Chord transfer and leaflet management for Barlow's valve repair

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Barlow's disease is one of the most challenging phenotypes of degenerative mitral valve pathology, characterized by excessive leaflet tissue, diffuse prolapse, elongated chordae, and annular dilation. Successful repair requires restoration of physiologic leaflet motion and stable coaptation and prevents systolic anterior motion. This manuscript describes an algorithmic approach for Barlow's valve repair centered on chord transfer and leaflet management. Chord transfer utilizes normally functioning secondary chords as support for prolapsing leaflet segments. By mobilizing and reattaching these chords to areas of excess height or unsupported leaflet tissue, balanced leaflet motion can be restored. The technique is detailed step-by-step, including identification of abnormal chordal structures, selection of appropriate chords and precise re-implantation to restore coaptation geometry. Additional leaflet management strategies to address Barlow's disease include cleft closure, assessing and correcting areas of asymmetry, smoothing of irregular edges. Operative images and descriptions illustrate how to safely execute these modifications while preserving leaflet integrity and subvalvular architecture. This approach aims to simplify and standardize repair with a reliable method to repair a complex Barlow's valve without use of artificial neochord implantation.

Keywords: Barlow's disease; degenerative mitral regurgitation (DMR); systolic anterior motion (SAM); chord transfer; mitral valve repair algorithm

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Introduction

Many surgeons think Barlow's valve repair is much more difficult than isolated posterior leaflet mitral repair. Reports indicate a disappointing use of repair in only 56% of patients with anterior leaflet prolapse (1). We have not found that to be the case, and it does not have to be that way (2). Using the technique we describe here, which is quite different than prior reports, we take the experience and art out of the process of repair (3). This technique of repair replaces surgical judgement with simple math to achieve the goals of mitral repair; a post-repair leaflet coaptation length (CL) between 5 and 10 mm without residual prolapse or restricted leaflet motion. This reduces the risk of residual or recurrent mitral regurgitation (MR) from too small a CL, or systolic anterior motion (SAM) from too much coaptation which shifts the coaptation point towards the septum. If there is no remaining prolapse or restricted leaflet motion, and the CL is within the CL 5–10 mm target then there should be an excellent early and late result. We reported only 0.2% SAM using the algorithm in 1,026 patients, and at 10 years only 0.3% reintervention and 1.4% of patients with recurrent severe MR (3). When the technique of repair is broken down to a series of defined steps that are determined by a formula, not judgement, even Barlow's level of complex disease is easily repaired.

Operative Technique

Degenerative mitral regurgitation (DMR) is characterized

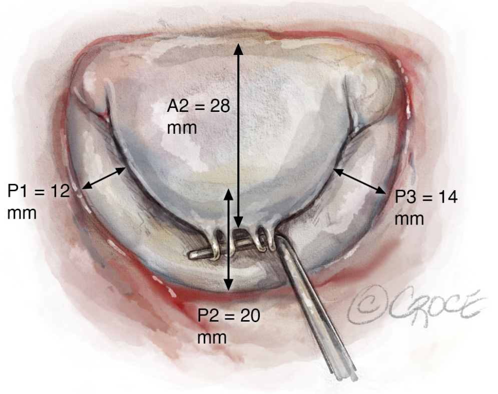

Figure 1 Quantitative algorithm-guided surgical technique based on A2 anterior leaflet length measurement is our preferred approach. Normal A2 length ranges from 18–22 mm; in patients with degenerative mitral regurgitation (DMR), the average increases to approximately 28 mm. A2 lengths >30 mm are common in Barlow's disease and may exceed 40 mm, with excess tissue contributing to post-repair systolic anterior motion. Posterior leaflet prolapse occurs in 80% of cases without anterior leaflet involvement, most often involving an elongated P2 segment averaging 20 mm (normal 8–12 mm).

by elongated leaflets. The surgical technique using our quantitative algorithm is primarily based on the length of the anterior leaflet at A2 (3). This is measured using transesophageal echocardiography (TEE), and also commercially available calipers (Caliper ring handle 11", Scanlon, St Paul, MN, USA). Other means can be used for measurement including a flexible ruler or measuring the opening of a pair of pickups to give a good approximation of length. Normal A2 length is 18–22 mm (*Figure 1*). In our experience there is wide variability in patients with DMR with an average A2 leaflet length of approximately 28 mm. But A2 lengths over 30 mm are common in Barlow's disease, and some are over 40 mm. This excess tissue is one of the contributing factors for post-repair SAM. Posterior leaflet prolapse occurs without anterior leaflet prolapse in 80% of patients. The P2 segment is elongated most often and averages 20 mm (normal range, 8–12 mm). The numbers in the figure come from our published data (4). We rely on two numbers to perform all DMR repairs: A2 length is the most important. The posterior leaflet is reconstructed to half the length of A2, or 15 mm maximum to reduce the risk of SAM. Knowing these numbers, a ring with the correct anteroposterior (AP) diameter is chosen so that the CL is in the target zone of 5–10 mm. The second important number is the distance from the coaptation point to the nearest point on the septum (C-Sept) during peak systole which we have found easy to measure and understand compared to the aortic-mitral angle (5). C-Sept is acquired from the intraoperative TEE. A C-Sept less than 25 mm indicates a higher risk for SAM and in these unusual circumstances (about 10%) we reconstruct the posterior leaflet to less than half of A2, or sometimes we choose a larger ring AP diameter. The most common cause of SAM is too small a ring AP diameter (6) or the posterior leaflet is too long. Both of those push the coaptation point closer to the septum.

Barlow's disease is characterized by bileaflet prolapse which is found in 15% of repairs, as reported in our series and most reports (2). In addition to the TEE images, saline infused into the left ventricle with a bulb syringe makes the location of the anterior and posterior leaflet prolapse evident. Frequently we use a blue ink pen to mark the midpoint of the location of prolapse on both leaflets, so it is easy to see when the left ventricle is empty. The free edge at the margin on both sides of the anterior prolapse is marked with a 4-0 Prolene suture to aid visualization and in planning chord transfer. The posterior leaflet sutures on each side of the prolapsing segment are not shown in this illustration (*Figure 2*). Most often with bileaflet disease the prolapse is 10–15 mm wide on each leaflet free edge. We have stuck with the tried-and-true principles of posterior leaflet resection. The resection is not the classic quadrangular resection, and with the excess tissue with Barlow's disease it is wider than a triangular resection. It forms a trapezoid shape with a gap at the base along the annulus of 2–6 mm on average. Rarely (not shown) the gap is wider than 10 mm at the annulus and compression sutures can be placed as a horizontal mattress suture to compress the annulus and reduce the gap by 50% or more.

We correct anterior leaflet prolapse with a classic Carpentier technique using the patient's own tissue for reconstruction instead of neochords. Chord transfer from normal length and quality mid-body chords is accomplished by first resecting the posterior leaflet prolapsing segment. During resection the surgeon should visualize and preserve the mid-body secondary chords (shown ghosted in the illustration). Two to four chords are typically located in the area to be removed. Sometimes the resection is made a little wider to encompass adjacent mid-body chords. The insert indicates that excess leaflet tissue out to the free edge is included in the resected portion. It should be trimmed

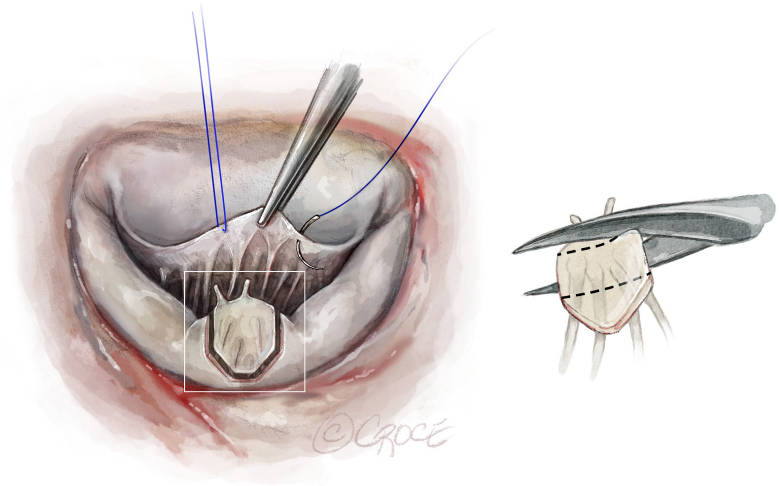

Figure 2 The free edge margins on either side of the anterior leaflet prolapse are marked with 4-0 Prolene sutures to assist visualization and chord transfer planning. Posterior leaflet marking sutures on each side of the prolapsing segment are not shown in this illustration. In bileaflet disease, the prolapse typically measures 10–15 mm along each leaflet free edge. Anterior leaflet prolapse is corrected using a classic Carpentier technique, employing the patient's own tissue rather than Gore-Tex neochords. The insert indicates that excess leaflet tissue out to the free edge is included in the resected portion. It should be trimmed away so that just the chords with some overlying leaflet tissues are transposed. Typically, the section of chords with leaflet tissue that is transferred is about 4 mm wide. Rarely, if desired, the section of leaflet can be split in half, and the chords will cover a wider section from A1 to A3.

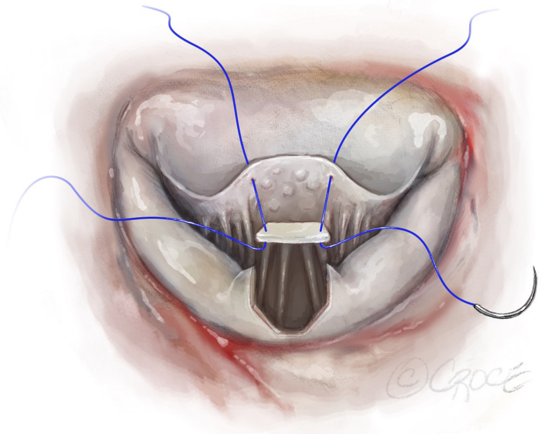

Figure 3 The free edge ruptured chords should be excised, and excess tissue should also be trimmed so that only the chords and overlying leaflet tissue are transposed. The selected posterior leaflet segment is aligned with the prolapsing portion of the anterior leaflet, secured with sutures at the medial and lateral margins to ensure correct orientation and avoid rotation or entanglement. Sutures are placed full-thickness through both leaflet free edges; the leaflet tissue allows a few millimeters of stretch to cover the prolapsed area. Leaflet reconstruction is performed with 5-0 braided sutures, which provide soft, low-profile knots and greater flexibility than Prolene.

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The anterior leaflet free edge with ruptured chords should be excised but prolapsed chords can be left intact. It is easy to line up the portion to be transferred to the prolapsing segment of the anterior leaflet. One simple suture on the medial and one on the lateral edges of the prolapse orients it properly (*Figure 3*). Take care that the transferred segment does not rotate or otherwise get entangled. The sutures should be placed through the full thickness on the free edge of the anterior leaflet and the posterior leaflet. The leaflet is forgiving and can be stretched several millimeters apart to cover the prolapsed segment. I use 5-0 braided sutures for all leaflet reconstruction. The knots are soft and low profile and more forgiving than Prolene.

Between the sutures on either end I add figure-of-eight sutures (*Figure 4*). This typically needs three or four sutures which are placed full thickness. On either end I typically add another simple suture to smooth out any irregular areas. For all leaflet suturing it is best to reduce or eliminate irregular

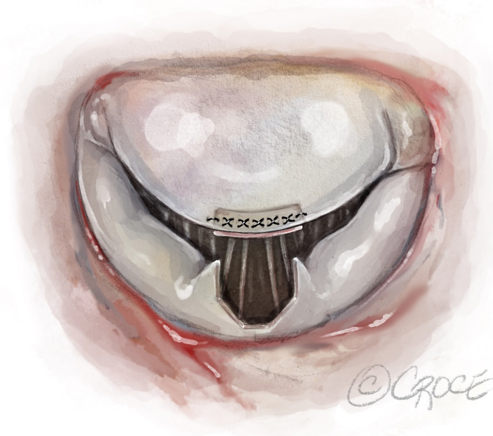

Figure 4 Between the medial and lateral anchoring sutures, three to four full-thickness figure-of-eight sutures are placed, with additional simple sutures at each end to smooth irregularities. Reducing uneven leaflet surfaces prevents small coaptation jets sometimes seen on intraoperative echo; these minor jets usually resolve on follow-up studies. The aim is complete elimination of mitral regurgitation on post-repair transesophageal echocardiography (TEE).

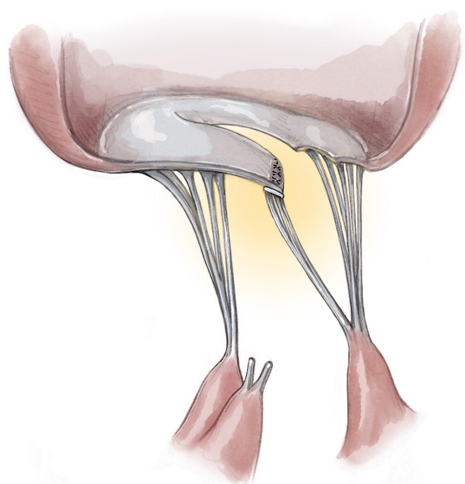

Figure 5 Achieving optimal leaflet coaptation length is the primary objective of mitral valve repair. Viewing the repair both in cross-section and from the surgeon's perspective illustrates the completed chordal transfer from the posterior to the anterior leaflet.

surfaces. If these are in contact at the coaptation line, they can create a small jet seen on echocardiography. These are of no concern long term, as they tend to resolve and are not visible by follow-up transthoracic echocardiograms. But it is best to have no MR at all on the post repair TEE so you are not concerned about it.

Achieving the right length of leaflet coaptation is the primary goal of how I perform mitral valve repair. For me it helps to think of the cross section of the valve as well as the surgeon's view. This shows the completed transfer of chords from the posterior to anterior leaflet (*Figure 5*).

Chord transfer is performed before reconstruction of the posterior leaflet so that you can easily visualize the subvalvular apparatus through the resection and ensure the chords are not twisted. At the base of the resection is usually a small 2–6 mm gap at the annulus and this is closed with a 2-0 braided plication stitch. Once it is tied you can pull it towards you and attach it to the drape. That rotates the valve towards you, brings it closer, and makes the next steps easier. Once that is complete the next step is to reconstruct the posterior leaflet according to the algorithm (3). The normal anterior to posterior leaflet length ratio is 2:1. Therefore, I measure posterior leaflet reconstruction to recreate this ratio using the calipers mentioned in *Figure 1*. In Barlow's disease the A2 often exceeds 30 mm, and in these cases, I reconstruct the posterior leaflet to 15 mm or less to reduce the amount of excess tissue that could push the coaptation point towards the septum and cause SAM. In this illustration the A2 length is 28 mm, therefore the reconstructed P2 should be 14 mm long (*Figure 6*). I use the calipers to identify 14 mm above the annulus then employ a partial folding plasty, so the new leaflet free edge is at 14 mm. The first 5-0 suture goes in at a point (typically about 2 mm) below the desired height of 14 mm (1). The needle is then passed from the ventricular side, through a free edge chord, and exits the leaflet (2). The needle is passed from the opposite chord on the free edge into the ventricle (3) and finally from the ventricle at a point that will fold the leaflet to the desired height (4). We have reported our early experience with this technique (4). Each "new' free edge is supported by the adjacent remaining chords. It can be varied according to the anatomy. Sometimes after resection the height of the leaflet is fine and a partial folding plasty is not needed. Sometimes one side is longer than the other and the suture placement should be altered so each side reaches the target length.

It is easy to simulate this by using a sheet of paper. Tear a portion out of the middle of the free edge of the paper to simulate a resected P2. Then fold the paper to the desired point on each side. You can see the two portions of the paper (i.e., leaflet) overlap this way, and you can envision

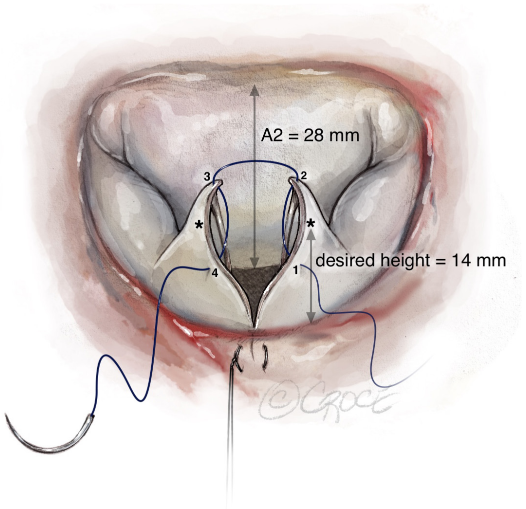

Figure 6 Chord transfer is performed before posterior leaflet reconstruction to visualize the subvalvular apparatus and ensure chords are not twisted. The resection base usually leaves a 2–6 mm annular gap, closed with a 2-0 braided plication stitch. Tightening and securing it to the drape rotates the valve toward the surgeon for better exposure. Posterior leaflet reconstruction follows the standard algorithm, maintaining a 2:1 anterior-to-posterior leaflet ratio. Using calipers, the posterior height is set—for example, with an A2 length of 28 mm, P2 is reconstructed to 14 mm via a partial folding plasty. 5-0 sutures placed just below the target height fold the leaflet precisely. Each new free edge is supported by adjacent chords and adjusted for asymmetry. This reproducible technique has largely replaced sliding plasty (<1% of repairs) and ensures optimal coaptation height.

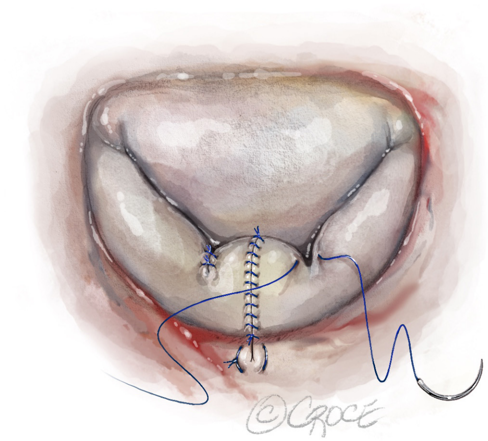

Figure 7 Leaflet closure is performed in two layers with running 5-0 braided sutures, though Prolene is acceptable. The first layer is full-thickness, and the second smooths the leaflet surface at the coaptation zone to minimize small residual jets. If trivial or mild MR appears on post-repair TEE, confirm the jet originates from the coaptation zone and not the suture line. Surface jets are typically stable, with no effect on long-term durability, but a mid-body suture-line jet can enlarge and should be repaired with a small pericardial patch. After resection, segmental indentations (P1–P3) may widen; clefts extending >50% toward the annulus are routinely closed (~80%) to prevent jets and ensure even chordal tension. This method achieves <mild MR in 94% of intraoperative TEEs. MR, mitral regurgitation; TEE, transesophageal echocardiography.

passing a suture through to fold the paper where you want. This is an easy way to achieve a precise reconstruction to the desired height. Before this technique I performed sliding plasty in 40% of my patients. That requires judgement, more time and effort, and is not as reproducible. Nowadays I do sliding plasty in less than 1% of patients. Partial folding plasty is easier and more precise—it allows the surgeon to achieve the target CL 100% of the time.

The leaflets are closed in two layers with running 5-0 braided suture (*Figure 7*). Many people use Prolene which is fine. The first layer is closed full thickness. The second layer is important to help smooth the leaflet surface, especially at the coaptation zone, to reduce small residual jets. If the TEE post repair shows trivial or even mild MR it is important to clarify if the origin of the jet is at the coaptation zone from a small irregular surface that likely will stay stable (and likely will not even be visible on transthoracic echocardiograms). These small jets have not been a problem regarding late durability in our experience (7). One exception is the rare occurrence of a jet through the suture line of the mid body leaflet closure. When the left ventricle generates high systolic pressure that small tear can easily become larger and significant. If a jet like that is identified on TEE, even if mild, it is prudent to reclamp and repair that area with a small patch of autologous pericardium to eliminate the leak.

The segments (P1, P2, P3) are separated by indentations that may open wider after resection. Some of these indentations are "cleft-like" because they are deep and extend more than 50% of the distance between the free edge and the annulus (8,9). I routinely (approximately 80%) close any cleft that can lead to a small residual jet. In addition, the normal chords disperse the systolic tension on the chords. It is just a theory, but distributing this load across several chords may contribute to our high 10-year durability (2,3). We have not seen any increase in gradient related to this routine practice of closing clefts. Intraoperatively we have

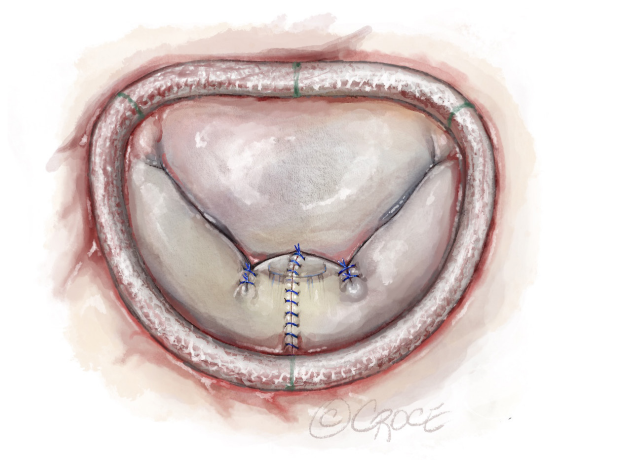

Figure 8 Final saline testing confirms valve competence. In Barlow's disease, small leaflet edge irregularities may create minor coaptation jets; marking them with blue ink aids identification after drainage. Over 90% close with a simple 5-0 suture, and added stitches smooth the coaptation zone. The repair should be symmetrical—any asymmetry may indicate subtle prolapse or restriction, often clarified by reviewing pre-repair TEE. Minor defects are corrected with commissuroplasty or free-edge remodeling. A complete remodeling ring standardizes anterior–posterior closure and ensures long-term durability and compatibility with future valve-in-ring therapy. TEE, transesophageal echocardiography.

reported less-than-mild MR on TEE is very high (94%) (7).

Thoroughly testing the completed repair with the saline test is an important last step. With Barlow's disease the free edge of each leaflet may have small irregular "V" shaped areas that create small jets at the coaptation point. If there is a small residual jet, I mark that area with a blue pen which makes it easy to identify the location when the saline is removed and the ventricle is empty. In over 90% of those instances this small, localized defect is easily closed with a simple 5-0 suture. Sometimes there is an irregular surface in the coaptation zone that can be smoothed with an additional one or two sutures. The completed repair should be symmetrical (*Figure 8*). Areas of asymmetry should be investigated as they may indicate residual areas of prolapse, or areas of subtle restriction. If there is an asymmetric area of prolapse it is worth re-reviewing the pre-repair TEE to help sort this out. The most common finding is a small area near a commissure (usually medial) that indicates anterior leaflet prolapse that was not appreciated on TEE because it did not cause an appreciable jet. That area may be competent, there is no leak demonstrable with the saline test, but it is asymmetric. That may be an area where disease progression can occur. If on inspection there are one or two elongated chords then I consider a commissuroplasty, or a small area of free edge remodeling with a simple suture. I use a complete remodeling ring in all patients because that fixes the AP closure predictably and permanently, more than a band (again, using the algorithm). The ring is placed the same in all patients with the widest distance corresponding to the commissures. Also, a complete ring is the best landing zone just in case there is a failure at some point and the patient may be a candidate for a future valve in ring approach instead of a reoperation surgeons should consider the "lifetime management" of repair patients, just as they do with aortic or mitral valve replacement. An important consideration therefore is to implant a ring purpose-built for possible late valve-in-ring treatment (10,11).

The proper CL is determined by the AP distance of the ring. The traditional sizing by commissure to commissure, trigone to trigone, anterior leaflet surface area, or a band with "normal" mitral annular dimension do not have achieve a consistent result. The illustration demonstrates that the same length leaflets can be treated successfully by a range of sizes and provide a CL within the target of 5–10 mm so there are no SAM and excellent late durability. I have seen surgeons perseverate between small differences in ring size, for instance whether to use a 32 or 34 mm ring. Those minimal differences make little difference in the CL. Conceptually, after correcting for prolapse, the two leaflets are squeezed into the AP ring distance. If A2 is 28 mm and the posterior leaflet is (therefore) 14 mm then 42 mm of leaflet is available (28+14 mm). A ring with an AP diameter of 28 mm (42–28 mm) yields 14 mm of coaptation, and since the leaflets are not prolapsing it is split evenly between the two leaflets (7 mm each leaflet; *Figure 9A*). If you use a ring with an AP diameter of 22 mm (42–22=20 mm), then there will be 10 mm CL (*Figure 9B*). These days I target an 8 mm CL for bileaflet repairs with a normal C-Sept. You can solve the problem differently to determine the right AP diameter. You need 16 mm overlap to get 8 mm CL on each leaflet. For A2 of 28 mm (and 14 mm posterior), 42–16=26 mm. A ring with an AP diameter of 26 mm will work well, even if your measurement is off a little or the reconstruction is off a little. I have not used a classic ring "sizer" in over 15 years, and the CL has been between 5 and 10 mm in 100% of repairs for many years (not yet published). When I target an 8 mm CL the echo is within 1–2 mm of that number in over 90% (not yet published). My partners and alumni

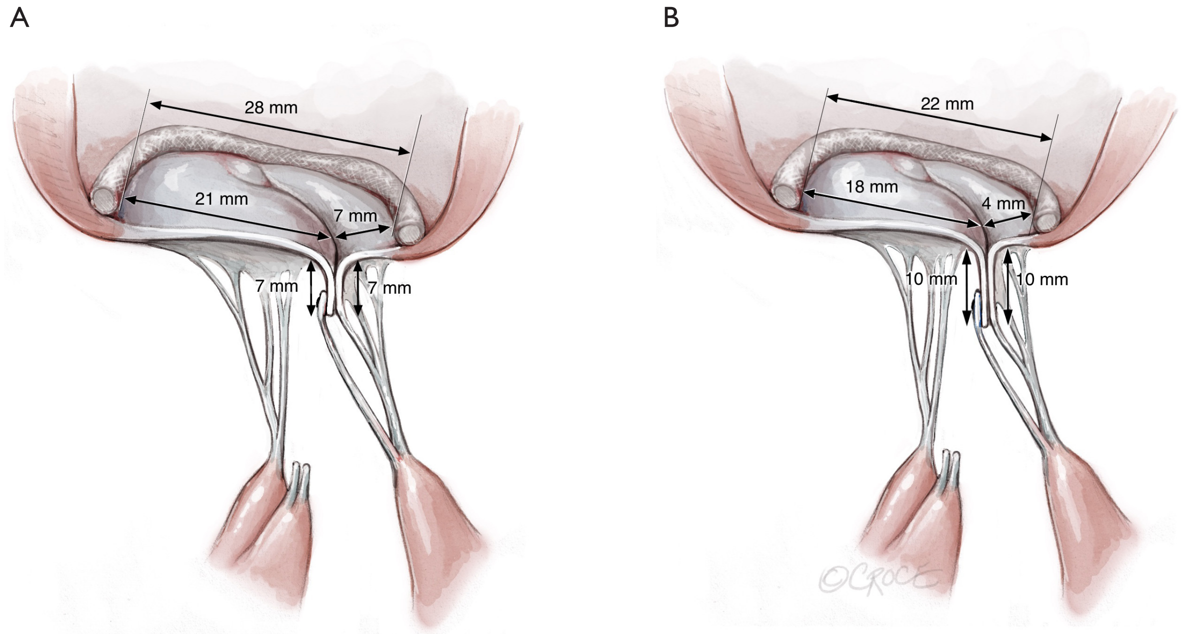

Figure 9 Proper coaptation length is determined by the AP diameter of the ring. Traditional sizing by commissure-to-commissure, trigone-to-trigone, or anterior leaflet area does not achieve consistent results. The illustration shows that identical leaflet lengths can yield a target CL of 5–10 mm across a range of ring sizes, preventing SAM and ensuring durability. After prolapse correction, the combined leaflet length is distributed within the AP ring distance. For example, with A2=28 mm and P2=14 mm (total 42 mm), a ring with AP =28 mm provides a 14 mm CL (7 mm per leaflet; A), while an AP =22 mm yields 10 mm CL (B). Targeting an 8 mm CL works well. For the leaflet lengths in this illustration, total overlap of 16 mm produces it (42–16=26 mm AP). A ring with an AP of 26 mm thus provides ideal coaptation. Using this mathematical approach, consistent 5–10 mm CL has been achieved in 100% of repairs, with 90% within ±2 mm of the 8 mm target. AP, anteroposterior; CL, coaptation length; SAM, systolic anterior motion.

trainees from Northwestern use the same technique. We hope this more precise repair technique replaces decades of teaching that experience is mandatory for successful repair. Math is.

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Footnote

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Conflicts of Interest: The author reports speaking fees and (or) royalties from Edwards Lifesciences, Atricure and Genesee. Besides, he serves as an advisory board member for Arthrex and Abbott, a surgical primary investigator of REPAIR-MR Trial (unpaid) for Abbott. The author has no other conflicts of interest to declare.

References

1. Khairallah S, Rahouma M, Gambardella I, et al. Trends in the Management of Anterior Mitral Leaflet Regurgitation. JAMA Netw Open 2024;7:e246726.
2. Nisivaco S, McCarthy PM, Kruse J, et al. Late results of chord transfer and other techniques for anterior leaflet repair without neochords. J Thorac Cardiovasc Surg 2024;168:1045-1056.e3.

3. McCarthy PM, Herborn J, Kruse J, et al. A multiparameter algorithm to guide repair of degenerative mitral regurgitation. J Thorac Cardiovasc Surg 2022;164:867-876.e5.
4. Abicht TO, Andrei AC, Kruse J, et al. A simple approach to mitral valve repair: posterior leaflet height adjustment using a partial fold of the free edge. J Thorac Cardiovasc Surg 2014;148:2780-6.
5. Maslow AD, Regan MM, Haering JM, et al. Echocardiographic predictors of left ventricular outflow tract obstruction and systolic anterior motion of the mitral valve after mitral valve reconstruction for myxomatous valve disease. J Am Coll Cardiol 1999;34:2096-104.
6. McCarthy PM, Bolling SF. Commentary: If you cram you get SAM. J Thorac Cardiovasc Surg 2021;162:578-9.
7. Imielski B, Malaisrie SC, Pham DT, et al. The impact of intraoperative residual mild regurgitation after repair of degenerative mitral regurgitation. J Thorac Cardiovasc Surg 2021;161:1215-1224.e4.
8. Mantovani F, Clavel MA, Vatury O, et al. Cleft-like indentations in myxomatous mitral valves by three-dimensional echocardiographic imaging. Heart 2015;101:1111-7.
9. McCarthy PM. Mitral leaflet clefts: innocent bystander or covert foe? Heart 2015;101:1087-8.
10. Guerrero ME, Bapat VN, Mahoney P, et al. Contemporary 1-Year Outcomes of Mitral Valve-in-Ring With Balloon-Expandable Aortic Transcatheter Valves in the U.S. JACC Cardiovasc Interv 2024;17:874-86.
11. Allen KB, Romary DJ, Grier EA, et al. Bench Testing of a New, Semi-Rigid, Saddle-Shaped, Complete Mitral Annuloplasty Ring Designed to Circularize During Transcatheter Mitral Valve-in-Ring Procedures. Structural Heart 2025. [Epub ahead of print]. doi: 10.1016/j.shj.2025.100791.

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