was attached to anterior and posterior papillary muscle and the base to remnant anterior leaflet after debridement of sclerotic rough zone (Fig. 6).

Reconstruction techniques depending on the type and location of the lesions are summarized in Table 2.

Size of prosthetic ring was decided according to inter-trigon distance in the usual manner. Undersized annuloplasty was not performed in any case because sufficient leaflet tissue was created with the pericardium. In active endocarditis or in type IIIa lesions accompanying stenosis, prosthetic ring was not used as long as valve competence was obtained without it.

Postoperative care and patient follow-up

Anticoagulation with warfarin was continued during the first three months postoperatively and continued thereafter if the patient had atrial fibrillation. Transthoracic echocardiography was recorded before discharge, and at out-patient follow-up. Data of latest study were employed.

Statistical data were calculated using SPSS 17.0 (IBM Japan, Tokyo, Japan).

RESULTS

All patients were discharged on foot. There was no stroke, wound infection, re-exploration for bleeding or respiratory failure. Operative data are summarized in Table 1. No patient was converted to valve replacement. In 18 patients, this procedure was employed after attempted repair with conventional techniques, which prolonged average procedure time. Two patients underwent second run of cardiopulmonary bypass because of residual leak. One was repaired with additional stitches on the suture line of the pericardium and one with an edge-to-edge stitch at commissure.

Table 2: Reconstruction technique depending on the type and location of the lesions

Location	Shape of pericardium	Type of lesion (number of cases)
Anterior leaflet	Triangle	Healed IE (1), Consolidating deg. (1), Congenital MS (1),
	Double triangles	Consolidating deg. (1), Rheumatic (2) Congenital cleft (1),
Commissure	Wide triangle	Active IE (3)
Posterior	Narrow pentagon	Active IE (1), redo (2), MAC (2), healed IE (1)
	Double pentagons	Consolidating deg. (4), Active IE (2), MAC (1), Consolidating deg. (2)

IE: infectious endocarditis; MAC: mitral annular calcification; MS: mitral stenosis; deg.: degeneration.

Five of 8 patients who underwent Maze procedure were converted to sinus rhythm. As a result, 4 patient had post-operative atrial fibrillation and received continual anti-coagulation.

During follow-up (1–59 months; mean, 12.7 months), mitral regurgitation was less than moderate in all patients but one. In a 63-year-old female patient who underwent reconstruction of posterior leaflets with double-pentagon pericardium for active endocarditis, recurrence of severe mitral regurgitation suddenly occurred 8 months after the operation. Urgent re-do surgery revealed detachment of a pericardial leg from the anterior papillary muscle. Because the detached pericardium kept its original shape and had suture knot on it and the papillary muscle was also intact, disruption of suture material (CV4 Gore-Tex) was suspected. The mitral valve was successfully re-repaired with re-attachment

of the pericardium to the anterior papillary muscle with 4–0 polypropylene sutures and placement of 34 size Cosgrove band (Edwards Lifescience) that was not originally employed because of infected mitral annulus. Recurrent infection or hemolysis did not occur. One embolic event occurred. A 66-year-old female patient with rheumatic mitral stenosis and regurgitation who underwent anterior leaflet reconstruction and the Maze procedure suffered minor brain infarction 1 month postoperatively, although she was in sinus rhythm and under adequate anti-coagulation. She recovered without neurological sequelae. In this patient, post-operative mitral valve area was 1.21 cm^2, and moderate stenosis persisted.

Echocardiographic data

The last echocardiographic study was performed 9.7 months (range 1–50) postoperatively on average. Mitral valve regurgitation was none or mild in all patients except one who needed re-operation. Mean mitral valve area estimated from pressure half time was 2.84 (range 1.23–6.47, 95% CI 2.37–3.29) cm^2. Except for one patient who had moderate mitral stenosis as mentioned above, all patients had a mitral valve area larger than 2.1 cm^2. Average peak transmitral inflow speed was 145 cm/s (range 79–194, 95% CI 131–160). Maximal and mean pressure gradients were 9.0 mmHg (range 2.5–15, 95% CI 7.3–10.6) and 2.0 mmHg (range 1–5, 95% CI 1.6–2.4), respectively. Average ejection fraction was 62% (range 48–81, 95% CI 58–67). There was no sign of shrinkage, calcification or elongation of the pericardial leaflet-chordae on echocardiography, and the pericardium kept pliability. Systolic anterior movement of mitral valve or accelerated blood flow in left ventricular outflow was not observed throughout repeated studies.

DISCUSSION

When mitral leaflet and corresponding chordae became widely defective, simultaneous reconstruction of leaflet and chordae is sometimes necessary for successful valve repair. Some surgeons have used Gore-Tex suture and GTAP in combination to reconstruct extensively destructed valve area because of endocarditis [6, 7]. This method is naturally conceivable because this is a combination of two commonly used techniques. However, adequate adjustment of the lengths of multiple artificial chordae seems to be technically demanding, and multiple knots on the coaptation zone could disturb valve competence. In addition, using two different foreign materials does not have theoretical advantages in terms of durability, because total durability of this complex is decided by the shorter one of them. Therefore, use of pericardium also for the chordal part of the mitral valve seems rational when corresponding leaflet needs reconstruction with a pericardium. A seamless structure may also be advantageous to prevent regurgitation. Because leaflet zone and chordal zone of the pericardium have no apparent distinction, the opposing leaflet can contact any part of the smooth and seamless pericardial leaflet–chordae complex, creating an adequate area of coaptation. Strict adjustment of the length of the pericardium is therefore not necessary.

Historically, seamless reconstruction of chordae and leaflet with one piece of pericardium is not a totally new concept. In 1949, Templeton *et al.* reported replacement of posterior tricuspid valve leaflet and chordae with a piece of T-shaped pericardium in a dog model [8]. However, report of systematic application of this method cannot be found, and its relevance in clinical setting is not yet clear. We have already reported the mid-term results of our first case operated in 2009 [5], and Kassem *et al*. reported a similar method for reconstruction of commissural part in 2012 [9].

A possible drawback of this technique is potential inflow obstruction by a flat pericardium that does not have a chord structure. One patient with rheumatic mitral stenosis and regurgitation showed moderate post-operative mitral stenosis, although regurgitation was well controlled. Enough mobilization of leaflet with thorough debridement of consolidated tissue and commissurotomy seemed necessary before adopting this technique. In the rest of the patients, no sign of mitral stenosis was shown on postoperative echocardiography, presumably because the replaced area was limited compared with all remnant mitral structures those were pliable enough. Another drawback is that systolic anterior movement of the anterior leaflet could occur if the reconstructed posterior leaflet is too large. Care should be taken to avoid oversizing of the pericardium or choosing an annular ring that is too small.

Finally, longevity of this repair depends on that of the pericardium. Our longest follow-up is only 5 years, case number is limited and this is an observational study without control group. We applied this technique for patients who otherwise had valve replacement, and therefore, comparison with valve replacement in larger series and long-term follow-up are necessary to draw definitive conclusions.

However, we consider that this procedure is relatively easy to perform and worth trying especially in young patients instead of immediate valve replacement.

Conclusion

Defective mitral leaflets and chordae were reconstructed seamlessly with a piece of pericardium, and short to mid-term follow-up results were promising.

Conflict of interest: none declared.

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