Comparison of Coapsys annuloplasty and internal reduction mitral annuloplasty in the randomized treatment of functional ischemic mitral regurgitation: Impact on the left ventricle

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Background: Functional mitral regurgitation is associated with both annular and ventricular distortion. Aggressive reduction annuloplasty for functional mitral regurgitation acts primarily at the annulus, with variable impact on the left ventricle. The Coapsys device externally reshapes the left ventricle to correct functional mitral regurgitation. Left ventricular reshaping was analyzed in a randomized study.

Methods: The RESTOR-MV study randomizes patients with coronary artery disease and functional mitral regurgitation to either reduction annuloplasty and coronary artery bypass grafting (the RA group) or Coapsys annuloplasty and bypass grafting (the CO group). The Coapsys device consists of epicardial pads connected by a cord. It was placed without cardiopulmonary bypass under echocardiographic guidance and sized to reduce annular dimension and improve leaflet coaptation. Internal reduction annuloplasty was performed by device placement. Intraoperative transesophageal echocardiograms were analyzed in 7 patients having reduction annuloplasty and 7 having Coapsys annuloplasty.

Results: Baseline mitral regurgitation (0-4 scale) was similar for the RA (3.0 ± 0.6) and the CO groups (3.0 ± 0.6). Intraoperative mitral regurgitation was reduced from 2.86 ± 0.7 to 0.5 ± 0.7 ($P < .01$ pre vs post) for the RA group and from 2.64 ± 0.9 to 0.5 ± 0.7 ($P < .01$ pre vs post) for the CO group. Annular anteroposterior diameter was reduced with both techniques: RA, 3.45 ± 0.39 to 2.34 ± 0.37 cm ($P < .01$ pre vs post); CO, 3.40 ± 0.27 to 2.85 ± 0.34 cm ($P < .05$ pre vs post). Long-axis dimensions were unchanged with both techniques. Short-axis dimensions measured at three levels were significantly reduced only in the CO patients: basal diameter 4.77 ± 0.58 to 3.58 ± 0.38 cm ($P < .01$ pre vs post); mid diameter 4.88 ± 0.55 to 3.57 ± 0.43 cm ($P < .01$ pre vs post); and apical diameter 4.39 ± 0.46 to 3.38 ± 0.34 cm ($P < .01$ pre vs post).

Conclusions: Coapsys and reduction annuloplasty techniques both acutely reduce functional mitral regurgitation and annular dimension. The Coapsys device provided significantly greater left ventricular reshaping than did reduction annuloplasty. Further evaluation will assess the long-term valvular function and ventricular geometric stability associated with both techniques.

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Read at the Thirty-first Annual Meeting of The Western Thoracic Surgical Association, Victoria, BC, Canada, June 22-25, 2005.

Received for publication June 23, 2005; revisions received Nov 8, 2005; accepted for publication Nov 29, 2005.

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J Thorac Cardiovasc Surg 2006;131:1095-8
0022-5223/\$32.00

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doi:10.1016/j.jtcvs.2005.11.046

Functional ischemic mitral insufficiency is a ventricular disease characterized by a combination of annular enlargement and subvalvular displacement.^{1,2} Although internal reduction annuloplasty treats the annular component, this technique fails to affect the subvalvular component. Several proponents of functional mitral regurgitation repair suggest that in some patients, the localized subvalvular ventricular distortion is so advanced that aggressive undersizing annuloplasty alone is inadequate

Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
IDE	= investigational device exemption
LV	= left ventricle (ventricular)
RESTOR-MV	= <i>Randomized Evaluation of a Surgical Treatment for Off-pump Repair of the Mitral Valve</i>

for producing a durable result.^{3,4} The advent of directed ventricular shape change technology offers the surgeon the opportunity to treat functional mitral insufficiency by both external reduction annuloplasty and ventricular reshaping. This study compares the intraoperative geometric effects of internal reduction annuloplasty and the Coapsys annuloplasty system (Myocor, Inc, Maple Grove, Minn) in the treatment of functional mitral insufficiency.

Material and Methods

The RESTOR-MV (*Randomized Evaluation of a Surgical Treatment for Off-pump Repair of the Mitral Valve*) multicenter investigational device exemption (IDE) primary study group randomizes patients with coronary artery disease and functional mitral insufficiency to either coronary artery bypass grafting (CABG) plus open internal reduction annuloplasty or CABG plus correction of the mitral insufficiency with the Coapsys device. All investigative sites had institutional review board approval and all patients signed informed consent forms to participate in this study. Inclusion and exclusion criteria for study admission have been previously published.⁵ The first 7 patients in each study group with complete intraoperative echocardiographic data sets are the subjects of this report.

Coapsys Device

Although previously described,⁵⁻⁷ the procedure is briefly detailed here. The Coapsys ventricular shape-change device consists of two epicardial pads connected by a flexible suture-like cord (Figure 1). With the use of specially designed instruments and epicardial echocardiographic guidance, the cord is passed through the left ventricle (LV) (between the papillary muscles and bisecting the ventricle) and then sequentially tightened to improve leaflet coaptation and stabilize the ventricular wall. The precise placement is accomplished by use of a suction-cup stabilized instrument (jig) with anterior and posterior locators. The posterior locator is positioned externally between the papillary muscle insertions, about 2 cm below the insertion of the posterior leaflet. The anterior locator is placed on the right ventricular side of the left anterior descending coronary artery, about halfway down the longitudinal axis of the ventricle. These locations are determined by handheld epicardial echocardiography. This jig then guides a thin blunt-tipped needle through the LV from one locator to the other. The needle provides a thin conduit for passage of the Coapsys cord through the ventricle; pads are connected to both ends of the cord. Sizing is then conducted under real-time color flow Doppler imaging to quantify mitral insufficiency. The cord length is shortened and final length is determined by elimination of mitral

Figure 1. Coapsys device.

insufficiency or a maximum shortening of 35%. Although one of the patients had the CABG performed on pump, all of the Coapsys deployments were done off pump.

Internal Reduction Mitral Annuloplasty

Aggressive internal reduction mitral annuloplasty was accomplished by implanting an undersized annuloplasty device, a typical reduction of 1 to 2 sizes. The devices were chosen at the discretion of the surgeon. Annuloplasty devices implanted included the following: C-G Future band (26, 28; Medtronic, Inc, Minneapolis, Minn), Carpentier-Edwards Physio Annuloplasty Ring (26, 26; Edwards Lifesciences, Irvine, Calif), Duran (27, 27; Medtronic, Inc), and Séguin Annuloplasty Ring (24; St Jude Medical, Inc, St Paul, Minn).

For this study, functional mitral valve regurgitation was defined as mitral valve dysfunction resulting from dilatation of the mitral valve annulus, displacement of the LV papillary muscles, chordal tethering of the mitral valve leaflets, or any combination of these factors. All patients had concomitant coronary disease requiring revascularization. Intraoperative transesophageal echocardiography was used to acquire long-axis, 2-chamber (septal-lateral), and 4-chamber views required to measure geometric changes as well as to quantify mitral regurgitation (0 to 4 scale). The sphericity index was calculated as the ratio of the dimensions of ventricular short- to long-axis dimensions in the long-axis plane. LV volume was approximated in diastole from the long-axis views with the use of

TABLE 1. RESTOR-MV Study subset patient basic characteristics

	Internal reduction annuloplasty	Coapsys device	P value*
N	7	7	NA
Male (%)	57.1	86	.28
Mean age (y)	67.4 ± 7.5	63.3 ± 10	.42
Previous MI	4 (57%)	5 (71%)	.50
Mean no. of grafts	2.71 ± 1.4	2.71 ± 1.1	>.99
Preop mean LVEF (%)	40.0 ± 9.1	39.4 ± 8.1	.90
Preop acute MI (%)	0	0	>.99
On pump	7 (100%)	1 (14.3%)	.002
Operative time (min)	324.4 ± 48.4	314.4 ± 81.7	.78
Hospital mortality (%)	0	0	>.99

NA, Not available; MI, myocardial infarction; LVEF, left ventricular ejection fraction. *Unpaired *t* test for continuous variables; χ^2 test for categorical variables.

TABLE 2. Intraoperative annular and ventricular dimensions measured by TEE long axis views

	Internal reduction annuloplasty		Coapsys implant	
	Pre	Post	Pre	Post
Annular AP diameter (cm)	3.45 ± 0.39	2.34 ± 0.37*	3.40 ± 0.27	2.85 ± 0.34†
Basal diameter (cm)	4.83 ± 1.12	4.93 ± 0.82	4.77 ± 0.58	3.58 ± 0.38*
Mid diameter (cm)	4.84 ± 0.81	5.01 ± 0.70	4.88 ± 0.55	3.57 ± 0.43*
Apical diameter (cm)	4.06 ± 0.96	4.45 ± 0.69	4.39 ± 0.46	3.38 ± 0.34*
LV long-axis length (cm)	7.6 ± 1.17	7.8 ± 1.09	8.1 ± 1.08	7.8 ± 0.78
LV sphericity (mid diameter/long axis)	0.65 ± 0.12	0.63 ± 0.09	0.61 ± 0.08	0.46 ± 0.07†
LV volume diastole (mL)†	126.5 ± 62.7	128.9 ± 35.9	132.7 ± 36.1	91.0 ± 11.5*

TEE, Transesophageal echocardiography; AP, anteroposterior; LV, left ventricular. * $P < .01$ pre vs post; † $P < .05$ pre vs post. (Data are mean ± SD.)

a stacked disk model. Short-axis diameters were measured at the annulus and at 3 equidistant latitudes perpendicular to the long axis.

Results

The two randomized patient groups were similar with respect to basic characteristics (Table 1). Intraoperatively, mitral regurgitation was reduced from 2.86 ± 0.7 to 0.5 ± 0.7 ($P < .01$) for reduction annuloplasty and from 2.64 ± 0.9 to 0.5 ± 0.7 ($P < .01$) for Coapsys annuloplasty. Geometric data and analysis are presented in Table 2. Annular anteroposterior diameter was reduced with both techniques: 3.45 ± 0.39 cm to 2.34 ± 0.37 cm ($P < .01$) for reduction annuloplasty and 3.40 ± 0.27 cm to 2.85 ± 0.34 cm ($P < .05$) for Coapsys annuloplasty. The long-axis dimension was unchanged for both reduction (7.59 ± 1.17 to 7.8 ± 1.09 cm) and Coapsys annuloplasty (8.11 ± 1.08 to 7.78 ± 0.78 cm). Ventricular diameters measured at the 3 levels were significantly reduced only in the Coapsys patients: basal diameter 4.77 ± 0.58 to 3.58 ± 0.38 cm ($P < .01$); mid diameter 4.88 ± 0.55 to 3.57 ± 0.43 cm ($P < .01$); and apical diameter 4.39 ± 0.46 to 3.38 ± 0.34 cm ($P < .01$). LV diastolic volume was reduced only in the Coapsys patients. Hemodynamics were similar for both groups when quantifying mitral insufficiency at both intraoperative times. Figures 2 and 3 represent typical diastolic images before and after intervention with both operative strategies.

Discussion

Both surgical approaches, Coapsys annuloplasty and internal reduction mitral annuloplasty, have initial efficacious results in

the treatment of the mitral insufficiency. The surgical literature has suggested that the long-term outcome of repair for functional mitral insufficiency is problematic and survival is known to be poor in these patients.⁸⁻¹⁰ Importantly, the degree of pre-existing LV dysfunction is not directly associated with the amount of functional mitral insufficiency.¹¹ Additionally, while authors have attempted to show a link between this poor survival outcome and the underlying poor LV function in this population,^{8,12} it is not clear whether or not some of this poor outcome may be attributable to recurrent mitral insufficiency.¹³ Certainly some believe that there are very dysplastic ventricles with such localized distortion of the subvalvular geometry that repair is inappropriate. Whether examining baseline leaflet coaptation distortion^{3,14} or lateral papillary muscle displacement,⁴ surgeons are identifying subpopulations based on ventricular distortion in which internal reduction annuloplasty for functional ischemic mitral insufficiency has a high likelihood of failure.

There is experimental evidence that elimination of mitral insufficiency does not prevent further deleterious LV remodeling.¹⁵ Interestingly, the control group will provide information as to whether long-term ventricular dimensions stabilize, improve, or worsen¹⁶ after reduction annuloplasty alone and whether the acute positive ventricular reshaping effect of the Coapsys device is sustained. Additionally, we may be able to determine whether annuloplasty device preference has an impact on procedural and long-term outcome.

The Coapsys device is unique in that it not only addresses the annular distortion but also corrects the ventricular changes

Figure 2. Preoperative (A) and postoperative (B) echocardiographic views after internal reduction mitral annuloplasty. LA, Left atrium; Ao, aorta.

Figure 3. Preoperative (A) and postoperative (B) echocardiographic views after application of the Coapsys device. LA, Left atrium; Ao, aorta.

by reshaping the ventricle in the anteroposterior dimension. This may have several consequences. First, the posterior pads of the device typically extend apically to the insertion site of the papillary muscles and place tension in an anterosuperior direction. This restores the papillary muscles to a more subvalvular position, with decreases in the annular to coaptation point distances and in the tenting area.⁵ Second, unlike reduction mitral annuloplasty, the LV is positively reshaped by the Coapsys device. This reduction of ventricular sphericity may have significant long-term consequences; progressive increases in sphericity after reduction annuloplasty are associated with recurrent mitral insufficiency.¹⁶ Third, the reduction of ventricular volumes with the Coapsys device may indeed have a secondary role as a heart failure therapy, in addition to its primary role in the treatment of mitral insufficiency.

Limitations

This study primarily deals with intraoperative dimensional and functional changes. The RESTOR-MV trial is ongoing with primary end points at 1 year and should provide long-term information regarding the geometric stability of both the degree of mitral insufficiency and ventricular reshaping. Likewise, the potential clinical benefits of the ventricular shape change will be evaluated, as well as the safety profile of the device.

Conclusions

Both the Coapsys device and standard mitral annuloplasty acutely reduce functional mitral insufficiency and annular dimension. The Coapsys device, however, provides significantly greater LV reshaping as compared with standard mitral annuloplasty. Further evaluation will assess the long-term valvular function and ventricular geometric stability after both techniques.

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