Mitral annuloplasty ring design and selection: Flexible bands are (mostly) all you need

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It is well accepted that use of a prosthetic annuloplasty is mandatory for mitral valve (MV) repairs done for degenerative mitral regurgitation (MR). However, the choice of prosthesis—between a complete ring or a flexible or semirigid posterior band—remains a topic of debate. Since Carpentier first introduced his novel method of MV repair in 1969 using a rigid annuloplasty ring, the common practice has slowly shifted from use of a complete ring to wider use of a posterior annuloplasty device, although most repairs for degenerative disease in the United States are still done using a complete ring.1,2 In our experience, a posterior band is nearly always sufficient in the treatment of MR due to degenerative disease, for 3 simple reasons: (1) it achieves the fundamental goals of MV repair, (2) it minimizes unnecessary risks of a complete ring without compromising durability of repair, and (3) it shows favorable hemodynamic outcomes compared with a complete ring. We show herein why most MV repair experts today choose a posterior annuloplasty device when repairing degenerative disease.

FUNDAMENTAL GOALS OF MV REPAIR ARE ACHIEVED USING A BAND

The fundamental goals of MV repair are to: (1) preserve or restore normal leaflet motion, (2) provide a large surface of coaptation, and (3) remodel and stabilize the annulus. In degenerative MR, a flexible posterior band does all 3 sufficiently. It is important to understand that the normal MV annulus is anteriorly integrated into the fibrous skeleton of the heart, connecting the anterolateral and posteromedial trigones to the aortomitral curtain, whereas posteriorly, the annulus is comprised of a thin band of connective tissue. Furthermore, the 3-dimensional mitral annulus shape changes throughout the cardiac cycle.3 The annulus has a natural saddle configuration, with the midpoints of the anterior and posterior annuli as the highest points and the trigones as the lowest points of the saddle. During diastole, the saddle dilates, flattens, and rounds to allow for maximal transmural flow. In systole, the anterior mitral annulus contracts and displaces inward to allow for maximal flow in the left ventricular outflow tract (LVOT) while ensuring coaptation of the mitral leaflets. The saddle shape of the mitral annulus helps maintain leaflet curvature, diminishing leaflet stress through the cardiac cycle.4 As such, maintaining the saddle shape when repairing the MV might diminish leaflet stress leading to longer durability of repair. Degenerative MR can span a range of leaflet pathology from fibroelastic deficiency to Barlow’s valve, which must be dealt with using targeted techniques including leaflet resection, height reduction, or neochord application.5,6 However, in most cases of degenerative MR, the annulus shows symmetrical dilation along the posterior aspect, causing the signature wide U-shaped smile of the coaptation line to become closer to a deep V from the surgeon’s perspective (ie, height is greater than the width of the MV).7 To achieve optimal leaflet coaptation, the systolic annular dimension must be restored to a width:height ratio of 4:3.8 Although a complete rigid ring does this by securing the annulus in a permanently systolic (and flattened) configuration, a flexible posterior band serves to stabilize and remodel annular dilatation while allowing natural movement of the anterior leaflet.
and aortomitral curtain, preserving diastolic transmural flow as well as systolic LVOT flow.

SIMPLIFYING SUCCESS, MINIMIZING RISK

When performing MV repair for degenerative MR, one must be acutely aware of the risks inherent to placing repair sutures all around the MV annulus. The key anatomic structures around the mitral annulus include (from the surgeon’s view) the circumflex artery between the anterior commissure counterclockwise to P2, the coronary sinus between the posterior commissure clockwise to P2, the bundle of His near the posteromedial trigone, and the aortic valve between the anterolateral and posteromedial trigones. The portion of the annulus needing annuloplasty reduction in degenerative MR usually extends posteriorly from trigone to trigone. Limiting the annuloplasty device and thus suture placement to this portion of the valve simplifies the procedure, reduces ischemic time, and minimizes risk to the aortic valve. Placing sutures along only the posterior annulus simplifies the exposure of the MV via Sondagard’s groove, through which exposure of the anterior intertrigonal annulus proves most challenging. Using a posterior band virtually eliminates the risk of aortic insufficiency caused by misplaced anterior annular sutures catching the noncoronary or left coronary cusp. Although the possibility of this complication is well known to the practicing mitral surgeon, few have published their own series of aortic complications during mitral repair, making the true incidence unknown.

Although sizing practices for annuloplasty devices vary among surgeons and institutions, Carpentier’s original dictum that “many imperfect results following valve repair are due to improper sizing of the anterior leaflet and inadequate ring selection” holds true. Use of a complete ring greatly increases the risks associated with incorrect sizing, which can either fail to provide adequate leaflet coaptation if the ring is too large or lead to systolic anterior motion (SAM) and LVOT obstruction if the ring is too small. “Overcorrection” of the mitral annulus with an undersized ring decreases the LVOT diameter by fixing the position of the anterior mitral annulus and restricting the natural inward motion of the aortomitral curtain toward the center of the MV during systole. When additional predisposing conditions are present, such as a hyperdynamic left ventricle and a large anterior leaflet, undersizing a complete ring can lead to SAM with LVOT obstruction. Over a 30-year experience with nearly 2000 mitral repairs, Loulmet and colleagues showed that use of a posterior band significantly decreased the risk of SAM compared with use of a complete ring without compromising success of repair. Analysis of long-term outcomes indicate that there is no difference in durability after repair with either a posterior band or a complete ring. Therefore, introduction of the additional risk associated with placing anterior stitches for a complete ring are not justified in most degenerative MR cases.

HEMODYNAMIC ASSESSMENT OF RING VERSUS BAND

Although the long-term success of repair with either a flexible band or a complete ring are comparable, newer hemodynamic data favor the use of a band over a ring to achieve lower transmural gradients and more physiologic flow patterns. Chan and colleagues studied the functional effect of mitral repair with either a band or a ring in 275 patients and reported that patients who had a complete ring repair had higher transmural pressure gradients, larger left atrial volumes, lower exercise tolerance, higher B-type natriuretic peptide levels, and lower quality of life scores. In a study of 301 patients, Hiraoka and colleagues reported that when annuloplasty size was <30 mm, mean transmural gradient was significantly higher in patients with a complete ring annuloplasty compared with those who received a band annuloplasty, which in turn was correlated with higher pulmonary artery systolic pressure. The use of an undersized complete ring increases the risk of creating functional mitral stenosis, a risk obviated by the use of a flexible posterior band, which allows some physiologic diastolic expansion of the mitral annulus. Flow dynamic studies using 4-dimensional magnetic resonance imaging have shown that annuloplasty disturbs normal interventricular flow patterns in the left ventricle, a relationship that is exacerbated with smaller annuloplasty ring sizes and complete rings. More recently, Morichi and colleagues showed that mitral annuloplasty led to significantly higher levels of energy loss in the left ventricle and aortic outflow, the clinical implication of which is a higher cardiac workload. Additionally, their data showed that a flexible posterior band induced flow patterns that most closely resembled that of a healthy volunteer with the least amount of energy loss, likely because of the preserved physiologic motion of the anterior mitral annulus. Although further longitudinal studies using this novel parameter are needed, present evidence using state of the art assessment of flow dynamics favors the use of a flexible posterior band over a complete semirigid ring.

EXPERT OPINION AND EXCEPTIONS

Perhaps the most convincing argument to use a flexible posterior band over a complete ring is the least scientific one: that the experts favor it and their results are proof. Long-term results of large series from Hartzell Schaff of the Mayo Clinic, Tirone David of Toronto General Hospital, David Adams of Mount Sinai, Steve Bolling of the University of Michigan, and Marc Gillinov of the Cleveland Clinic, representing some of the most high-volume mitral surgeons in North America, show that results of annuloplasty using a posterior band are excellent. Long-term...
results of Ottavio Alfieri’s group from Milan show that use of a band over a ring had no effect on long-term recurrence of MR, and that their practice has largely shifted from commonplace use of a complete ring to that of a flexible posterior band.13

Of course a posterior annuloplasty device is not appropriate in 100% of patients. Importantly it is imperative to distinguish patients with purely degenerative pathology, in whom the anterior intertrigonal annulus rarely dilates, from those with ischemic or mixed pathology in whom the annulus might show circumferential dilation and the ventricular dynamics are themselves pathological.21 In rare patients with degenerative disease or in those with mixed functional disease, the anterior mitral annulus has dilated and might benefit from annuloplasty with a complete ring. However, in our experience, and in the experience of many published experts in the field, when treating purely degenerative MR, a flexible posterior band is most often right the answer.

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**References**


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