A novel and simple technique for correction of posterior leaflet prolapse due to chordal elongation or rupture

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Objective: The study objective was to evaluate the midterm results of a technique for correction of posterior leaflet prolapse without resection or use of artificial chordae.

Methods: From May 2009 to October 2013, 96 patients with isolated posterior leaflet prolapse (n = 36) or bileaflet prolapse (n = 60) with or without chordal rupture underwent posterior leaflet repair at the Prince Sultan Cardiac Center. The novel Uniscallop (“U”) technique was used in 46 patients (group U), based only on scallop suture without resection or artificial chordae application. A conventional approach (quadrangular or triangular resection, focal sliding, artificial chordae) was adopted in the remaining 50 patients (group C). In both groups, the annulus was reshaped using a 40- or 50-mm–long band. Postoperative echocardiography was performed in all patients after a mean follow-up of 18 ± 13 months in group U and 20 ± 9 months in group C.

Results: There were no early or late deaths. No patients in either group showed systolic anterior motion. Both surgical strategies were successful in obtaining a significant reduction in mitral regurgitation grade. Left ventricular function was maintained, and tricuspid regurgitation grade was reduced overall. Moderate mitral regurgitation during follow-up developed in only 1 patient in group C, as the result of dehiscence of a plication stitch.

Conclusions: Although the rationale for the use of the U technique is different from what is generally accepted, the midterm results of this approach are comparable to those obtained with more conventional techniques, remaining stable after a mean follow-up of 18 months. (J Thorac Cardiovasc Surg 2014;148:1407-12)

Supplemental material is available online.

We report the midterm results of this procedure comparing the echocardiographic results with those obtained by using a more conventional technique during the same time frame.

MATERIAL AND METHODS
From May 2009 to October 2013, 96 patients with isolated PL prolapse (n = 36) or bileaflet prolapse (n = 60) with or without chordal rupture underwent PL repair at the Prince Sultan Cardiac Center. There has been a progressive modification of the surgical technique, with a switch from the conventional approach (resection with focal sliding or use of artificial chordae in addition to scallop suturing and longitudinal plication, if required) to a novel technique (without resection or use of artificial chordae) that we have called the Uniscallop (“U”) technique. Patients were divided into 2 groups according to the surgical technique used.

Preoperative data are reported in Table 1. Patients in both groups were similar, because in general, patients with MV prolapse have common characteristics. The institutional review board approved the study and waived patient consent.

Surgical Technique
All patients underwent surgery with a median sternotomy. Perioperative transesophageal echocardiography was obtained in all patients. Patients treated with the conventional technique (group C) underwent operation as previously described. In group U, our strategy aimed at the correction of PL prolapse without resection or use of artificial chordae, and with leaflet fixation in vertical position, changing a bileaflet valve into a unileaflet one. This goal was achieved through the following steps.

Modification of posterior leaflet height. In group C, 1 or more U-sutures (4-0 Prolene) were used for longitudinal plication of the scallop(s) to reduce PL height if exceeding 15 mm. In group U, height...
reduction was aimed at making the height of the scallops uniform to change the PL from a multiscalloped to a single scalloped leaflet (Figure 1).

Change of posterior leaflet from a multiscalloped to a single scalloped leaflet. Once the height is similar, all scallops are sutured together (4-0 Prolene) to prevent excess leaflet motion at the level where chordal elongation is more pronounced and to limit total PL movement to the portion with a lower degree of chordal elongation (Figure 1). If the prolapse involves all scallops, suturing allows us to consider the PL as a whole and not composed of different segments, independently of any prolapse grade. Scallops are identified by the indentations, which sometimes can be less evident, because they can be of different length.

In patients with chordal rupture, the donor scallop (ie, the scallop with normal or elongated chordae close to the one with ruptured chordae) is positioned below the receiving scallop (ie, the scallop with ruptured chordae) to support it. The rim of the receiving scallop is then sutured to the body of the donor scallop (Figure 2). It is worth noting that the portion of a scallop without chordae will not cause leaflet prolapse, and thus MR, if it is 10 mm or less.

Annular over-reduction. The MV annulus is reshaped using a 40-mm (SMB40) or 50-mm (SMB50) band. The band is flexible, made of radiopaque silicone core, and covered by a knitted polyester fabric coated with Carbofilm (Sorin, Saluggia, Italy). It is inserted from trigone to trigone using multiple imbricated U-sutures to reduce the stress on the annulus. The septal lateral distance obtained is, as a mean, 21 mm for the SMB40 and 24 mm for the SMB50. The choice of the band depends on the anterior leaflet (AL) length. Because the purpose of the correction is to obtain a coaptation length of 5 mm or greater, the SMB40 or SMB50 is used if the AL length is less than 30 mm or 30 mm or more, respectively. The use of these bands is aimed at moving the posterior annulus toward the anterior annulus pivoting on 2 fixed points (the trigones). The PL is then attracted posteriorly with subsequent increased annulus toward the anterior annulus pivoting on 2 fixed points (the trigones). The PL is then attracted posteriorly with subsequent increased

Anterior leaflet prolapse. In patients with associated AL prolapse, 2 or more artificial chordae (polytetrafluoroethylene; 4-0 Gore-Tex, WL Gore & Associates, Inc, Flagstaff, Ariz) are used. The length of neochordae is adjusted as previously described. Any deviant cusp, if present, is sutured with the main body of the leaflet.

Tricuspid regurgitation. Correction of moderate or greater tricuspid regurgitation was performed in all patients, if present, whereas correction of mild tricuspid regurgitation was performed only in patients with annular enlargement.

Echocardiographic Evaluation

All patients underwent standard preoperative echocardiography. MR was graded as mild (grade 1), moderate (grade 2), moderate to severe (grade 3), and severe (grade 4) according to different parameters, including regurgitant jet area and its ratio to the left atrial area, number and direction of regurgitant jets, and vena contracta width. Ejection fraction was calculated using a modified Simpson’s biplane method. The severity of tricuspid regurgitation, as assessed by Doppler echocardiography, was graded on a scale from 1 to 4 (1, mild; 2, moderate; 3, moderate to severe; 4, severe). Pulmonary artery systolic pressure was estimated as the sum of the gradient across the tricuspid valve (calculated from the simplified Bernoulli equation) and the right atrial pressure. The latter was estimated using inferior vena cava size and response to respiration in the subcostal view.

Statistical Analysis

Results are expressed as mean value ± standard deviation, unless otherwise indicated. Statistical analysis comparing 2 independent groups was performed with unpaired 2-tailed Student t test for the means or chi-square test for categoric variables. Preoperative and postoperative data were compared with paired 2-tailed Student t test. SPSS software (SPSS Inc, Chicago, Ill) was used for statistical analysis.

RESULTS

Operative data and surgical techniques for both groups are reported in Table 2. The PL had 3 scallops in 67 patients (69.8%), 2 scallops in 15 patients (15.6%), and 4 scallops in 15 patients (15.6%), and 6 scallops in 1 patient (1.1%). A deviant cusp in the AL was present in 28.3% of cases (n = 17). No patient died within 30 days of surgery or during follow-up. All patients underwent echocardiography postoperatively. There was no or trivial residual MR in all but 1 patient in group W, who required a second pump run with successful correction of MR, which was due to intermittent tethering of second-order chords of the AL.

Cardiopulmonary bypass and crossclamp times were significantly shorter in group U as a result of the simplicity of the surgical technique.

After a mean follow-up of 19 ± 11 months, all patients underwent transthoracic echocardiography. Length of follow-up was not significantly different between groups (mean, 18 ± 13 [2-36] months in group U; mean, 20 ± 9 [3-38] months in group C; P = .3799).

Postoperative echocardiographic data are reported in Table 3. Both strategies were successful in obtaining a significant reduction in MR. The final aspect of the MV was comparable for all techniques (Figure E1). Left ventricular function was maintained, and tricuspid regurgitation grade was overall reduced. Residual MR grade was lower in group U (0.2 ± 0.4 vs 0.4 ± 0.5, P = .0340), because a patient in

### Table 1. Preoperative data

<table>
<thead>
<tr>
<th>Group U (n = 46)</th>
<th>Group C (n = 50)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>38 ± 17</td>
<td>37 ± 13</td>
</tr>
<tr>
<td>Female gender</td>
<td>29</td>
<td>22</td>
</tr>
<tr>
<td>NYHA class</td>
<td>2.3 ± 0.8</td>
<td>2.0 ± 1.0</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Barlow disease</td>
<td>19</td>
<td>17</td>
</tr>
<tr>
<td>Bileaflet prolapse</td>
<td>32</td>
<td>28</td>
</tr>
<tr>
<td>PL chordal rupture</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>

NYHA, New York Heart Association; PL, posterior leaflet.
group C had moderate MR during follow-up as a result of dehiscence of a plication stitch.

DISCUSSION

Although repair is the treatment of choice for MV prolapse, incidence of repair in the real world is approximately 70% of the total number of procedures\(^7\). The percentage can be higher or lower, depending on the level of specific expertise. PL prolapse is the most common finding in patients with degenerative MV disease and often can be isolated. Surgical techniques include P2 quadrangular or triangular resection, annular plication, sliding plasty or focal sliding, and use of artificial chordae. Results are good and relatively stable. However, at least 10% of patients, among whom some underwent surgery but were asymptomatic, show recurrent MR (grade 3 or 4\(^+\)) at 10 years from surgery\(^8\). In the experience of David and colleagues\(^9\), freedom from moderate or severe MR in patients who had MV repair for isolated PL prolapse was 80% ± 4% at 12 years.

With time, there has been an evolution of surgical techniques. Nonresecting techniques have been part of the therapeutic armamentarium of all surgeons, but the possibility of repairing PL prolapse only with artificial chordae was first emphasized by Perier and colleagues\(^10\). These authors reported the long-term results of 225 patients (21.5% of all those undergoing operation during the study period) undergoing repair of PL prolapse with the “respect rather than resect” approach. The use of nonresecting techniques was based on the surgeon’s choice.

Several authors have suggested different approaches to correction of PL prolapse that do not involve partial or complete scallop resection\(^11-15\). In a series published by our group in 2006\(^1\), nonresecting techniques also were used in 40 patients, including application of artificial chordae when P2 insertion was longer than one third of the posterior MV annulus (n = 28) and longitudinal plication of the scallops (n = 11). In a later study comparing resecting with nonresecting techniques, we observed similar results with both approaches\(^16\).

The main finding of our study is that PL prolapse can be corrected only by annular over-reduction associated with scallop suturing and, if necessary, longitudinal plication of the scallops for height adjustment. The elements of this technique are not new, and all of them are used in selected cases, but we demonstrated that they are enough to correct PL prolapse. If chordae are elongated, the suture line is at the level of the adjacent free rims of the scallops. If the chordae are ruptured, the donor scallop is positioned below the receiving scallop and the suture line connects the rim of the receiving scallop with the body of the donor scallop (Figure 2). The only precaution is to leave 10 mm or less of free margin without chordae. If chordal rupture involves the portion of P1 or P3 segments close to the commissure, it is commonly treated by obliterating the commissure. The only limit to this strategy is the rare event when all PL chordae are torn. Although we never encountered such a case, artificial neochordae application may be the only solution.

Over-reduction of the mitral annulus is part of the strategy we described. The implant of a short band from

![Figure 1](image-url)
trigone to trigone is able to reproduce what is performed in functional MR surgery, changing a bileaflet valve into a unileaflet valve. This goal can be achieved with devices that reshape the mitral annulus, provided the same strategy (over-reduction) is applied. It is crucial to avoid PL movement to prevent the occurrence of SAM, because MV leaflets meet at the border rather than inside the mitral annular area. Of 52 patients (6.6% in whom SAM developed, Varghese and colleagues found that the PL was involved in 49 (94.2%). This complication is relatively frequent after MV repair. In the retrospective study of Brown and colleagues, SAM was identified in 8.4% of cases at the end of the procedure, decreasing to 3% at discharge. At a median follow-up of 5.4 years, 18.3% of patients in whom SAM developed intraoperatively still showed this complication. However, SAM virtually does not occur after MV repair for functional MR, and we applied the same concept (PL verticalization) to minimize or eliminate this frustrating complication.

It is worth discussing the possibility that mitral stenosis may occur postoperatively. Several studies demonstrated significant gradients, at rest or on effort, after over-reduction of the mitral annulus for functional MR. Although there is no general consensus on this issue, we believe that a different situation exists when applying the same concept to correction of PL prolapse. When a 40- or 50-mm–long band is implanted from trigone to trigone with an intertrigonal distance of approximately 25 mm, mitral annular circumference is such to generate a theoretic anatomic orifice of 3.0 to 4.5 cm². The mean functional area is slightly less than 3.5 cm² (Table 3), because left ventricular end-diastolic pressure, being low, causes high diastolic gradient and high transmitral flow. In addition, the AL is in its physiologic preopening position (from 20° to 25°), thus minimizing the opening velocity. As a result, the MV will function normally both at rest and during effort. The situation is different after annular over-reduction for functional MR. Left ventricular end-diastolic pressure can be higher than normal, the velocity of AL opening will be lower, and functional MV area can be affected by the different underlying disease. As a consequence, functional mitral stenosis can be observed in some cases, although its impact on long-term outcome seems to be limited.

Our patients had low rest gradients across the MV and were asymptomatic in their daily life. In a recent study, Mesana and colleagues reported that mean gradients are smaller in patients in whom a band was used to repair degenerative MV prolapse, and their results agree with our findings.

Study Limitations

Patients were not randomized, and the use of the U technique was adopted progressively until the moment it became the technique of choice for correction of PL.
prolapse. However, the U technique was used for up to 4 years at the time of the study, and we were able to apply it to all patients, including those with Barlow disease. During this time frame, the most relevant aspect was the possibility for the younger surgeons to learn how to correct bileaflet prolapse with optimal early and midterm results. However, a different technique is not a guarantee of a better outcome, especially if compared with the excellent results of more conventional procedures. Even if after an 18-month follow-up the residual MR grade was lower with the U technique, we have to wait for a longer follow-up to know whether this technique has its place in the surgical treatment of PL prolapse of the MV.

CONCLUSIONS
An increasingly better understanding of the pathophysiology of PL prolapse has led to the introduction of new surgical options for the correction of this disease. We are aware that the bar for repairing PL prolapse or chordal rupture is high and that good results can be obtained using conventional techniques. Nevertheless, there is always space for a surgical strategy different from the well-established ones, especially if it is easy to perform and prevents SAM, a well-known complication of MV prolapse repair. The midterm results of the U technique are good and comparable to those obtained with more conventional techniques. Echocardiographic results are stable, but a longer follow-up is needed to evaluate the impact of this technique. Echocardiographic results are stable, but a longer follow-up is needed to evaluate the impact of this technique. Echocardiographic results are stable, but a longer follow-up is needed to evaluate the impact of this technique. Echocardiographic results are stable, but a longer follow-up is needed to evaluate the impact of this technique.

References


FIGURE E1. Transthoracic echocardiography (short-axis view) in a patient in group U. Bileaflet prolapse (A) causing severe MR (B). C. At 18 months after surgery, there is no evidence of MR. This echocardiographic finding is common to all patients, regardless of the technique used.