

Surgical anterior ventricular endocardial restoration performed with total arterial revascularization: Serial 5-year follow-up

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Objective: We evaluated the changes in left ventricular (LV) function and volumes after surgical anterior ventricular endocardial restoration.

Methods: A total of 63 patients who had undergone surgical anterior ventricular endocardial restoration and total arterial revascularization were included. Echocardiography and myocardial single photon emission computed tomography were performed to examine LV function and volumes preoperatively, early postoperatively, and annually thereafter to 5 years after surgery. Coronary angiography was performed at 5 years postoperatively.

Results: Operative mortality was 7.9% (5 of 63). Echocardiograms performed before discharge demonstrated a significantly improved LV ejection fraction that was maintained at 5 years, significantly decreased early postoperative LV end-diastolic and end-systolic volume indexes that were slightly increased at 1 year and then maintained at 5 years, and early postoperative decrement of the stroke volume index that had disappeared at 1 year and had not reappeared by 5 years. Postoperative myocardial single photon emission computed tomography showed an LV ejection fraction that had gradually improved until 2 years and was maintained at 5 years, significantly decreased LV end-diastolic and end-systolic volume indexes that were maintained at 5 years, and a stroke volume index that was unchanged until 2 years and slightly increased at 3 to 4 years. The arterial graft patency rate in the left coronary territory was 95.7% (67 of 70) at 5 years. The 10-year overall survival and adverse event-free rate were 59.2% and 61.2%, respectively.

Conclusions: Improved LV ejection fraction and reduced volume indexes were maintained and the stroke volume index had not decreased at 5 years after the procedure. Preserved patency of the arterial grafts might have an important role in maintaining improved LV function. (*J Thorac Cardiovasc Surg* 2014;148:529-35)

Surgical anterior ventricular endocardial restoration (SAVER), initially described by Dor and associates¹ as endoventricular circular patch plasty, has been a surgical treatment option for the failing ischemic myocardium. The midterm clinical outcomes demonstrated relatively good midterm survival and a high degree of freedom from readmission for heart failure up to 5 years postoperatively in patients with advanced ischemic cardiomyopathy.^{2,3} Several studies using echocardiography, magnetic resonance imaging, and gated single photon emission computed tomography (SPECT) have demonstrated postoperative changes in left ventricular (LV) function.⁴⁻⁶ However, most of these studies were cross-sectional investigations performed at a defined point after SAVER.

The aim of the present study was to demonstrate the serial changes in LV function and volume indexes using echocardiography and myocardial SPECT for ≤ 5 years after SAVER performed concomitant with total arterial coronary artery bypass grafting (CABG).

METHODS

Patient Characteristics

The institutional review board reviewed the study protocol and approved it as a minimal-risk retrospective study (approval no. H-1201-006-392) that did not require individual patient consent according to the institutional guidelines for waiving consent.

From 1999 to 2005, 63 patients (44 men and 19 women) who had undergone SAVER with concomitant total arterial CABG were studied. The mean patient age at surgery was 62.7 ± 9.0 years. Hypertension ($n = 38$, 60.3%) and diabetes mellitus ($n = 27$, 42.9%) were common comorbidities (Table 1).

Operative Strategy

SAVER was performed using cardiopulmonary bypass and cold blood cardioplegic arrest ($n = 48$, 76.2%) or ventricular fibrillation ($n = 15$, 23.8%) with moderate hypothermia (25° - 28° C). The mean cardiopulmonary bypass time was 153 ± 66 minutes, and the mean aortic crossclamp time in 48 patients was 66 ± 25 minutes. The left ventricle was opened parallel to the left anterior descending coronary artery. An endoventricular circular pursestring suture using a 2-0 monofilament suture was placed circumferentially in the transitional zone between the normal and diseased myocardium. A balloon was inserted into the ventricular base, and the LV diastolic volume was adjusted to 50-70 mL/m² by

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Abbreviations and Acronyms

| | |
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| CABG | = coronary artery bypass grafting |
| ITA | = internal thoracic artery |
| LV | = left ventricular |
| LVEDVI | = LV end-diastolic volume index |
| LVEF | = LV ejection fraction |
| LVESVI | = LV end-systolic volume index |
| SAVER | = surgical anterior ventricular endocardial restoration |
| SPECT | = single photon emission computed tomography |
| STICH | = Surgical Treatment for Ischemic Heart Failure |
| SVI | = stroke volume index |

tightening the pursestring suture. A commercially available woven vascular patch, with the size determined by the circumference of the circular suture after balloon removal, was used to close the defect. Coronary revascularization was performed after SAVER, and most revascularizations were performed under an on-pump beating heart after releasing the aortic crossclamping. The left internal thoracic artery (ITA) was used in all patients. It was commonly anastomosed to the left anterior descending coronary artery territory (n = 52, 82.5%). The additional arterial conduits used for total arterial revascularization were the right ITA (n = 38) and right gastroepiploic artery (n = 33; Table 2). When bilateral ITAs were used as in situ grafts, the right ITA was anastomosed to the left anterior descending coronary artery (n = 7, 11.5%). The mean number of distal anastomoses was 2.5 ± 0.9 . Mitral annuloplasty was performed when preoperative echocardiography revealed mitral regurgitation of moderate or greater degree (n = 11, 17.5%). Partial flexible rings were inserted in all 11 patients (Duran AnCore ring, Medtronic, Inc, Minneapolis, Minn, in 6, and Cosgrove-Edwards ring, Edwards Lifesciences, Irvine, Calif, in 5). One patient underwent mitral valve replacement because of combined rheumatic mitral pathologic features.

Evaluation of Clinical Outcomes

The patients underwent regular postoperative follow-up examinations at the outpatient clinic at 3- or 4-month intervals and were interviewed by telephone for confirmation of their condition if the last clinic visit had not occurred at the scheduled time. The clinical follow-up period for all patients was completed on December 31, 2012. The follow-up data were complete for 52 of the 57 survivors (91.2%), with a median follow-up duration of 103 months (range, 6-160). Operative mortality was defined as any death within 30 days, including death after hospital discharge. Cardiac death was defined as any death related to cardiac events, including sudden death during the follow-up period. Major adverse cardiac or cerebrovascular events included cardiac death (including sudden death during follow-up); acute myocardial infarction; heart failure needing readmission; reoperation or coronary intervention; and cerebrovascular accident.

Evaluation of LV Function

The LV ejection fraction (LVEF), LV end-diastolic and end-systolic volume index (LVEDVI and LVESVI, respectively), and stroke volume index (SVI) were measured preoperatively using transthoracic echocardiography and myocardial SPECT. For echocardiographic evaluation, the modified biplane Simpson method was used to calculate the LVEF and LV volumes. Myocardial SPECT images were obtained using dual-head gamma cameras (Vertex EPIC, ADAC Laboratories, Milpitas,

Calif). The images were reconstructed into 16-frame gated images using a filtered back-projection technique. The LV volumes were automatically calculated using a software package (QGS, Cedars-Sinai, Los Angeles, Calif) in which an automatic myocardial border detection algorithm was implemented.⁷ Postoperative echocardiographic evaluations were performed before discharge and annually thereafter to 5 years. Postoperative myocardial SPECT was performed at 3 months and annually thereafter to 5 years.

Angiographic Evaluation of Graft Patency

Early (10 ± 13 days), 1-year (12.2 ± 1.1 months), and 5-year (61.1 ± 7.2 months) follow-up coronary angiography was performed regardless of the patients' angina symptoms in 92% (58 of 63), 98.1% (52 of 53), and 80.5% (33 of 41) of the patients available for follow-up for each period, respectively. Graft patency was graded as described by FitzGibbon and colleagues.⁸ Steno-occlusion was defined as occluded or stenosis of $\geq 75\%$ diameter.⁸

Statistical Analysis

Statistical analysis was performed using the IBM SPSS, version 19 (IBM, Armonk, NY) and Statistical Analysis Systems, version 9.1 (SAS Institute, Cary, NC), software packages. Data are presented as mean \pm standard deviation, median and range, or proportions. $P < .05$ was considered statistically significant. Angiographic patency rates were compared using a generalized estimating equation. Serial changes in LVEF, LVEDVI, LVESVI, and SVI were also analyzed using generalized estimating equations. All pairwise comparisons on time were performed using the Sidak method. Survival rates were estimated using the Kaplan-Meier method.

RESULTS**Clinical Outcomes**

The operative mortality was 7.9% (5 of 63 patients). The postoperative complications included atrial fibrillation (n = 17, 27.0%), low cardiac output syndrome (n = 13, 7.9%), reoperation for bleeding (n = 8, 12.7%), acute renal failure (n = 5, 7.9%), perioperative myocardial infarction (n = 5, 7.9%), and mediastinitis (n = 1, 1.6%). Late deaths during the follow-up period occurred in 19 patients, including 8 cardiac deaths. The 5- and 10-year overall survival rates were 72.4% and 59.2%, respectively. During the follow-up period, 5 patients underwent percutaneous coronary intervention because of progression of native coronary artery disease in 3 patients and occlusion of the right gastroepiploic artery conduit anastomosed to the posterior descending coronary artery in 2 patients. None of patients underwent redo-CABG. Eight patients required readmission for management of aggravated congestive heart failure. Another 3 patients experienced cerebrovascular events during the follow-up period. The 5- and 10-year freedom from major adverse cardiac or cerebrovascular event rates were 73.8% and 61.2%, respectively (Figure 1).

Echocardiographic Results

The serial echocardiographic examinations demonstrated that the LVEF had improved significantly early after surgery (preoperative vs early postoperative,

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