Innovations
2020, Vol. 15(1) 22–25

DOI: 10.1177/1556984520901487
journals.sagepub.com/home/inv
SAGE

Mitral Valve Repair Techniques With Neochords: When Sizing Matters

Lorenzo Di Bacco[1], MD, Antonio Miceli[1], MD, PhD, and Mattia Glauber[1], MD

Abstract

Mitral valve (MV) repair procedures have evolved over time and multiple approaches have been proposed also for the repair with neochords implantation. This article compiles the currently available approaches for implanting and sizing neochords, to restore a proper coaptation of the MV leaflets and a good systo-dyastolic movement. The described techniques are aimed at standardizing chordal measurement, in order to reduce variability in chordal length. The placement of annuloplasty ring before chordae implantation should be avoided. Regardless of the technique chosen, it is important that the implanted chordae do not interfere with normal native chordae, to avoid the risk that neochordae may heal together or get damaged. This article aims to give an overview of the most common sizing techniques available.

Keywords

mitral repair, loops, chordal sizing

Central Message

All MVR techniques with neochords implantation aim to standardize chordal sizing, to restore the most physiologic leaflet motion and valve competence. Across all techniques, one of the most important parameters for repair success is chordal sizing.

Introduction

Mitral valve (MV) repair procedures have evolved over time and multiple approaches have been proposed for the treatment of degenerative MV regurgitation, although the "Resect" and "Respect" approaches still remain the most commonly adopted ones. Both these techniques aim at restoring a proper coaptation of the MV leaflets and a good systo-dyastolic movement.

In the case of MV regurgitation caused by chordal elongation, rupture, or leaflet scallops' prolapse, the correction could be satisfactorily achieved by replacing the diseased chordae with polytetrafluoroethylene (PTFE) sutures. Since the clinical introduction of this technique in the late 1980s, the procedure is nowadays well established,[1,2] proven to be safe and effective for both the anterior and posterior leaflets,[3] and allowing for a more physiologic repair preserving leaflet mobility, compared to resection.

Techniques

Several techniques could be used to achieve chordal replacement:

1. *Make it with a ring*: After MV exposure, a careful analysis of the subvalvular chordal apparatus and leaflet scallops' height is necessary to identify the type of leaflet defect; a 2-0 braided sutures can be placed around the mitral annulus to improve its exposure and ring sizing. The correct identification of the papillary muscle (PM), belonging to the ruptured or elongated chordae, is also very important since PTFE chordae repair should reproduce the native chordal arrangement. During chordal implantation, the corresponding PM group must be selected avoiding crossing the midline when the neochordae are implanted to prevent excessive leaflet tethering.
Chordae that are fixed to the posteromedial PM should be attached to the medial half of the MV, and loops attached to the anterolateral PM should be attached to the lateral half.[4,5]

[1]Minimally Invasive Cardiac Surgery Department, Istituto Clinico Sant'Ambrogio, San Donato Group, Milano, Italy

Corresponding Author:
Mattia Glauber, Minimally Invasive Cardiac Surgery Department, Istituto Clinico Sant'Ambrogio, Via Faravelli 16, Milano 20149, Italy.
Email: mattia.glauber@gmail.com

After this first step, a double needle 4-0 PTFE suture is passed as an anchor stitch through the fibrous tip of the PM head and a single or double Teflon pledget is placed to avoid papillary lesions. Then, the suture is passed along the ideal coaptation line of the mitral leaflet from the ventricular to the atrial side. In order to identify the ideal coaptation line, the left ventricle (LV) is filled with saline solution as hydrodynamic test. This will be used as a reference point for neochordae placement and it can be marked with ink for easier identification. The aim of this approach is to restore a coaptation surface of at least 7 mm that is associated with a higher freedom from reoperation (Supplemental Video 1).[6] One or more PTFE chordae could be placed with this technique.

At the end of the procedure, the correct chordal length and tension must be assessed: the posterior annulus is used as landmark for the height of the neochordae, relying on the principle of basal marginal chordae equivalence, where the height of a marginal (primary) chorda is always equal to that of the corresponding basal (tertiary) chorda.[4]

The Livanova Memo 3D ReChord and Memo 4D annuloplasty rings have been developed according to this concept and they are designed to allow a correct chordal sizing: with these devices, once ring sizing is performed, the prosthetic ring is parachuted on the annulus and tied up. The neochordae are first passed through the corresponding loop and then inserted in the P2 prolapsing segment along the coaptation surface, achieving a "hockey stick" effect. Finally, the coaptation line is brought to the adjacent annulus and PTFE sutures are tied at the level of posterior prosthetic ring in correspondence to the involved loop. Once the MV repair is complete, the loops are removed and the coaptation line is marked with a sterile pen to allow its view (Supplemental Video 2). In patients with isolated P2 prolapse, a good surface of coaptation was achieved in all mitral segments using a pair of PTFE neochordae on P2.[7]

2. *Do it free-hand*: Perier and colleagues proposed another technique for chordae implantation and measurement, here reported: after valve exploration, in order to clarify the regurgitation mechanism and to plan the best treatment strategy, the repair starts by identifying PM tips.[8]

   A figure of 8 with a 4-0 ePTFE is placed through the fibrotic part of the anterior and posterior PM tips. If the prolapsed area is greater than the middle portion of P2, additional artificial chordae may be necessary. These sutures must be placed through the PM head that anchors the diseased chordae with respect to the geometry of the subvalvular apparatus. The 2 ePTFE sutures are then brought up from the atrial side of the leaflet to the free edge and then back through the atrial side, 4–5 mm away from the free edge. The distance between 2 arms of the suture should be approximately 3 mm to avoid plication of the tissue.

   The next step is the ligation of the artificial chordae at the proper length; a 4-0 polypropylene suture placed through the free edge of the leaflet of P1 is used as landmark. By pulling gently on the artificial chordae, it is possible to bring the prolapsing part of the leaflet up to the same level as the reference point, then the ePTFE sutures are tied on the atrial side (3–4 knots are necessary). The artificial chordae should not only correct the prolapse but also prevent the posterior leaflet from moving anteriorly toward the LV outflow tract, which can occur in the case of excessive tissue height. In such case, the artificial chordae should be shortened by bringing the free edge of the prolapsed area 5–8 mm below the landmark point.

   The PTFE sutures are then passed on the ventricular side of the leaflet and tied on the ventricular surface. There are 2 reasons to tie the knots on the ventricular side: (1) to avoid any irregularity of the coaptation surface due to the prominent remnant and (2) to avoid any motion of the leaflet along the artificial chordae, which may create unnecessary repeated tension.

   Prominent knot remnants visible on postoperative echocardiography may be erroneously described as vegetations. Passing the artificial chordae again through the leaflet on the atrial side immobilizes the remnants underneath the leaflet tissue, thereby obscuring them from view on postoperative echo.In this way, the surface of coaptation is as smooth as possible, with very few irregularities due to foreign material.[8]

   As an alternative to Perier and colleagues, the proper length of chordae could be identified in different ways. After ideal coaptation margin identification as described above, both armored ends are passed from ventricular to atrial side twice as loop fashion.

   Once elongated or ruptured chordae are correctly replaced, ventricular cavity is filled with saline solution in order to keep chordae in tension. Passing the armored ends twice on the leaflet impedes excessive sliding of chordae, allowing a self-regulation of their length. Then, chordal length could be adjusted pulling the suture with a knot pusher in order to obtain the best coaptation result. Then, chordae are gently knotted to avoid an erroneous shortening, leading to chordal tethering.

3. *The "Dubai" Stitch*: Safadi and colleagues have proposed a novel sizing technique, achieved by means of an adjustable PTFE simple loop with a specific stitch called "sliding stitch." The adjustment concept is similar to the tie knot modulation around the neck. The loop engages both the leaflet and the PM in a single passage and it incorporates an original sliding knot designed to regulate chordal length. In this case, a 4-0 ePTFE suture is passed through the free edge of the prolapsed leaflet from the atrial side and to the fibrotic

portion of the PM. The first arm coming out of the leaflet margin corresponds to the narrow end of the tie, while the second arm, emerging from the PM, corresponds to the large end of the tie; this is brought anteriorly to the first arm and a single knot is performed. The second arm is then passed behind the circle string on its free middle segment emerging from the PM and a second simple knot is tied. Two knots are gently approximated by simultaneously pulling 2 arms, thus completing the simple-loop artificial chorda (Supplemental Video 3).

The chord size adjustment is achieved by pulling up the first arm and pushing down the sliding stitch toward the coaptation area, or the other way round if the chord became excessively short and below the coaptation level.[9] Once the correct chord sizing is reached, the knot could be pulled in the ventricle cavity in proximity of PM, simply with a suture sliding, leaving smooth coaptation margin (Supplemental Video 4).

4. *The loop technique*: This technique, proposed by Gillinov and colleagues, aims to support prolapsing mitral scallops by using presized chordal loops, anchored to the PM tips, facilitating chordal placement during MV repair.[10] A set of 3 loops is usually used, with a length that ranges from 12 to 24 mm. A native chorda near the prolapse area is selected as a landmark and then a sizing caliper is placed in the ventricle with the tip positioned at the insertion level of this chorda on the PM. The caliper is adjusted to determine the length of the normal chorda, keeping the leaflet under tension. In the case of absence of native chordae, the length is determined as the distance from the annular plane to the tip of a PM.

   Two sutures are passed through the tip of the PM, a second pledget is added, and the suture is tied to the PM.

   Each loop is configured with a double-armed suture and it is then sequentially fixed to the leaflet free edge at the site of prolapse: each suture attached to the loop is passed through the leaflet from the ventricular to the atrial side, approximately 3–5 mm from the leaflet edge; 2 sutures should be no more than 5 mm apart from one another at the leaflet edge. If less than 3 loops are necessary, the extra loop can be removed by simply cutting it and sliding it out.

   Borger and colleagues have proposed a similar technique for MV repair with premeasured ePTFE chordal loops.[9] Loops that are fixed to the postero-medial PM should be attached to the medial half of the MV, and loops attached to the anterolateral PM should be attached to its lateral half, in order to avoid a restriction. This "do not-cross the midline" rule can be facilitated by the visualization of the midline of the valve and it prevents an excessive tethering of the leaflet free edge.

   The lengths of the loops are determined by measuring the distance between the PM and the envisioned line of leaflet coaptation with a caliper; the level of leaflet coaptation is several millimeters below the annulus for the posterior mitral leaflet (PML) and nearly at the level of the annulus for the anterior mitral leaflet (AML); AML sizing must be more precise to prevent residual mitral regurgitation. The distal jaw is positioned 3–5 mm below the tip of the chosen PMs and the proximal jaw is placed at the expected level of coaptation.

   Melnitchouk's Rule could be helpful to determine loops' size.[11] The distance between the mitral annulus and the LV apex is measured using the 2-chamber long-axis view of transesophageal echocardiography:

   - For PML neochords: mitral annulus distance to LV apex (cm) × 2 = # mm loop length.
   - For AML neochords: [mitral annulus distance to LV apex (cm) × 2] + 10 = # mm loop length.

   Loop sizes fall within the following ranges in most patients: PML 10–16 mm; AML 20–26 mm; and commissures 16–20 mm.

   At the end, loops are fixed on the fibrous tip of PMs as previously described: an end of the suture is passed through the prolapsing segment of the leaflet, approximately 5–8 mm from its free edge, and 2 ends are tied over the free edge of the leaflet. The distance between anchoring sutures on the leaflet free edge is also 5–8 mm.

Conclusions

All these techniques aim at standardizing chordal measurement as much as possible, in order to reduce variability in chordal sizing. As a matter of fact, chordal sizing can be technically demanding and has a high risk of suboptimal suture length achievement, leading to significant chordal forces and leaflet stresses alteration and early repair failure. All these are key parameters affecting the long-term outcome of the repair, even if no residual regurgitation was present at early echo assessment.

Polytetrafluoroethylene chordae placement can be even more difficult in a minimally invasive setup. After MV exploration, all the necessary chordae, even placing one or two in excess, should be passed on the PM tip and on the leaflet's ideal coaptation margin before ring placement. At the end of the repair, unnecessary chordae should be removed or ligated. The placement of annuloplasty ring before chordae implantation should be avoided, because after ring placement the mitral annulus becomes more rigid, limiting leaflets excursion and subvalvular apparatus exposure, in particular in patients with small mitral annulus.

In case one or more chordae need to be added after ring delivery, a 5-0 prolene stitch passed from the free margin of the leaflet to the annulus can be placed, to plicate the leaflet and expose the subvalvular apparatus.

Also the above-described "Dubai Stitch" could be helpful in this case; with this technique requiring only one passage on the PM tip, a lower exposure of mitral apparatus is necessary.

To conclude, regardless of the chosen technique, it is important that the implanted chordae do not interfere with normal native chordae, to avoid the risk that neochordae heal together or get damaged. All these techniques are reported to be viable options with replicable results. There is growing evidence that the "non-resection" technique has potential advantages including preserved leaflet mobility, a larger surface of coaptation and preserved annular geometry; moreover, it allows to implant a larger annuloplasty ring.

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. David TE. Replacement of chordae tendineae with expanded polytetrafluoroethylene sutures. *J Card Surg* 1989; 4: 286–290.
2. Zussa C, Frater RWM, Polesel E, et al. Artificial mitral valve chorde: experimental and clinical experience. *Ann Thorac Surg* 1990; 50: 367–373.
3. Lange R, Guenther T, Noebauer C, et al. Chordal replacement versus quadrangular resection for repair of isolated posterior mitral leaflet prolapse. *Ann Thorac Surg* 2010; 89: 1163–1170.
4. García Fuster R, Martín E, Paredes F, et al. Artificial chordae in the setting of complex mitral valve repair: early outcomes using the folding leaflet technique. *Interact Cardiovasc Thorac Surg* 2014; 18: 586–595.
5. Neely RC and Borger MA. Myxomatous mitral valve repair: loop neochord technique. *Op Tech Thorac Cardiovasc Surg* 2015; 20: 106–123.
6. Lio A, Miceli A, Ferrarini M, et al. Implanting neochordae for the repair of mitral valve prolapse using a prosthetic ring with chordal sizing system: a modified technique for myxomatous leaflets. *Multimed Man Cardiothorac Surg* 2018.
7. Glauber M, Ferrarini M and Miceli A. Minimally invasive mitral valve repair using a semi-rigid annuloplasty ring with a new chordal sizing system: the Memo3D ReChord. *Ann Cardiothorac Surg* 2015; 4: 298–300.
8. Perier P, Hohenberger W, Lakew F, et al. Minimally invasive repair of posterior leaflet mitral valve prolapse with the "respect" approach. *Ann Cardiothorac Surg* 2013; 2: 833–838.
9. Safadi F, Yilmaz A and Glauber M. New adjustable "DUBAI" artificial chord for mitral repair: innovative method to ensure accurate length. *Innovations* 2018; 13(3 Suppl): S64–S65.
10. Gillinov M, Quinn R, Kerendi F, et al. Premeasured chordal loops for mitral valve repair. *Ann Thorac Surg* 2016; 102: e269–e271.
11. Axtell AL, Moonsamy P, Dal-Bianco JP, et al. Minimally invasive nonresectional mitral valve repair can be performed with excellent outcomes. *Ann Thorac Surg* 2020; 109: 437–444.