The Heart Surgery Forum #2012-1068
15 (5), 2012 [Epub October 2012]
doi: 10.1532/HSF98.20121068

Microsizing Using Inside Suture Placement. A Simple and Versatile Technique for Precision Adjustment of Ring Annuloplasties

Mark M. Levinson, MD, Justin Miller, RNFA

Hutchinson Regional Medical Center, Hutchinson, Kansas, USA

Dr. Levinson

ABSTRACT

Introduction: A new and simple technique for eliminating residual leaks during mitral annuloplasty, called microsizing, is described.

Methods: Microsizing is performed by moving one or more annuloplasty sutures from the outside to the inside of the prosthetic ring. This maneuver advances discrete segments of the annulus toward the opposing leaflet by a distance equal to the thickness of the ring (approximately 3 mm). Microsizing is a simple method for precision adjustment of annular shape and size to eliminate focal gaps, regardless of the cause.

Results: A series of 63 consecutive patients with moderate to severe mitral regurgitation (MR) were repaired over a 10 year period, all with intraoperative transesophageal echocardiography guidance. No patient required valve replacement (repair success rate 100%). Concomitant (non-mitral valve) procedures were performed in 53 patients (84.1%). Fifty patients (79.3%, Group 1) underwent successful repair using traditional suture placement in the prosthetic ring. Thirteen patients (20.6%, Group 2) had one or more sutures repositioned to the inside of the ring ("micro-sized") as a new strategy to eliminate residual leaks. Mean post repair MR grade was lower when microsizing was used (0.15 for Group 2 versus 0.30 for Group 1). No micro-sized patient experienced systolic anterior motion (SAM) or mitral stenosis. There were no repairs with greater than trace MR, late ring dehiscences, recurrent regurgitation, or reoperation in the entire series. There was one death (1.6%) in a non-micro-sized patient from intra-operative abdominal hemorrhage secondary to an IABP complication.

Conclusion: Microsizing is a simple variation of suture placement that allows custom shaping of the mitral annulus by advancing selected portions toward the opposing leaflet, eliminating gaps, and improving coaptation. This technique is safe, simple, and reproducible without causing stenosis, SAM, or late failure.

Presented at the 61st meeting of the European Society for Cardiovascular and Endovascular Surgery, April 25-28, 2012, Dubrovnik, Croatia.

Received May 18, 2012; accepted October 11, 2012.

Correspondence: Mark M. Levinson, MD, Hutchinson Regional Medical Center, 1701 E. 23rd St., Hutchinson, KS 67502, USA (e-mail: mmlevinson@hsforum.com).

INTRODUCTION

The singular goal of surgical repair for mitral regurgitation (MR) is to eliminate all leakage, regardless of cause. Although there are many possible anatomic and physiologic abnormalities in regurgitant valves, the repair is finished once the leak is stopped. The principles taught by Carpentier and others have given practicing surgeons a useful set of guidelines and repair options that have yielded a high success rate for all types of MR [Carpentier 1971, 1983]. There are some valves, however, in which a residual leak remains after an otherwise proper Carpentier-style repair. Various strategies have been proposed to deal with these leaks, including (1) division of basal chords to increase posterior leaflet mobility, (2) the Kron suture to relieve tethering of basal chords by a dilated ventricle [Kron 2002], (3) Carpentier's "magic suture," (4) edge-to-edge repair with the Alfieri stitch [Maisano 1998], (5) purposeful downsizing of the ring, (6) use of a custom-shaped ring such as the IMR ETlogix (Edwards Lifesciences), (7) papillary muscle repositioning [Dreyfus 2001], and (8) leaflet extension with pericardial patching to enlarge the coaptation surface area [Sauvage 1966; Kincaid 2004; Auber 2007; de Varennes 2009].

Purposeful downsizing of the ring risks exaggerated forward displacement of the closure apparatus, with subsequent systolic anterior motion (SAM) and left ventricular outflow tract obstruction [Grossi 1992; Lee 1993]. To counteract this tendency, Carpentier proposed a sliding-leaflet technique to reduce the height of the posterior leaflet and thus allow downsizing while still preserving a closure line that is well posterior to the left ventricular outflow tract [Perier 1994].

The vast number of different repair techniques currently available can be challenging for the average surgeon to understand or apply. It is not always clear which strategy to use, and the wrong judgment or a technical failure leads to valve replacement, owing to either stenosis/SAM or residual leaks ("failed repair") [Grossi 1992; Ibrahim 2002; Perier 2008]. Surgeons and patients need a simpler and more reproducible method for mitral annuloplasty that allows an adequately sized ring to be implanted without residual leakage, stenosis, or SAM.

This report presents a new and simple technique that we have termed microsizing. This technique increases the chances of success and accurately closes residual leaks after

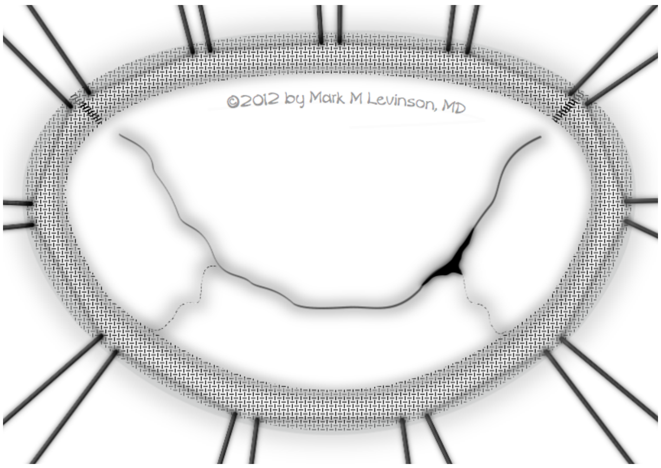

Figure 1. A typical residual gap at the cleft between the P2 and P3 scallops after ring placement. This leak occurs commonly in a variety of situations, especially left ventricular dilatation or ischemic mitral regurgitation.

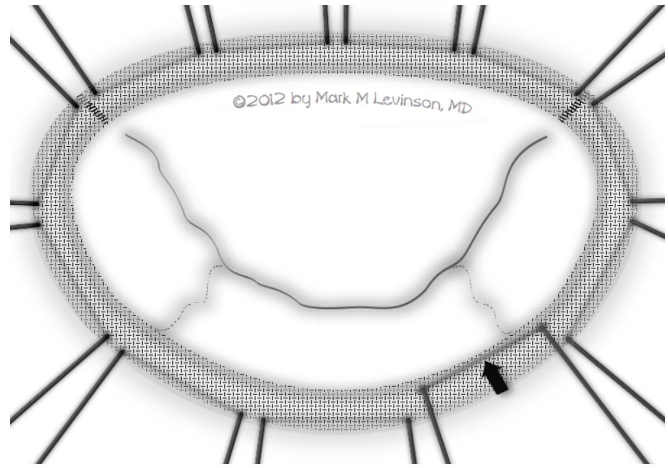

Figure 2. This gap is easily closed by moving a single suture from the outside to the inside of the ring. The suture chosen should be the one in the posterior annulus at the base of the leak (at the 5-o'clock position in this case). By moving this discrete portion of the posterior annulus 3 mm forward (arrow), coaptation is augmented solely at the site of the leak.

conventional ring annuloplasties. We have discovered that the final shape and size of the mitral orifice can be adjusted precisely by moving individual sutures from the outside to the inside of the ring, essentially advancing discrete segments of the valve closer to the opposite leaflet by a distance equal to the thickness of the ring (typically 3 mm). Such adjustment is usually sufficient to seal mild to moderate leaks without the need to downsize the entire ring or to use more complex techniques such as resections or sliding plasties. This report describes the surgical technique and our results obtained with ring microsizing.

METHODS

All repairs were performed through a sternotomy with induction normothermic 4:1 anterograde blood cardioplegia and maintainence 24°C intermittent retrograde cardioplegia. The left atrial appendage was ligated from the outside or the inside in every case. Exposure to the mitral valve was typically through the interatrial groove and was assisted with 2 retractor blades held on separate Martin arms. Visualization of the valvular structures was further enhanced by immediate placing all annuloplasty sutures and then drawing the valvular apparatus closer to the surgeon by tethering the sutures into a reusable holding ring. Evaluation of the valve was delayed until this essential step was performed.

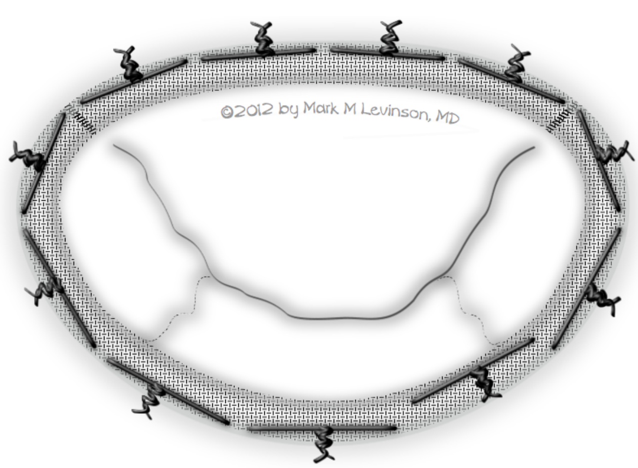

Figure 3. Final appearance of a single microsized (inside) suture after knot tying.

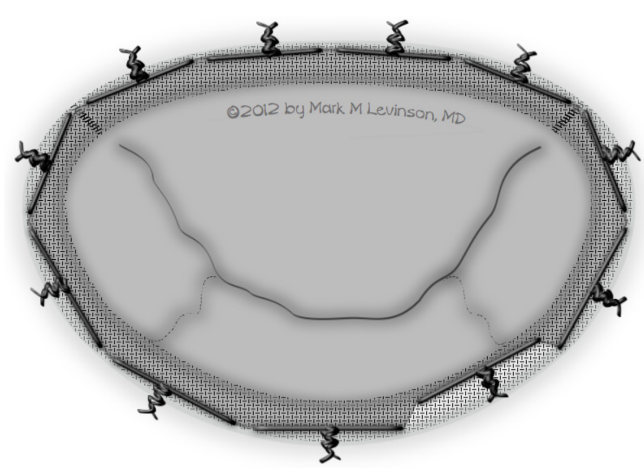

Figure 4. The gray-shaded region illustrates the final orifice area after microsizing a single suture to close a gap between scallops P2 and P3. Downsizing the entire ring in this situation would leave a much smaller orifice area, predisposing to SAM or stenosis.

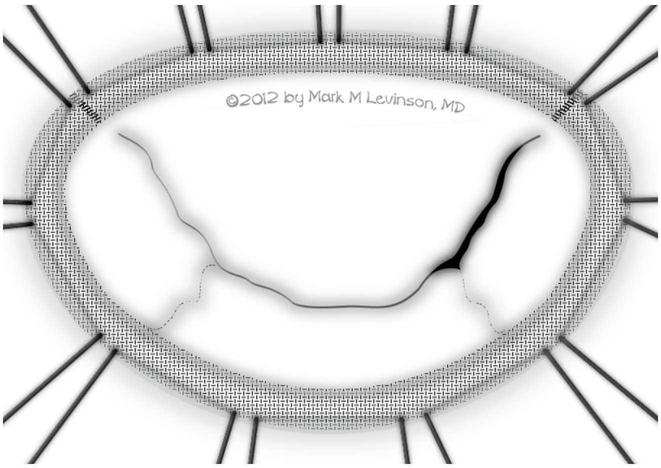

Figure 5. An example of a more extensive residual gap after initial seating of the ring. This gap is due to a coaptation deficiency from anterior leaflet section throughout A3-P3.

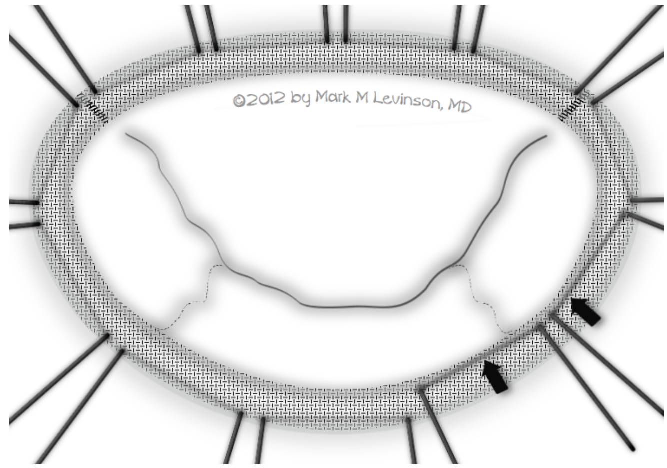

Figure 6. This residual leak between anterior leaflet section A3 and the P3 scallop can be closed by using inside placement of 1 arm of the suture at 4 o'clock (arrows) and both arms of the suture at 5 o'clock. There is no harm in placing just 1 arm of a mattress suture on the inside circumference.

Next, repeated saline pressure testing was used to confirm the site and the nature of the leak. Often, the leak was already gone by this stage because of the forward displacement and posterior annular reduction created by traction on the sutures. Lastly, the subannular and chordal structures were inspected with the assistance of a nerve hook, as recommended by Carpentier et al [1971].

For cases of P2 prolapse, infolding, rather than resection, was the preferred initial repair strategy [McGoon 1960]. Leaflet resection was reserved for unsatisfactory results with

Table 1. Demographics for All Patients, Group 1 (Non-Microsized) and Group 2 (Microsized) Mitral Valve Repairs*

Demographic Characteristic	All Patients	Group 1	Group 2
Total, n	63 (100%)	50 (79.4%)	13 (20.6%)
Men, n	34 (54.0%)	28 (56.0%)	6 (46.2%)
Women, n	29 (46.0%)	22 (44.0%)	6 (46.2%)
Mean age, y	69.5	70	67
Concomitant patients, n†	53 (84.1%)	43 (86.0%)	10 (76.9%)
Concomitant procedures, n (mean no.)‡	76 (1.43)	65 (1.30)	11 (1.10)
CABG, n	36 (57.1%)	30 (60.0%)	6 (46.2%)
AVR, n	11 (17.5%)	10 (20.0%)	1 (7.7%)
TVRp, n	12 (19.0%)	12 (24.0%)	0 (0.0%)
Afib ablation, n	11 (17.5%)	8 (16.0%)	3 (23.1%)
Asc aorta, n	5 (7.9%)	4 (8.0%)	1 (7.7%)
Other, n	1 (1.6%)	1 (2.0%)	0 (0.0%)
>1 Concomitant procedure, n	18 (23.7%)	16 (37.2%)	2 (15.4%)
Redo, n	5 (7.9%)	3 (7.0%)	2 (15.4%)
Death, n	1 (1.0%)	1 (2.0%)	0 (0.0%)
Stroke, n	0 (0.0%)	0 (0.0%)	0 (0.0%)
IABP, n	2 (3.2%)	2 (4.0%)	0 (0.0%)

*CABG indicates coronary artery bypass grafting; AVR, aortic valve replacement; TVRp, tricuspid valve repair; Afib, atrial fibrillation; Asc, ascending; IABP, intra-aortic balloon pump.

†Number of patients undergoing concomitant procedures.

‡Data are presented as the number of patients with concomitant procedures (mean number of concomitant procedures per patient).

Table 2. Carpentier Classification of Leaflet Motion*

Carpentier Classification	All Patients (n = 63)	Group 1 (Non-Mictrosized, n = 50)	Group 2 (Microsized, n = 13)
Type 1 (normal motion), n	34 (53.9%)	27 (54%)	7 (53.8%)
Ischemic, n	10 (15.8%)	8 (16%)	2 (15.4%)
Dilated, n	23 (36.5%)	18 (36%)	5 (10%)
SBE, n	1 (1.5%)	1 (2%)	0 (0%)
Type 2 (increased motion), n	13 (20.6%)	11 (22%)	2 (15.4%)
FED (myomatous), n	10 (15.8%)	8 (16%)	2 (15.4%)
Barlow syndrome, n	3 (4.7%)	3 (6%)	0 (0%)
Type 3 (restricted motion), n	2 (3.2%)	2 (4%)	2 (15.4%)
Rheumatic, n	2 (3.2%)	0 (0%)	2 (15.4%)
Multiple types, n	9 (14.3%)	7 (14%)	2 (15.4%)
Unknown, n	5 (7.9%)	5 (10%)	0 (0%)

*SBE indicate subacute bacterial endocarditis; FED, fibroelastic deficiency.

infolding and/or neochordae. Once the leak was corrected, an appropriate ring was chosen which would permanently maintain the nonleaking orifice's shape and dimension, regardless of the anterior leaflet surface area.

Residual focal leaks were closed by means of 2 primary strategies. Early in this series, clefts between scallops were closed with 5-0 Prolene interrupted figure-of-eight sutures. Later in this series, these leaks were handled with microsizing the suture(s) at the base of the leak, as describe below and illustrated in Figures 1-14.

If a few millimeters of forward traction on one or more posterior sutures temporarily sealed the leak, this location was then treated with microsizing. The needles of the same

Table 3. Details of Repair Techniques Used*

	Repair Strategy, n
All patients	63 (100.0%)
Ring only	38 (44.4%)
Microsized ring	13 (20.6%)
Resection	2 (3.2%)
Triangular	2 (3.2%)
Quadrant	0 (0.0%)
Other	0 (0.0%)
Infolding	6 (9.5%)
P2	6 (9.5%)
Cleft closure	18 (28.6%)
A1–A2	0 (0.0%)
A2–A3	3 (4.8%)
P1–P2	7 (11.1%)
P2–P3	8 (12.7%)
Sliding plasty	0 (0.0%)
Suture repair	4 (6.3%)
Alfieri	3 (4.8%)
Kron	0 (0.0%)
Magic stitch	1 (1.6%)
Neochordae	7 (11.1%)
Simple	6 (9.5%)
Mohr loops	1 (1.6%)

*All patients underwent implantation of an annuloplasty ring, with 25 patients receiving additional repairs as indicated.

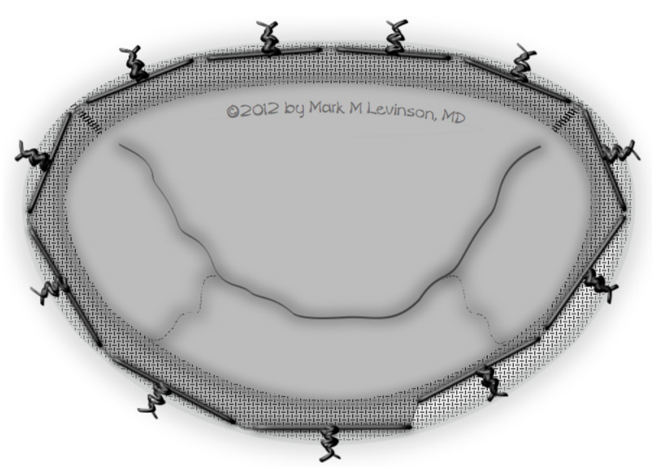

Figure 7. The gray-shaded area indicates the final orifice obtained after complete microsizing of 1 suture plus partial microsizing of the adjacent suture.

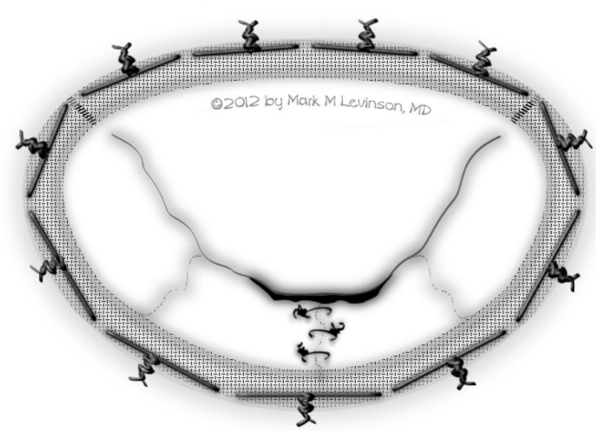

Figure 8. In this case, a classic ring repair caused systolic anterior motion due to a tall P2 scallop. This motion was treated with a P2 triangular resection, but saline testing afterwards revealed a residual gap at the site of resection, probably due to an overly aggressive resection or to an original ring size that was slightly too large.

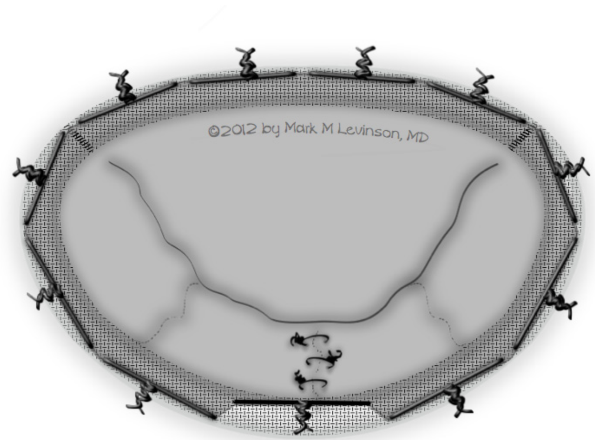

Figure 9. This leak was eliminated without downsizing or exchanging the ring by simply removing the original 6-o'clock suture at the base of the leak and placing a new suture through the annulus, which was anchored on the inside of the ring, thereby reshaping the orifice (gray-shaded area).

sutures were driven through the cloth on the inside of the ring during initial implantation (Video 1 online).

A residual leak remaining after completion of any type of repair could usually be resolved by removing selective sutures at the base of the leak and replacing them on the inside edge of the ring. Figures 1-4 and Video 2 online demonstrate a typical residual leak at the classic location (P2-P3 cleft) treated by microsizing a single suture (usually at the 5-o'clock position as viewed by the surgeon). If a leak was not eliminated by microsizing a single suture, then inside placement of one or both arms of the adjacent suture would often fix the problem. We refer to transferring a single arm of a double-armed suture to the inside of the ring as partial microsizing. Figures 5-7 illustrate microsizing of the suture at 5 o'clock with partial microsizing of the suture at 4 o'clock to close an extensive A3-P3 gap.

Figures 8 and 9 show microsizing of the suture at the 6-o'clock position to seal a residual leak remaining after a triangular resection. An extensive gap through the majority of the

Table 4. Mean Sizes of Annuloplasty Rings Implanted in this Series

	Mean Ring Size, mm
All patients	30
Ring-only repairs	29
Group 1 (non-microsized)	29
Group 2 (microsized)	32

Table 5. Mean Regurgitation Grade before and after Repair for All Patients, Group 1 (Non-Microsized), and Group 2 (Microsized)

Mitral Regurgitation Grade	Before Repair	After Repair
All Patients*	57 (100.0%)	57 (100.0%)
0 (None)	0 (0.00%)	42 (73.7%)
1 (Trace)	0 (0.00%)	15 (26.3%)
2 (Mild)	2 (3.5%)	0 (0.00%)
3 (Moderate)	24 (42.1%)	0 (0.00%)
4 (Severe)	31 (54.4%)	0 (0.00%)
Mean MR Grade	3.51	0.26
Group 1*	44	44
0 (None)	0 (0.00%)	31 (70.5%)
1 (Trace)	0 (0.00%)	13 (29.5%)
2 (Mild)	2 (4.5%)	0 (0.00%)
3 (Moderate)	20 (45.5%)	0 (0.00%)
4 (Severe)	22 (50.0%)	0 (0.00%)
Mean MR Grade	3.45	0.30
Group 2	13	13
0 (None)	0 (0.00%)	11 (84.6%)
1 (Trace)	0 (0.00%)	2 (15.4%)
2 (Mild)	0 (0.00%)	0 (0.00%)
3 (Moderate)	4 (30.8%)	0 (0.00%)
4 (Severe)	9 (69.2%)	0 (0.00%)
Mean MR Grade	3.69	0.15

*Six missing data points.

Table 6. Mean Dimensions for the Physio Ring Classic as Published in Edwards Lifesciences' Product Brochure*

	Ring Size, mm									
	24	26	28	30	32	34	36	38	40	Mean
EOA, mm^2	274	325	380	440	504	572	645	722	804	
Outer diameter, mm	28.7	30.7	33	34.9	37	39.1	41.2	43	45.3	
Inner diameter, mm	22.9	24.9	27	28.9	31	32.9	34.8	37	38.7	
Difference, mm	5.8	5.8	6.0	6.0	6.2	6.2	6.4	6.4	6.6	6.2
Microsizing, mm (difference/2)	2.9	2.9	3.0	3.0	3.1	3.1	3.2	3.2	3.3	3.1

*The true thickness is one half the difference between the inner and outer dimensions (Figure 16); thus, the maximum distance available to shift the annulus with inside suture placement averages 3.1 mm. EOA indicates effective orifice area.

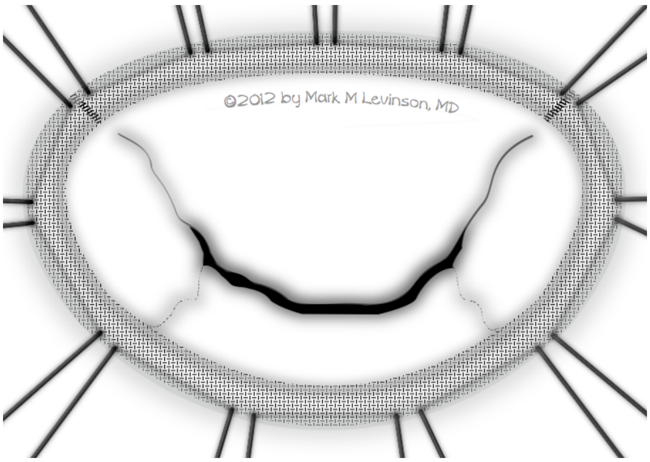

Figure 10. This case illustrates a generalized residual leak, which is most typical if the selected ring turns out to be too large.

Figure 11. Rather than downsizing the entire ring, the solution for this type of gap is to move most of the posterior sutures to the inside of the ring. This preserves the transverse dimension of the larger device, while foreshortening just the septolateral dimension by another 3 mm. This procedure allows the surgeon to craft an entirely new ring size and shape not available with one of the commercially available devices. In addition, the final orifice area will be larger than it would be after downsizing to a smaller prosthesis.

orifice (Figure 10) can be closed by microsizing multiple posterior sutures, essentially creating a new ring size intermediate between the commercially available sizes. Figures 12-14 illustrate a case of a complex residual leak caused in part by a large calcified nodule in the base of the P2 scallop. This leak was completely sealed by microsizing 2 sutures and partial microsizing of a third. These types of custom annular adjustments that are available with microsizing increase the coaptation zone at discrete locations while preserving the maximum lateral dimensions and orifice area available from the prosthesis.

RESULTS

Sixty-three consecutive patients with moderate to severe MR underwent repair by a single surgeon over a period of 10 years. No patient was excluded if valve repair was the goal at the beginning of the case ("intent-to-treat"). Table 1 summarizes the demographics of the entire group, as well as those of the non-microsized patients (Group 1) and the microsized patients (Group 2). The patients comprised 34 men (54.0%) and 29 women (46.0%), with a mean age of 69.5 years. Concomitant (non-mitral valve) procedures were performed at the same surgery in 53 patients (84.1%). These procedures included 36 coronary revascularizations (57.1%), 11 aortic valve replacements (17.5%), 12 tricuspid valve repairs (19.0%), 11 atrial fibrillation ablations (17.5%), and 5 ascending aorta/aortic root replacements (7.9%). The mean number of concomitant procedures was 1.43 per mitral valve repair (Table 1).

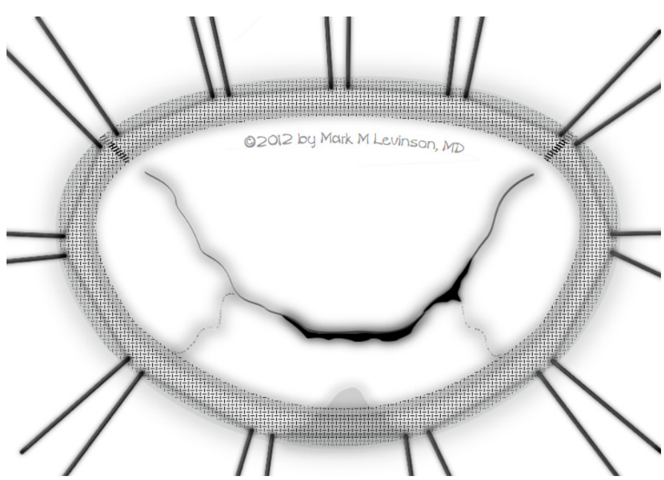

Figure 12. In this case, a complex residual leak is associated with a dense, calcified nodule within the body of the P2 scallop.

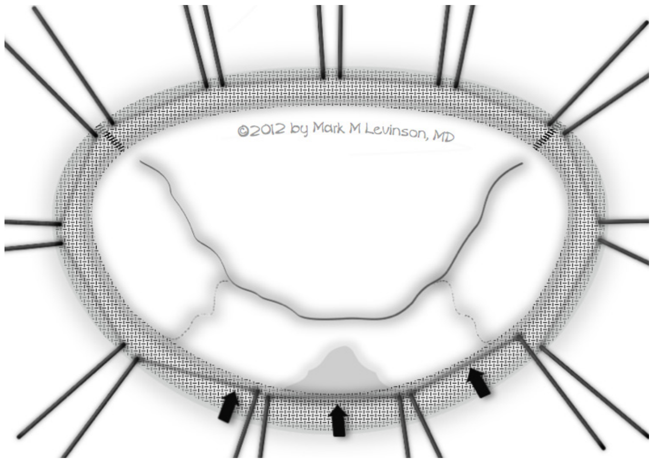

Figure 13. Instead of resecting this nodule, or downsizing the entire repair, this gap can be easily closed by advancing just the posterior annulus at the base of the gap (arrows). The calcified nodule and the associated leaflet tissue are moved forward 3 mm to improve coaptation at the site of the leak, without requiring any morecomplicated resection techniques.

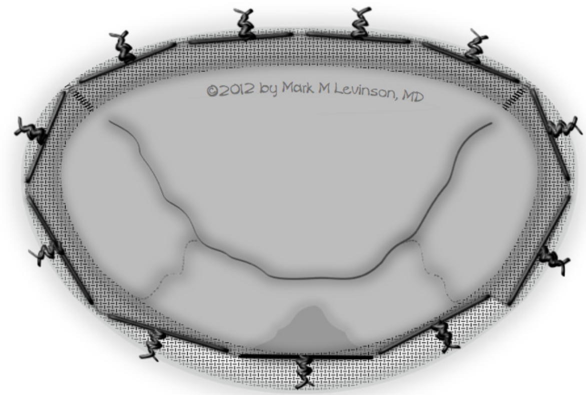

Figure 14. Final orifice size and shape after microsizing 2½ sutures to close this complex residual leak.

Table 2 lists leaflet motion abnormalities according to Carpentier's classification. For the entire cohort of patients, 34 (53.9%) presented with a type 1 abnormality, 13 (20.6%) presented with a type 2, and 2 patients (3.2%) presented with a type 3 abnormality. Multiple leaflet abnormalities were present in 9 patients (14.3%); the type was unknown for 5 patients (7.9%). In the microsized patients (Group 2), 7 patients (53.8%) had a type 1 abnormality, 2 (15.4%) had a type 2 abnormality, 2 (15.4%) had a type 3, and 2 (15.4%) had multiple abnormalities.

All patients (100%) underwent ring-supported repairs with the first-generation Carpentier-Edwards Physio Annuloplasty Ring (Edwards Lifesciences) exclusively [Carpentier 1995]. Ring-only repairs were performed in 38 patients (44.4%) (Table 3). Leaflet resection was used in only 2 patients (3.2%), and both procedures involved a triangular resection of redundant P2 tissue in patients with a type 2 pathology [Gazoni 2007]. There were no quadrant resections or sliding-leaflet plasties in the entire series. A sutured repair was performed in 4 patients: Alfieri stitch in 3 patients (4.8%) and Carpentier's "magic stitch" in 1 patient (1.6%). Gore-Tex CV-4 neochordae were used in 7 patients (11.1%). One patient (1.6%) underwent multiple loop implantations as described by Von Oppell and Mohr [Von Oppell 2000]. All others were simple neochordae, as described by Frater et al [Frater 1983, 1990].

Microsizing to eliminate primary or residual leaks was performed in 13 patients (20.6%) in this series (Table 3). Placement of 1, 2, or 3 sutures through the inside of the ring was needed to close small gaps detected with saline testing. This was done either before or after ring placement. In some

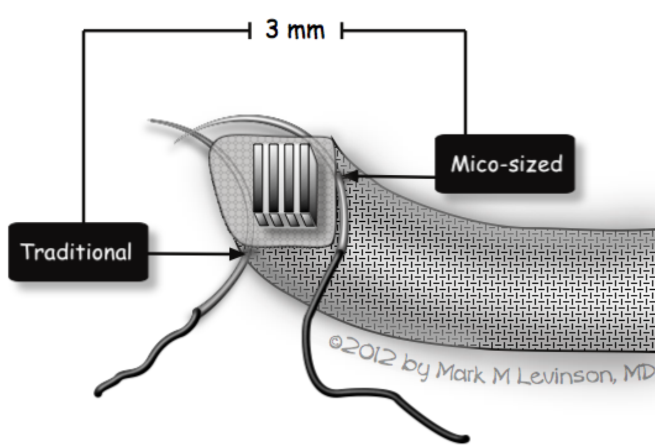

Figure 15. The Physio ring is constructed of layered nitinol-polyester bands surrounded by foam and cloth. Traditional needle placement is through the outer perimeter of the ring; however, driving the needle through the inside edge will shift the annular tissue forward toward the opposing leaflet by a mean distance of 3 mm.

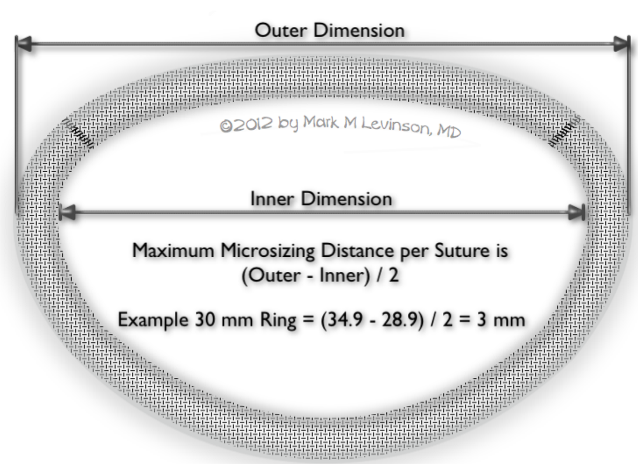

Figure 16. The thickness of a Carpentier-Edwards Physio (Classic) annuloplasty ring is one half the difference between the outer and inner physical dimensions. This yields a mean thickness of approximately 3 mm (see Table 6 for data published by Edwards Lifesciences).

cases, forward traction on one or more posterior annuloplasty sutures during initial saline testing stopped these focal leaks. Such results indicated the need for and the locations of microsizing sutures during initial ring implantation. In other cases, the decision to microsize was made after ring implantation but before the sutures were tied.

The mean ring size for the entire group was 30 mm (Table 4). For the patients who underwent a ring-only repair (no other strategy used), the mean ring diameter was 29 mm. Larger rings (32 mm) were used in microsized patients than in non-microsized patients (29 mm; Table 4).

A single patient in Group 1 experienced SAM after a conventional (non-microsized) ring annuloplasty, which was re-repaired at the same surgery by adding a P2 triangular resection plus P2 microsizing (Figures 8 and 9).

Table 5 presents the pre- and postrepair transesophageal echocardiographic MR grade for the entire group and for the 2 subgroups. The mean prerepair regurgitation grade for the entire group was 3.51 (Group 1, 3.45; Group 2, 3.69). Following repair, the mean regurgitation grade was 0.26 for the entire group (Group 1, 0.30; Group 2, 0.15). Postrepair MR was absent (grade 0) in 42 (73.7%) of the 57 patients for whom the grade was known: 31 (84.1%) of 44 patients in Group 1 and 11 (84.6%) of 13 patients in Group 2. Fifteen (26.3%) of 57 patients demonstrated postrepair grade 1 MR; 13 (29.5%) of 44 patients in Group 1 and 2 (15.4%) of 13 patients in Group 2. There were no cases of MR grade 2, 3, or 4 after any repair.

The single death, in a Group 1 (non-microsized) patient, was due to intraoperative abdominal bleeding and left ventricular dysfunction, for an overall mortality rate of 1.6%. Intra-aortic balloon support was needed for 2 patients in Group 1 (3.2%), one of whom survived and the other being the patient who died. Neither patient received microsizing. There was no stroke, deep sternal wound infection, or dialysis in any patient in this series. No mitral valves were replaced for a failed repair attempt (success rate, 100%). During the long-term follow-up, there were no reoperations for residual or recurrent regurgitation, endocarditis, or other causes. There was no ring dehiscence in any patient.

DISCUSSION

Restoration of valve competence is possible in more than 90% of nonrheumatic MR cases. Despite well-documented advantages and success rates with repair techniques, many surgeons are still unable to reach these goals. The Society of Thoracic Surgeons database shows that the average repair rate for MR in the United States is still only 70%. For the surgeon who does not have a predominately valve-based practice, it is difficult to develop the skills and judgment needed to master the wide spectrum of available repair techniques. Indeed, low-volume valve surgeons have been reported to have a much lower rate of repair than valve-specialty surgeons.

The fundamental principle for restoring competency is to implant a prosthetic ring that remodels the orifice so that the posterior annular circumference becomes two thirds of the total circumference, with a 3:4 ratio between the anteroposterior and lateral dimensions [Carpentier 1971, 1995]. This annular reduction also advances the posterior leaflet forward, increasing its apposition to the anterior leaflet and reducing or eliminating malcoaptation and leakage. However, overly aggressive reduction of the valve circumference in an attempt to avoid residual leaks can have serious consequences [Lee 1993], especially for type 3 valves, or for valves with excessive tissue, such as in Barlow syndrome. Thus, it is important for surgeons to have options to prevent, or deal with, residual coaptation failures without resorting to downsizing the entire orifice or using complicated resection-reconstruction techniques that require considerable experience and judgment to master.

For the authors, microsizing has turned out to be the tool of choice for preventing residual leaks. It is quick, simple, reproducible, and within the skill set of every surgeon, regardless of valve experience or training. By transferring one or more annuloplasty sutures from the outside to the inside of the ring, it is possible to easily correct discrete regions of malcoaptation. Microsizing is very versatile and can be safely used in combination with any other technique, including (but not limited to) leaflet resection (Figures 8 and 9) and artificial chordae. It can also be used independently at different locations around the valve orifice without interfering with each other. If necessary, microsizing can be used throughout the entire posterior circumference to essentially create a new ring size intermediate between the sizes of commercially available rings (Figures 10 and 11). For example, if a 32 ring appears too large and a 30 is a bit too small, the surgeon can construct the equivalent of a 31 ring by microsizing all or part of the posterior annuloplasty sutures.

Microsizing can also be performed at virtually any time before closure of the atrium, making it the ideal "bail out" strategy for residual leaks following any type of repair. Before knot tying, an untied suture can be retrieved from the ring with a nerve hook and then replaced through the cloth of the inner circumference by means of a free needle, such as a French eye. To microsize after knot tying, one can cut the suture(s) in the posterior annulus at the base of the leak, place a new suture or sutures in the atrial tissue parallel to the ring, and then pass it to the inside by pushing the blunt end of the needle underneath the prosthesis. Finally, the sharp tip of each needle is passed through the cloth on the inside of the ring.

The explanation of how microsizing works begins with understanding how rings are designed and built. The Physio ring is composed of a structural core made from an array of preformed nitinol bands separated by polyester strips that are then wrapped with a layer of foam and cloth (Figure 15) [Carpentier 1995]. The structural core provides a defined shape and size that permanently fixes the dimensions of the repaired annulus. The ring's physical thickness (as reported by Edwards Lifesciences) is just larger than 3 mm (Figure 16 and Table 6). The core makes it difficult to drive needles through the center of the device; thus, most annuloplasty sutures end up going through the outer perimeter between the cloth and the outer metal band (Figure 15).

It is important to understand that the final shape and size of the mitral orifice are determined by where the sutures enter the ring. Moving a stitch (or stitches) to the inside circumference also moves the annular tissue gathered within each stitch toward the opposing leaflet by a distance corresponding to the thickness of the ring. This small, but meaningful, displacement is often enough to augment coaptation at the site of a gap and correct mild to moderate leaks. The same benefits can be obtained over a wider area by microsizing more than 1 suture. Additional precision can be obtained safely, if needed, by inside placement of a single arm of a double-armed suture (Figures 6, 7, 13, and 14), a variation we call partial microsizing.

Our results demonstrate several important trends, although the numbers are too small for statistical comparison. The prerepair MR grade was more severe in the microsized cases (Group 2 mean of 3.69 versus 3.45 in Group 1, Table 5), yet the postrepair MR grade was 50% lower than in the non-microsized cases (Group 2 mean of 0.15 versus 0.30 in Group 1). Additionally, larger rings were implanted in the microsized patients (Group 2 mean of 32 mm versus 29 mm in Group 1, Table 4). These data suggest that a strategy of slight upsizing can be very successful if microsizing is to be used to close any residual leaks.

Also important to note is that we were able to achieve a high and reproducible success rate with mitral valve repair over a 10-year period despite a low annual case volume (a mean of only 6 repairs per year). This success rate was accomplished without relying on leaflet resection, sliding-leaflet plasty, chordal transfers, or other more involved techniques. In addition, we were able to successfully repair all types of leaflet and valve abnormalities, including rheumatic and Barlow syndrome deformities (although the number of such cases was small). Additionally, no cases of SAM were observed after microsizing.

Microsizing has also been durable, with no late disruptions or reoperations in our series. We believe these results are due to a relative protection against disruption with inside suture placement. Should the ventricle attempt to dilate, the force vector exerted on inside sutures acts to press the stitch closer to the device (compared with traditional outside sutures, which would be pulled away from the device by the same forces).

At the present time, the authors have had no experience with microsizing partial rings or bands. In addition, we have no experience with any complete ring other than the Physio Classic. Given that all annuloplasty devices have a defined thickness, however, translocation of sutures from outside to inside should cause an effect analogous to that described in this report. Each device may have a different thickness, but the ability of microsizing to perform precision annular adjustments should be directly proportional to the thickness of the device used.

Although no formal hemodynamics studies have been performed for microsized valves, transesophageal echocardiography consistently showed elimination of regurgitation, thereby indicating that microsizing is a versatile and powerful adjunct in the repair of MR that any surgeon can apply safely in any situation.

REFERENCES

Auber S, Flecher E, Rubin S, Acar C, Ganjbakhch I. 2007. Anterior mitral leaflet augmentation with autologous pericardium. Ann Thorac Surg 83:1560-1.

Carpentier A, Deloche A, Dauptain J, et al. 1971. A new reconstructive operation for correction of mitral and tricuspid insufficiency. J Thorac Cardiovasc Surg 61:1-13.

Carpentier A. 1983. Cardiac valve surgery—the "French correction." J Thorac Cardiovasc Surg 86:323-37.

Carpentier AF, Lessana A, Relland JY, et al. 1995. The "physio-ring": an advanced concept in mitral valve annuloplasty. Ann Thorac Surg 60:1177-86.

de Varennes B, Chaturvedi R, Sidhu S, et al. 2009. Initial results of posterior leaflet extension for severe type IIIb ischemic mitral regurgitation. Circulation 19:2837-43.

Dreyfus GD, Bahrami T, Alayle N, Mihealainu S, Dubois C, De Lentdecker P. 2001. Repair of anterior leaflet prolapse by papillary muscle repositioning: a new surgical option. Ann Thorac Surg 71:1464-70.

Frater RWM, Gabbay S, Shore D, Factor S, Strom J. 1983. Reproducible replacement of elongated or ruptured valve chordae. Ann Thorac Surg 35:14-26.

Frater RW, Vetter HO, Zussa C, Dahm M. 1990. Chordal replacement in mitral valve repair. Circulation 82(suppl):IV125-30.

Gazoni L, Fedoruk LM, Kern JA, et al. 2007. A simplified approach to degenerative disease: triangular resections of the mitral valve. Ann Thorac Surg 83:1658-65.

Grossi EA, Galloway AC, Parish, MA, et al. 1992. Experience with twenty-eight cases of systolic motion after mitral valve reconstruction by Carpentier technique. J Thorac Cardiovasc Surg 103:466-70.

Ibrahim MF, David TE. 2002. Mitral stenosis after mitral valve repair for non-rheumatic mitral regurgitation. Ann Thorac Surg 73:34-6.

Kincaid EH, Riley RD, Hines MH, Hammon JW, Kon ND. 2004. Anterior leaflet augmentation for ischmic mitral regurgitation. Ann Thorac Surg 78:564-8.

Kron IL, Green R, Cope JT. 2002. Surgical relocation of the posterior papillary muscle in chronic ischemic mitral regurgitation. Ann Thorac Surg 74:600-1.

Lee KS, Stewart WJ, Lever HM, Underwood PL, Cosgrove DM. 1993. Mechanism of outflow obstruction following failed valve repair: anterior displacement of leaflet coaptation. Circulation 88(suppl):II24-9.

Maisano F, Torracca L, Oppizzi M, et al. 1998. The edge-to-edge technique: a simplified method to correct mitral insufficiency. Eur J Cardiothorac Surg 13:240-6.

McGoon DC. 1960. Repair of mitral insufficiency due to ruptured chordae tendinae. J Thorac Cardiovasc Surg 39:357-62.

Perier P, Clausnizer B, Mistarz K. 1994. Carpentier "sliding leaflet" technique for repair of the mitral valve: early results. Ann Thorac Surg 57:383-6.

Perier P, Hohenberger W, Lakew F, et al. 2008. Toward a new paradigm for the reconstruction of posterior leaflet prolapse: results of the "respect rather than resect" approach. Ann Thorac Surg 86:718-25.

Sauvage LR, Wood SJ, Berger KE, Campbell AA. 1966. Autologous pericardium for leaflet advancement. J Thorac Cardiovasc Surg 52:849-54.

Von Oppell UO, Mohr FW. 2000. Chordal replacement for both minimally invasive and conventional mitral valve surgery using premeasured Gore-Tex loops. Ann Thorac Surg 70:2166-8.