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/m² and creatinine > 1.2 mg/dl were significant preoperative contributing factors to all deaths, and the latter was to CHF deaths.


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...
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 (LV Dd 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 ventriculotomyn when MR is mild. In cases of mild MR with no
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 proce-
dure 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 overlapp-
ing 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 posteroinferior 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 χ²
analysis was used when appropriate. The repeated mea-
sure 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 melli-
tus, LVEDVI > 110 ml/m², LVESVI > 70 ml/m², 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 fre-
cquency of angina or CHF between the two groups.
Hypertension, however, was significantly greater in fre-
cquency in the LVRM group (p = 0.014). Most patients in
both groups had anteroseptal infarction. The LV dimen-
sion and volume in the LVRM group were greater than
those in the LVR group, with a significant difference in
LV Ds (p = 0.046). The LV EF 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 anasto-
moses 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 plica-
tion 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

<table>
<thead>
<tr>
<th></th>
<th>LVR (n = 22)</th>
<th>LVRM (n = 25)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>60.1 ± 12.8</td>
<td>62.4 ± 11.4</td>
<td>0.526</td>
</tr>
<tr>
<td>HT</td>
<td>8</td>
<td>18</td>
<td>0.014</td>
</tr>
<tr>
<td>DM</td>
<td>11</td>
<td>9</td>
<td>0.333</td>
</tr>
<tr>
<td>HL</td>
<td>10</td>
<td>5</td>
<td>0.062</td>
</tr>
<tr>
<td>Angina</td>
<td>15</td>
<td>16</td>
<td>0.763</td>
</tr>
<tr>
<td>CHF</td>
<td>10</td>
<td>15</td>
<td>0.319</td>
</tr>
<tr>
<td>OMI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AS</td>
<td>16</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>PI</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Multi</td>
<td>6</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>AS + PI</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AS + L</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>AS + PI + L</td>
<td>2</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>PI + L</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>LVDd (mm)</td>
<td>56 ± 9</td>
<td>59 ± 6</td>
<td>0.183</td>
</tr>
<tr>
<td>LVEDV (ml/m²)</td>
<td>43 ± 9</td>
<td>48 ± 8</td>
<td>0.046</td>
</tr>
<tr>
<td>LVESVI (ml/m²)</td>
<td>89 ± 28</td>
<td>102 ± 26</td>
<td>0.106</td>
</tr>
<tr>
<td>LVEF (%)</td>
<td>38 ± 10</td>
<td>31 ± 9</td>
<td>0.026</td>
</tr>
<tr>
<td>MR grade</td>
<td>0.4 ± 0.5</td>
<td>1.6 ± 0.8</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

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

The changes of the LVEDV, LVESVI, LVEF, and MR grade in the two groups at preoperative, immediate postoperative, and midterm postoperative stages are presented in Fig. 1. The LVEDV 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 mid-term 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

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

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.

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),

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.

- 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.

Fig. 1. Changes in echocardiographic parameters.

Fig. 1.

\*\*, p < 0.01; \*\*\*, p < 0.001.
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.\textsuperscript{5–10} 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,\textsuperscript{11} second-order chordal cutting,\textsuperscript{12} papillary muscle imbrication,\textsuperscript{13} and selective elevation of posterior papillary muscle by string\textsuperscript{14} or localized LV plasty PME.\textsuperscript{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.\textsuperscript{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).
References


