Autologous repair of "very asymmetric" bicuspid aortic valves using geometric ring annuloplasty

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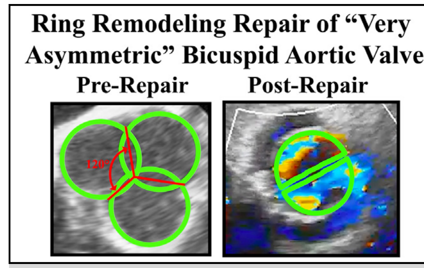


Remodeling of "very asymmetric" bicuspid valves achieved using the 180° annuloplasty ring.

CENTRAL MESSAGE

Bicuspid valves with 3 equal-sized sinuses have been difficult to repair. With geometric ring annuloplasty, the 180° bicuspid ring remodels the annulus into equal-sized fused and nonfused segments, converting every valve to "symmetrical" geometry. "Very asymmetrical" valves become routine candidates for repair, as with any other bicuspid configuration.

Video clip is available online.

Repair of regurgitant bicuspid aortic valves (BAVs) can yield good long-term results and achieve excellent long-term survival.[1-3] Favorable results stem from in-depth understanding of BAV anatomy and function. A repair-oriented anatomical classification of BAV has been presented: type A—symmetrical valve with commissural orientation of 180° to 160°; type B—asymmetrical BAV with commissural orientation of 159° to 140°; and type C—"very asymmetrical" BAV with commissural orientation of 139° to 120°.[4] It has been shown that increasing valve asymmetry is associated with more technical difficulty and lower repair durability.[5]

Although repair methods for types A and B are quite well established, the approach to very asymmetric BAV remains controversial. The El Khoury group prefers valve tricuspidization using a pericardial patch to create a new commissure, preserving 120° orientation.[6] However, this approach often fails because of pericardial degeneration. Others try to achieve more symmetrical valve orientation by either fused sinus plication[7] or nonfused sinus patch augmentation.[8] These methods are somewhat subjective and it is difficult to achieve complete valve symmetry. In the joint experience of the Brussels and Homburg/Saar groups, valve replacement for an expected or an actual unsatisfactory repair result was more frequent in type C compared with types A and B. Also in only 36% was bileaflet repair performed whereas the neocommissure was created in most patients.[4] Our method provides a relatively simple solution to this surgically demanding scenario, with the goal of increasing the number of repairable aortic valves.

Our approach is on the basis of using an internal bicuspid annuloplasty ring to not only provide annular reduction, but also to routinely achieve 180° valve symmetry. The HAART 200 ring (BioStable Science and Engineering) has a circular base geometry with 180° subcommissural posts (Figure 1, *A*). It is sized according to intercommissural

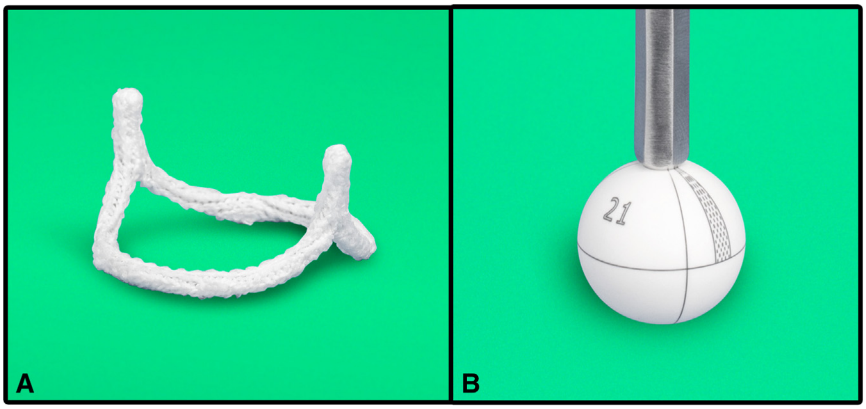


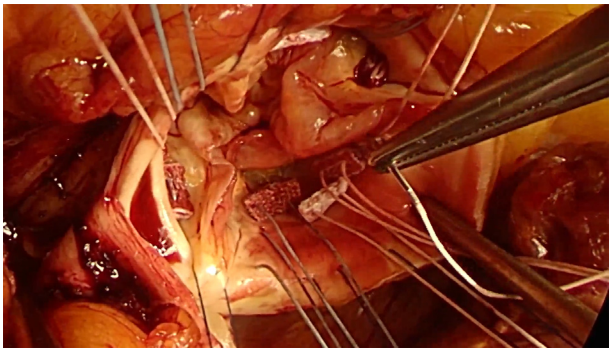
FIGURE 1. A, The bicuspid annuloplasty ring used for remodeling of "very asymmetric" bicuspid valves. B, The ball sizer that is placed into the nonfused sinus behind the leaflet to measure leaflet free-edge length.

diameter and keeps that dimension unchanged. With transannular suturing, the ring brings the sinus-to-sinus dimension centrally to improve leaflet coaptation. More important, the ring remodels the fused and nonfused sinuses into equal annular segments. In this way, the ring establishes 180° valve geometry, no matter the preoperative configuration. This study was approved by the institutional review board of West Virginia University for retrospective analysis of deidentified clinical data (2005016064; Approval date May 29, 2020; expiration date May 28, 2025).

CASE VIDEO SUMMARY (SURGICAL TECHNIQUE)

A video is provided to illustrate the concepts involved (Video 1). After inspecting the valve to assess symmetry and relative leaflet configurations, the ring and valve are sized. The nonfused leaflet serves as a reference, and its free-edge length is measured with a ball sizer that predicts required ring diameter (D) as: D = free-edge length/1.5 (Figure 1, *B*). That size ball also should fit the intercommissural distance.[9] First, the commissural mattress sutures are placed from one sinus into the subcommissural triangle, through the commissural ring post, and then back to the subcommissural triangle out the other sinus. To facilitate proper commissural suture placement, blue dots are marked 3 to 5 mm below the tops of both subcommissural triangles to ensure the commissural ring posts are implanted reproducibly. The bottom commissural horizontal mattress suture of 3-0 braided polyester is passed 2 mm deep to the leaflet–aortic junction, at a pledget width below the blue dot—then through the base of the ring post—then out the other side, 2 mm deep to the leaflet–aortic junction below and above the valve. The top horizontal mattress suture is passed into the blue dot—through the tip of the ring post—and out the other side—adding a fine Dacron supra-annular pledget. The second subcommissural suture is placed similarly. Again, it is important to pass the sutures 2 mm deep in the aortic annulus and away from the leaflet to prevent leaflet–Dacron contact that could abrade the leaflet. Also, the ring posts should be positioned low in each subcommissural triangle to raise the commissural tops relative to the base of the valve.

Next, the ring is carefully passed below the valve, keeping commissural sutures tight. To prevent gaps, 3-0 braided annular sutures that loop the ring are placed close to the commissural sutures and into the nonfused annulus top-down, 2 mm deep to the leaflet insertion, and retrieved behind the ring. Then, the sutures are passed bottom-up through the annulus in front of the ring, effectively looping the ring. Fine Dacron supra-annular pledgets are added throughout. After 2 looping sutures are placed adjacent to the commissural stitches, 1 to 3 middle nonfused looping sutures are passed, once again 2 mm deep to the leaflet–2aortic junction. Finally, the lateral fused annular looping sutures are placed top-down next to the



VIDEO 1. An illustrative case video is presented of bicuspid valve repair in the setting of "very asymmetrical" sinus geometry. The 3 equal-sized sinuses and annular segments are remodeled by the annuloplasty ring to convert the valve to a symmetrical two-leaflet 180° configuration, no matter the prerepair geometry. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00521-1/fulltext.

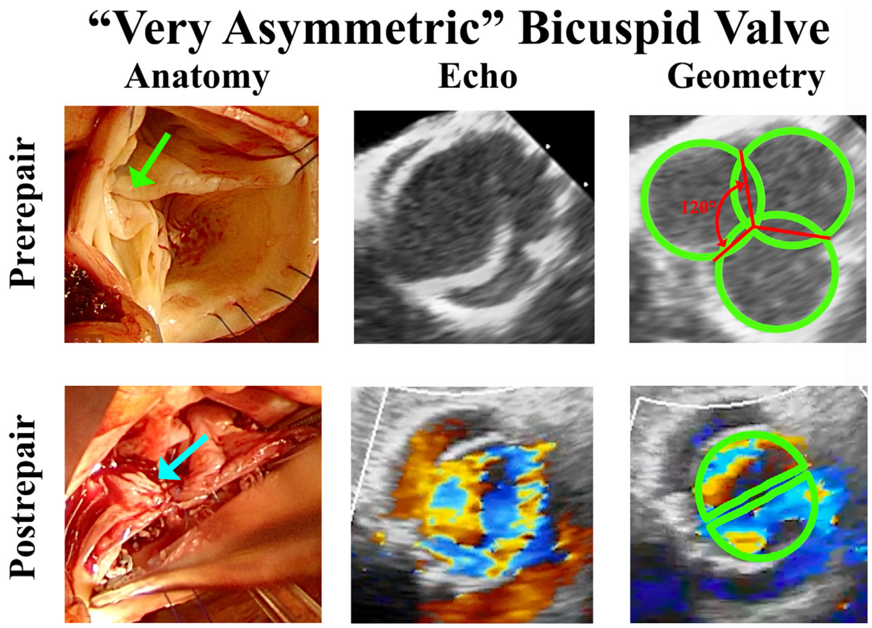


FIGURE 2. Pre- and postrepair views of valve anatomy, echocardiography (*Echo*), and geometry are shown to illustrate the precise valve and annular remodeling that occurs with this approach. The *green arrow* indicates the commissural fusion and cleft. The *blue arrow* illustrates the cleft closure. The *green shapes* indicate the sinuses of Valsalva.

commissural sutures, retrieved behind the ring, and then passed bottom-up back into the aorta 2 mm deep to the leaflet. The second left sinus and right sinus looping sutures are passed close to the raphe. If a gap still remains under the raphe, an additional looping suture can be used to straddle the raphe and to eliminate the gap. In general, the entire annulus should be controlled by sutures, with no gaps, and more sutures often are required in larger valves.

The 2 commissural sutures are tied first—slowly and tightly to wrap the commissure around the ring post. Then, 1 arm of the suture is passed down and lateral through the pledget (away from the leaflet), tied again, and cut short to prevent leaflet–suture contact. The second commissural suture also is tied and fixed laterally. The nonfused looping sutures followed by fused annular looping sutures are tied tightly, laterally fixed, and cut short. At this stage, both leaflets have been moved centrally. Ample fused leaflet tissue usually exists, because of major differential fused annular reduction. Prolapse correction by leaflet plication then is guided by the concept that a bicuspid valve during systole should be a cylinder with equal inflow and outflow circumferences. Thus, leaflet free-edge length should be shortened by plication to half of the ring circumference. For example, half the circumference of a 23 mm ring is 36 mm and of a 25 mm ring 39 mm.

Plication is guided by measuring free-edge length with a silk suture, and then free-edge length is shortened to half the ring circumference. Plication sutures of 6-0 Prolene are placed to the right and left of the nodulus, to reduce the nonfused free-edge to the desired length. This also raises the nonfused leaflet to a proper effective height. Linear cleft closure then is started in the middle of the thickened cleft tissue using simple interrupted 5-0 Prolene sutures. This linear closure increases the geometric height of the fused leaflet to match the nonfused leaflet as the reference. The interrupted suture line usually requires 2 to 5 sutures, to the limit of the cleft tissue. The goal is to achieve a similar free-edge length to that of the reference nonfused leaflet (Figure 2). With testing by commissural stretching, free-edge lengths and effective heights should match nicely, with good leaflet vertical coaptation. The aortotomy is closed with a running suture.

Postrepair echocardiography routinely shows a competent valve with good leaflet motion and low gradients. Using the algorithms described, the leaflets open well with a circular orifice, because the fused and nonfused annuli have been remodeled from 3 equal sinuses to 2 equal hemiannular geometries (Figure 2). In the presented case, the peak gradient was 22 mm Hg, and the mean gradient 12 mm Hg, with a trace of aortic regurgitation on the immediate postoperative transesophageal echocardiography. A month later, the peak gradient was 20 mm Hg, the mean was 11 mm Hg, and there was no detectable aortic regurgitation.

Longitudinal outcomes with geometric ring annuloplasty have been excellent,[10] and this approach allows routine repair of BAV defects with "very asymmetric" geometry. Although commissural angles were not specifically measured in previous studies, intermediate type BAVs and unicuspid valves accounted for approximately one-fifth of that series, and these defects frequently display 3 equal-sized sinuses.[11,12] In our analysis at 7.5 years of maximal follow-up, aortic regurgitation remained low, and gradients acceptable. At the latest echocardiography follow-up, specific values for aortic regurgitation grade averaged 0.4 ± 0.8, and mean valve gradient 12.3 ± 5.9 mm Hg.[10] Thus, the concepts in this brief report supplement those in previous reports with regard to applicability of geometric ring annuloplasty in the "very asymmetric" BAV subgroup.

CONCLUSIONS

In summary, geometric ring annuloplasty for BAV repair remodels the annulus into equal fused and nonfused segments with 180° commissures. This major remodeling allows routine repair of "very asymmetric" bicuspid valves with 3 equal sinuses, without the need to add pericardium, or to perform complex sinus or reimplantation procedures. Thus, prerepair sinus configuration becomes less important, because after repair, all valves assume 180° geometry.

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