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Early results of non-resectional, vertical folding mitral valve repair for mid-posterior mitral valve prolapse

Posterior mitral kapak orta segment prolapsusunda rezeksiyonel olmayan, dikey katlı mitral kapak tamirinin erken dönem sonuçları

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ABSTRACT

Background: This study aims to report early results of the non-resectional, vertical folding mitral valve repair for mid-posterior mitral valve prolapse.

Methods: Data of consecutive 32 patients (18 males, 14 females; mean age 61.3±12.5 years; range 43 to 75) who underwent non-resectional, vertical folding mitral valve repair for mid-posterior mitral valve prolapse between November 2011 and March 2016 were retrospectively analyzed.

Results: The median follow-up was 33 months (range, 3 to 48 months). Repair failure requiring replacement did not occur in any patient. During follow-up, nearly none of the patients (n=31, 96.9%) experienced aggravation of the degree of mitral regurgitation.

Conclusion: Our study results show that non-resectional, vertical folding mitral valve repair for mid-posterior mitral valve prolapse has several advantages such as simplicity, reversibility, and reproducibility without consuming surgical time. In particular, for surgeons with a limited experience, this technique is a valuable alternative and should be considered as a technical armamentarium.

Keywords: Mitral valve prolapse; mitral valve repair; non-resectional.

ÖZ

Amaç: Bu çalışmada posterior mitral kapak orta segment prolapsusunda rezeksiyonel olmayan, dikey katlı mitral kapak tamirinin erken dönem sonuçları bildirildi.

Çalışma planı: Kasım 2011 - Mart 2016 tarihleri arasında posterior mitral kapak orta segment prolapsusu için rezeksiyonel olmayan, dikey katlı mitral kapak tamiri yapılan ardışık 32 hastanın (18 erkek, 14 kadın; ort. yaş: 61.3±12.5 yıl; dağılım 43-75 yıl) verileri retrospektif olarak incelendi.

Bulgular: Medyan takip süresi 33 ay (dağılım, 3-48 ay) idi. Hiçbir hastada replasman gerektiren tamir başarısızlığına rastlanmadı. Takip süresince, neredeyse hastaların hiçbirinde (n=31, %96.9) mitral yetmezliğin derecesinde kötüleşme görülmedi.

Sonuç: Çalışma sonuçlarımız posterior mitral kapak orta segment prolapsusunda rezeksiyonel olmayan, dikey katlı mitral kapak tamirinin cerrahi süresini harcamadan kolaylık, geriye döndürülebilirlik ve tekrar edilebilirlik gibi çeşitli avantajları olduğunu göstermektedir. Özellikle deneyimi az cerrahlar için bu teknik değerli bir alternatif olup, teknik araç olarak akılda bulundurulmalıdır.

Anahtar sözcükler: Mitral kapak prolapsusu; mitral kapak tamiri; rezeksiyonel olmayan.

Posterior mitral leaflet (PML) prolapse caused by chordae elongation or rupture is the most common lesion seen in degenerative mitral valve disease.[1] Fortunately, this type of mitral regurgitation can be usually successfully repaired with well-known standard surgical techniques, such as resection of the affected leaflet through annuloplasty.[2] Sometimes, to overcome systolic anterior motion which can occur after a simple resection and closure of the affected lesion, the sliding technique is required.[3] However, the

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complexity of this procedure has led to its perception as a troublesome operation. Furthermore, the resected margin of the thin leaflet may not hold the tensile suture string and a wrongly resected margin is not reversible. Therefore, several non-resectional repair techniques have been developed, particularly for mitral regurgitation resulting from prolapsing PMLs.

In the present study, we describe a simple, non-resectional, vertical folding mitral valve repair technique for prolapsing mid-PMLs and report our early results.

PATIENTS AND METHODS

Between November 2011 and March 2016, a total of 32 consecutive patients (18 males, 14 females; mean age 61.3±12.5 years; range 43 to 75) underwent surgery for mitral valve repair with the non-resectional, vertical folding technique for prolapsing mid-PML (P2 lesion) regardless of the presence of chordae ruptures. Patients who had the same lesion, but who required additional repair techniques, such as neochordae insertion, commissural plication or obliteration, and closure for the accentuated scallop were excluded from the study. The pre- and postoperative data were collected and analyzed retrospectively. The study protocol was approved by the Catholic University of Korea Institutional Review Board (IRB). The study was conducted in accordance with the principles of the Declaration of Helsinki.

After a detailed inspection of mitral valve pathology using left atriotomy, the prolapsing mid-PML was identified with the saline pressure test. Then, the prolapsing portion of the PML was pushed down vertically into the left ventricle until the remaining lateral, and the medial border of the inverted portion of the leaflet were approximately at the level of the counterpart normal anterior leaflet. The initial suture (5-0 monofilament polypropylene) was placed, parallel to the free margin, at the remaining lateral and medial border of the inverted portion of the prolapsing PML, resulting in the vertical folding of the PML. Usually, this initial single suture was enough to lead the prolapsing mid-PML to be competent. With an additional, horizontal, wide-spacing suture (i.e., positioned perpendicularly along the wrinkle of the folded PML) closer to the annulus, the tented bulging portion of the folded PML after the initial suture was made to be flattened and more rigid for stability. A slight reduction in the height of PML was achieved with these sutures. In case of residual minimal regurgitant flow through the tip of pleating PML, the leading edge of the folded portion was placed, side down, to obliterate the cleft portion, diminishing the minor regurgitant flow through the cleft and preventing possible systolic anterior motion. Finally, sutures for an annuloplasty ring were placed and the repair was completed by implantation of an annuloplasty ring (Figure 1). However, if unsatisfied residual mitral regurgitation was shown by a subsequent saline pressure test, the suture was cut and re-positioned. Each step of the procedure was revocable without any time limit. After weaning off cardiopulmonary bypass, valve competence was re-evaluated by intraoperative transesophageal echocardiography and transthoracic echocardiography at discharge.

Pre- and postoperative transthoracic echocardiographic assessment of mitral regurgitation

According to the recommendations of the American Society of Echocardiography,[4] the severity of mitral regurgitation by mainly quantitative measures including regurgitant volume, regurgitant fraction, and regurgitant orifice area were assessed.

Follow-up and data collection

To evaluate mitral valve competency following surgery, transthoracic echocardiography was repeated at intervals of about six months for the first year and every year afterwards. In cases with perioperative sinus rhythm, warfarin was prescribed only for six months following surgery, preserving an international normalized ratio (INR) of 1.5 to 2.0. Then, aspirin was prescribed for life-long time. For patients who suffered from recurring atrial fibrillation despite the maze procedure, warfarin was prescribed indefinitely with an INR of 2.0 to 3.0 with amiodarone postoperatively for three months to return sinus rhythm to normal.

Statistical analysis

Descriptive statistics were expressed as mean ± standard deviation for continuous variables and as percentages and frequencies for categorical variables. For comparison of repeated data between two sets of data within a group at different time periods, the paired t test was used. A p value of 0.05 or less was considered statistically significant in all cases. The SPSS software package 14.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis.

RESULTS

The median follow-up was 33 months (range, 3 to 48 months). Pre- and postoperative data are summarized in Table 1. All mitral valve regurgitations were caused

by a myxomatous origin. Median cardiopulmonary bypass time and aortic cross-clamp time were 106 and 74 min, respectively. In the majority of patients, the first suture on the free margin of the prolapsing PML was sufficient to reduce most of the regurgitant flow of the mitral valve with the saline pressure test. There were no in-hospital mortality or complications. Repair failure requiring replacement did not occur in any patient. Systolic anterior motion resulting in the left ventricular outflow obstruction was not detected as assessed by intraoperative transesophageal echocardiography. All patients (100%) completed clinical follow-up. Postoperatively, all patients were in the New York Heart Association Functional Class I (n=28, 87.5%) or II (n=4, 12.5%). Comparing the pre- and postoperative follow-up variables, the left atrial size decreased from 49.9±3.3 to 43.5±5.7 mm ($p<0.05$) and systolic pulmonary artery pressure from 38.5±5.4 to 34.1±7.1 mmHg ($p>0.1$). In addition, a substantial reduction in the left ventricular end-diastolic diameter was detected (62.3±8.5 vs. 53.1±5.2 mm; $p<0.01$). During follow-up, nearly none of the patients experienced aggravation of the degree of mitral regurgitation. One patient was placed under close surveillance due to asymptomatic recurrent mitral regurgitation (mild grade at discharge to mild-to-moderate grade at the final follow-up visit).

DISCUSSION

Despite excellent success rates for prolapsing PMLs using the Carpentier technique (triangular or quadrangular resection with sliding annuloplasty, if necessary, along with an annuloplasty ring), non-resectional reconstructive procedures have evolved over a period of time.[5-11] The evolution may be due to concerns, such as the stressed cut-through phenomenon of sutures used to approximate the resected leaflet, irreversibility caused by inaccurate leaflet resection resulting in necessary valve replacement, or the time-consuming complexity of the sliding annuloplasty. The 'respect rather than resect' approach is one of these techniques. However, these procedures are based on neochordae formation on prolapsing PMLs,[12] and the determination of the precise length of the artificial chordae is another obstacle in its technical feasibility by surgeons.

Thanks to their technical simplicity, several leaflet folding techniques have been used for prolapsing PMLs, irrespective of the leaflet resection status. The first pleating of a prolapsing PML was reported by Dr. Dwight C. McGoon of the Mayo Clinic in 1960, although the term folding was not used in the published paper.[13] McGoon pleated a prolapsing, triangular-shaped flail PML vertically into the left ventricle.

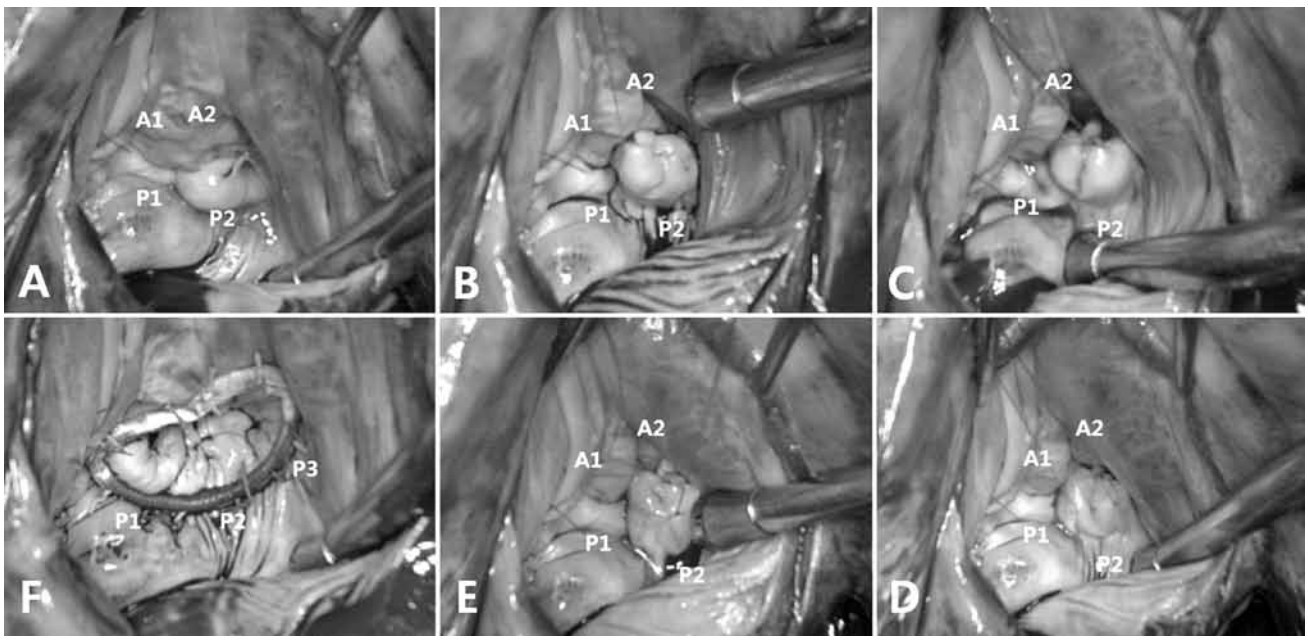

Figure 1. Surgical technique of non-resectional, vertical folding mitral valve repair. **(a)** Identification of the prolapsing zone of mitral valve, **(b, c)** the first suture parallel to the free margin resulting into the inversion of the prolapsing zone, **(d, e)** the additional, wide-spacing suture getting closer to the annulus resulting into flattening of the prolapsing zone and shortening the length of it. **(f)** Completion of repair by implantation of an annuloplasty ring.

Table 1. Patient demographics

Characteristic	Value			
	n	%	Mean±SD	Range
Total number of the patients	32			
Gender				
Male	18	56.25		
Age (year)			61.3±12.5	43-75
Ejection fraction			51.5±6.5	
Hypertension	24	75		
Diabetes	15	46.9		
Smoking	9	28.13		
Renal failure required hemodialysis	2	6.25		
New York Heart Association functional class				
II	2	6.25		
III	25	78.13		
IV	5	15.62		
Preoperative mitral regurgitation grade				
Moderate	2	6.25		
Moderate to severe	9	28.12		
Severe	21	65.63		
Concomitant procedures				
Aortic valve replacement	2	6.25		
Tricuspid annuloplasty	17	53.13		
Maze procedure	20	62.5		
Atrial septal defect	2	6.25		
Annuloplasty ring (size, mm)				
Carpentier-Edwards Physio I ring				
28 mm	2			
30 mm	5			
Colvin-Galloway Future ring (Medtronic Inc.)				
28 mm	15			
30 mm	9			
32 mm	1			
Postoperative mitral regurgitation grade (at discharge)				
None to trivial	29	90.63		
Mild	3	9.37		
>Moderate	0	0		

SD: Standard deviation.

Despite of his concern for the fate of the resultant slight bulkiness of the pleating portion of the leaflet, a resection procedure of the inverted portion of pleating leaflet was not performed to avoid a devastating postoperative regurgitation from occurring due to the suture cut-through.[14]

In 2000s, this previous procedure was revisited to overcome the difficulty of the current procedure, the standardized sliding annuloplasty, which requires irreversible leaflet cutting and skilled annulus plication to minimize the risk of systolic anterior motion. Grossi et al.[15] folded the cut edges of the leaflet down to a common central point of the mitral posterior annulus after performing a quadrangular resection of prolapsing PMLs to minimize and obviate the extent of the posterior mitral annulus plication in the case of excessive leaflet height (Figures. 2a, b). Da Col et al.[16] and Suri et al.[17] performed a modified technique which involved flipping the margin over (i.e., PML ventricularization) after minimal triangular resection was performed with additional neochordae insertion or annuloplasty ring to prevent stiff movement of PML resulting from the wide resection associated with annular plication (Figures 2c, d).

The diverse mitral folding leaflet techniques listed above were performed concomitantly with the

resection of leaflet. Therefore, these procedures are so-called 'after-resection' mitral folding techniques. However, some surgeons continue to modify folding techniques for mitral valve repair which facilitate repair without leaflet resection for surgeons with a limited experience or without performing additional procedures requiring intricate technical complexities.

Mihaljevic et al.[5] and Tabata et al.[6] also described horizontal folding techniques for prolapsing PMLs using multiple sutures from the free edge of the leaflet to the annulus with a resultant reduction in the height of the PML. However, compared to Mihaljevic et al.,[5] Tabata et al.[6] used a separate suture for the leaflet folding from that used for the annuloplasty ring, and the height of PML was able to be adjusted after the settlement of the annuloplasty ring. These techniques inevitably led to the creation of a neo-free leaflet edge (Figures 2e, f).

Calafiore et al.[7] folded the mid-portion of redundant PML horizontally inside the annuloplasty ring, from the annulus to the mid-portion of the prolapsing PML,

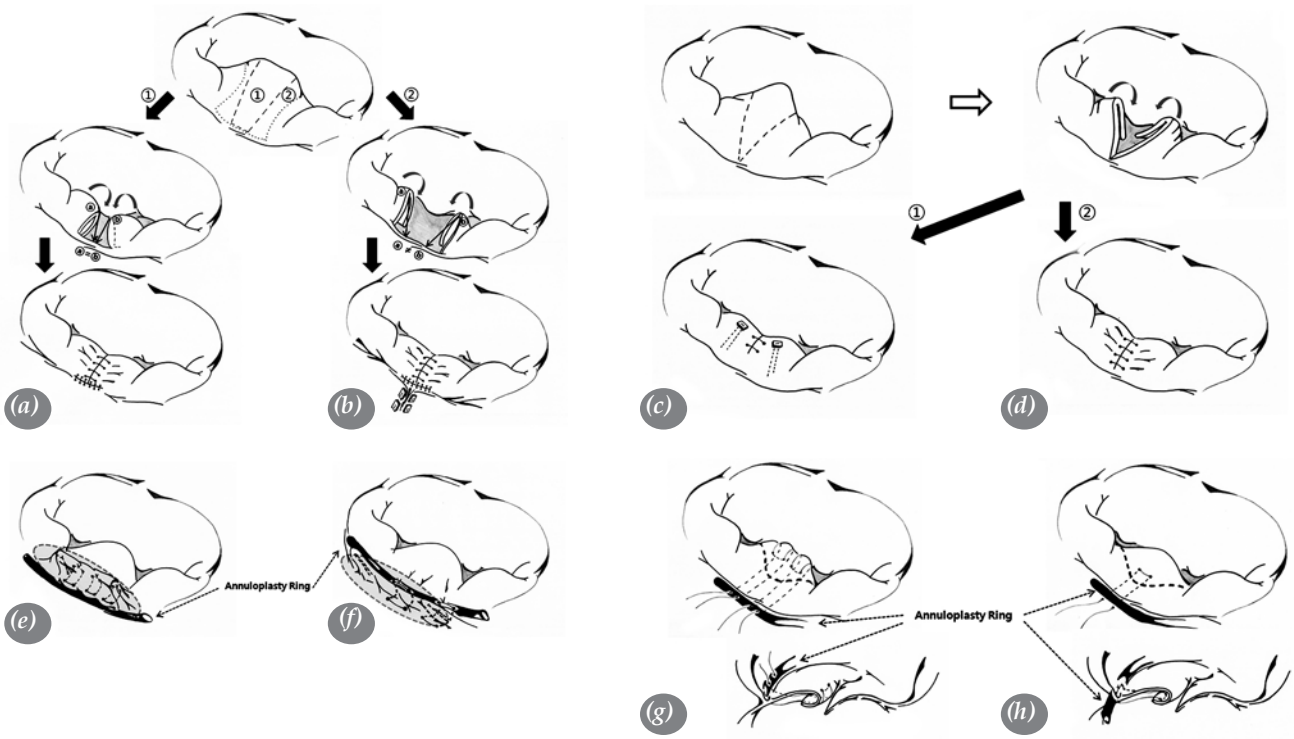

Figure 2. After quadrangular resection, posterior mitral leaflet folding technique, described by Grossi et al.[15] **(a)** In the case of prolapsing posterior mitral leaflets with excessive leaflet height, Points a and b will be brought down to a common point on the posterior mitral annulus with no annular plication. **(b)** In the case of a large prolapsing posterior mitral leaflet with excessive leaflet height, Points a and b will be brought down to a different point on the posterior mitral annulus with annular plication. After triangular resection, the posterior mitral leaflet folding technique, described by Da Col et al.[16] and Suri et al.[17] are pictured. **(c)** In the case of a prolapsing posterior mitral leaflet with a limited extent, the leading edge is folded down a little after a triangular resection of the middle posterior mitral leaflet is performed with an additional pair of neochordae inserted; technique by Da Col et al.[16] **(d)** In the case of the tall remaining lateral and medial border after a triangular resection of the middle posterior mitral leaflet, the leading edge is folded down in half without neochordae insertion, resulting in the ventricularization of the atrial side of the leaflet; technique by Suri et al.[17] Without leaflet resection and annular plication, the posterior mitral leaflet horizontally folding technique without the change of native coaptation line, as described by Calafiore et al.[7] and Hashim et al.[8] are shown. These techniques are performed similarly in the area between the posterior mitral annulus and the mid portion of the prolapsing posterior mitral leaflet. **(e)** The folded leaflet located inside of the annuloplasty ring; technique by Calafiore et al.[7] **(f)** The folded leaflet (ovoid shaded area) is located outside of the annuloplasty ring; technique by Hashim et al.[8] Without leaflet resection, the posterior mitral leaflet horizontally folding plasty technique results in a change of the native coaptation line, described by Mihaljevic et al.[5] and Tabata et al.[6] These techniques include the use of multiple sutures from the prolapsing free edge of posterior mitral leaflet to the posterior mitral annulus and annuloplasty ring insertion. **(g)** The same sutures are used for the leaflet folding and the annuloplasty ring; technique by Mihaljevic et al.[5] **(h)** Separate sutures are used for the leaflet folding and the annuloplasty ring; technique by Tabata et al.[6]

using several interrupted sutures to reduce the height of the PML. Hashim et al.[8] modified the horizontal folding technique, placing all the folding excessive PML outside the annuloplasty ring. However, both techniques yielded no change in the native coaptation line. The authors, therefore, suggested that the neo-free leaflet edge formation had a potential to adversely affect the function of the valve (Figures 2g, h).

Furthermore, Smith et al.[9] reported that the successful repair of a prolapsing PML using vertical folding technique in case of posterior mitral annular calcification. Annular procedures such as annuloplasty sutures or rings are not usually feasible for patients with severe posterior mitral annular calcification. In addition, Woo et al.[10] and Tsukui et al.[11] routinely applied the similar direction-modified or vertical folding technique and reported favorable mid-term results. With the aid of an annuloplasty ring, the optimal coaptation of the mitral leaflet was achieved by embedding a prolapsing PML into the left ventricle, thereby, resulting in a vertical folding leaflet, and subsequent anatomical morphology equivalent to a triangular resection. In particular, thanks to its technical simplicity and reversibility, the role of this procedure as a minimally invasive approach for mitral valve repair has been suggested.

The procedure herein described is somewhat different from the other techniques. In our technique, the prolapsing PML was inverted into ventricular side vertically, instead of horizontally. In addition, our technique differs slightly, in that the leading edge of the folded portion is placed side down to obliterate the cleft portion. This last stich is very useful to reduce the height of the PML further after the folding procedure, resulting in good coaptation without a systolic anterior motion. Also, the additional horizontal wide-spacing suture placed closer to the annulus is essential to push down a bulging shape of the folding PML following the first stich and to reduce the length of PML (Figures 3a, b). Initially, we used this procedure only in cases of redundant myxomatous PML without ruptured chordae tendinae, particularly P2 lesions. Currently, however, this surgical technique is widely applied for prolapsing anterior and posterior mitral leaflets, including cases of ruptured chordae, regardless of the presence of the lesion, along with neochordae insertion or annular plications.

Nonetheless, this technique has several potential risks such as infection and thromboembolism caused by the inverted bulky tissues, although there have been no reports of these complications.[11] Another

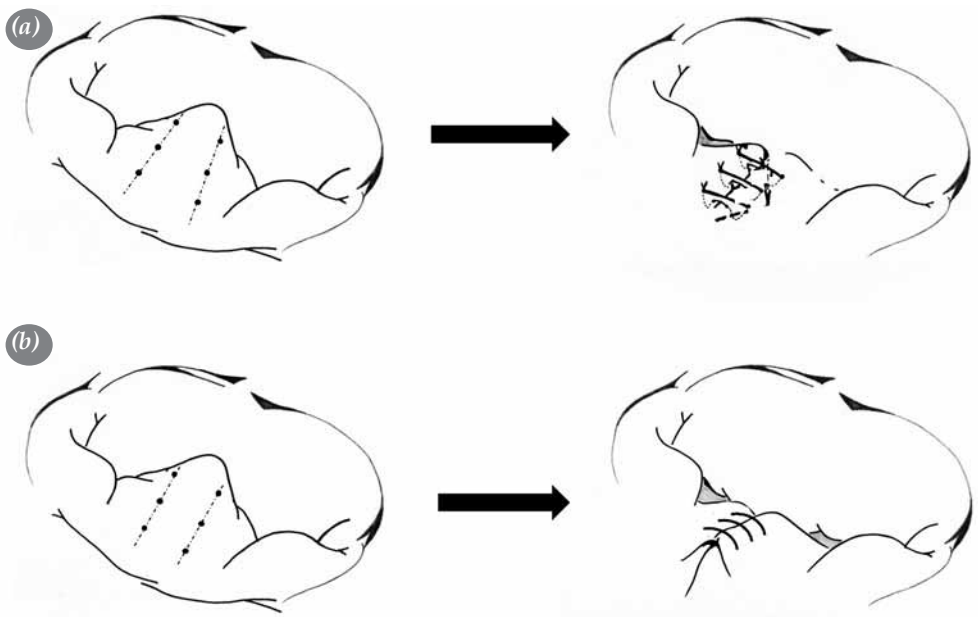

Figure 3. Our suture technique for non-resectional, vertically folding mitral valve repair is depicted. **(a)** An additional horizontal wide-spacing suture (i.e., positioned perpendicularly along the wrinkle of folded posterior mitral leaflet) near the annulus is needed to prevent the bulging shape of the folded leaflet. **(b)** However, a horizontally parallel suture near the annulus may result into the dome-shaped tent of the folded leaflet.

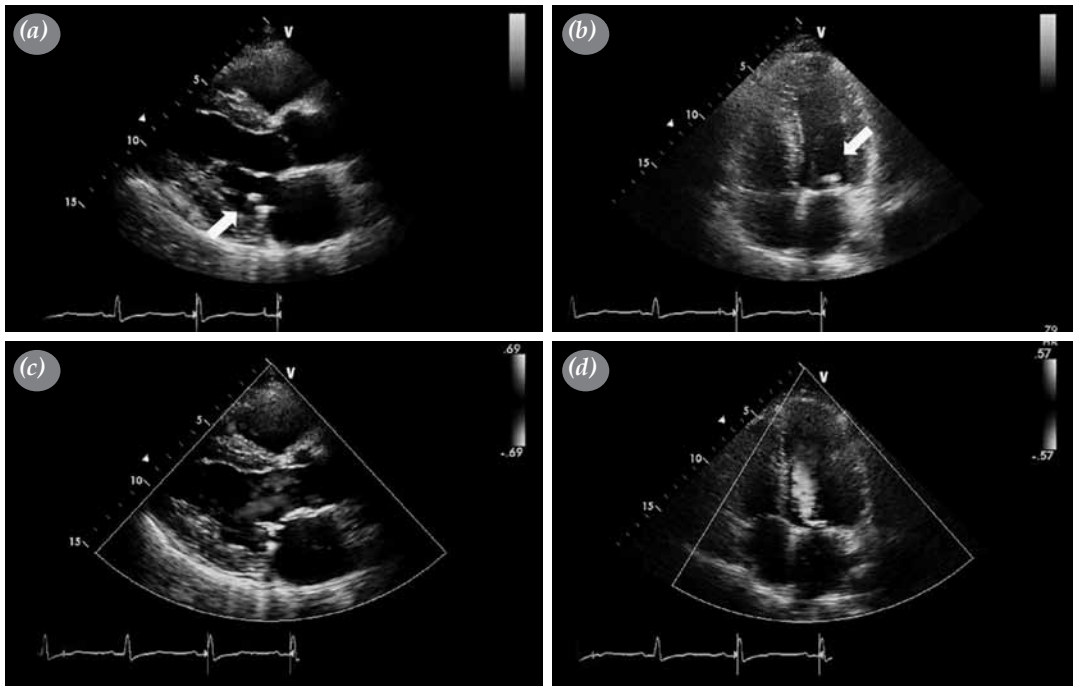

Figure 4. A restrictive rigid folding bulky portion (arrow) in posterior mitral leaflet is clearly shown **(a, b)** despite a competent mitral valve without systolic anterior motion **(c, d)** by follow-up echocardiography.

risk is the degenerative change of the valve elsewhere due to the difference of the leaflet thickness, resulting in an impairment of function. Initially, we were concerned about the impairment of PML movement coming from the disparity between the freely flexible non-folding portion and restrictive rigid folding bulky portion in the long-term, even with successful intraoperative echocardiographic results (Figure 4). However, compared to the standard technique (the Carpentier technique), no difference in the movement of the repaired PML (i.e., the simple buttress role of the folded posterior leaflet for the only functional anterior leaflet; unicuspidization of the mitral valve) was found using follow-up echocardiography.

On the other hand, the study has several limitations. First, the current study is a retrospective observational study without a control group. Second, a limited follow-up duration with a small sample size is another limitation of the study. Third, this technique was only applied to the mitral regurgitation resulting from a prolapsing PML, particularly P2 lesions. Nevertheless, this study is encouraging, as it shows good follow-up results.

In conclusion, surgeons who perform cardiac repair techniques sometimes confront challenging cases. This non-resectional, vertical folding mitral valve repair for the prolapsing mid-posterior mitral leaflet is one of several modifications and has some merits, such as technical simplicity, reversibility and reproducibility, even if performed by surgeons with a limited experience with favorable early and mid-term results. Therefore, we believe that this technique is a valuable alternative and should be considered as a technical armamentarium to correct myxomatous mitral regurgitation, and can be used as a treatment of choice in prolapsing mid-posterior leaflet.

Declaration of conflicting interests

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