customized for each individual patient and that is quickly and easily reproducible.

References


Simplified nonresectional leaflet remodeling mitral valve repair for degenerative mitral regurgitation

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Mitral valve repair surgery for mitral regurgitation (MR) has a multi-decade history beginning in the 1950s with Davila and colleagues'1 circumferential suture mitral annuloplasty and Lillehei and colleagues'2 suture commissural fusion. In 1960, McGoon3 pioneered direct leaflet repair via interrupted suture plication of the prolapsed leaflet segment. By the next decade, Carpentier and colleagues4 had developed a host of novel reconstructive techniques ranging from leaflet resection to native chordal repositioning, all augmented by remodeling prosthetic ring annuloplasty. Decades later, the classic quadrangular resection remains for most surgeons, the mitral valve repair technique of choice. The capability for high-probability mitral repair success now justifies early operation in asymptomatic patients.5 The opportunity for patients to undergo minimally invasive operations and percutaneous transcatheter repair has only further magnified the drive toward earlier surgery and the need for near 100% valve repair success.6-9

Despite the overwhelming success of quadrangular resection, minor drawbacks persist relating to irreversibility of leaflet resection, time-consuming leaflet reaproximation with sliding annuloplasty, monoleaflet function, and systolic anterior motion (SAM) risk. Neochord construction mitigates many of these but has the challenge of precise sizing and possibility of leaving excessive tissue, risking SAM. In seeking a mitral repair technique that avoids the potential negatives of leaflet resection and neochords, while also facilitating minimally invasive operations by reducing leaflet manipulation and simplifying suture management, we used a slight modification of the McGoon3 plication repair in 87 patients. Single suture imbrication of excess prolapsed tissue onto the noncoaptation ventricular side of the leaflet efficiently remodeled the leaflet into a smooth nonprolapsed coapting surface.

OPERATIVE TECHNIQUE

A minimally invasive approach was used in the majority of patients and has been described by Woo.6 In these patients and patients undergoing sternotomy, mitral ring annuloplasty sutures were placed immediately after atriotomy and retracted under slight tension to optimize exposure and inspection of leaflet pathology (Figure 1, A). As originally7 and subsequently10 described, the McGoon repair entailed an interrupted suture placed through the leaflet margin at one end of the prolapsed segment and brought out through the other end. Additional sutures were placed in parallel toward the annulus with progressively widening amount of leaflet tissue sutured. Tying the sutures pleated the leaflet, generating “slight bulkiness of the plicated portion”10 and eliminating the prolapse.
Our technique differs slightly, in that the leading edge of the prolapsed segment was grasped and inverted into the left ventricle, imbricating a small portion of leaflet tissue and presenting 2 short, near-apposing lines of tissue easily approximated with a double-running CV5 polytetrafluoroethylene (Gore-Tex; WL Gore & Associates Inc, Flagstaff, Ariz) suture, which then fixates the inverted leaflet tissue (Figure 1, B). The width of inverted segment is narrowed instead of widened as the annulus is approached. With the excess leaflet tissue transposed to the ventricular side of the leaflet, a smooth coaptation surface remains.

Saline pressure testing at this time usually demonstrates elimination of MR. The repaired mitral leaflet will usually appear fully restored, resembling a normal leaflet (Figure 1, C). Nevertheless, a ring annuloplasty was always performed to reshape the annulus, reduce demands on the leaflets, and prevent future annular dilatation. A complete ring was sized to the entire mitral valve orifice area (Figure 1, D). A composite intraoperative video of a minimally invasive P2 prolapse repair including pre- and post-bypass transesophageal echocardiography (TEE) is provided (Video 1).

RESULTS
This study received University of Pennsylvania Institutional Review Board approval (810968). Between May
The first patient had a preoperative left ventricular ejection fraction of 15% and underwent mitral plus tricuspid valve repair. His IABP was removed after 40 hours, and he was discharged on postoperative day 12. The second patient had a preoperative left ventricular ejection fraction of 35% and received mitral repair, aortic valve replacement, and tricuspid repair. She underwent IABP removal after 17 hours and was discharged on postoperative day 13.

Clinical follow-up was 100%. Eighty-six of 87 patients were alive, and all were free of MR signs and symptoms. No patient required reoperation for recurrent MR. Echocardiographic follow-up has been obtained at the discretion of the referring cardiologists. In many cases, in the absence of clinical symptoms or examination suggesting MR, referring cardiologists have opted to defer surveillance echocardiograms. Echocardiograms have been obtained on 58 patients with a mean follow-up of 1 year. This revealed a mean MR grade of 0.4, and no patients had significant (>2+) MR. Results were equivalent between minimally invasive and sternotomy cases. Several patients had echocardiography follow-up 3 years after surgery and continued to have no MR.

**DISCUSSION**

The McGoon repair was probably first overshadowed by the introduction of prosthetic mitral valve replacement and then later supplanted by Carpentier’s techniques. Nevertheless, long-term follow-up of 116 patients who underwent leaflet plication at the Mayo Clinic from 1958 to 1980 revealed good durability with only 20 patients requiring reoperation for recurrent MR, 10 because of annuloplasty failure. The widespread adoption of the classic Carpentier quadrangular resection supports its elegance, reproducibility, and durability. Long-term freedom from reoperation for recurrent MR has been reported as high as 98% at 14 years. Despite the overwhelming success, some drawbacks exist: (1) Resection is irrevocable; inability to reconstruct mandates valve replacement. (2) Resecting a wide prolapsed segment yields a diminutive minimally functional posterior leaflet or monoleaflet repair. (3) Annuloplasty rings implanted in these settings tend to approximate the anterior leaflet size. In some patients, this smaller valve may risk dynamic mitral stenosis, as learned from ischemic MR repair. (4) The potential for resecting insufficient tissue, particularly in Barlow’s pathology, and reducing the septal–lateral dimension with ring annuloplasty may adversely alter the height of the posterior leaflet, risking SAM, and overly reduce posterior annular arc length, reducing mitral orifice area. (4) Leaflet sliding requires precise, time-consuming leaflet detachment and reattachment that can also reduce leaflet surface area and functionality. Time prolongation is magnified in minimally invasive operations. (5) Annuloplasty rings implanted in these settings tend to approximate the anterior leaflet size. In some patients, this smaller valve may risk dynamic mitral stenosis, as learned from ischemic MR repair. (6) The potential for resecting insufficient tissue, particularly in Barlow’s pathology, and reducing the septal–lateral dimension with ring annuloplasty may adversely alter the height of the posterior leaflet, risking SAM, and overly reduce posterior annular arc length, reducing mitral orifice area.
relationship between the anterior and posterior leaflets, risking SAM.

Surgeons continue to evolve this classic repair. In seeking to preserve leaflet area, a triangular resection reduces the amount of leaflet cutting and suturing and precludes the need for annular plication or leaflet sliding.14 To ensure proper posterior leaflet height reduction after triangular resection, an innovative technique of folding part of the residual leaflet during reapproximation has also been described.15 Horizontally folding prolapsed leaflet tissue under itself without resection has also been reported.16 Prolapse can alternately be corrected with polytetrafluoroethylene (Gore-Tex) neochords, which may be premeasured using TEE.17 Overly redundant leaflet tissue can be addressed with a combined leaflet height-reducing and neochond procedure, such as the creative “haircut repair.”18 The biomechanical advantage of preserving leaflet tissue has also been studied in a laboratory setting. Sophisticated ex vivo left heart simulator analysis of explanted, manipulated mitral valves has shown enhanced coaptation length and leaflet mobility with a nonresectional repair technique compared with quadrangular resection.19

Potential drawbacks with these modifications still exist. A triangular resection still entails leaflet cutting and reapproximation. An aggressive folding plasty can overly reduce the posterior leaflet surface area, yielding a monoleaflet repair. Precise neochond sizing can be difficult. A neochond tied in a cardioplegia-arrested ventricle may be foreshortened. On ventricular filling, the leaflet will be tethered, yielding residual MR. A neochond tied overly long will yield persistent leaflet prolapse and MR.

The interest in preserving leaflet tissue, coupled with the drive for efficient, minimally invasive techniques may reinvigorate the appeal of leaflet plication. Inverting a small amount of leaflet into the ventricle eliminates excessive redundant tissue while preserving functionally useful mobile leaflet tissue for coaptation surface. Slightly reducing the size of the posterior leaflet by this manner effectively balances the height relationship of the anterior and posterior leaflets and avoids an excessively high posterior leaflet that may predispose one to SAM. Finally, this approach avoids posterior annulus arc length reduction, preserving a maximal mitral valve total orifice area. In some respects, this technique resembles a small triangular resection without the need for resection.

This repair is also easily fine-tuned with additional passes of the suture. We frequently use the first half of the double-running suture line to invert a minimal amount of leaflet tissue, gently pressure test with saline to examine leaflet geometry, and then use the second half of the suture to reinforce the first line or, if needed, invert additional tissue by placing slightly wider bites. Polytetrafluoroethylene (Gore-Tex) suture does not damage leaflet tissue and can be easily removed and repositioned if desired. This reversibility offers a significant advantage over resection techniques and does not preclude using other repair techniques. The rapid and efficient single suture technique particularly facilitates minimally invasive operations. Although P2 segment repairs were most common, P1 and P3 segment and anterior leaflet disease were also addressed with this technique.

Limitations of this repair include potentially inverting too much tissue and restricting the leaflet. This can be corrected by removing the Gore-Tex suture and resuturing with less tissue. Also, excess bulky tissue may produce anterior protrusion of the repaired leaflet, risking SAM. Calcified leaflets may be difficult to bend and invert. Limitations of the study are its retrospective nature and duration of follow-up. All patients are undergoing continued long-term follow-up.

CONCLUSIONS

This study reports a series of 87 patients who underwent nonresectional leaflet remodeling mitral valve repair. Prolapsed leaflet tissue was inverted into the left ventricle yielding a functional leaflet and eliminating MR. Good perioperative outcomes were observed.

References


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Implantation of a Sapien XT aortic bioprosthesis with the NovaFlex catheter through a subclavian access

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Transcatheter aortic bioprosthesis implantation is a new option for patients at high surgical risk with severe symptomatic aortic valve stenosis.1 The main alternatives to transfemoral access are currently the transapical approach with an Edwards Sapien prosthesis (Edwards Lifesciences, Inc, Irvine, Calif) and the subclavian approach with the Medtronic CoreValve prosthesis (Medtronic, Inc, Minneapolis, Minn),2 with some observational and noncontrolled data indicating that the latter could be less invasive.3 The subclavian approach was not developed with the new generation Sapien XT bioprosthesis delivered by its NovaFlex catheter (Edwards Lifesciences) because of theoretic technical issues, including difficulties in aligning the prosthesis over the balloon in the patient, outside the delivery sheath in the ascending aorta.

We report the implantation of a Sapien XT bioprosthesis with the NovaFlex catheter through a left subclavian approach.

CLINICAL SUMMARY

An 82-year-old woman was referred for symptomatic severe aortic stenosis with New York Heart Association functional dyspnea class III, indexed effective orifice area of 0.45 cm²/m², mean gradient of 38 mm Hg, maximal gradient of 61 mm Hg, peak aortic jet velocity of 3.7 m/s, stroke volume of 70 mL, and left ventricular ejection fraction of 25%.

The patient had a history of diabetes mellitus, obesity (body mass index 36.7 kg/m²), chronic obstructive and restrictive pulmonary disease (forced expiratory volume in 1 second of 800 mL [55%], forced vital capacity of 1.4 L [56%]), peripheral artery disease, and coronary artery disease with history of previous percutaneous coronary intervention on the left anterior descending artery with no remaining significant stenosis. Low-dose (15 µg) dobutamine echocardiography detected contractile reserve (effective orifice area of 0.49 cm²/m², mean gradient of 49 mm Hg, maximal gradient of 75 mm Hg, peak aortic jet velocity of 4.3 m/s, stroke volume of 87 mL, and left ventricular ejection fraction of 37%).

A transcatheter aortic valve implantation was proposed, because this patient was considered a high-risk surgical candidate for whom conventional surgery was contraindicated (logistic EuroSCORE of 46.48%, Society of Thoracic Surgeons Score of 13.4%).

The aortic annulus, as measured by transesophageal echocardiography, was 24 mm. The iliofemoral arteries were not suitable for transarterial access (Figure 1, A). A transapical approach was contraindicated because of severe respiratory dysfunction. The computed tomographic scan showed a left subclavian artery without stenosis with a diameter of 8 mm (Figure 1, B and C) and a distance of 13.6 mm between the aortic annulus and the ostium of the left subclavian artery (Figure 1, D and E).

The procedure was performed with the patient under general anesthesia through surgical cutdown and isolation of the left axillary artery. After heparinization (50 UI/kg, activated clotting time of 200–250 seconds), the 19F sheath was directly inserted in the axillary artery toward the aortic arch over an Amplatz extra stiff wire (Cook Medical Inc, Bloomington, Ind). The sheath was then advanced through the aortic arch into the ascending aorta. The subclavian arch was cannulated with an 8F arterial catheter (Edwards Lifesciences) for monitoring and systemic arterial pressure measurements. A 19F Amplatz extra stiff wire (Cook Medical Inc) was advanced over the balloon in the patient, outside the delivery sheath in the ascending aorta.

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