Robotic Mitral Valve Repair Through Nonresectional Posterior Leaflet Remodeling

Alfonso Agnino¹, MD and Amedeo Anselmi², MD, PhD

Abstract
The nonresectional posterior leaflet remodeling technique through free margin running suture (FMRS) has been recently introduced for the management of complex degenerative lesions of the posterior mitral leaflet. It aims at providing a novel tool in the mitral surgeon’s armamentarium to improve the reproducibility and durability of repair, namely in cases characterized by more severe degenerative disease (Barlow and extensive fibroelastic deficiency lesions). Although FMRS can be performed through any surgical access, its features render it particularly adapted to minimally invasive mitral surgery. We describe for the first time the characteristics of FMRS in the context of robotic-assisted mitral repair. A stepwise approach is employed for presentation. The diffusion of robotic-assisted mitral repair has been limited by both economic and reproducibility issues; we hypothesize that FMRS may be helpful in improving the reproducibility of minimally invasive and robotic-assisted mitral surgery. We also discuss the initial clinical results of FMRS.

Keywords
mitral valve repair, robotic surgery, outcomes

Introduction
Robotic-assisted mitral surgery is characterized by a peculiar methodology for exposure and conduction of surgery, and by the need for a dedicated learning curve.¹ The nonresectional posterior leaflet remodeling technique or free margin running suture (FMRS) has been recently proposed;² its early and mid-term follow-up have been published recently.³,⁴ Herein, we depict the first performance of such technique in robotic-assisted mitral valve repair. Its general features and its characteristics potentially capable to facilitate and standardize robotic-assisted mitral repair in complex mitral anatomy are discussed.

Central Message
The free margin running suture can be proposed for the management of complex degenerative lesion of the posterior mitral leaflet. It is feasible under a robotic-assisted approach and may improve reproducibility of this strategy.

Technique
A 58-year-old male patient presented severe, symptomatic (NYHA class III) mitral regurgitation due to degenerative disease. His body mass index was 22.6, and his previous medical history was insignificant. Transthoracic and transesophageal echocardiography evidenced prolapse and flail of the P2 and P3 segments of the mitral valve, with moderate annular dilatation. A minimally invasive, robotic-assisted approach was decided for mitral valve repair. At preoperative evaluation, the anatomic features of the mitral valve suggested the employment of the FMRS technique. After establishment of double-lumen ventilation (right lung exclusion) and placement of a percutaneous right internal venous jugular cannula, the patient was installed in a supine position with a drape beneath the right hemithorax. A DaVinci X (Intuitive Surgical Inc., Sunnyvale, CA, United States) surgical system was employed with a 3D thoracoscope. Four thoracic ports were positioned at the second, third, and fifth intercostal spaces for the insertion of robotic arms. A 3-cm minithoracotomy was performed (third right intercostal space) as a working port for the insertion of prosthetic ring and valve testing. Cardiopulmonary bypass was established through peripheral cannulation via the...
right groin with bicaval drainage. An aortic endo-clamping technique was employed in the present case (Intracllude, Edwards Lifesciences Inc., Irvine, CA, United States), although a minimally invasive transthoracic clamp can be also adopted. After left atriotomy in the Sondergaard groove, a dynamic retractor was positioned within the left atrium at the level of the interatrial septum. The Supplemental Video describes exposure and technique performance in a stepwise manner.

Intraoperative exploration confirmed the echocardiographic findings. The P2 and P3 scallops presented extensive flail with excess tissue. There was a myxomatous infiltration and thickening of the P2 and P3 segments, and their height approached the anterior annulus when unfolded. These features were compatible with a Barlow forme fruste case. The anatomical requirements for the performance of the FMRS posterior leaflet remodeling include the existence of at least 1 normal (in terms of height and morphology) segment within the posterior leaflet (in this case P1). A double-armed 4-0 Gore-Tex suture is employed; 2 rows of suture are passed parallel to the free margin of the prolapsing segments until the normal scallop, where the sutures are tied (Fig. 1, Fig. 2). A new coaptation line is therefore created at the height of the normal scallop, while the excess tissue in the prolapsing region(s) is turned into coaptation surface. Enhanced degrees of freedom with robotic arms with respect to conventional minimally invasive mitral surgery instruments facilitate the performance of the repair. In case the normal scallop is represented by P3 and backhand sutures are required all along the posterior mitral leaflet, robotic instruments smoothen the placement of stitches and enhance their precision. A 36-mm complete ring (Physio II, Edwards Lifesciences, Irvine, CA, United States) was implanted. Hydrostatic testing confirmed correction of the flail and absence of residual mitral regurgitation. The left atrium was then closed with 4-0 Polypropylene sutures.

After de-airing and release of aortic endo-clamping, the heart was defibrillated and cardiopulmonary bypass was weaned (cardiopulmonary bypass [CPB] time: 175 min; aortic clamp time: 121 min). Control transesophageal echocardiography indicated the absence of residual mitral regurgitation; the average transmirtal gradient was 5 mmHg, the coaptation length was 13 mm, and there was no systolic anterior motion of the anterior mitral leaflet. The postoperative course was uneventful; the mechanical ventilation time ICU stay were 3 and 28 h, respectively.

**Discussion**

About 20 years after the initial experiences, the reproducibility, safety, and effectiveness of robotic mitral valve repair remain debated, particularly in cases with more complex mitral anatomy. This may represent one reason for the limited diffusion of robotic-assisted mitral surgery, alongside increased economic costs. Additionally, the very long-term follow-up of mitral valve repair using conventional techniques (including leaflet resection and artificial chordal implantation) indicates that patients with more complex mitral anatomy (e.g., extension of myxomatous disease) are at increased risk of recurrence of regurgitation. The FMRS nonresectional posterior leaflet remodeling technique has been recently proposed for the management of extensive degenerative lesions of the posterior mitral leaflet, in order to
copy particularly with such more complex repair cases. It was expected that the creation of a particularly large coaptation surface was to ameliorate the long-term freedom from recurrent regurgitation, through a greater coaptation “reserve” as well as a better distribution of forces applied to the repaired mitral leaflets and subvalvular apparatus. The shift toward this type of repair techniques in our experience was also suggested by the observation that about half of the cases of recurrence of mitral regurgitation were due to fibrosis and restriction of posterior leaflets late after segmental resection and reconstruction. The initial follow-up in the first 37 FMRS recipients indicated no mitral regurgitation recurrence at an average 2.1 ± 1.4 years after surgery, and only 1 case of residual mild-to-moderate (2+/4+) regurgitation. A larger follow-up in a cohort of 103 consecutive recipients at 2 centers confirmed only 1 case (0.9%) of 2+/4+ residual mitral regurgitation at an average 1.9 ± 1.3 years follow-up. In the same series, no patient required a second CPB run to correct systolic anterior motion of the anterior mitral leaflet, possibly due to the frequent implantation of large-sized rings, despite all of them were complete rings.

The straightforwardness of the FMRS repair technique allows the effective and rapid management of a complex anatomical condition through the minimally invasive approach with or without robotic assistance, where the optimization of surgical times is of importance for the overall success. Ambidexterity of robotic arms is useful when backhand sutures are required from the P1 toward the P3 segments for FMRS performance (i.e., P3 being the normal reference segment). Such sutures can therefore be placed forehand (left robotic arm) as opposed to conventional minimally invasive approach. For the management of multisegmental posterior leaflet disease with great amount of excess tissue, FMRS avoids segmental resection and reconstruction, annular plication, and placement of multiple artificial chordae (requiring access to papillary muscles, length adjustment, etc.). All these steps are replaced by 2 rows of continuous suture in an easily accessible portion of the valve apparatus and by the tying of only 1 knot. Novel surgical techniques are therefore expected to enhance the reproducibility and safety of robotic-assisted mitral valve repair, since these elements are likely to translate into reduced aortic clamp times, including during the learning curve. In the first half of our robotic program that started in May 2019 (when the presented patient was operated on), the CPB and aortic clamp time in robotic FMRS recipients (N = 13) were 175 ± 20.9 and 108.7 ± 10.5 min. These were conversely 182.7 ± 4.7 and 98.4 ± 7.6 min in the second half of the FMRS robotic program (P < 0.001 for both comparisons). The increase in CPB time despite decreasing clamp time must be attributed to the unavailability of the Intraclude device in the last period (adding on-pump time for the insertion/extraction of cardioplegia cannula). Nevertheless, the FMRS technique can be employed through any surgical approach including median sternotomy. Additional repair procedures (such as artificial chordal placement, edge-to-edge repair, and indentation closure) can be performed in association with FMRS. Artificial chordae can be added at the level of the reconstructed posterior leaflet if required. One significant feature of the FMRS technique lies in the creation of a considerable coaptation surface; in a follow-up series in 103 patients, average coaptation length at discharge was 12 ± 2 mm. Ongoing follow-up evaluation will be required to verify whether such observation will translate into improved durability of repair versus alternative techniques in the context of extensive degenerative disease.

Appropriate performance of the FMRS technique must be based on the verification of anatomic requirements, including excess tissue in the prolapsing segment(s). In the absence of excess tissue (localized forms of fibroelastic deficiency), FMRS can induce distortion of the paracommissural segments and mitral regurgitation. As the coaptation is shifted toward the anterior leaflet, there is an increased risk of systolic anterior motion. Therefore, care must be paid to avoid undersized annuloplasty namely in predisposed patients (narrow aortomitral angle, dynamic septal bump, and long anterior leaflet).

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding
The author(s) received no financial support for the research, authorship, and/or publication of this article.

Supplemental Material
Supplemental material for this article is available online.

References
1. Gillinov AM, Mihaljevic T, Javadikasgari H, et al. Early results of robotically assisted mitral valve surgery: analysis of the first 1000 cases. J Thorac Cardiovasc Surg 2018; 155: 82–91.
2. Agnino A, Parrinello M, Panisi P, et al. Novel nonresectional posterior leaflet remodeling approach for minimally invasive mitral repair. J Thorac Cardiovasc Surg 2017; 154: 1247–1249.
3. Agnino A, Lanzone AM, Albertini A, et al. Follow-up of the novel free margin running suture technique for mitral valve repair. Thorac Cardiovasc Surg 2019; 67: 557–560.
4. Anselmi A and Agnino A. Extended follow-up of the free margin running suture technique for mitral repair. In: 33rd Annual Meeting of the European Association for Cardio-thoracic Surgery, Lisbon, Portugal, 3-5 October. Windsor, UK: EACTS, 2019.
5. Anyanwu AC and Adams DH. Etiologic classification of degenerative mitral valve disease: Barlow’s disease and fibroelastic deficiency. Semin Thorac Cardiovasc Surg 2007; 19: 90–96.
6. David TE, David CM, Tsang W, et al. Long-term results of mitral valve repair for regurgitation due to leaflet prolapse. J Am Coll Cardiol 2019; 74: 1044–1053.
7. Shimokawa T, Kasegawa H, Katayama Y, et al. Mechanisms of recurrent regurgitation after valve repair for prolapsed mitral valve disease. Ann Thorac Surg 2011; 91: 1433–1438.