Mitral valve repair using adjustable posterior leaflet neochords

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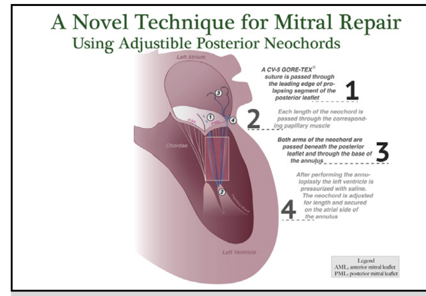


Illustration of a novel technique for mitral valve repair using adjustable looped neochords.

CENTRAL MESSAGE

We report on a novel technique for implantation of neochordae to the posterior leaflet and demonstrate excellent safety and efficacy in a series of 22 patients.

See Commentaries on pages 55, 56, and 58.

▶ Video clip is available online.

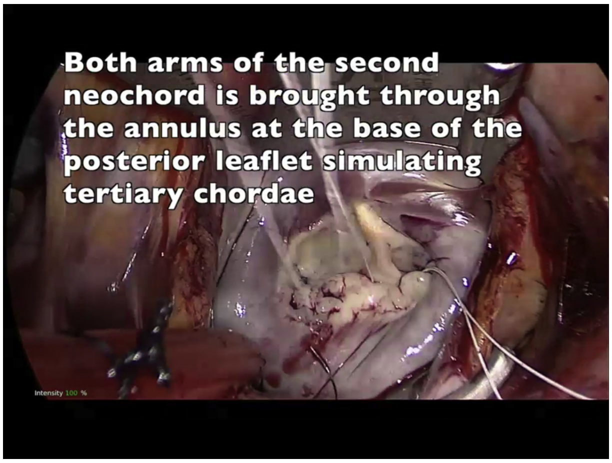
Mitral valve regurgitation (MR) is a common disorder[1] that has been found to be a powerful predictor of serious morbidity and mortality.[2] As such, the management of MR has evolved over time and has trended toward a more aggressive surgical approach to mitral valve pathology.[3,4] This trend is likely a product of the appreciation of the risks associated with untreated MR but also partly attributable to the tremendous progress that has been made with operative mitral valve repair.[5,6] Minimally invasive approaches[7] and robotic mitral surgery[8] have entered the mainstream and continue to grow in popularity.[9] Concurrently, leaflet remodeling techniques continue to evolve and nonresectional approaches[10,11] have gained favor as a means to reduce posterior leaflet height without compromising posterior leaflet mobility while maximizing a smooth coaptation zone between the mitral leaflets. Although it is evident that a physiologic approach to mitral valve repair yields superior long-term results, it is less clear how to safely and reliably apply these techniques in a minimally invasive platform. As such, we sought to develop a method for posterior mitral valve leaflet remodeling that has been optimized for thoracoscopic surgery and report our experience on 22 patients treated with a novel adjustable neochord method.

METHODS

From December 2016 through August 2018, 22 patients underwent mitral valve repair utilizing the adjustable posterior neochord technique at Yale New Haven Hospital. During the same time period, a total of 106 mitral valve surgeries were performed by the senior author. The decision to place adjustable posterior neochords was at the discretion of the operative surgeon at the time of surgery on the basis of anatomic suitability. All patients included in the study had preoperative, intraoperative, and postoperative echocardiographic assessment of the mitral valve. Demographic and other patient-related data were obtained from the Yale New Haven Hospital medical records. Follow-up information was obtained from data collected at postoperative clinic visits and via written correspondence from local physicians. The study was approved by the Yale Institutional Review Board and individual consent was waived for aggregate data.

OPERATIVE TECHNIQUE

A minimally invasive approach was used in the majority of patients included in the study. Cardiopulmonary bypass was initiated through access to the femoral artery and vein. The chest was accessed through a thoracotomy incision in the right fourth intercostal space. Myocardial arrest was achieved through combination of antegrade and retrograde cardioplegia. The left atrium was then entered through the interatrial groove and exposure of the valvular apparatus was obtained using the Estech Atrial Lift System (Atricure, Mason Ohio) and the Collar papillary muscle exposure device (Miami Instruments, Miami, Fla). After identification of the prolapsing segment(s) each arm of a CV-5 Gore-Tex (W. L. Gore and Associates, Flagstaff,



VIDEO 1. Surgical technique demonstrating use of adjustable Goretex neochord for posterior leaflet prolapse. Video available at: https://www.jtcvs.org/article/S2666-2507(20)30100-0/fulltext.

Ariz) suture was inserted into the leaflet edge and brought down to the corresponding papillary muscle belly in a single pass and then brought behind the posterior leaflet through the base of the annulus and temporarily secured on the atrial side of the annulus. A single suture was thereby looped from leaflet edge, to papillary muscle twice, and then through the annulus twice. Depending on the level or width of prolapsed segment additional neochords were placed in similar fashion. After placement of the neochords, annuloplasty sutures were placed and the annuloplasty secured using a Core-knot device (LSI Solutions, Victor, NY). With the annuloplasty ring in place, the valve is tested for competency by pressurizing the left ventricle with saline with the mitral annulus engaged. A suture placed through the annuloplasty ring and gentle traction is applied to restore ventricular geometry with the ventricle pressurized. The valve is visually inspected for regurgitation and the neochordae are dynamically adjusted to address residual prolapse or to correct restriction. The neochords are then secured using the TIE Intracorporeal Knot Placement Assist Device (Miami Instruments, Miami, Fla). The atrium is closed in a standard fashion and the patient weaned from bypass (Video 1).

RESULTS

The patients' preoperative and echocardiographic characteristics are shown in Table 1. Seventy-seven percent of procedures were performed through a minimally invasive approach where full sternotomy was reserved for patients with a contraindication to peripheral cardiopulmonary bypass or in those who required concomitant procedures. A total of 36 procedures were performed on 22 patients included in the cohort (listed in Table 1). Average cardiopulmonary bypass time for the cohort was 119 minutes with an average crossclamp time of 103 minutes.

All attempts at mitral valve repair were successful and several adjunctive techniques used in addition to the placement of neochords to the posterior leaflet. A median of 2 posterior adjustable neochords were placed in each patient with a range of 1 to 6 and were most commonly placed to P2. Our strategy for valve repair utilizes a variety of adjunctive techniques that are selectively employed to accommodate patient specific variations in the mitral pathology. Several techniques were performed in addition to neochordae to the posterior leaflet with the most common being suture closure of a residual cleft between the posterior leaflet segments. Four patients required an annular advancement, or a mattress suture placed between the posterior annulus and the body of the posterior leaflet to decrease the height of the posterior leaflet. One patient required partial resection of P2 due to persistent prolapse that was not amenable to neochord implantation. Prolapse of the anterior leaflet was typically managed with placement of simple neochordae to the prolapsing segment and was performed in a total of 5 patients.

Postprocedurally, 72% of patients had no detectable MR on echocardiography and the remaining 27% of patients had a grade of trace or mild. Six-month echocardiographic follow-up data were available in 6 patients and at this time point 100% of patients had undetectable or trace MR.

No patients required reintervention on the mitral valve during the study period and there were no cases of systolic anterior motion noted postoperatively. Patients were routinely extubated within 4 hours of admission to the intensive care unit and the average length of stay in the intensive care unit was 2 days with a range of 2 to 7 days. The average hospital length of stay was 7 days with a range of 3 to 27 days.

The most common complication noted during the immediate perioperative period was new-onset atrial fibrillation observed in 31% of patients followed by development of pleural effusion seen in 9% of patients. There were no deaths during the study period and no major complications were observed, including renal failure, cerebrovascular accident, or myocardial infarction. One patient in the cohort required reoperation for a femoral access site complication.

DISCUSSION

Degenerative MV is a common condition that is estimated to affect as many as 6 million patients in the United States alone.[1] The long-term risks associated with untreated severe mitral regurgitation have been well documented[2] and earlier intervention is being recommended on account of a growing body of literature to suggest improved clinical outcomes with surgical repair before the development of class I triggers.[4,12,13] At the same time, there is a great deal of evidence demonstrating the safety and long-term durability of modern mitral valve repair[14] owing to the rapid advances

TABLE 1. Demographic, preoperative, and operative characteristics for patients included in the cohort

Characteristic			
Demographic			
No. of patients	22	22	6
Male gender	15 (72)		
Age	62 ± 12 (29-80)		
Coronary artery disease	5 (24)		
Atrial fibrillation	9 (29)		
Chronic renal insufficiency	2 (9)		
Diabetes	2 (9)		
CVA	1 (4.5)		
Prior cardiothoracic surgery	2 (9)		
Bileaflet prolapse/Barlow	2 (9)		
Posterior leaflet prolapse/flail	20 (91)		
Echocardiogram	Pre	Post	6 mo
EF	58.2 ± 8.9	53.8 ± 11.5	60.6 ± 3.04
MR	6.9 ± 0.3	0.35 ± 1.35	0.33 ± 0.51
None to trace		16 (72)	6 (100)
Mild		6 (27)	
Moderate			
Severe	22 (100)		
MV gradient		4.1 ± 1.54	2.7 ± 0.67
Operative			
Minimally invasive approach	17 (77.2)		
CBP (min)	119 ± 33		
Crossclamp (min)	103 ± 31		
Ring size	31.55 mm (28-34) Mode 30		
No. of posterior neochords	2.29 ± 1, 2 (1-6)		
No. of anterior neochords	0.48 ± 1		
Quadrangular resection (n)	1		
Folding plasty (n)	1		
Annular advancement (n)	4		
Cleft closure (n)	10		
Ring type			
Carpentier-Edwards Physio III*	11 (50)		
Simulus Semi-Rigid Ring†	9 (41)		
Medtronic Profile 3D†	1 (4.5)		
Cosgrove-Edwards Band*	1 (4.5)		
Concurrent procedures‡			
CABG	2 (9)		
TVR	3 (14)		
Left atrial appendage ligation	4 (18)		
Maze	5 (22)		
Perioperative			
ICU length of stay (d)	2.54 ± 1.47 (1-7)		
Hospital length of stay (d)	6.63 ± 4.9 (3-26)		
30-d readmission	3 (14)		
Death	0		
Stroke	0		
MI	0		
Re-exploration	0		
Access site complication	1 (4.5)		
Atrial fibrillation	7 (31)		
Pleural effusion	2 (9)		
PPM placement	1 (4.5)		

Values are presented as mean ± standard error of the mean (interquartile range), n (%), or median (range). *CVA*, Cerebrovascular accident; *EF*, ejection fraction; *MR*, mitral regurgitation; *CBP*, cardiopulmonary bypass; *CABG*, coronary artery bypass grafting; *TVR*, tricuspid valve repair; *ICU*, intensive care unit; *MI*, myocardial infarction; *PPM*, permanent pacemaker. *Edwards Lifesciences LLC, Irvine, Calif. †Medtronic, Inc, Minneapolis, Minn. ‡Thirty-six total procedures in 22 patients.

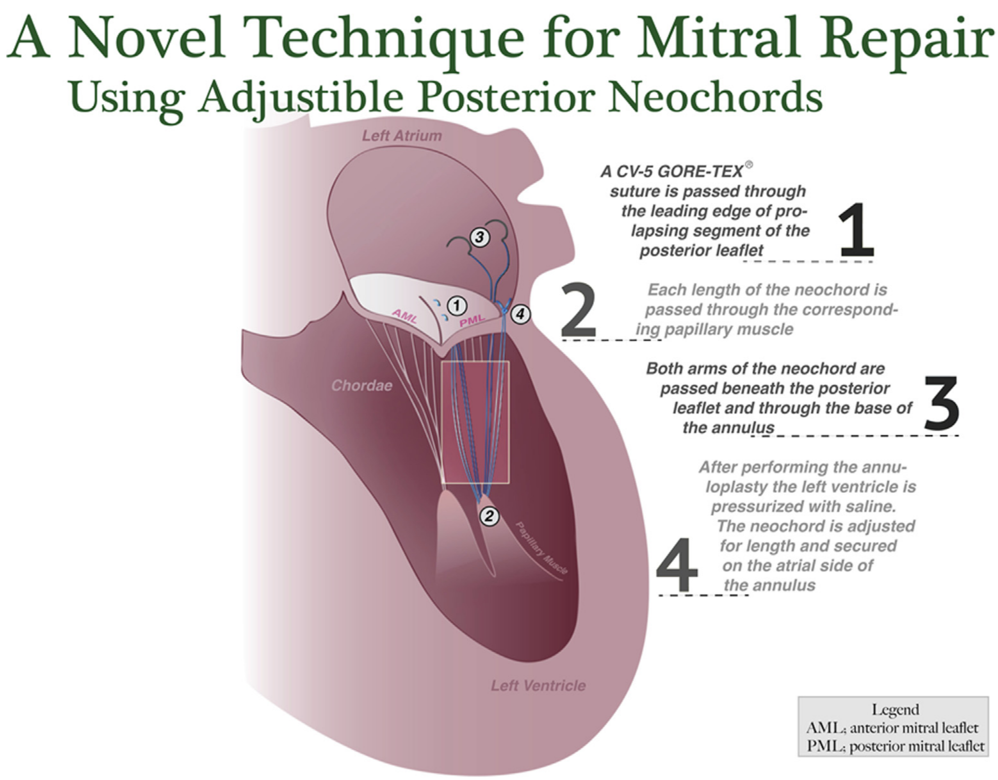


FIGURE 1. Illustration of a novel technique for mitral valve repair using adjustable looped neochords. Step 1: Each arm of a CV-5 Gore-Tex (W. L. Gore and Associates, Flagstaff, Ariz) suture is inserted into the leaflet edge as a mattress. Step 2: Both lengths of the neochord are implanted into the corresponding papillary muscle. Step 3: passed through the base of the annulus and temporarily secured on the atrial side of the annulus. Step 4: The valve is then tested for competency and the length of the neochord is adjusted to create an adequate zone of coaptation. *AML*, Anterior mitral leaflet; *PML*, posterior mitral leaflet.

in both technique and technology. A variety of methods for valve repair have been proposed and as of yet there is no definitive evidence to support any single approach over another—although all appear to outperform valve replacement and as such a repair first strategy has been recommended by most professional societies.

The well-known quadrangular resection for mitral valve repair was first popularized by Carpentier in the now classic report given at the American Association for Thoracic Surgery meeting in 1983[15] and consists of a partial or complete resection of P2 with subsequent reconstruction as a means to address P2 prolapse. Excellent long-term results have been described using this technique,[16] including 98% freedom from reoperation over a 14-year follow-up.[17] Despite excellent efficacy and apparent interoperator reproducibility, several concerns regarding the physiologic and hemodynamic implications of resectional techniques. In experimental models posterior leaflet resection has been shown to decrease posterior leaflet mobility[18] in vivo and to increase posterior leaflet stress[19] in silico when compared with neochord placement. A recent meta-analysis[20] partially corroborates experimental data and suggests a long-term benefit to left ventricular function with neochord implantation, although this finding did not reach statistical significance in the single randomized control study[21] comparing both methods of repair. Higher rates of reoperation for systolic anterior motion have also been reported with the resectional repair,[22,23] although this appears to be limited to studies utilizing a minimally invasive approach and has not been reported where a sternotomy is performed.[17,24] Taken together, these data suggest that degenerative mitral valve prolapse can be durably repaired using any of several techniques; however, neochordae may yield advantages over leaflet resection in a minimally invasive approach.

There are certainly drawbacks to implantation of neochordae that must be considered when selecting an approach to valve repair. Chief among them is the tight therapeutic window for the effective length of the neochord. If the effective length is dependent on the length of the chord as well as its position on the leaflet and papillary, then it follows that minimal variation in either could produce an ineffective or even dangerous result. To address this shortcoming, we propose an alternative method for the implantation of neochords and report excellent safety and efficacy in a series of 22 patients. The novel element of our method is that the looped neochord is secured behind the annulus and on the atrial side—a modification that imparts several benefits over alternative techniques. The added traction on the neochord as it passes behind the annulus allows the surgeon to place the neochord, implant the annuloplasty ring, and test the valve without having to permanently secure the neochord. As such, the neochord can be tested at several effective lengths, allowing the surgeon to titrate chord length to resolution of prolapse and regurgitation as demonstrated in Figure 1.

CONCLUSIONS

Mitral valve repair using the loop technique is a safe and reliable method that appears to impart significant long-term advantages over traditional techniques. Here we report on a novel technique for implantation of neochordae to the posterior leaflet and demonstrate excellent short-term echocardiographic and clinical results in a small series of 22 patients treated at the authors' institution.

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