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Nonresectional Single-Suture Leaflet Remodeling for Degenerative Mitral Regurgitation Facilitates Minimally Invasive Mitral Valve Repair

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Abstract

Background—Both leaflet resection and neochordal construction are effective mitral repair techniques, but they may become incrementally time-consuming when using minimally invasive approaches. We have used a single-suture leaflet-remodeling technique of inverting the prolapsed or flail segment tissue into the left ventricle. This repair is straightforward, expeditious, and facilitates a minimally invasive approach.

Methods—Ninety-nine patients with degenerative mitral regurgitation (MR) underwent a minimally invasive single-suture repair of the mitral valve from May 2007 through December 2012. Preoperative and perioperative echocardiograms as well as patient outcomes were analyzed and compared with those obtained from patients undergoing minimally invasive mitral valve repair using quadrangular resection at the same institution during the same period.

Results—All 99 patients had a successful mitral repair through a sternal-sparing minimally invasive approach. Ninety-one of the 99 patients had zero MR on postoperative echocardiogram, and 8 of 99 had trace to mild MR. Patients in the nonresectional group had significantly shorter cardiopulmonary bypass and cross-clamp times compared with the quadrangular resection group (115.8 ± 41.7 minutes versus 144.9 ± 38.2 minutes; $p < 0.001$; 76.2 ± 28.1 minutes versus 112.6 ± 33.5 minutes; $p < 0.001$, respectively). The mean length of stay was 7.5 ± 3 days. All patients were discharged alive and free from clinical symptoms of MR. There have been no reoperations for recurrent MR on subsequent average follow-up of 1 year.

Conclusions—An effective, highly efficient, and thus far durable single-suture mitral leaflet-remodeling technique facilitates minimally invasive repair of degenerative MR.

During the past decade, minimally invasive approaches to mitral valve repair have gained popularity owing to improved cosmesis, less postoperative pain, and shorter hospitalizations [1–4]. Additionally, numerous reports have validated the short- and long-term outcomes of

these repair techniques, an especially important finding to consider when advocating for early repair in asymptomatic patients [5, 6]. However, during complex minimally invasive repair, classic resectional techniques have minor drawbacks, including time-consuming reconstruction that may lead to increased cardiopulmonary bypass and aortic cross-clamp times, potential for monoleaflet function, and dynamic mitral stenosis or even systolic anterior motion when excessive leaflet tissue is malpositioned.

In an attempt to address some of these minor drawbacks we developed and have previously reported on a simplified, nonresectional leaflet-remodeling technique to repair degenerative mitral regurgitation (MR) [7]. In the current study, we used this nonresectional technique to repair the mitral valve in 99 patients with degenerative MR through a minimally invasive approach and compared short-term outcomes with those in patients receiving minimally invasive mitral valve repair using a standard quadrangular resection.

Patients and Methods

Patient Selection

From May 2007 to December 2012, 1,992 mitral valve operations (628 mitral replacements, 1,364 mitral repairs) were performed at the University of Pennsylvania. Of these, we compared 99 consecutive patients who underwent a minimally invasive nonresectional, single-suture mitral leaflet-remodeling repair against a control group of 193 consecutive patients undergoing a minimally invasive quadrangular resection. Preoperative and postoperative data were retrospectively acquired and analyzed. This study was reviewed and approved by the University of Pennsylvania Institutional Review Board (protocol 810968).

Operative Technique

The minimally invasive approach used in the nonresectional group has been previously described by Woo and MacArthur [7, 8, 9]. Briefly, a 4-cm right third intercostal space anterolateral chest incision was used together with femoral vessel cannulation for cardiopulmonary bypass. Mitral ring annuloplasty sutures were placed immediately after atriotomy and retracted under slight tension, optimizing exposure and allowing identification of leaflet pathology. The leading edge of the prolapsed segment of the mitral valve was identified and inverted into the left ventricle. This maneuver generated two near apposing edges of leaflet tissue (Figs 1A–1C), which were sutured together with a double-armed CV-5 Gore-Tex suture (W.L. Gore & Assoc, Flagstaff, AZ), fixing the redundant leaflet tissue into the ventricle. The width of inverted tissue was narrowed as the annulus was approached and redundant tissue was ventricularized, resulting in a smooth plane of coaptation (Fig 1D). In a subset of 39 patients, the CV-5 suture was first passed into the posterior ventricular myocardium to a depth of 3 to 4 mm to further aid in positioning the coaptation plane posteriorly. This suture was tied loosely, and the needles were subsequently passed through the leading edge of the diseased segment at a width one half that of the prolapsed segment [9]. The suture was then run toward the annulus as above, again resulting in a smooth plane of coaptation. A semirigid ring annuloplasty was performed in all patients to reshape the annulus, reduce demands on the leaflets, and prevent future annular dilatation. Atriotomy closure, removal of air, and weaning from cardiopulmonary bypass were

performed in standard fashion. Patients in the minimally invasive quadrangular resection group underwent similar exposure of the mitral valve, and quadrangular resection was performed using standard techniques. A semirigid ring annuloplasty was performed in all patients.

Statistical Analysis

Continuous variables were reported as mean $\pm$ standard deviation. Student's *t* test was used to compare continuous variables, and χ^2 test was used to compare categorical variables. Statistical significance was set at a probability value of less than 0.05. Analyses were performed with STATA (StataCorp, College Station, TX) statistical software package, version 12.1.

Results

Four months after the close of the study, data were collected and analyzed. A total of 99 patients underwent minimally invasive mitral valve repair using a nonresectional, single-suture leaflet-remodeling technique. Preoperative patient characteristics are presented in Table 1. Ninety-one patients had no MR after repair, and the remaining 8 patients had trace to mild MR on immediate postoperative transesophageal echocardiography. The valve dysfunction in the nonresectional group was most often prolapse or flail of the P2 leaflet; however, the nonresectional technique was successful with a host of different valve dysfunctions, including isolated anterior prolapse or flail and even combined anterior and posterior prolapse or flail (Table 2). All repairs were successful on the first attempt, no patient required repeated cross-clamp, and there were no mitral valve replacements (100% repair rate).

Patients in the nonresectional group had significantly shorter cardiopulmonary bypass and aortic cross-clamp times when compared with the quadrangular resection group (115.8 ± 41.7 minutes versus 144.9 ± 38.2 minutes; $p < 0.001$; 76.2 ± 28.1 minutes versus 112.6 ± 33.5 minutes; $p < 0.001$, respectively), although there was no difference between blood transfusion or stroke (Table 3). The average length of stay was slightly shorter in the quadrangular resection group (6.5 ± 3.7 versus 7.5 ± 3 days; $p = 0.011$), likely owing to the slightly higher yet not statistically significant rate of postoperative atrial fibrillation in the nonresectional group (30% versus 26.4%; $p = 0.491$) for which patients were kept in the hospital until a therapeutic international normalized ratio was achieved on sodium warfarin therapy. In the nonresectional group, no patient had systolic anterior motion or evidence of functional mitral stenosis. There were no perioperative myocardial infarctions or deaths, and 1 patient had a mild stroke from which he completely recovered before discharge, without evidence of any neurologic deficits.

All patients were discharged from the hospital alive. There have been no reoperations and no recurrence of significant MR. Fifteen patients were lost to follow-up, and 3 patients died of noncardiac causes. Outpatient surveillance echocardiograms occurred at the discretion of the primary cardiologist. Fifteen patients were seen by their cardiologist but had no postoperative echocardiography for review. The remaining 69 patients had postoperative echocardiograms available, with an average follow-up time of 12.6 months (range, 2 to 34

months). Forty-three (63%) patients continued to have no MR, 19 (29%) patients had trace to mild MR, and 6 (8%) patients had mild to moderate MR.

Comment

Improved repair rates and outcomes in patients undergoing early surgical intervention for MR have been reported by Gillinov and associates [10] and more recently by Stevens and colleagues [11]. The push to repair asymptomatic MR mandates near 100% success while minimizing morbidity in this relatively healthy patient cohort [10–12]. Although minimally invasive mitral valve repair for degenerative MR has evolved during the past 10 to 15 years with excellent short- and long-term outcomes, there are some improvements that can be made. Ideally, minimally invasive repair approaches should offer patients smaller incisions than standard sternotomy, less postoperative pain, and shorter hospital stays. However, this should not come at the price of increased complications or sacrificing durability of repair. In the current study, we have shown that our previously described nonresectional, single-suture mitral leaflet-remodeling technique allows for drastically reduced cardiopulmonary bypass and aortic cross-clamp times when compared with minimally invasive quadrangular leaflet resection. Additionally, at this time in our follow-up, available echocardiographic data support the durability of this repair technique.

Papillary-based neochordal replacement has been very successful and shown to be durable for the long term [13, 14]. Even this technique, however, is not without its drawbacks, such as tedious measurement of neochord length and the potential for leaving excess leaflet tissue, risking systolic anterior motion of the mitral valve. In the current study we have presented a unique way to approach MR without the need for precise neochord measurement while also preserving leaflet tissue. Our cross-clamp and bypass times (76.2 ± 28.1 minutes, 115.8 ± 41.7 minutes, respectively) compare very favorably with those reported for neochordal techniques (78 ± 27 minutes, 124 ± 37 minutes, respectively) even when the premeasured “loop technique” was used [14].

Limitations of this study include its retrospective nature and short-term patient follow-up. This repair technique is relatively new, and thus we are continuing to follow up patient outcomes as they become available. Potential limitations of the repair include an overly aggressive plication of prolapsed tissue, which may result in a restricted, stenotic leaflet. The converse may also limit this repair, as underestimating the amount of tissue to imbricate may result in anterior protrusion of the bulky leaflet, risking systolic anterior motion. These limitations can easily be addressed at the time of operation, as the repair suture can be removed and replaced incorporating more or less tissue as the case demands. Calcified leaflets may also pose a challenge, as it may be difficult to manipulate this tissue.

In conclusion, this represents a series of 99 patients with severe, degenerative MR successfully and durably repaired with a minimally invasive, nonresectional, single-suture leaflet-remodeling technique. This repair, in which a portion of the prolapsed or flail leaflet is ventricularized resulting in a smooth plane of coaptation, is highly efficient thereby facilitating minimally invasive surgery.

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Fig 1.

Composite images displaying a nonresectional, single-suture leaflet remodeling mitral valve repair in progress. (A) Annuloplasty sutures are placed and gentle traction is applied to expose the dysfunctional leaflet. The redundant leaflet tissue is grasped and inverted into the left ventricle. (B) A double-armed CV-5 Gore-Tex suture is passed through the leading edge of the prolapsed leaflet and (C) tightened to display two near apposing lines of leaflet tissue for suturing. (D) The suture is then run back toward the annulus, creating a smooth plane of coaptation and a competent repair.

Table 1Preoperative Data^a

Variable	Nonresectional (n = 99)	Quadrangular (n = 193)	p Value
Age (y)	60 ± 13	57 ± 10	0.0346
Sex			
Male	62 (63%)	156 (81%)	0.001
Female	37 (37%)	37 (19%)	
Atrial fibrillation	28 (28%)	50 (26%)	0.664
HTN	44 (44%)	75 (39%)	0.358
Diabetes	6 (6%)	9 (5%)	0.609
Ejection fraction	0.61 ± 0.07	0.59 ± 0.07	0.0277
NHYA class			
I, II	94 (95%)	173 (90%)	0.462
III, IV	5 (5%)	20 (10%)	

^aValues are mean ± standard deviation or number (%).

HTN = hypertension; NYHA = New York Heart Association.

Table 2Valve Dysfunction^a

Valve Segment	Nonresectional
P1	2 (2%)
P2	57 (57.6%)
P3	8 (8.1%)
P1/P2	7 (7.1%)
P1/P3	1 (1%)
P2/P3	9 (9.1%)
P1/P2/P3	3 (3%)
Isolated anterior	7 (7.1%)
Anterior and posterior	5 (5.1%)

^aValues are number (%).

Table 3Perioperative Data^a

Variable	Nonresectional (n = 99)	Quadrangular (n = 193)	p Value
Cardiopulmonary bypass time (min)	115.8 ± 41.7	144.9 ± 38.2	<0.001
Aortic cross-clamp time (min)	76.2 ± 28.1	112.6 ± 33.5	<0.001
Blood transfusions	28 (28%)	36 (19%)	0.06
Ring annuloplasty size (mm)	31.6 ± 3.4	32.9 ± 2	<0.001
Stroke	1 (1%)	4 (2%)	0.545
Postoperative atrial fibrillation	30 (30%)	51 (26.4%)	0.491
Postoperative length of stay (days)	7.5 ± 3	6.5 ± 3.7	0.011

^aValues are mean ± standard deviation or number (%).