Original Article

Left Ventricular Reconstruction with or without Mitral Annuloplasty

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Objectives: The aim of this study was to review characteristics of patients undergoing left ventricular reconstruction (LVR) with or without mitral annuloplasty (MAP) for postinfarction ventricular remodeling.
Patients and Methods: Forty-seven patients were divided into two groups: LVR (LVR group, n = 22) and LVR with MAP (LVRM group, n = 25). Echocardiographic parameters including left ventricular (LV) dimensions, LV end-diastolic and end-systolic volume indexes, and LV ejection fraction (LVEF) at immediate and midterm postoperative stages were evaluated. The perioperative contributing factors to all deaths and death from congestive heart failure (CHF) were analyzed in all 47 patients.
Results: Patients in the LVRM group had greater preoperative LV dimension and volume, and significantly lower LVEF, with notably frequent use of intra-aortic balloon pumping. All postoperative deaths occurred within 1 year from surgery. The LV end-diastolic volume > 110 ml/m^2 and creatinine > 1.2 mg/dl were significant preoperative contributing factors to all deaths, and the latter was to CHF deaths.
Conclusions: The coexistence of ischemic mitral regurgitation with LV dilatation required more aggressive surgical approaches for the patients with more impaired LV function. More intensive postoperative management is required for patients with enlarged hearts and renal dysfunctions. (Ann Thorac Cardiovasc Surg 2009; 15: 165–170)

Key words: left ventricular reconstruction, mitral annuloplasty

Introduction

Over the past decade, aggressive surgical procedures, including mitral annuloplasty (MAP) or left ventricular reconstruction (LVR) and coronary artery bypass grafting (CABG), have been performed for functional or morphological abnormality following postinfarction left ventricular (LV) remodeling. In this study we reviewed clinical features of patients undergoing LVR alone and LVR with MAP performed for patients with LV dilatation with or without ischemic mitral regurgitation (IMR) caused by postinfarction LV remodeling.

Patients and Methods

From February 2000 to October 2005, 47 patients underwent LVR with or without MAP in addition to CABG for advanced ischemic heart disease with previous myocardial infarction (MI). They were divided into two groups

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depending on the type of operative procedure: the LVR + CABG group (LVR group, n = 22), and the LVR + MAP + CABG group (LVRM group, n = 25).

All patients were admitted for preoperative treatment of congestive heart failure (CHF) and underwent transthoracic echocardiography (TTE) within a week before the operation, 1–2 weeks following surgery (immediate postoperative stage), and at least 6 months postoperatively (intermediate postoperative stage). The LV diastolic and systolic dimensions (LVDd and LVDs) were measured through a long-axis view. The LV end-diastolic and end-systolic volume indexes (LVEDVI and LVESVI) and the LV ejection fraction (LVEF) were calculated by the modified biplane Simpson's method. Mitral regurgitation (MR) was classified as none (grade 0), mild (1), moderate (2), moderately severe (3), and severe (4). The changes of these parameters were statistically analyzed in each group.

All operations were performed by a single surgeon (R.S.). CABG was performed using as many arterial grafts as possible, aiming at complete revascularization. With respect to the selection of an annuloplasty ring for MAP, our practice has been to use the Carpentier-Edwards rigid or 'Physio' rings (Edwards Lifescience, Irvine, CA) through the left atriotomy when preoperative MR is more than moderate, and to use partial flexible rings (flexible linear reducer) through the left ventriculotomy when MR is mild. In cases of mild MR with no previous history of CHF, we performed LVR alone.

We have performed four different types of LVR, including the Dor procedure, the septal anterior ventricular exclusion (SAVE) procedure, the overlapping procedure, and linear closure. The Dor procedure performed in our series is what we call an "original" procedure, placing a purse-string suture around scar tissue and securing a circular Dacron patch. The "original" Dor procedure was performed during the initial 2 years of the study period and was later replaced by the SAVE procedure or the overlapping procedure, aiming to develop a more elliptical LV shape. Technical details of the SAVE and overlapping procedures have been presented elsewhere.[1,2]

With respect to the selection of SAVE or the overlapping procedure, SAVE was indicated in cases in which the residual LV volume, after exclusion of the infarcted region, was so small as to potentially cause diastolic dysfunction. Linear closure was performed in two cases with postero-inferior infarction, following inferior ventriculotomy and partial resection of infarction scar tissue.

Statistical analysis

Data are presented as mean ± standard deviation (SD) of the mean. For group comparison, the Student's t-test or χ^2 analysis was used when appropriate. The repeated measure of analysis of variance (ANOVA) with Fisher's LSD test was used to analyze the data between three stages in each group. Stepwise multiple regression analysis was used to determine the perioperative contributing factors related to all postoperative deaths or deaths from CHF, including patients aged >75, hypertension, diabetes mellitus, LVEDVI > 110 ml/m^2, LVESVI > 70 ml/m^2, LVEF < 30%, creatinine > 1.2 mg/dl, total bilirubin > 1.2 mg/dl, MAP, cardiopulmonary bypass (CPB) time, and aortic clamp time. A p value of less than 0.05 was considered statistically significant.

Results

The preoperative patient profiles of the two groups are presented in Table 1. There was no significant difference in patient age, associated coronary risk factors, or frequency of angina or CHF between the two groups. Hypertension, however, was significantly greater in frequency in the LVRM group (p = 0.014). Most patients in both groups had anteroseptal infarction. The LV dimension and volume in the LVRM group were greater than those in the LVR group, with a significant difference in LVDs (p = 0.046). The LVEF in the LVRM group was significantly lower than that in the LVR group (p = 0.026).

The details of the procedures are shown in Table 2. The durations of CPB (p = 0.020) and myocardial ischemia (p = 0.060) in the LVRM group were longer than those in the LVR group. There was no significant difference in the number of distal bypass graft anastomoses between the two groups. The Dor procedure was performed more frequently at the beginning of this study, leading to a higher proportion in the LVR group. Subvalvular apparatus procedures (including papillary muscle approximation [PMA], papillary muscle elevation [PME], and chordal cutting) were limited to the LVRM group. PME aims at a selective relocation of the posterior papillary muscle and is accomplished by localized plication of the LV underlying the papillary muscle.[3] Concomitant procedures, including tricuspid annuloplasty and Maze procedure and the use of intra-aortic balloon pumping (IABP) (p = 0.033), were performed with

Table 1. Preoperative patient characteristics

	LVR (n = 22)	LVRM (n = 25)	P value
Age (yrs)	60.1 ± 12.8	62.4 ± 11.4	0.526
HT	8	18	0.014
DM	11	9	0.333
HL	10	5	0.062
Angina	15	16	0.763
CHF	10	15	0.319
OMI			
AS	16	18	
PI	0	1	
Multi	6	6	
AS + PI	3	3	
AS + L	0	0	
AS + PI + L	2	2	
PI + L	1	1	
LVDd (mm)	56 ± 9	59 ± 6	0.183
LVDs (mm)	43 ± 9	48 ± 8	0.046
LVEDVI (ml/m^2)	89 ± 28	102 ± 26	0.106
LVESVI (ml/m^2)	58 ± 27	71 ± 24	0.110
LVEF (%)	38 ± 10	31 ± 9	0.026
MR grade	0.4 ± 0.5	1.6 ± 0.8	<0.001

The LVDd, LVDs, LVEDVI, and LVESVI were greater, and LVEF was significantly lower in the LVRM group, than those in the LVR group.

LVR, left ventricular reconstruction; LVRM, left ventricular reconstruction with mitral annuloplasty; yrs, years old; HT, hypertension; DM, diabetes mellitus; HL, hyperlipidemia; CHF, congestive heart failure; OMI, old myocardial infarction; AS, anteroseptal; PI, posteroinferior; multi, multiterritory; L, lateral; LVDd, left ventricular diastolic dimension; LVDs, left ventricular systolic dimension; LVEDVI, left ventricular end-diastolic volume index; LVESVI, left ventricular end-systolic volume index; LVEF, left ventricular ejection fraction; MR, mitral regurgitation.

Table 2. Operative details

	LVR (n = 22)	LVRM (n = 25)	P value
CPB (min)	149 ± 38	175 ± 33	0.020
Ischemia (min)	108 ± 33	124 ± 22	0.060
CABG	4.0 ± 1.3	3.4 ± 1.7	0.197
MAP			
CE		12	
FLR		13	
LVR			
Dor	11	5	
SAVE	6	7	
Overlapping	5	11	
Linear	0	2	
Subvalvular			
PMA		5	
PME		2	
CC		4	
TAP	0	5	
Maze	0	4	
Emergency	2	3	0.747
IABP	1	7	0.033

The CPB time and frequency of IABP in the LVRM group were significantly greater than those in the LVR group.

LVR, left ventricular reconstruction; LVRM, left ventricular reconstruction with mitral annuloplasty; CPB, cardiopulmonary bypass; CABG, coronary artery bypass grafting; MAP, mitral annuloplasty; CE, Carpentier-Edwards ring; FLR, flexible linear reducer; SAVE, septal anterior ventricular exclusion; PMA, papillary muscle approximation; PME, papillary muscle elevation; CC, chordal cutting; TAP, tricuspid annuloplasty; IABP, intra-aortic balloon pumping.

greater frequency in the LVRM group.

The changes of the LVEDVI, LVESVI, LVEF, and MR grade in the two groups at preoperative, immediate postoperative, and midterm postoperative stages are presented in Fig. 1. The LVEDVI and LVESVI were significantly reduced immediately after the operation ($p < 0.001$) but increased again, though to a small degree, at the midterm stage ($p < 0.01$ versus preoperative stage) in both the LVR and LVRM groups. The LVEF increased at the immediate postoperative stage in the LVR ($p < 0.05$) and LVRM ($p < 0.01$) groups. Although the LVR group showed further increase in LVEF at the midterm stage, the LVRM group did not. The MR grade in the LVRM group was significantly reduced ($p < 0.001$) immediately after the operation, and it remained at a low level at the midterm postoperative stage.

The postoperative clinical course of the two groups is summarized in Table 3. Although the mean period of the intensive care unit (ICU) stay in the LVRM group was much longer than that of the LVR groups, its median value did not significantly differ between the two groups. There were two in-hospital deaths resulting from CHF, one occurring in LVR (Dor, n = 2) and one in LVRM (SAVE, n = 1; overlapping, n = 1) groups. Another patient undergoing the overlapping procedure in the LVRM group died of sepsis immediately after the operation. During the follow-up period, 1 patient (SAVE) in the LVR group succumbed to pneumonia. Five additional deaths occurred in the LVRM group. Three patients (SAVE, n = 2; overlapping, n = 1) died of CHF and one (linear closure) of sepsis. Another patient (Dor) with uneventful course died suddenly without a clear underlying cause. The postoperative survival curve is shown in Fig. 2. All postoperative deaths following LVR with or

Table 3. Postoperative course

	LVR (n = 22)	LVRM (n = 25)	P value
Immediate p/o			
ICU stay (day)	3.5 ± 5.5	5.8 ± 7.2	0.231
[Median]	2.0	3.0	
In-hospital death	2	3	0.747
CHF	2	2	
Sepsis	0	1	
Intermediate p/o			
Follow (month)	49 ± 17	42 ± 16	0.743
Death	1	5	0.113
CHF	0	3	
Sepsis	0	1	
Pneumonia	1	0	
Unknown	0	1	

The mean period of ICU stay in the LVRM group was longer; however, its median value was not. There were two in-hospital deaths from CHF, one each in the LVR and LVRM groups, and an additional three deaths from CHF after hospital discharge in the LVRM group.
LVR, left ventricular reconstruction; LVRM, left ventricular reconstruction with mitral annuloplasty; p/o, postoperative; ICU, intensive care unit; CHF, congestive heart failure.

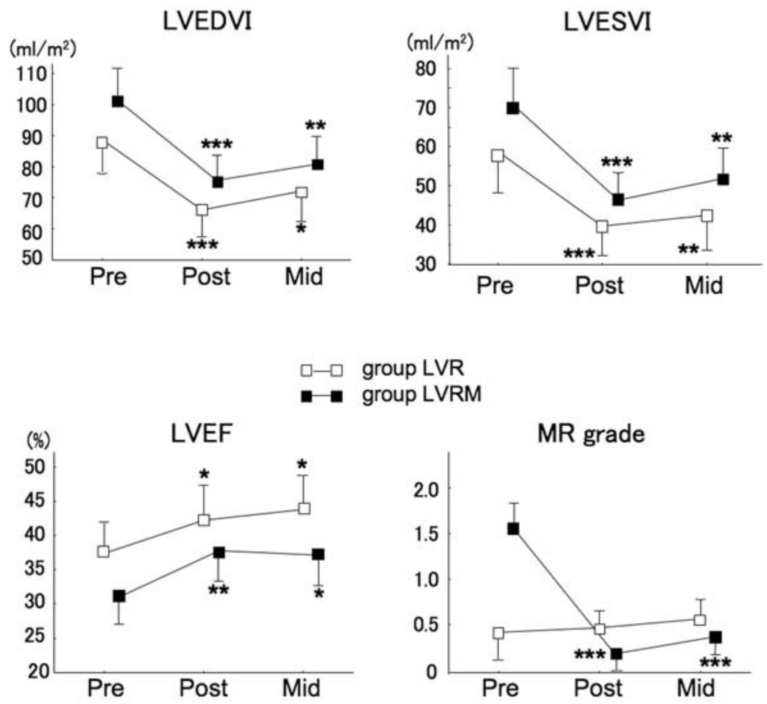

Fig. 1. Changes in echocardiographic parameters.
The LVEDVI and LVESVI reduced significantly immediately after operation, but increased slightly at the midterm postoperative stage in both groups. The postoperative LVEF increased slightly with time in the LVR group; however, it did not in the LVRM group.
LVEDVI, left ventricular end-diastolic volume index; LVESVI, left ventricular end-systolic volume index; LVEF, left ventricular ejection fraction; MR, mitral regurgitation; pre, preoperative stage; post, immediate postoperative stage; mid, midterm postoperative stage; LVR, left ventricular reconstruction; LVRM, left ventricular reconstruction with mitral annuloplasty.
*, $p < 0.05$; **, $p < 0.01$; ***, $p < 0.001$.

without MAP occurred within 1 year.

Stepwise multiple regression analysis showed that LVEDVI > 110 ml/m^2 ($p = 0.016$) and creatinine > 1.2 mg/dl ($p = 0.017$) were significant preoperative risk factors to all postoperative deaths, and only creatinine > 1.2 mg/dl was significant to deaths from CHF ($p = 0.004$). Concomitant MAP was not a significant risk factor ($p = 0.616$) to deaths from CHF.

Discussion

The initial objective of LVR was LV volume reduction to improve pump function on the basis of Laplace's law for patients with end-stage postinfarction LV remodeling. Dor presented an original LVR procedure for advanced ischemic cardiomyopathy,[4] which has been the gold standard of LVR[5,6] with some technical modifications.[7] Because LV dilatation and IMR are known to originate from a common etiology (postinfarction LV remodeling), a simultaneous operation addressing IMR and LV dilatation may be required in selected cases, such as those in the LVRM group.

Besides CABG, MAP is established as the procedure of choice for significant IMR. However, several authors have postulated recently the possible limitations of MAP alone in avoiding a postoperative recurrence of IMR in some cases, because progressive LV remodeling may further relocate papillary muscles and increase tethering forces, leading to IMR recurrence.[8–10] This concern has raised the development of new surgical approaches, such as the aforementioned subvalvular procedures. As shown in Table 2, we are keen to perform subvalvular procedures simultaneously for patients with IMR in the LVRM group. Several subvalvular procedures designed to reduce tethering forces were reported, including PMA,[11] second-order chordal cutting,[12] papillary muscle imbrication,[13] and selective elevation of posterior papillary muscle by string[14] or localized LV plasty PME.[3]

Some characteristics observed in the LVRM group should be noted. First, these patients had more advanced LV remodeling before the operation that was associated with larger LV volume and lower LVEF. Second, the absence of interval improvement of LVEF at the midterm follow-up, even after complete coronary revascularization, may indirectly suggest that myocardial viability has already been reduced remarkably before the operation. To confirm this hypothesis, qualitative and quantitative evaluations of myocardial viability should be performed preoperatively. Third, a higher incidence of associated tricuspid regurgitation and atrial fibrillation in the LVRM group can reflect an increase in pressure and volume loading on the heart. It is not surprising that a more depressed pump condition before the operation can predispose to a greater frequency of IABP insertion and a higher postoperative mortality rate.

These characteristics of the LVRM group are closely linked to the operative outcomes shown in Table 3. Because of the greater value of the SD and median value of the period of ICU stay in the LVRM group, a few sicker patients were thought to increase its mean value. No patient died of CHF after hospital discharge in the LVR group. In contrast, 3 patients expired with CHF during follow-up in the LVRM group. The postoperative survival curve in Fig. 2 clearly shows other unique aspects in the clinical course following these procedures. No deaths occurred beyond 1 year postoperatively in patients undergoing LVR with or without MAP.

Multiple regression analysis showed that preoperative renal dysfunction and enlarged LV were significant contributing factors in causing postoperative death. Our results are similar to those previously reported by other groups.[15,16] In regard to cases with already advanced LV remodeling and depressed pump function, there seems to be little room for improvement. However, our study indicates that more intensive management for these high-risk patients at the immediate postoperative period and during the follow-up period might play a key role in improving overall survival after LVR with or without MAP.

Our study has several limitations, including the small size of the patient cohort, a short follow-up period, and the different procedures of MAP and LVR performed in the same group. Myocardial viability was not evaluated with MRI. The Dor and overlapping procedures were performed at different times in the study period. However, we believe that this retrospective review may disclose some characteristic profiles and outcomes of patients requiring simultaneous LVR and MAP, which have common etiological backgrounds (postinfarction LV remodeling).

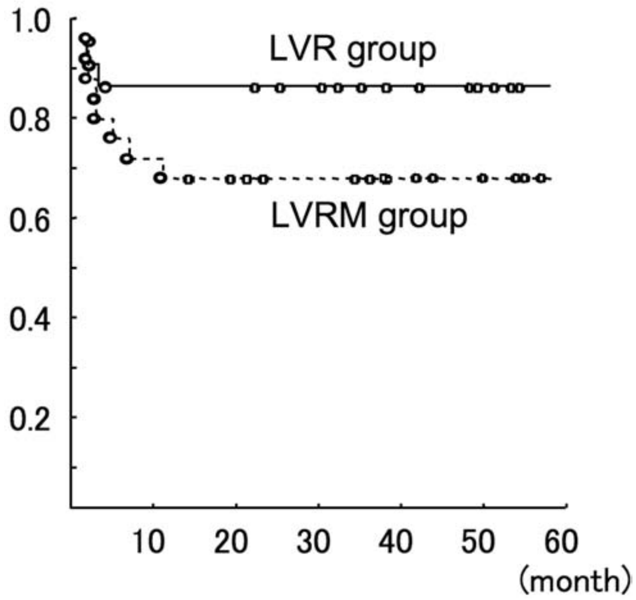

Fig. 2. Cumulative proportion survival curve.
All postoperative deaths occurred within 1 year following LVR with or without MAP, and no patients were deceased after that initial stage.
LVR, left ventricular reconstruction; LVRM, left ventricular reconstruction with mitral annuloplasty.

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