Safety and Efficacy of Surgical Ventricular Restoration in Unstable Patients With Recent Anterior Myocardial Infarction

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Background—The effects and efficacy of surgical ventricular restoration (SVR) in ischemic cardiomyopathy caused by chronic anterior myocardial infarction (MI) are well established. Normally, SVR is delayed at least 3 months after MI to allow the healing of infarcted tissue. Some patients have instability <30 days after anterior MI, with increased risk for morbidity and mortality.

Objectives—This study tests the safety and efficacy of SVR in the setting of subacute complicated anterior MI, in terms of early and late outcome.

Methods and Results—74 patients (62±10 years) were submitted to SVR at ≤30 days after anterior MI for clinical instability and were retrospectively selected from a series of 430 patients undergoing SVR at our center, between 1998 and 2001. The surgical indications included: angina (60%); New York Heart Association class 4 (62%); clinical signs of heart failure (18%); life-threatening arrhythmias (12%); and cardiogenic shock in 4% (or 3) patients. Follow-up is available for 93% of patients. All patients had coronary artery bypass grafting (CABG) (3.1±1.2) with internal mammary artery (IMA) utilization. An endoventricular patch was used in 17 patients (23%); direct ventriculotomy closure was used in the remaining patients. Operative mortality was 5.4% (4/74). Hemodynamic parameters improved significantly in patients with dilated hearts and reduced ejection fraction. Mitral regurgitation that resulted was significantly reduced. Survival at 3 years was 87% in the overall population and 85% in patients 70 years or older.

Conclusions—This study reports the largest series of patients with complicated, recent anterior MI treated with SVR. The results show that SVR is feasible, has acceptable in-hospital mortality, and has good early and late outcome. Further experience is needed to establish whether SVR, which excludes the infarcted region, can prevent the long-term adverse remodeling of LV dilated hearts after anterior infarction. (Circulation. 2004;110[suppl II]:II-169–II-173.)

Key Words: myocardial infarction ■ heart failure ■ remodeling ■ cardiovascular surgery

Complications after anterior myocardial infarction (MI), including angina, heart failure (HF), and ventricular arrhythmias, may occur within 30 days from the acute event; patients with complicated anterior MI are at high risk for death and for major adverse events, despite the aggressive therapeutic approach to acute MI.1–3 Dilatation of the left ventricular (LV) cavity with further remodeling occurs in ~20% of patients with anterior MI,4 despite early revascularization. Moreover, an increase of end systolic volume index ≥45 mL/m² after MI identifies patients with 30 days to 1 year of increased risk for major cardiac events and mortality.5 Elderly patients and the presence and severity of HF are strong predictors of mortality that have been reported as high as ≥25% at 1 year in these subsets of patients.3,6

Alternative strategies of treatment are therefore advisable to improve prognosis in these high-risk patients.

The effects and efficacy of surgical ventricular restoration (SVR) are well-established in chronic postinfarction ischemic cardiomyopathy, but few data exist on the efficacy of SVR in the setting of acute/subacute complicated anterior MI with dilated ventricle.7–9

SVR is normally delayed at least 3 months to allow the healing of infarcted tissue, but when patients present with clinical instability as unstable angina or heart failure (HF), indications for this type of surgery have not been established.

Aim of the present retrospective study is to report the safety and efficacy of SVR and associate coronary artery bypass graft (CABG) in subacute, complicated anterior MI in terms of early and late outcome.

Patients and Methods

From January 1998 to January 2002, 430 patients underwent SVR at San Donato Hospital. Clinical, hemodynamic, surgical, and follow-up data were collected using Microsoft Excel. For the present study, we retrospectively selected patients with anterior MI who underwent SVR without associate procedures except CABG within 30 days or less from the acute event. We found 74 patients (mean age 62±10 years) satisfying these selection criteria and they represent the study population. All patients had an echocardiographic study before and after surgery at discharge (7 to 10 days).
Surgical Procedure

The procedure was conducted under total cardiac arrest with aortic clamping. Antegrade crystalloid cardioplegia was usually applied and, in some selected patients with severe depression of pump function, blood cold cardioplegia was used. Complete coronary revascularization, including the left internal mammary artery on left anterior descending artery to preserve the septal branches, was first performed. Then, the ventricle was opened and the transitional zone and papillary muscles were carefully checked.

An endoventricular circular suture (Fontan stitch) was performed at the transitional zone starting from the apex, going medially toward the septum, superiorly toward the aortic valve, laterally toward the base of the 2 papillary muscles, and ending at the level of the apical reference stitch. Since 2001, the procedure has been performed with the help of a preshaped device (Chase Medical) inflated at 50 to 60 mL to size and reshape the ventricle. When the infant is recent, as it is in this series of patients, the transitional zone may not be clearly identified and palpation of the muscle can help in localizing the site where it becomes thinner (transitional zone), and the device helps in following the appropriate curvature of the suture plane.

Finally, the opening of the ventricle is closed with a dacron patch if the diameter is 3 cm or greater; if it is smaller than 3 cm, the closure is performed with simple stitches. In the last case, a second stratum with the excluded tissue is sutured on the first suture to avoid bleeding.

Statistical Analysis

Statistical analysis was performed using the SPSS statistical Package. All data are expressed as mean±SD. Means were compared with an unpaired, 2-tailed Student t test. Categorical variables were compared using Fisher exact test for 2×2 contingency tables and Pearson χ² test for larger tables. Survival was estimated by using Kaplan–Meyer survival curves. P<0.05 was considered statistically significant.

Results

All patients had CABG with revascularization of the left anterior descending artery through the left internal mammary artery. Circumflex artery was grafted in 53% and right coronary artery in 44% of patients; the average number of grafts was 3.1±1.2. Endoventricular patch was used in 17 patients (23%); a direct closure was performed in the remaining patients. Intraventricular thrombi were removed in 10 patients. The average cross-clamping time was 44±16 minutes, and the extracorporeal circulation time was 66±18 minutes. Two patients needed postoperative inaortic balloon pumping; in-hospital mortality was 5.4% (4 patients). Causes of death were low cardiac output in 3 patients and multiorgan failure in 1 patient. Among preoperative variables, patients who died had a significantly higher functional class (all were in class IV) and a higher rate of unstable angina, but no differences were observed in hemodynamic parameters. Among operative variables, patients who died had a significantly higher cross-clamping and extracorporeal circulation time, as well as a longer duration of ventilation. Operative complications are listed in Table 2. Fifteen patients had postoperative bleeding requiring blood transfusion; 3 of them needed re-exploration, and surgical homeostasis was obtained. The site of bleeding was at the ventriculotomy level in 1 patient. Hemodynamic results in the overall group are reported in Table 3.

Twenty-one patients were age 70 years or older (mean age 74±3). At univariate analysis, patients older than 70 had higher values of preoperative creatinine (1.6±0.4 versus 1.4±0.3; p=0.009) with more frequent renal failure complicating the intervention (p=0.038), higher systolic pulmonary pressure (44±22 versus 28±9 mm Hg; p=0.039), and longer duration of ventilation (44±22 versus 28±9; p=0.001). Two operative deaths occurred among those older patients, accounting for 10% mortality rate.

Twenty-eight patients had preoperative ejection fraction (EF) ≤35% (38%); they had greater end diastolic and end systolic volumes preoperatively. Diuretics were more frequently used in this subset of patients (28% versus 13%);

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p = 0.05). Hemodynamic results in this subset of patients are reported in Table 4.

Table 5 reports clinical and hemodynamic data in patients divided according to the presence/absence of congestive HF (CHF).

Mild to moderate mitral regurgitation (MR) graded by echo in a semi-quantitative way was present in 37 patients (50%). Preoperatively, 27 patients had grade 1 + MR, 8 patients had grade 2 +; 1 patient had grade 3 +, and 1 patient had grade 4 +. After surgery, no patient had grade 3 to 4 + and 4 patients still had grade 2 +. No patient had associate mitral valve repair in this study population.

A complete follow-up was obtained in 93%. Preoperative clinical and hemodynamic characteristics of 5 patients lost to follow-up were not significantly different from survivors at univariate analysis. Mean follow-up was 40 ± 15 months. Kaplan–Meyer survival curve for the overall population is reported in Figure 1 and for patients divided by age in Figure 2.

**Discussion**

This study reports the effects and efficacy of SVR in a population with ≤ 30 days complicated anterior MI presenting with clinical instability caused by severe postinfarction angina, HF, and life-threatening arrhythmias as single or combined symptoms. The results indicate that SVR is feasible and effective with an acceptable operative mortality rate and improves hemodynamic values and survival.

SVR is a treatment option for chronic postinfarction ischemic cardiomyopathy, but very few studies report the effects of SVR on the outcome of patients with acute/subacute complicated anterior MI. The surgical approach consists of excluding the anterior and septal scar with an endoventricular suture, thus reducing circularly the cavity. Coronary revascularization relieves ischemia, adding benefit for pump function improvement in the geometric rebuilding.

**LV Dilatation**

LV remodeling after an anterior MI is a complex phenomenon that may occur very early after MI and tends to progress with time. LV remodeling induces changes in size and shape of the ventricle, leading to LV dysfunction that may deteriorate toward cardiogenic shock in the early phases or may ultimately lead to severe HF in early and late phases.

Because LV dilatation progresses after an acute anterior MI, the 30-day and 1-year mortality increase; for an end systolic volume of 80 mL/m², mortality rate at 1 year can be as high as 30%.

The average end systolic volume index in our patients was 69 mL/m² (median 60 mL/m²), and in patients with depressed EF the average value was 95 ± 32 mL/m² (median 88 mL/m²). According to what is reported in the literature, life expectancy should be very poor in such patients, but our results show that SVR improves 5-year survival. Overall survival rate, including operative mortality, is in fact 87% at 3 years, and we believe that this is because of the marked reduction of volumes and complete revascularization.

**LV Pump Function**

It has been reported that there is a significant improvement in EF after SVR in the present series EF did not increase significantly when the overall population was considered. If we consider patients with decreased EF (≤35%), we observe a significant improvement (from 29 ± 6 to 38 ± 9%; p = 0.001), whereas no changes were observed in patients with higher EF (from 46 ± 8 to 45 ± 8%; NS). This behavior has been observed frequently in our patients after SVR, i.e., patients who have pump function improvement are those with dilated hearts, reduced EF, and signs or symptoms of HF. In fact, dividing patients according to the presence/absence of CHF (Table 5), we observed not only significant differences in preoperative variables but also significant improvement in EF in CHF patients; (35 ± 10% to 41 ± 10% in patients with CHF and 45 ± 8% to 41 ± 6% in patients without CHF). In this particular series of patients, angina was an indication for revascularization in a consistent number of patients and SVR was performed with the intent to arrest LV remodeling by excluding the scar. These patients had smaller volumes and

**TABLE 4. Hemodynamic Results According to Preoperative EF**

<table>
<thead>
<tr>
<th></th>
<th>EF ≤ 35% (n = 28)</th>
<th>EF &gt; 35% (n = 42)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Preoperative</td>
<td>Postoperative</td>
</tr>
<tr>
<td>EDVI</td>
<td>132 ± 36</td>
<td>74 ± 29</td>
</tr>
<tr>
<td>ESVI</td>
<td>97 ± 32</td>
<td>50 ± 21</td>
</tr>
<tr>
<td>EF</td>
<td>29 ± 6</td>
<td>38 ± 9</td>
</tr>
</tbody>
</table>

*P = 0.0001 vs preoperative; † P = 0.001 between groups.

EDVI indicates end diastolic volume index; ESVI, end systolic volume index.

**TABLE 5. Preoperative Variables Significant (or Almost Significant) at Univariate Analysis According to the Presence/Absence of CHF**

<table>
<thead>
<tr>
<th></th>
<th>CHF (Yes)</th>
<th>CHF (No)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>63 ± 10</td>
<td>57 ± 9</td>
<td>0.07</td>
</tr>
<tr>
<td>Preoperative NYHA class</td>
<td>3.8 ± 0.4</td>
<td>1.5 ± 0.5</td>
<td>0.000</td>
</tr>
<tr>
<td>Diastolic Diameter, mm</td>
<td>62 ± 10</td>
<td>51 ± 5</td>
<td>0.02</td>
</tr>
<tr>
<td>Intervent Septum, mm</td>
<td>11 ± 3</td>
<td>14 ± 3</td>
<td>0.06</td>
</tr>
<tr>
<td>ESVI, mL/m²</td>
<td>78 ± 35</td>
<td>44 ± 12</td>
<td>0.01</td>
</tr>
<tr>
<td>EF, %</td>
<td>35 ± 12</td>
<td>45 ± 8</td>
<td>0.01</td>
</tr>
<tr>
<td>ECC time, min</td>
<td>68 ± 17</td>
<td>53 ± 16</td>
<td>0.01</td>
</tr>
<tr>
<td>Diuretics</td>
<td>0.69 ± 10.5</td>
<td>0.27 ± 0.5</td>
<td>0.016</td>
</tr>
</tbody>
</table>

ESVI indicates end systolic volume index; EF, ejection fraction; ECC, extracorporeal circulation; Intervent, interventricular.
Mitral Regurgitation

Dilatation of the ventricle induces LV geometric changes that lead to mitral valve dysfunction (displacement of papillary muscles, tethering of the leaflets, and annular dilatation). The incidence of mitral regurgitation is quite consistent in our series of patients; it is severe in few patients and mild to moderate in the majority. Functional MR associated with postinfarction dilated ventricles not only brings a clinical worsening because of higher pulmonary pressures and further volume overload on the LV but also severely affects prognosis.14

In the study group, no patient had mitral repair by inclusion criteria; in fact, we wanted to test the safety and efficacy of SVR with CABG in high-risk, clinically unstable patients in the early phase after anterior MI. It is known that mitral repair/replacement associated to SVR increases mortality;14,15 it is our policy to repair the mitral valve when MR is more than moderate (3/4+ at echocardiogram) or the mitral annulus is >36 mm in the presence of marked dilatation of the ventricle. In the present series, 2 patients had severe MR preoperatively, but they were not repaired because of the extremely severe clinical conditions. Results after SVR show a clear improvement in MR in these 2 patients (from 4+ to 0+ and from 3+ to 2) and, overall, there was a significant reduction in MR, with only 4 patients still having grade 2+. We think that the improvement in mitral functioning is caused by the improved LV geometry, re-approach of papillary muscles, and reduced wall tension.

HF and Elderly

Although cardiogenic shock complicating MI has been studied extensively, the hospital course of patients presenting with HF complicating acute MI is less well described. Recently it has been reported that HF complicating MI, as evaluated by Killip classification, brings a high mortality rate for class III and IV at 30 days and 6 months (14% and 23%, respectively).6 The national registry of MI recently reported that the presence of congestive HF is the strongest predictor of in-hospital outcome.2 Thirty-day mortality rate in patients with cardiogenic shock complicating MI has been reported as high as 50% when revascularization was the only treatment performed (percutaneous or surgical).16,17 Three of our patients underwent emergency operation for cardiogenic shock. They all survived the operation and 1 patient died 39 months after surgery. Forty-six patients had New York Heart Association class IV and 13 had clinical signs of HF (basal rales and/or gallop), despite full medications. Operative mortality was strongly associated with functional class and the presence of clinical findings of HF, thus confirming that clinical status is the strongest predictor of death.

Despite the improvement of treatments, advanced age remains one of the principal determinant of mortality in patients with acute MI; HF in the elderly increases in-hospital mortality 2.25-fold (95% CI, 1.02 to 4.97).6,18 Postdischarge mortality is also high, being reported as 10% at 6 months (mostly because of recurrence of MI)6 and 36% at 1 year in patients 70 years of age or older with Q-wave MI.19 Patients 70 years of age or older in our study had a higher operative mortality rate (10% versus 5.4%; NS; Fisher exact test). However, patients who survived did clinically well, with a late mortality rate in 3 at 24 months, 43 months, and 44 months from surgery, respectively. Figure 2 shows that survival curve was not significantly different in this subset of patients compared with the younger population.

A limitation of the study is that the pre-SVR treatment during acute MI has not been specifically collected in our database; therefore, this retrospective study does not allow us to report how many patients had been treated with thrombolysis or with primary PTCA, but the majority had early revascularization, because it has been our policy to treat acute MI with early revascularization since 1996.

In conclusion, this study reports the largest series of patients with complicated, recent anterior MI treated with SVR. The results show that SVR is feasible in the immediate complicated anterior infarction interval (≤30 days), has an acceptable operative mortality, and has a good early and late outcome. Whether SVR can prevent the progressive LV remodeling in the long-term remains undetermined. Late echocardiographic studies with volume measurements are needed.

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