Papillary muscle relocation and mitral annuloplasty in ischemic mitral valve regurgitation: Midterm results

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Objectives: The surgical approach for ischemic mitral regurgitation remains unclear. Many studies are in favor of adding the subvalvular procedure to mitral annuloplasty to reduce recurrent mitral regurgitation. This study reports the clinical and echocardiographic outcomes of papillary muscle relocation combined with mitral annuloplasty.

Methods: From 2003, 115 patients with severe ischemic mitral regurgitation who underwent papillary muscle relocation plus nonrestrictive mitral annuloplasty and coronary artery bypass grafting were retrospectively analyzed. Patients' mean age was 52 ± 12.8 years, New York Heart Association class III or IV was 71%, and preoperative left ventricular ejection fraction was $43\% \pm 6\%$. The study end points were New York Heart Association functional class, reversal in left ventricle remodeling, reduction of mean tenting area and mean coaptation depth, freedom from cardiac-related deaths and events, and freedom from recurrent mitral regurgitation. Follow-up data were obtained in all patients and were 100% complete. Mean follow-up was 45 ± 6 months.

Results: Five-year freedom from cardiac-related death and events was $91.3\% \pm 1.6\%$ and $84\% \pm 2.2\%$, respectively. Recurrent mitral regurgitation more than moderate occurred in 3 patients (2.7%). Reversal in left ventricular remodeling, measured by a change in the end-diastolic and systolic diameter, was observed in our patients ($P < .05$). The postoperative mean tenting area and mean coaptation depth were 1.1 ± 0.2 cm² and 0.5 ± 0.2 cm, respectively; 95% of the patients were in New York Heart Association functional class I and II.

Conclusions: In patients with ischemic mitral regurgitation, papillary muscle relocation plus nonrestrictive mitral annuloplasty promotes a significant reversal in left ventricular remodeling, with a considerable decrease in tenting area and coaptation depth. Our approach is a durable method to reduce the recurrence of mitral insufficiency. (J Thorac Cardiovasc Surg 2014;148:1947-50)

In the era of mitral valve reconstruction, the surgical approach for ischemic mitral regurgitation (IMR) remains an open issue.^{1,2} Many surgeons prefer restrictive mitral valve annuloplasty (R-MA), whereas others prefer mitral valve replacement with subvalvular apparatus preservation to avoid postoperative mitral regurgitation (MR).³⁻⁸ The incidence of recurrent MR after isolated R-MA was 5% to 20% in several reports.^{9,10} On the other hand, many authors have advocated postinfarction ventricular remodeling as the key issue in the development of IMR and suggest adding a subvalvular apparatus

procedure to annuloplasty to reduce the risk of recurrent mitral valve insufficiency.¹¹⁻¹³ This study reports the midterm results of the clinical and echocardiographic outcomes of papillary muscle (PPM) relocation in conjunction with nonrestrictive mitral annuloplasty (NR-MA) in IMR.

MATERIALS AND METHODS

Patients

From March 2003, 115 patients (mean age, 52 ± 12.8 years; 56% were male) with severe IMR (effective regurgitant orifice area ≥ 20 mm², regurgitant volume ≥ 30 mL) who had PPM relocation in conjunction with NR-MA and coronary artery bypass grafting (CABG) were retrospectively analyzed. New York Heart Association (NYHA) class greater than II was present in 81 patients (71%), and mean left ventricular ejection fraction (LVEF) was $43\% \pm 6\%$. According to Carpentier's functional classification,¹⁴ all patients with IMR presented restrictive systolic leaflets motion (Carpentier's type III b) and annular dilatation (Carpentier's type I). Mean coaptation depth and mean tenting area were 1.3 ± 0.1 cm and 3.2 ± 0.9 cm², respectively. MR was defined as ischemic when caused by coronary artery disease in patients who had a previous myocardial infarction 2 weeks or more before hospital admission for CABG and exhibited normal valve apparatus anatomy. Exclusion criteria were recent myocardial infarction (< 15 days), PPM infarction causing its elongation or rupture, organic mitral valve lesions (rheumatic, infective, degenerative),

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Abbreviations and Acronyms

CABG	= coronary artery bypass grafting
CI	= confidence interval
HR	= hazard ratio
IMR	= ischemic mitral regurgitation
LV	= left ventricular
LVEF	= left ventricular ejection fraction
MR	= mitral regurgitation
NR-MA	= nonrestrictive mitral annuloplasty
NYHA	= New York Heart Association
PPM	= papillary muscle
R-MA	= restrictive mitral valve annuloplasty

previous cardiac surgery, and concomitant aortic valve surgery. Baseline patient characteristics are shown in [Table 1](#).

End Points

The study end points were as follows: incidence of early mortality and outcomes, freedom from cardiac-related deaths and events, freedom from recurrent MR 2 or greater, NYHA functional class, reverse in left ventricular (LV) remodeling, evaluation of tenting area, and coaptation depth. A cardiac event was defined as the occurrence of at least 1 of the following: myocardial infarction, congestive heart failure, cardiac death, revascularization (CABG or percutaneous intervention), new onset of atrial fibrillation, redo operation on the mitral valve, worsening in NYHA functional class, recurrent MR grade of 2 or greater, and hospital readmission.

Surgical Technique

All patients underwent conventional multivessel CABG via a longitudinal median sternotomy under normothermic cardiopulmonary bypass with intermittent antegrade cold-blood cardioplegia. The bypass grafts used were the internal thoracic artery and the long saphenous vein in all patients. All distal anastomoses were performed during a single aortic crossclamping. The proximal graft anastomoses were performed during side-clamping ([Table 1](#)).

Mitral valve annuloplasty was performed using the Carpentier-Edwards Physio ring (Edwards Lifesciences, Irving, Calif) or the Saddle Rigid ring (St Jude Medical, Minneapolis, Minn). The ring size was determined according to the surface of the anterior leaflet. In regard to our non-restrictive annuloplasty, we used the normal-sized ring, not the undersized. In patients who undergo PPM relocation, the use of a ring according to the anterior leaflet surface may be effective without having to risk an undersizing. Rings were inserted using deep horizontal U sutures and Ticon 2-0 stitches (Syneture, Norwalk, Conn).

Relocation of the PPMs was performed using a polytetrafluoroethylene suture (CV-4 Gore-Tex; WL Gore & Associates Inc, Flagstaff, Ariz) placed first at the head of each PPM and subsequently through the ipsilateral mitral annulus while the heart was arrested, according to the technique described by Kron and colleagues.¹² We relocate both PPMs to minimize the mitral valve tenting. In most cases, 1 head of the anterior PPM was relocated. On the other hand, among the 3 heads of the posterior PPM, we relocated the anterior and posterior heads. It is important to relocate both heads of the posterior PPM because from the anterior, one head arises from the chordae for the anterior leaflet responsible for the seagull sign and respective tenting, and from the posterior, one head arises from the chordae to the posterior leaflet (P2 and P3 scallops).¹⁵

All patients underwent postoperative transesophageal assessment of the LV and valve function. Mitral valve repair was considered successful if

there was no or trivial residual MR and a coaptation surface of approximately 0.8 cm.

Follow-up

All patients were followed by our cardiologists at 6-month intervals. Preoperative and postoperative clinical status were determined according to the criteria of the NYHA functional class and the Canadian Cardiovascular Society for heart failure symptoms and angina, respectively. Clinical follow-up data were obtained in all patients and were 100% complete. Mean follow-up was 45 ± 6 months.

Statistical Analysis

The numeric values are expressed as mean $\pm$ standard deviation. The frequency ratios are given as percentages. LV end-diastolic and end-systolic diameters, and LVEF percentage were analyzed using the paired *t* test and Wilcoxon signed-rank test. Variables were put into a Cox regression model. Where appropriate, hazard ratios (HRs) are presented with 95% confidence intervals (CIs). Actuarial survival and other time-related events were analyzed with the Kaplan–Meier method. Log-rank test was used to compare statistical significance level. SPSS software (SPSS Inc, Chicago, Ill) was used.

RESULTS**Early Outcomes**

Of the entire population, 4 patients (3.4%) died in-hospital. Causes of in-hospital death were low cardiac output in 2 patients, sepsis in 1 patient, and multiorgan failure in 1 patient. Intra-aortic balloon pump implantation was required to treat postoperative cardiogenic shock in 2 patients (1.7%). Renal failure requiring dialysis was present in 4 patients (3.4%). All data are shown in [Table 2](#).

TABLE 1. Baseline and intraoperative data

Baseline	
Mean age (y)	52 $\pm$ 12.8
Male gender	65 (56%)
Diabetes mellitus	38 (33%)
COPD	12 (10.4%)
Hypertension	70 (60%)
Renal failure*	9 (7.8%)
Unstable angina	35 (30.4%)
CHF	44 (38%)
Atrial fibrillation	6 (5.2%)
NYHA >II	81 (71%)
euroSCORE	8.8 $\pm$ 2.6
LVEF	43 $\pm$ 6
LVEDD	58.8 $\pm$ 12
LVESD	48.1 $\pm$ 9
Mean tenting area	3.2 $\pm$ 0.9
Mean coaptation depth	1.3 $\pm$ 0.1
Intraoperative	
CPB time (min)	114 $\pm$ 20
Crossclamp time (min)	85 $\pm$ 10
Grafts/patient	2.8 $\pm$ 0.5

Values are mean $\pm$ standard deviation or number (%). CHF, Congestive heart failure; COPD, chronic obstructive pulmonary disease; CPB, cardiopulmonary bypass; euroSCORE, European System for Cardiac Operative Risk Evaluation; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter; NYHA, New York Heart Association.

*Serum creatinine greater than 1.5 mg/dL.

TABLE 2. Early outcomes and follow-up data

Early outcomes	
Bleeding with re sternotomy	6 (5.2%)
Renal failure (dialysis)	4 (3.4%)
ETI >72 h	7 (6%)
LCOS	2 (1.7%)
Sepsis	1 (0.8%)
MOF	1 (0.8%)
IABP	2 (1.7%)
ICU stay (d)	2.1 ± 1.8
In-hospital mortality	4 (3.4%)
Follow-up data	
Late mortality	5 (4.5%)
NYHA class >II	4 (3.6%)
Hospital readmission for CHF	4 (3.6%)
Recurrent MR ≥II	3 (2.7%)
Mean tenting area (cm ²)	1.1 ± 0.2
Mean coaptation depth (cm)	0.5 ± 0.2
LVEDD (mm)	49 ± 5
LVESD (mm)	39 ± 4
Mean LVEF%	49 ± 3

Values are presented as mean ± standard deviation or number (%). CHF, Congestive heart failure; ETI, endotracheal intubation; IABP, intra-aortic balloon pump; ICU, intensive care unit; LCOS, low cardiac output syndrome; LVEDD, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter; MOF, multiorgan failure; MR, mitral regurgitation; NYHA, New York Heart Association.

Late Outcomes

Kaplan–Meier estimate for cumulative survival at 5 years was 91% ± 1.3% after PPM relocation plus NR-MA. Five-year freedom from cardiac-related death rate was 91.3% ± 1.6% (Figure 1, A). Late cardiac deaths occurred in 5 patients (4.5%). Causes of late death were congestive heart failure in 2 patients, arrhythmias in 2 patients, and sudden death in 1 patient. The following independent variables for late mortality in the entire population were found by Cox analysis: LVEF 30% or less ($P = .003$; HR, 8; 95% CI, 2.2-37) and NYHA class III or greater ($P = .006$; HR, 5.5; 95% CI, 1.5-44). Five-year freedom

from cardiac-related events was 84% ± 2.2% (Figure 1, B). Five-year freedom from recurrent MR grade of 2 or greater was 97.3% ± 1.1% (Figure 1, C). At follow-up, NYHA functional class improved from 3.1 ± 1.1 to 1.3 ± 0.3 ($P = .018$).

Echocardiographic Data

Recurrent moderate or more than moderate MR occurred in 3 patients (2.7%). Significant reversal in LV remodeling measured by a change in LV end-diastolic and end-systolic diameters was observed in our patients ($P < .05$). The LVEF improved from 43 ± 6 to 49 ± 3 ($P < .05$). Postoperative mean tenting area was 1.1 ± 0.2 cm², and postoperative mean coaptation depth was 0.5 ± 0.2 cm, with significant reduction in respect to preoperative data ($P < .001$) (Table 3).

CONCLUSIONS

Although the surgical treatment of severe IMR in patients presenting for CABG is recommended by the American College of Cardiology/American Heart Association and European Society of Cardiology/European Association for Cardiothoracic Surgery guidelines,^{1,2} the best surgical approach is still under debate. Several clinical studies provide only limited information about the dilemma to repair or replace the mitral valve in patients with severe IMR.^{5,7} This conflicting decision is mainly affected by the lack of prospective studies and often by the comparison of clinical outcomes for both procedures in dissimilar patient groups.

Currently, R-MA is still associated with poor outcomes in many series^{16,17} for many reasons. First, there is a wide heterogeneity in the literature in the type of prosthetic ring (eg, complete, band, rigid, flexible, pericardium) used to achieve mitral annuloplasty, which inexorably leads to dissimilar results. Second, R-MA was performed in all patients with IMR despite the degree of LV dilatation and

FIGURE 1. Kaplan–Meier log-rank test used to compare cardiac-related deaths (A), cardiac-related events (B), and recurrent MR grade of 2 or greater. MR, Mitral regurgitation.

TABLE 3. Comparison of echocardiographic data from preoperative to follow-up

Variable	Preoperative	Follow-up	P value
Mean tenting area (cm ²)	3.2 ± 0.9	1.1 ± 0.2	<.001
Mean coaptation depth (cm)	1.3 ± 0.1	0.5 ± 0.2	<.001
LVEDD (mm)	58.8 ± 12	49 ± 5	<.05
LVESD (mm)	48.1 ± 9	39 ± 4	<.05
Mean LVEF%	43 ± 6	49 ± 3	<.05

Values are mean ± standard deviation or number (%). LVEDD, Left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVESD, left ventricular end-systolic diameter.

dysfunction and the severity of mitral valve tenting associated with PPM displacement. Thus, surgeons routinely perform R-MA as a unique surgical solution for a complex LV disease. Several authors have proposed different surgical techniques (eg, PPM relocation, second chordae cutting, PPM sling)¹¹⁻¹³ in addition to R-MA to improve long-term repair results. In this series, we present our experience on PPM relocation. This technique was first introduced by Kron and colleagues¹² and may be easy and reproducible.

LV reverse remodeling has been observed after R-MA.^{4,8} However, it is not clear whether PPM relocation has a favorable effect on LV reverse remodeling for isolated R-MA. Our group recently published 2 articles that compare the results of PPM relocation and NR-MA with isolated R-MA.^{15,18} We demonstrated that PPM relocation reduces the tenting area and coaptation depth, leading to a low incidence of recurrent MR and promoting a better reverse in LV remodeling compared with isolated R-MA.

PPM relocation is a safe method, with low early and late mortality. This technique reduces the tenting area and coaptation depth, leading to a low incidence of recurrent MR and probably avoiding further displacement of the PPMs. Moreover, PPM relocation promotes a better reverse in LV remodeling.

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