Assessment of Papillary Muscle Repositioning in Mitral Valve Replacement in Patients With Ischemic Mitral Regurgitation

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Abstract:

Background: The aim of this study was to investigate the feasibility of performing papillary muscle repositioning (PMR) for subvalvular-sparing mitral valve replacement procedures in patients with ischemic mitral regur-gitation and to determine the early and late effects of this procedure on the clinical outcome and left ventricular mechanics.

Methods: We prospectively randomly allocated 50 patients with severe ischemic mitral regurgitation and left ventricle dysfunction who were candidates for coronary artery bypass graft surgery and mitral valve replacement into a total chordal-sparing mitral valve replacement group or a PMR group. Echocardiography was performed preoperatively, at discharge, and after 3 years to determine the left ventricular dimensions, shape, and function.

Results: The reduction in the left ventricle volumes and sphericity index in the PMR group was more significant than that in the other group. With regard to the left ventricular end-systolic and left ventricular end-diastolic volumes, sphericity index, and ejection fraction, the PMR group showed better results ($p < 0.05$), but the difference in New York Heart Association functional class after 3 years was not statistically significant between the two groups ($p > 0.05$).

Conclusions: The PMR technique described herein can dramatically help ischemic patients by affecting the left ventricular shape and function more efficiently compared with the complete retention of the mitral subvalvular apparatus if the mitral valve is to be replaced.

The myocardium experiences remodeling in the wake of myocardial infarction: the ventricle dilates and the papillary muscles become displaced and, thus, ischemic mitral regurgitation (IMR) occurs [1-3].

It is known that IMR is not only the dysfunction of the valve but also the subvalvular structure, with the latter comprising the left ventricle (LV) free wall, papillary muscles, and chorda tendinea [4]. This process is done through the annuloventricular continuity [5], which becomes of particular importance in patients with LV dysfunction and low preoperative ejection fraction.

Valve repair is favored over replacement in most cases of IMR. However when repair is not possible, valve replacement is performed. The earliest mitral valve replacement techniques destroyed the subvalvular structure and put the patient at risk of low cardiac output syndrome after operation [6]. Recommendations to preserve the subvalvular structure by keeping the native chordae or bioprostheses with a view to maintaining ventricular annular continuity had promising results [7] and lowered the incidence of low cardiac output syndrome [5]. Be that as it may, some surgeons are still reluctant to opt for subvalvular sparing operations in that they are more complex and time consuming and there remains a risk of complications such as LV outlet obstruc-

tion with some of the chordae preservation techniques or prosthetic valve malfunction due to the interaction of the preserved chordate with prosthetic leaflet motion.
In our previous study, we introduced a new papillary repositioning technique for subvalvular sparing mitral valve replacement in a LV dysfunction population with degenerative or rheumatic valves [8]. In this study, we sought to evaluate the efficacy of this technique and its early and late outcomes with respect to the LV mechanics in patients with IMR and LV dysfunction undergoing mitral valve replacement during coronary artery bypass graft surgery (CABG).

Material and Methods

From May 2005 through January 2006, 50 patients with IMR and LV dysfunction were selected for mitral valve replacement and CABG at Day General Hospital in Tehran. The patients were randomly divided into a complete (anterior and posterior) chordal-sparing mitral valve replacement (CMVR) group (n = 25) and apapillary muscle repositioning (PMR) group (n = 25; TI Table 1).
The ejection fraction of all the selected patients was less than 40%, and all the valves were considered irreparable at the time of surgery by the surgeon. Patients requiring additional surgical procedures were excluded from the study. Patients were randomly assigned into two treatment groups using block randomization (using two or three blocks).
Informed consent was obtained from all the patients, and the protocol was approved by our Review Board.

Surgical Technique

All the surgical procedures were performed during moderate hypothermic (approximately 28°C) cardiopulmonary with cold hyperkalemic cardioplegia delivered both through antegrade and retrograde routes. At our center, when papillary muscle distance is more than 20 cm and coaptation depth is more 10 cm, annuloplasty is performed with another procedure such as papillary muscle approximation or second order chordae cutting; but if the patient is evaluated and considered as not being able to tolerate the increased operative time, then the surgeon decides to proceed with replacing the valve. In this center, the patients with effective regurgitant orifice area more than 20 mm2 and right ventricle more than 30 mL are selected for mitral valve replacement. It is also important to emphasize that in this center, the decision on the type of repair or replacement is made by the group, the echocardiographist, the cardiologist, and the surgeon, and the surgeon is not the sole decision maker. The CMVR group patients had their entire subvalvular apparatus preserved, as indicated in our previous study
Fl (Fig 1) [8]. In the PMR group patients, all the chordal structures were excised, and the leaflets were resected from the base at a distance of 2 mm from the annulus. The heads of both papillary muscles were subsequently sutured with a 2-0 Ethibond suture (Ethicon, Somerville, NJ) to the posterior side of the corresponding annulus, leaving no space between the heads of the papillary
F2 muscles and the annulus (Fig 2). The choice of a smaller distance in this series of ischemic patients by comparison with those in our previous study was prompted by the fact that the former predominantly had posterior LV dilation and increased papillary muscle distance. If the papillary muscle had fibrous tissue, 2-0 Ethibond suture on a double-armed needle was sewn to the fibrous tip. If there was no fibrous tissue, the suture was buttressed with a small soft felt pledget or pericardium and was tied snugly. Both needles of each suture were then passed through the annulus of the mitral valve at about 5 o'clock and 7 o'clock. The valve was finally implanted on the annulus, so that the heads of the papillary muscles were directly underneath the ring of the prosthetic valve.
A St. Jude mechanical prosthesis (St. Jude Medical, St. Paul, MN) or On-X mechanical prosthesis (Medical Research Institute, Austin, TX) were used in all the patients (31 mm, 38 patients; 29 mm, 24 patients; and 27 mm, 12 patients)

Table 1. Baseline Patient Characteristics

Variable	CMVR	PMR	p Valu
Age, mean ± SD	58.3 ± 7.13	53.8 ± 7.58	0.036
Male, %	60	80	0.123
Sinus rhythm, %	76	72	0.747
Diabetes mellitus, %	24	24	1.000
Hypertension, %	52	48	0.777
COPD, %	12	16	1.000

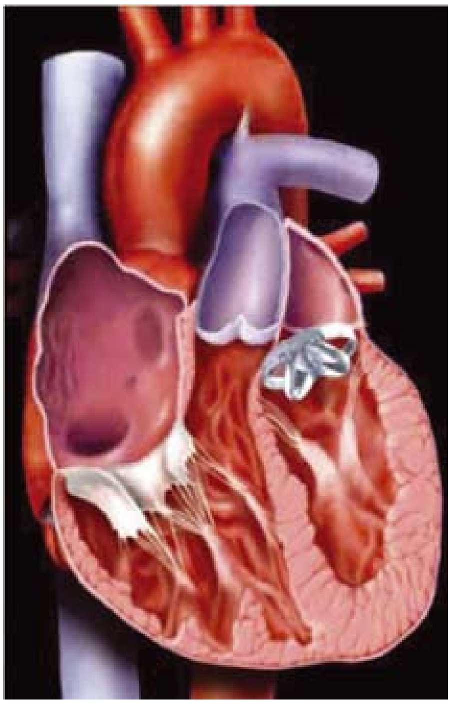

Fig 1. In the complete chordal preservation group, the subvalvular apparatus was retained in its anatomical position.

without significant differences between the two groups. In addition, all the patients received full revascularization.

Postpump transesophageal echocardiography was performed in all the patients. One patient in the CMVR group exhibited prosthetic valve malfunction due to the interference of prosthetic leaflet with the preserved chordae; the patient had to undergo a second pump for the valve to be removed and reimplanted. In all the other patients, postpump transesophageal echocardiography demonstrated no LV outflow tract obstruction or other prosthesis-related complications. In addition, the leaflets of all the prostheses were completely mobile without any limitation.

Echocardiographic Studies

All the patients underwent transthoracic echocardiography in addition to two-dimensional, M-mode, and color-flow Doppler echocardiographic studies with standard F3 acoustic windows preoperatively (Fig 3) and postopera-F4 tively (Fig 4), at hospital discharge and 3 years afterward, with GE Medical System, Vivid 7 (GE, Horton, Norway). Upon the completion of the study, all the results were interpreted by two experienced cardiologists in a blind fashion. The mean values for each measurement were derived from three consecutive heart beats in the patients in sinus rhythm and from five beats in patients in atrial fibrillation. The follow-up of all the patients was complete.

Simpson's rule method was used to measure the ejection fraction based on relative LV end-systolic volume and end-diastolic volume.

The LV sphericity index was calculated as the ratio of the LV internal diameter in the short axis compared with the LV length, measured as the distance from the mitral annulus to the apical endocardium in the LV long-axis view.

The echocardiographic data were determined according to the criteria of the American Society of Echocardiography.

Statistical Analysis

The numerical values were expressed as mean and standard deviation. The data were compared between the two groups using the unpaired t test for the continuous variables and \2 test for the categorical variables. Longitudinal changes in the parameters were compared between the two groups by repeated measurements.

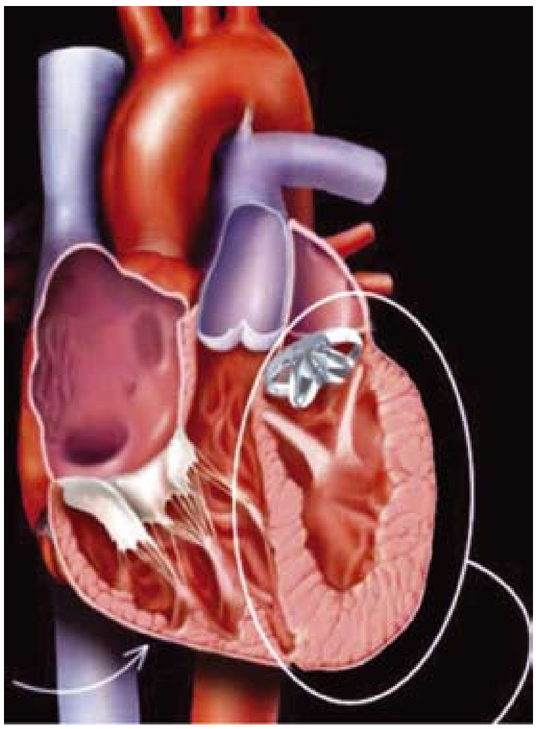

Fig 2. In the papillary muscle repositioning group, all the chordal structures were excised, and the heads of both papillary muscles were sutured to the corresponding annulus mitral valve at about 5 and 7 o'clock.

All the statistical analyses were performed using the SPSS Version 11.0 program (SPSS, Chicago, IL). A p value less than 0.05 was considered statistically significant.

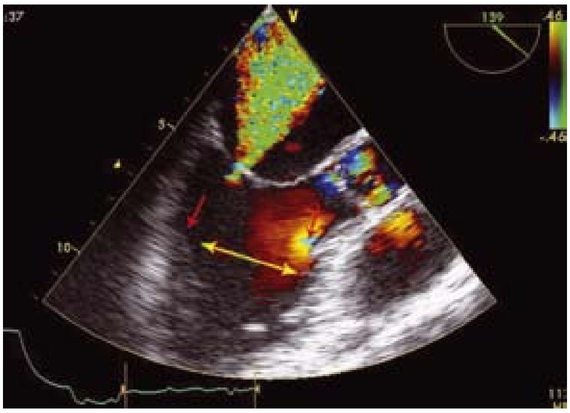

Fig 3. On transesophageal echocardiography, severe preoperative mitral regurgitation and increased papillary muscle distance is ob-served in the ventricle long-axis view. AQ: 1

Results

The number of male patients was higher in the PMR group (80%) than in the CMVR group (60%); this difference, however, was not statistically significant (p — 0.123). The mean age of the patients in the PMR group (53.8 ± 7.58 years) was not statistically significantly different (p = 0.036) from that of the patients in the CMVR group (58.3 ± 7.13 years). Other baseline patient characteristics, including ejection fraction, LV end-systolic and end-diastolic volumes, sphericity index, and preoperative New York Heart Association functional classification, were not sta-tistically significantly different between the two groups, nor was the statistical difference significant between the number of grafts received in the PMR group (3.54 ± 0.83) and that received in the CMVR group (3.54 ± 0.83; p > 0.05).

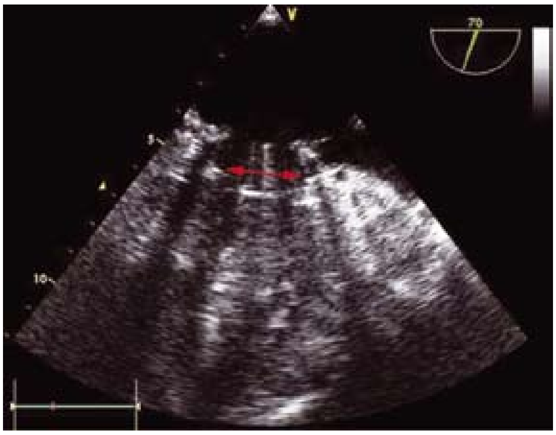

Fig 4. On transesophageal echocardiography, the left ventricle long-axis view, the retracted papillary muscle head below the prosthetic valve is observed. The transverse axis between the papillary muscles is reduced.

One patient in the CMVR group died in the operating room owing to postoperative pump failure, and another patient in the PMR group died on the fifth postoperative day as a result of respiratory failure. Moreover, 3 patients in the CMVR group and 1 in the PMR group died at follow-up in consequence of ischemic events or heart failure; these patients were not included in further analysis. No bleeding and thrombosis/embolic complications were detected in the follow-up period.

Whereas the CMVR group had a mean cross-clamp time of 33 ± 12 minutes, the PMR group scored a time of 31 ± 13 minutes, which was not longer than that in conventional mitral valve replacement operations. The cardiopulmonary bypass time was 45 ± 11 minutes in the CMVR group versus 42 ± 14 minutes in the PMR group.

With regard to the LV end-systolic and LV end-diastolic volumes, sphericity index, and ejection fraction, the PMR group showed better results (p < 0.05), but the difference in New York Heart Association class after 3 years was not statistically significant between the two T2 groups (p > 0.05; Table 2).

In the PMR group, the ejection fraction exhibited a considerable increase from the baseline (34% ± 4.79%) after surgery as demonstrated on transthoracic echocar-diography before discharge (43.13% ± 4.62%); ejection fraction continued its increase and reached 45.83% ± 1.90% at the third year of follow-up. In the CMVR group, the increase in ejection fraction from baseline (34% ± 4.79%) was not significant, and it reached 35.42% ± 4.4% before discharge and 35.83% ± 4.34% after 3 years.

Left ventricular end-diastolic volume showed a significant decline postoperatively, and this trend continued even after 3 years in both groups; the change in LV end-diastolic volume was more significant in the PMR group. Left ventricular end-systolic volume also demonstrated significant changes in the PMR group, showing a marked reduction in volume on postoperative transthoracic echocardiography, which was sustained even after 3 years. By contrast, changes in the LV end-systolic volume of the CMVR group were not significant.

The sphericity index also showed a significant decline postoperatively in the PMR group, which was sustained after 3 years; these changes were less significant in the CMVR group.

The New York Heart Association classification was better in the PMR group (1.33 ± 0.56) compared with the CMVR group (2 ± 0.78) after 3 years, but this difference was not statistically significant (p = 0.108).

Comment

Although for most patients with IMR, the best option is mitral valve repair with ring annuloplasty, this technique does not address the ventricle etiology of IMR, and a number of these patients suffer recurrence [9]. Reports exist that mitral valve replacement in high-risk patients has yielded equal or even possibly better results compared with mitral valve repair [10, 11]. For patients suffering from acute or chronic IMR with multiple comor-bidities, complex regurgitant jets (central jet or more than one jet), or severe tethering of both mitral leaflets, mitral valve replacement can be a better option [10, 12, 13]. Therefore, replacement tends to be the viable option when the feasibility of repair is minimal.

The early methods of valve replacement resulted in the excision of the chorda tendinea structure [6] and the disruption of ventriculoannular continuity, which contributed to ventricular contraction and maintenance of ejection fraction [5,14]. Preserving the ventriculoannular continuity is thought to be more important in patients with low preoperative LV function because they have a potential risk of postoperative heart failure.

Previous reports have indicated that a low preoperative LV function and ejection fraction is associated with a poor surgical outcome after mitral valve surgery [15]. Over the years, several methods of subvalvular structure preservation have been introduced to avert the possible worsening of LV function, but most of them are much too complex and time consuming to be employed in high-risk patients. Moreover, consensus has yet to emerge about which method can achieve a more optimal result in the early and late postoperative periods.

Table 2. Patient Characteristics According to Operative Procedure Group

	Group	Baseline Mean (SD)		Before Discharge Mean (SD)		Third Year Follow-Up Mean (SD)		p Value
Ejection fraction	CMVR	32.60	5.42	35.42	4.40	35.83	4.34	0.000
	PMR	34.00	4.79	43.13	4.62	45.83	1.90	
LVEDV	CMVR	173.88	23.67	155.54	20.57	141.33	19.14	0.000
	PMR	167.08	30.19	126.21	21.95	108.96	16.14	
LVESV	CMVR	97.25	17.58	88.79	16.98	85.50	17.20	0.017
	PMR	104.46	18.33	75.17	14.19	59.54	10.87	
Sphericity index	CMVR	67.17	5.12	63.96	4.23	61.17	4.03	0.000
	PMR	64.38	4.63	54.29	2.91	49.75	2.05	
NYHA	CMVR	3.13	0.54			2.00	0.78	0.108
	PMR	3.38	0.65			1.33	0.56	

LVEDV = left ventricular end-diastolic volume; abbreviations as in Table 1.
LVESV = left ventricular end-systolic volume; NYHA = New York Heart Association; other

These techniques were first introduced by Lillehei and colleagues [16], who reported a significant reduction in mortality in the chordal preserving technique. Further modifications were made thereafter because the majority of the earliest methods involved the preservation of the bulk of both valves and were thus associated with LV outflow obstruction [17]. David and colleagues [18] resected a trapezoid section of the anterior leaflet, Sintek and associates [19] excised the major portion of the anterior leaflet, and Feikes and coworkers [20] reattached the chordae to the posterior annulus. The existing literature abounds with other more or less similar techniques introduced over recent years [5, 21, 14]. Replacement of the chordae with polytetrafluoroethylene expanded sutures from the papillary muscles to the annulus has also been proposed to prevent the interference of the normal tissue with the implanted mitral valve [25]. It has been demonstrated that the preservation of all the chordae confers lower chamber volumes and better postoperative systolic functions compared with partial preservation [26], and that is the technique which we adopted in our CMVR group.

Chordal-sparing mitral valve replacement, albeit proven to yield better results, is still out of favor with many surgeons, on account of its technical complexity, prolonged cross-clamp time, potential interference with the mechanical valve leaflet motion, and the use of a smaller sized prosthetic valve. The insertion of a prosthetic mitral valve is often associated with redundant chorda tendinae, reduction in the LV size after surgery, and especially systolic anterior motion of the native anterior mitral leaflet, while the native intact valve may give rise to LV outflow tract obstruction [17, 26-29].

Seeking a straightforward and reproducible technique that would preserve the subvalvular apparatus and better restore the original ventricle geometry in patients with LV dysfunction, we excised both leaflets and all chorda tendi-nae structures and attached the papillary muscles to the annulus. Our technique resulted in a more elliptical ventri-cle, which is of particular importance in patients with functional mitral regurgitation who usually have a dilated and a more spherical ventricle. Ventricular modeling is known to persist even despite the surgical correction of IMR. Indeed, surgical techniques that limit ventricular dilation have been more effective in preventing LV remodeling and dilatation and worsening LV function when compared with the correction of IMR [30, 31].

In our previous study [8], we presented the papillary muscle repositioning technique and reported improvement in a group of patients with chronic degenerative or rheumatic mitral regurgitation and LV dysfunction. In this study, we utilized the same technique for patients with chronic IMR and LV dysfunction undergoing CABG and achieved good results, as attested to by improvement in the ejection fraction and reduction in the sphericity

index even after 3 years compared with the chorda tendinae preservation group. This improvement was achieved by preserving the subvalvular apparatus, reducing the volume load and the maintenance of better LV geometry.

We believe that our safe and straightforward technique of repositioning the papillary muscles in patients with IMR and LV dysfunction undergoing mitral valve replacement is capable of slowing the process of remodeling and maintaining a small and elliptical ventricle with a favorable ejection fraction for a relatively long period of time.

Uncited References

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