Editorial

What is the Optimal Surgical Therapeutic Target in Functional Ischemic Mitral Regurgitation: Annulus, Chord, Ventricle, or Papillary Muscle?

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Introduction

Optimal surgical treatment of functional ischemic mitral regurgitation (MR) remains controversial. To perform better surgical treatment, surgeons need to understand the mechanism of ischemic MR of each case and the benefits and limitations of various surgical procedures.

Mechanism of Ischemic Mitral Regurgitation

Ischemic MR results from geometric abnormalities of the ventricle, which result in the dysfunction of a morphologically normal mitral valve.[1)]

The basic mechanism of ischemic MR is believed to be augmented leaflet tethering because of the outward displacement of the papillary muscles (PMs) by the left ventricular (LV) dilation. Especially, the local remodeling of the LV region supporting the posterior PM is a necessary condition for the development of MR. The tethering distance from the PM tip to the mitral annulus is the final common pathway that determines the leaflet coaptation. Annular dilation and LV dysfunction may not be the central mechanism, but they contribute to the development of MR in the presence of augmented tethering.

Different Patterns of Leaflet Tethering; Asymmetrical and Symmetrical

There are basically two different types of tethering, i.e., asymmetrical and symmetrical, according to the different patterns of the LV dilation.[2)] These two shapes of tethering depend on the relationship of three vectors (posterior, apical, and lateral).

In the asymmetrical tethering group, the posterior leaflet is simply drawn more posteriorly than apically. This posterior restriction of the leaflet prevents it from reaching its normal and more anteriorly located coaptation point; thus the coaptation point moves posteriorly, creating the asymmetrical tethering shape. The anterior leaflet is also tethered, but less than the posterior leaflet. This leads to its relative prolapse, which causes posterior regurgitant jet.

In the symmetrical tethering group, there are apical and mediolateral tethering vectors in addition to the posterior component. The net result of these forces is more apical tenting, with the coaptation point being displaced more apically. The systolic motion of both leaflets is equally affected, and the regurgitant jet therefore has a central origin and direction.

Potential Surgical Therapeutic Targets

Theoretically, leaflet tethering can be relieved by modifying the components of the mitral complex or/and ventricle. So what is the optimal surgical therapeutic target in ischemic MR?

Paradox of Undersized Mitral Annuloplasty

The most common surgical procedure currently performed for ischemic MR is undersized mitral annuloplasty. Bolling and colleagues popularized this approach, using very small (size 24 to 26) mitral annuloplasty rings.[3)]

Undersized mitral annuloplasty, which brings the dilated posterior annulus anteriorly to reduce the anterior-posterior dimension and to restore the consumed coaptation zone, is simple to perform and usually effective in eliminating ischemic MR in the early postoperative period. The initial results for undersized mitral annuloplasty seemed encouraging, with low perioperative mortality. However, subsequent

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studies at various centers revealed that up to 30% of patients developed recurrent MR during follow-up.[4)]

What is the key parameter that predicts the recurrence of MR and the outcome of undersized mitral annuloplasty?

Calafiore and colleagues showed that a coaptation distance (the end-systolic distance between the coaptation point of mitral leaflets and the plane of mitral annulus) of more than 11 mm is associated with a high risk of MR recurrence after undersized mitral annuloplasty.[5)]

Otsuji's group observed a significant increase of posterior mitral leaflet (PML) tethering after undersized mitral annuloplasty.[6)] Augmented posterior displacement of the coaptation after annuloplasty in patients with persistent MR can be explained as a result of restricted PML excursion toward coaptation. This augmented PML tethering contributed to the reduced coaptation length with persistent MR after ring annuloplasty.

Magne and colleagues showed that in the presence of significant PML restriction (a preoperative systolic PML angle to the plane of mitral annulus of more than 45 degrees), undersized mitral annuloplasty may worsen the PML tethering and lead to persistent MR.[7)]

PML tethering might be the key parameter of ischemic MR, which determines not only the severity of MR, but also the long-term outcome of the undersized mitral annuloplasty.

On the other hand, even in patients without MR recurrence it is observed that undersized mitral annuloplasty creates functional mitral stenosis (MS) with high pulmonary artery pressure and a worse functional capacity.[8)]

In summary, undersized mitral annuloplasty reduces the anteroposterior diameter of the annulus and MR at the expense of augmented PML tethering and postoperative functional MS, paradoxically.

Chordal Cutting

Messas and colleagues proposed the hypothesis that cutting a limited number of critically positioned secondary chords can improve leaflet coaptation and reduce ischemic MR by eliminating the bend in the anterior leaflet.[9)] Although predominant concern for this procedure is possible deleterious effects on the LV function, several surgical groups have begun cutting secondary chords in combination with mitral annuloplasty and confirmed an increase of leaflet mobility and a decrease of MR recurrence without affecting the LV function. David's group showed encouraging short-term results during up to 2 years of follow-up, but the long-term results and durability of this procedure remain to be seen.[10)]

Ventricular Modification

Because ischemic MR is essentially a ventricular disease, surgical ventricular restoration therapy, if indicated, may be preferable.

In the event that localized LV dilation resulting from posterolateral transmural myocardial infarction is a major cause of ischemic MR, reducing the longitudinal length of the posterolateral fibrotic scarring segment, either by direct plication stitch or by using a small endoventricular patch with or without mitral annuloplasty, is an effective procedure to restore LV geometry and will result in the elimination of ischemic MR.[11,12)]

The plication of interpapillary myocardium in combination with LV restoration therapy decreases the distance of both PMs.[13)] This attenuates outward displacement of the PMs, helping to reserve coaptation of mitral leaflets to a certain degree.

Papillary Muscular Modification

The approximation of two PMs by the sling technique (tightening and securing the Gore-tex 4-mm tube sling encircling the trabecular base of both PMs) or a direct suturing of both PM tips increases the mitral leaflet mobility by suppressing the tethering resulting from a lateral displacement of the PMs.[14,15)] These techniques are aiming at the attenuation of longitudinal tethering distance as a secondary effect of repositioning the PMs to the midline.

A more radical solution to attenuate longitudinal tethering distance would be Kron's procedure. This procedure directs a relocation of the posterior PM by drawing the posterior PM tip closer to the mitral annulus just posterior to the right fibrous trigone.[16)] It may be useful for patients with a minimally dilated LV or posterolateral regional LV geometric changes causing ischemic MR.

Langer and Schäfers reported a modified posterior PM relocation transventricular suture technique as an adjunct to mitral annuloplasty, in which the PM is relocated in the direction of the midseptal fibrous annulus of the aortic root in the beating heart.[17)] They applied this technique in severe tethering cases with a coaptation distance of more than 10 mm, and the short-term result is encouraging. The transventricular STRING

suture, which is equivalent to a third-order chord, effectively attenuated tethering distance between a posterior PM tip and fibrosa without limiting the excursion of the anterior mitral leaflet. It might function as a seatbelt for the LV, limiting deleterious remodeling.

Mitral Complex Remodeling Procedure

With these notions in mind, we proposed a more-aggressive procedure aiming at a comprehensive remodeling of the entire mitral complex.[18] This remodeling procedure consists of three major concepts: undersized mitral annuloplasty, division and reconstruction of secondary chords, and bilateral PM relocation (drawing both anterior and posterior PM tips individually to the posterior mitral annulus under a beating heart). In the most severe tethering case, a relocation of both PMs might be more effective than a single PM relocation to completely eliminate ischemic MR.

Conclusion

Functional ischemic MR is a complex issue because the mechanism and severity of leaflet tethering are different in each case. No universal surgical treatment is available for this complex disease. Surgeons should select individualized optimal surgical treatment case by case, with the best understanding of the functional morphology of the mitral complex and the left ventricle.

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