Papillary muscle approximation combined with ventriculoplasty in patients with ischemic cardiomyopathy and functional mitral regurgitation: effects on mitral valve and LV shape

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Abstract

Recent studies define functional mitral regurgitation (MR) and worsened left ventricular (LV) systolic indices as the widening of the dimension between papillary muscle heads; consequently, narrowing this distance may improve the mitral valve and LV function. Thirty (22 males; mean age: 57±7 years) candidates for CABG underwent ventriculoplasty and in 50% of them papillary muscle approximation was also performed (group 1). All the patients had grade 3 to grade 4 MR with an interpapillary muscle distance of more than 2.5 cm. In group 1 the papillary muscles were drawn together by an encircling loop using a 4-mm Gore-Tex tube or umbilical tape. Mitral annuloplasty and Dor procedures were performed in all the patients. Postoperative echocardiography revealed significant changes in systolic and diastolic sphericity indices in the PMA group. There was one hospital death in each group, and within a short mean follow-up period of 9 months, there were no late deaths. Improvement of NYHA class and MR were significantly better in the PMA group. Papillary muscle approximation in selected patients has a clear effect on the mitral valve and LV shape by reducing tethering and sphericity due to the displacement of the papillary muscles.

Key Words: Ischemic mitral regurgitation; Papillary muscle approximation; Ventricular restoration

1- Introduction

Dilatation of the left ventricle occurs in a chronic process of ventricular remodeling after myocardial infarction. Those having a diffuse akinetic left ventricle with chronic heart failure have been known to be less favorable candidates for CABG, and cardiac transplantation is a possible option when medical treatment has failed.

In these patients, an increase in left ventricular end-systolic volume and sphericity indices is associated with inadequate approximation of the papillary muscles during systole and causes significant functional MR. Ring annuloplasty is the most widely accepted surgical procedure for functional ischemic MR, but variable outcomes and a high rate of late recurrence have been reported [1].

Endoventricular patch plasty, used for improving ventricular function and slowing the process of ventricular remodeling in patients with ischemic cardiomyopathy, reduces LV volume and tends toward a more physiologic reorganization of the ventricular cavity. However, some studies show that while systolic pump function improves after the Dor procedure, the left ventricle becomes more spherical. In addition, late mitral regurgitation is more frequent in patients with a larger and more spherical left ventricle [2]. The purpose of this study was to describe the technique and report the early results of papillary muscle approximation (PMA), combined with ventriculoplasty for ischemic cardiomyopathy and functional MR, and compare the result of this method with ventriculoplasty alone.

2. Materials & Methods:

2.1. Patient selection

Thirty (22 males and 8 females; mean age: 57±7 years) with ischemic cardiomyopathy were selected for this study.

Candidates were determined by preoperative and intraoperative echocardiography, demonstrating an increased interpapillary muscle distance, restricted leaflet motion, concave anterior leaflet, without other signs of anatomic valve disease and varying degrees of annular dilation in combination with reduced ventricular ejection fraction with scar tissue in the apex. Our general policy was to intervene on symptomatic MR, 4+ MR or grade 3+ MR and large LV volume. The preoperative ejection fraction was 23±6%, and an interpapillary muscle distance of more than 2.5 cm. The LV end-diastolic volume, assessed by echocardiography was 278±54 ml. New York Heart Association Class (NYHA) was III and IV.

The severity of mitral regurgitation was assessed quantitatively with the calculation of effective regurgitant orifice area, regurgitant fraction and regurgitant volume by PISA method.

We preferred to assess the mitral valve condition not by tenting area but by concavity area. Tethering of the mitral valve leaflets is expressed by concave leaflet configuration toward the left atrium. The leaflet concavity toward the LA, indicating abnormal MV tethering, is a strong indicator of FMR. This configuration reflects basic MV anatomy with PM displacement; tethering is exerted at the leaflet tips by marginal chordae and predominantly by secondary chordae that attach more basally and create an angulated bend in the body of the anterior leaflet [3].

In order to measure the interpapillary muscle distance, we used parasternal short axis view in TTE and transgastric view in TEE.

Left ventricular sphericity index calculated as the ratio of left ventricular internal diameter in short axis compared to left ventricular length (measured as distance from mitral annulus to apical endocardium in left ventricular long axis view).

We did full revascularization, mitral annuloplasty and Dor operation in all patients. But in half of them (15 patients) papillary muscle approximation was also performed (group 1).

2.2. Technique

In group 1 the mitral valve repairs for ischemic MR were performed using papillary muscle approximation and placing a pericardial annuloplasty ring. But in group 2 repair was performed only by pericardial annuloplasty.

All the LVs were reconstructed by utilizing the Dor procedure.

The operation was performed through a median sternotomy, aortic and bicaval cannulation, moderate hypothermic cardiopulmonary bypass and cold-blood retrograde cardioplegia. Distal coronary anastomoses were performed first, followed by other cardiac procedures in sequence as indicated. The mitral valve was routinely exposed through a superior septal incision. After the valve had been inspected and the pathophysiology had been confirmed, the mitral valve was brought closer into the operative field by placing several 3-0 braided polyester sutures in the posterior annulus. These were later used for the placement of a partial pericardial annuloplasty ring. Size of pericardial ring was selected by measuring free edge of anterior leaflet. The LV was opened at the center of the scar, and the endocardial scar was resected. In the event that the infarct segment was located in the anteroapical and septal regions, the incision was parallel to the left anterior ascending artery following the description of the surgical anterior ventricular endocardial restoration (SAVER) procedure [4]. The widening between the papillary muscle heads was evident; in group 1 the papillary muscles were drawn together by an encircling loop using a 4-mm Gore-Tex tube or umbilical tape (Fig. 1). Endoventricular circular patch plasty (DOR) was performed in all the patients. The principles of the procedure have been described as endoventricular circular patch plasty (EVCPP) by Dor and colleagues [5]. An encircling 2 to 0-monofilament suture was then passed around the endocardial fibrous scar to cinch the area and restore the normal internal ventricular curvature. The resulting orifice excluded the ventricular scar and became the platform for patch inser-

tion. Next, a Dacron circular patch was anchored to the fibrotic tissue to close the orifice and reconstruct the internal cavity. Finally, the excluded external tissue was folded over the patch to reinforce the suture line and provide additional hemostasis.

Fig. 1. The umbilical tape encircles the trabecular base of papillary muscles.

3-Results:

Intraoperative transesophageal echocardiography was used after separation from cardiopulmonary bypass in all the patients to assess LV shape (Fig. 2) and competency of the mitral valve (Fig. 3). All patients had acceptable residual MR. Postoperative care was equivalent to other patients undergoing mitral valve or coronary artery bypass grafting procedures. All the patients were first assessed within 1 month and every 3 months after discharge and then at 1 year. After that, they were annually evaluated with history, physical examination and transthoracic echocardiography.

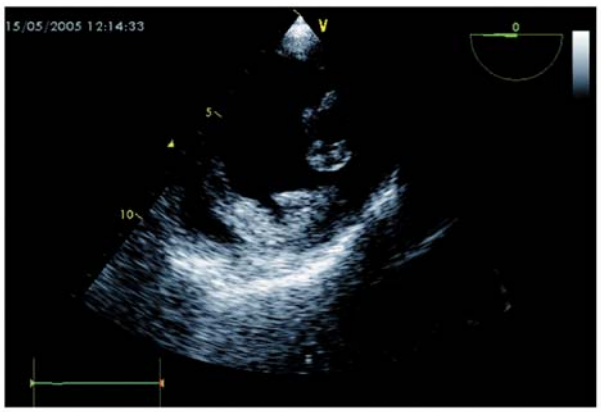

Fig. 2. Transgastric TEE showing the postoperative approximation of papillary muscles.

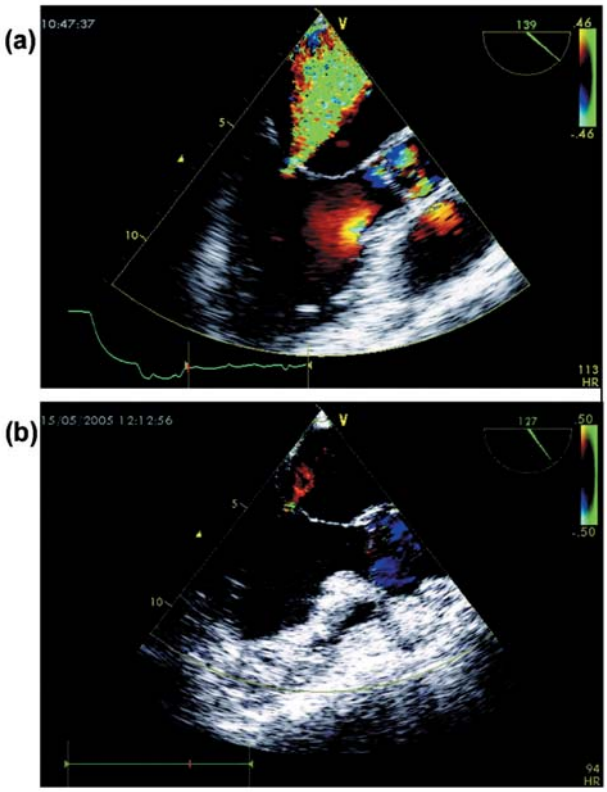

Fig. 3. Intraoperative TEE showing (a) the preoperative severe MR and (b) postoperative trivial MR.

Twenty-five of the 30 patients were weaned from cardiopulmonary bypass without IABP. Medical inotropic support was required in most cases using noradrenaline and milrinone. There was one hospital death in each group, one due to uncontrollable ventricular arrhythmia (in group 1) and another one because of pump failure (in group 2). The other patients recovered well and were followed up for 9 months (3-14 months). We used the last results of follow up as postoperative data. LV end systolic and diastolic volumes changed significantly in both groups and ejection fraction has been significantly improved in both groups, it reached to 36±4% in group 1 and 33±5% in group 2, but NYHA class was much better in group 1 than in group 2 (1.1 vs. 1.7).

Postoperative echocardiography in follow-up in PMA group revealed significant changes in the anterior mitral leaflet 'concavity area' from 44±8 to 8±2 and both systolic and diastolic sphericity indices from 65±11 and 48±9 to 55±7 and 38±6. Regurgitation was none to trivial in 12 and mild in 2 patients. But in con-

trol group there was no significant changes in sphericity indices and concavity area was significantly more than PMA group (Table 1), and there was significantly more residual MR in late follow up in this group (mean MR=1.5).

There were no thrombolytic events in either group.

Moreover, in PMA group, postoperative echocardiography revealed the papillary muscles remaining approximated.

4- Discussion

Severely dilated ischemic heart failure poses two major problems: enlarged remodeled LV and its concomitant, significant MR.

Recently, Buckberg reported that the conversion of the elliptical to spherical LV substrate might be responsible for ICM or DCM. Enlargement of the apex with a thin wall might precipitate the converting process from the elliptical to spherical LV shape and increase the interpapillary muscle distance, reducing the LV function and increasing the severity of MR [6].

Such patients are not good candidates for CABG, and unless transplantation is an option, both problems must be resolved. Many factors have been suggested to account for functional ischemic MR, such as dilatation and sphericalization of the left ventricle, altered leaflet tethering geometry, annular dilatation and papillary muscle discoordination. Failure rates for annuloplasty may be as high as 30% in patients with functional ischemic MR [7].

Newer methods of repair that are beginning to address the dysfunctional subvalvular apparatus involve complex judgment and repair methodology. For example, the pathophysiologic component of papillary muscle displacement with chordal tethering has been addressed by such techniques as anterior leaflet augmentation [8], secondary chord cutting [9], papillary muscle sling [10], papillary muscle relocation [11] and ventricular geometric restoration procedures [12].

Because both papillary muscles lie relatively posterior in the left ventricle, the leaflet tethering in ischemic MR is directed posterior to the central orifice of the mitral valve. On the basis of this anatomy, we sought a method of repair, in which displaced papillary muscles are drawn together so as to allow the level of leaflet coaptation to fall more posteriorly. Because many patients with ischemic MR are severely ill with poor ventricular function, our attempts also focused on devising a technique that (a) is easy to perform, (b) avoids annuloplasty with a small ring, (c) makes the subvalvular apparatus more normal and (d) has a conversion effect on the spherical LV shape.

Hvass et al. demonstrated that papillary muscle sling had an obvious effect on mitral leaflet mobility in 10 patients with ischemic MR [10], but they did not evaluate its effect on the ventricular shape. Matsui evaluated the effects of ventriculolasty and papillary muscle plication on 8 patients with ICM or DCM [13]. Nair and colleagues reported the result of papillary muscle plication [14]. Menicanti and associates reported

Table 1
Comparison between two groups

	Before surgery			After surgery		
	Case mean (S.D.)	Control mean (S.D.)	PV	Case mean (S.D.)	Control mean (S.D.)	PV
MR (0–4)	3.53 (0.52)	3.33 (0.49)	0.285	0.57 (0.76)	1.50 (0.86)	0.005
NYHA Class (1–4)	3.40 (0.51)	3.27 (0.46)	0.456	1.14 (0.36)	1.71 (0.73)	0.016
LVESV (ml)	177.1 (4.5)	168.7 (9.1)	0.011	81.0 (13.5)	90.6 (6.6)	0.027
LVEDV (ml)	283.9 (16.1)	271.3 (26.3)	0.123	171.0 (17.2)	183.7 (14.7)	0.045
EF (%)	23.0 (2.9)	23.5 (3.3)	0.640	36.0 (6.6)	32.9 (5.1)	0.169
Concavity area (mm^2)	44.0 (4.2)	45.9 (4.2)	0.220	8 (1.9)	24 (4.7)	0.000
Sys. Sphericity	65.1 (3.4)	67.0 (3.5)	0.138	55.0 (3.5)	63.4 (4.7)	0.000
Dias. Sphericity	48.1 (5.7)	47.5 (4.5)	0.750	37.9 (4.7)	51.4 (4.7)	0.000
Age (years)	57.0 (8.0)	58.5 (9.3)	0.647	–	–	–
PMD (cm)	2.99 (0.27)	2.84 (0.29)	0.148	–	–	–
Mitral annulus (cm)	3.94 (0.25)	3.88 (0.20)	0.517	2.79 (0.23)	2.76 (0.26)	0.705
Graft number	–	–	–	3.5 (1.1)	3.7 (1.7)	0.612

MR = Mitral Regurgitation; NYHA = New York Heart Association; LVESV = Left Ventricular End Systolic Volume; LVEDV = Left Ventricular End Diastolic Volume; EF = Ejection Fraction; Sys. = Systolic; Dias. = Diastolic; PMD = Papillary Muscle Distance.

favorable results of the endoventricular, mitral repair, ventricular reconstruction and CABG [12].

Owing to the fact that the Dor procedure alone could not reduce the basal dimensions of a dilated LV, we added PMA to the Dor operation to increase the remodeling effects of the ventricle. The Dor procedure combined with PMA is relatively safe and effective on the mitral valve and LV function for selected patients who have severely dilated hearts and are candidates for CABG. Long term follow-up, however, should be considered.

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