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Long-Term Outcomes of Left Ventricular Restoration in Patients Ineligible for Concomitant Coronary Artery Bypass Grafting

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ABSTRACT

Background: The prognosis of severe coronary artery disease (CAD) patients undergoing left ventricular restoration (LVR) and ineligible for concomitant coronary artery bypass grafting (CABG) is unclear. This study illustrates the clinical characteristics and the long-term survival of these patients in a retrospective cohort.

Methods: From January 1999 to March 2021, a total of 78 patients underwent surgical left ventricular restoration without concomitant CABG at our center. The primary endpoint was the major adverse cardiovascular and cerebrovascular events (MACCE). Kaplan–Meier analysis was performed to calculate survival, and compared by log-rank test, followed by multiple adjustments using Cox regression.

Results: The mean age was 55.3 ± 11.4 years. There were 76 (97.4%) true and 2 (2.6%) pseudo-aneurysms. Forty-six (59.0%) patients presented NYHA functional class III or IV. The mean EuroSCORE was 10.6 ± 3.2. Concomitant surgeries included mitral valve repair ($N = 3$), mitral valve replacement ($N = 2$), tricuspid valve repair ($N = 2$), ventricular septal defect closure ($N = 18$), maze procedure ($N = 1$), and appendage ligation ($N = 1$). Reoperation for bleeding was performed in one patient (1.3%). Prolonged ventilation was observed in 21 (26.9%) patients. Fourteen (17.9%) patients presented with low cardiac output and were supported with IABP. Operative death occurred in one (1.3%) patient. The median duration of echocardiographic follow-up was 53 months (interquartile range, 81.5) and was obtained in 46 (59.0%) patients. Left ventricular ejection fraction (LVEF) improved from 41.1% ± 10.5% to 45.6% ± 7.9% ($P < 0.001$), and the left ventricular end-diastolic dimension (LVEDD) fell from 57.8 ± 6.6 mm to 52.0 ± 6.2 mm ($P < 0.001$). The median patient follow-up time was 79.5 months (interquartile range, 53.5). Overall, 1-, 5-, and 10-year survival rates were 98.7%, 95.5% and 82.3%, respectively.

Conclusions: Patients with severe CAD and ineligible for concomitant CABG are in critical condition, and LVR could be a reliable approach to improving cardiac function with satisfactory early and long-term outcomes.

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INTRODUCTION

Background: Advanced diffuse coronary artery disease (CAD) is becoming an important entity of modern cardiology as the population ages and patients with historical coronary procedures no longer are suitable for further revascularization. Studies have shown that up to 12% of symptomatic patients undergoing coronary angiography are ineligible for revascularization [Mukherjee 2001]. Patients in whom coronary artery bypass grafting (CABG) could not be performed because of extensive and severe atherosclerotic involvement of distal coronary arteries had high mortality, especially in the presence of left ventricular dysfunction [Rocha 2005]. Gupta et al. found there was a wide distribution of left ventricular ejection fraction (LVEF) among angina patients with severe CAD not amenable to revascularization. A novel finding of this study showed that mortality was high regardless of LVEF [Gupta 2010].

Left ventricular aneurysm (LVA) is a serious mechanical complication of acute myocardial infarction, resulting in lower life expectancy and poorer quality of life. LVA continues to be one of the most costly and prevalent medical problems because of the aging population and more patients surviving acute myocardial infarction. The guidelines suggest that left ventricular aneurysmectomy during CABG should be considered in patients with New York Heart Association (NYHA) heart failure class III/IV, large left ventricular aneurysm, large thrombus formation, or if the aneurysm is the origin of arrhythmias [Neumann 2019; O'Gara 2013; Bakaeen 2021]. A subset of patients with left ventricular aneurysms caused by ischemia heart disease has severe CAD, which is not amenable to revascularization by percutaneous coronary intervention or coronary artery bypass surgery in the concomitant of surgical left ventricular reconstruction (LVR). However, there are scanty data about the clinical characteristics and long-term surgical outcomes of these patients. We reviewed all patients with LVR in our center in the past two decades and selected patients with left ventricular aneurysms caused by CAD who were ineligible for traditional revascularization. We aim to illustrate the clinical characteristics and report the long-term surgical outcomes of this population of patients with this distinct entity.

PATIENTS AND METHODS

Patients: We conducted a retrospective review of 1614 consecutive patients who underwent left ventricular reconstruction for left ventricular aneurysms associated with coronary artery disease between January 1999 and March 2021. In this database of Fuwai Hospital, 78 patients who needed further revascularization but were not amenable to having concomitant CABG performed due to various reasons were included in our study. (Figure 1) Among this subgroup of patients, 69 cases (88.5%) had surgical left ventricular restoration conducted during the period from 2009 to 2020. Patients with true aneurysms, where the left ventricular aneurysm wall consisted of fibrosis from prior transmural infarction as well as those with pseudoaneurysms where myocardial rupture was contained by adherent pericardium and/or scar tissue, were included. The study was approved by the Ethics Committee of Fuwai Hospital, Beijing. All patients previously had permitted us to access their medical records for research purposes.

Surgical techniques: The major indications for surgery were chronic heart failure, angina pectoris, ventricular arrhythmias, and embolization. The procedure was performed using cardiopulmonary bypass and moderate systemic hypothermia. Three types of left ventricular reconstruction, including linear ventriculoplasty [Cooley 1958], endocardial patch reconstruction (Dor procedure) [Lundblad 2003], and modified left ventricular reconstruction [Zheng 2009], were used depending on the aneurysm size and surgeons' personal preference. Major steps of modified left ventricular reconstruction were as follows: an endoventricular purse-string suture was placed with a 1-0 Prolene line suture; the suture was placed in the scarred tissue above the junctional zone between the normal myocardium; the suture was tied and created an opening of about 2 cm, and the ventricular chamber was reduced and kept in satisfactory geometry. The next closure was similar to standard linear ventriculoplasty [Zheng 2009].

Definitions and follow-up: Advanced age was defined as age ≥65 years. Preoperative renal failure was defined as a history of chronic renal failure or preoperative creatinine >133 μmol/l. Perioperative myocardial infarction was diagnosed, according to the fourth universal definition of myocardial infarction [Thygesen 2018]. Operative death was defined as death within 30 days after the operation, including death in the hospital or after discharge. Prolonged ventilation was defined as a cumulative duration of 24 hours or more of postoperative endotracheal intubation, starting from the transfer of the patient to the cardiac intensive care unit after completion of the index operation. The primary endpoint was the incidence of major adverse cardiovascular and cerebrovascular events (MACCE), which was a composite of all-cause death, non-fatal myocardial infarction, stroke (including hemorrhagic and ischemic events), and repeat revascularization. Patients were followed up by direct contact, telephone interviews, and outpatient clinic visits.

Statistical analysis: Continuous variables were expressed as the mean and standard deviation if they follow a normal distribution. Otherwise, they were presented as medians with an interquartile range. The Shapiro–Wilk test was used to confirm the normality of the continuous variables were normally distributed. Categorical variables were presented as percentages. The student's t-test was used to compare preoperative and postoperative continuous variables; the Chi-squared test or Fischer's exact test was used for the analysis of categorical variables. The cumulative survival rate and MACCE-free survival rate were calculated with Kaplan–Meier and compared using the log-rank test. Cox regression was used to determine risk factors associated with late mortality and subgroup comparisons. A significant difference was considered at $P < 0.05$. Statistical analyses were performed using Stata 15.0 (StataCorp, College Station, Texas, USA).

RESULTS

Demographics and presentation: In this group of 1614 patients with ischemic coronary heart disease who underwent LVR, 78 cases needed concomitant revascularization but could not be performed concurrently due to various reasons. This subset of patients accounted for 4.8% of the total study population. The mean age was 55.3±11.4 years, and 25.6% were women. The ventricular aneurysm was anterior in 73 (93.6%) patients and posterior in five (6.4%) patients. There were 76 (97.4%) true aneurysms and two (2.6%) pseudoaneurysms. A history of previous myocardial infarction was present in all 78 (100%) patients, with 18 (23.1%) having had previous percutaneous coronary interventions and none having had prior coronary artery bypass grafting. Ventricular arrhythmias were present in eight (10.3%) patients and atrial arrhythmias in two (2.6%) patients. No patient presented NYHA functional class I. Forty-six (59.0%) patients presented NYHA functional class III or IV. The mean EuroSCORE was 10.6 ± 3.2. Of the significant coronary lesions, the single-vessel disease was presented in more than half (64.1%) of the patients. Left ventricular embolization was presented in 29 (37.2%) patients. Additional patient characteristics are detailed in Table 1.

Operative parameters: More than one-half (53.8%) of the patients had modified left ventricular reconstruction performed, while linear repair technique was used in 33 (42.3%) patients and endocardial patch reconstruction (Dor procedure) was used in the remaining three (3.8%) patients. Seventy-six patients had elective operations, while two patients had emergency operations. Reoperation for bleeding was performed in one (1.3%) patient. A perioperative intra-aortic balloon pump (IABP) was utilized for improving myocardial contractility in 14 (10.2%) patients. Specifically, among this subgroup of patients who required IABP support, one patient previously had placed the ventricular assist device (VAD) during the operation due to the cardiopulmonary bypass (CPB), and it could not be removed after the ventriculoplasty finished. Concomitant cardiac surgeries included ventricular septal defect closure (23.1%), mitral valve repair (3.8%), mitral valve replacement (2.6%), tricuspid valve repair (2.6%), Maze procedure (1.3%), and left appendage ligation (1.3%). For the two patients who had concomitant mitral valve replacement performed, one was found to have moderate-to-severe mitral valve regurgitation through TEE after the LVR was finished. In the other patient, it was detected that both papillary muscles were infarcted, the dilated mitral annulus deformed after the left ventricular aneurysmectomy, a posterior mitral leaflet was prolapsed, and moderate mitral valve regurgitation was shown by preoperative echocardiography. The median cardiopulmonary bypass time was 66.0 minutes (interquartile range, 51.0), and the aortic cross-clamp time was 43.0 minutes (interquartile range, 28.3). Neither perioperative myocardial infarction nor perioperative stroke was observed in this study population. (Table 2)

Table 1. Demographics of patient population

Characteristics	(*N* = 78)
Age, years	55.3 ± 11.4
Female	20 (25.6%)
Body mass index	24.7 ± 3.2
Smoking	42 (53.8%)
Hypertension	28 (35.9%)
Diabetes	22 (28.2%)
Stroke or transient ischemic attack	9 (11.5%)
Hyperlipidemia	39 (50%)
Creatinine, μmol/L	100.3 ± 60.7
Family history of CAD	12 (15.4%)
Previous PCI	18 (23.1%)
Previous MI	78 (100%)
Interval from recent MI, months	3.0 [1.3, 12.0]
Previous coronary artery bypass grafting	0
Previous valve surgery	0
Ventricular tachycardia and fibrillation history	8 (10.3%)
Atrial fibrillation and flutter history	2 (2.6%)
Preoperative ICD	1 (1.3%)
True left ventricular aneurysm	76 (97.4%)
Pseudo left ventricular aneurysm	2 (2.6%)
Anterior aneurysm	73 (93.6%)
Posterior aneurysm	5 (6.4%)
EuroSCORE	10.6 ± 3.2
New York Heart Association heart failure class	
I	0
II	32 (41.0%)
III	34 (43.6%)
IV	12 (15.4%)
Significant coronary lesion	
Single vessel disease	50 (64.1%)
Double vessel disease	18 (23.1%)
Triple vessel disease	10 (12.8%)
Left main disease	2 (2.6%)
Ventricular thrombus	29 (37.2%)

Values are mean ± SD or n (%), or median [interquartile range]. CAD, coronary artery disease; PCI, percutaneous coronary intervention; MI, myocardial infarction; ICD, implantable cardioverter defibrillator

Postoperative and follow-up outcomes: Postoperative characteristics and follow-up outcomes are summarized in Table 3. The median length of stay was 27.5 days. The median time of ventilation and the intensive care unit stay was 18.0 hours and 69.5 hours, respectively. Prolonged ventilation was observed in 21 (26.9%) patients. Two (2.6%) patients needed re-intubation. Postoperative dialysis was present in two (2.6%) patients. Transfusion was observed in 37 (47.4%) patients. The median volume of blood transfusion was 800 ml. Fourteen (17.9%) patients presented with low cardiac output and were supported with IABP. No sepsis was observed in this group of patients. Operative death occurred in one (1.3%) patient, and the cause of death was heart failure followed by multiple organ

Table 2. Operative characteristics

Variable	(*N* = 78)
Ventriculoplasty	
Linear repair	33 (42.3%)
Modified left ventricular reconstruction	42 (53.8%)
Endocardial patch reconstruction	3 (3.8%)
Concomitant surgery	
Mitral valve repair	3 (3.8%)
Mitral valve replacement	2 (2.6%)
Ventricular septal defect closure	18 (23.1%)
Maze procedure	1 (1.3%)
Tricuspid valve repair	2 (2.6%)
Appendage ligation	1 (1.3%)
Cardiopulmonary bypass time, minutes	66.0 [55.0, 106.0]
Aortic cross-clamp time, minutes	43.0 [32.0, 61.0]
Redo for bleeding	1 (1.3%)
Perioperative myocardial infarction	0
Perioperative stroke	0
Perioperative IABP	14 (10.2%)
Perioperative VAD	1 (1.3%)

Values are n (%) or median [interquartile range]. IABP, intra-aortic balloon pump; VAD, ventricular assist device

Table 3. Postoperative and follow-up outcomes

Variable	(*N* = 78)
Operative mortality	1 (1.3%)
Low cardiac output syndrome	14 (17.9%)
Respiratory ventilator time, h	18.0 [13.0, 27.0]
Prolonged ventilation	21 (26.9%)
Re-intubation	2 (2.6%)
ICU stay time, h	69.5 [31.5, 114.0]
Transfusion	37 (47.4%)
Volume of blood transfusion, ml	800 [400, 1600]
Postop dialysis	2 (2.6%)
Sepsis	0
Length of stay, days	27.5 [18.0, 32.5]
Follow-up outcomes (N = 76)	
Permanent pacemaker	1 (1.3%)
Myocardial infarction	6 (7.9%)
Stroke	5 (6.6%)
Ischemic	2 (2.6%)
Hemorrhagic	3 (3.9%)
Repeat vascularization	5 (6.6%)
Overall mortality	8 (10.5%)
Operative mortality	1 (1.3%)
Cardiogenic death	6 (7.9%)
Malignancy	1 (1.3%)
MACCE	18 (23.7%)
Readmission	3 (3.9%)

Values are n (%), or median [interquartile range]. ICU, intensive care unit; MACCE, major adverse cardiovascular and cerebrovascular events

dysfunction syndromes. Follow-up was complete for 97.4%, and the median follow-up time was 79.5 months.Two (2.6%) patients were lost to follow-up because of patient migration and unknown reasons. One (1.3%) patient had installed a permanent pacemaker, due to sinus bradycardia caused by high-grade atrioventricular block 77 months after surgery. During the follow-up period, six (7.9%) patients had myocardial infarctions, and five (6.6%) patients underwent repeat revascularization (coronary stenting). Stroke occurred in five (6.6%) patients, of which two patients were ischemic and three patients were hemorrhagic. Readmission for heart failure was found in three (3.9%) patients. All-cause death occurred in eight (10.5%) patients, including one (1.3%) operative death, six (7.9%) cardiogenic deaths, and one death of malignancy (gallbladder cancer). The cumulative rate of MACCE was 23.7% (18/76). According to the Kaplan–Meier survival analysis, cumulative survival at 1, 5, and 10 years was 98.7%, 95.5%, and 82.3% (Figure 2A), whereas MACCE-free survival was 97.3%, 88.4%, and 67.0% (Figure 2B), respectively. (Figure 2)

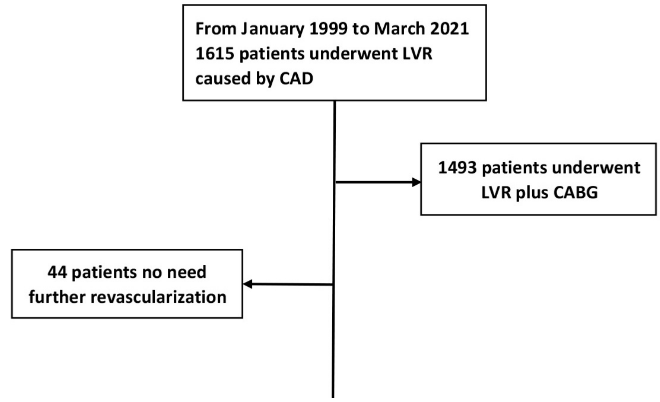

Figure 1. Flow chart of the patient enrollment process. A total of 1614 continuous patients underwent LVR during the study period. Excluded were 1492 patients for concomitant CABG and another 44 patients were excluded due to a mismatch of the indication of further revascularization. Seventy-eight patients were enrolled. (LVR, left ventricular reconstruction; CAD, coronary artery disease; CABG, coronary artery bypass grafting)

Echocardiographic data: The median duration of echocardiography follow-up was 53.0 [12, 93.5] months and was obtained in 46 (59.0%) patients. Global systolic function improved postoperatively, as the LVEF increased from 41.1% ± 10.5% to 45.6% ± 7.9% ($P < 0.001$), and the LVEDD fell from 57.8 ± 6.6 mm to 52.0 ± 6.2 mm ($P < 0.001$). Compared with the follow-up data, the EF further increased to 50.2% ± 8.5%, while the LVEDD did not continue to diminish. The mean LVEDD of follow-up was 54.6 ± 8.1 mm, falling in between preoperatively and postoperatively. The preoperative mitral regurgitation (MR) was improved after the surgery ($P = 0.004$), but this kind of situation was not sustained until the follow-up. Compared with the preoperative mitral regurgitation, the follow-up MR severity was decreased to some extent. Nevertheless, there was no statistically significant difference in this improvement ($P = 0.261$). (Table 4)

Subgroup analyses: Baseline characteristics of the subgroups are summarized in Table 5. (Table 5) In the subgroup analysis of advanced age (age ≥ 65 years), the female promotion of the advanced age group was much higher than the non-advanced age (age < 65 years) group ($P < 0.001$). No difference was observed regarding other baseline characteristics between these two subgroups. While in the subgroup analysis of different ventriculoplasty, there was no difference in baseline characteristics between the linear repair group and reconstruction group. In addition, the non-advanced age group showed a trend for a higher incidence of MACCE (Figure 2C), although with no statistical significance (Plog-rank = 0.410). Similarly, there was no difference in the MACCE occurrence rate (Plog-rank = 0.842) between the linear repair group and reconstruction group (Figure 2D).

Risk factor analyses: Univariable and multivariable Cox regression analyses were performed to search for possible risk factors for MACCE after left ventricular restoration. Univariate Cox regression analysis showed that neither different way of ventriculoplasty, mitral valve intervention, left main disease,

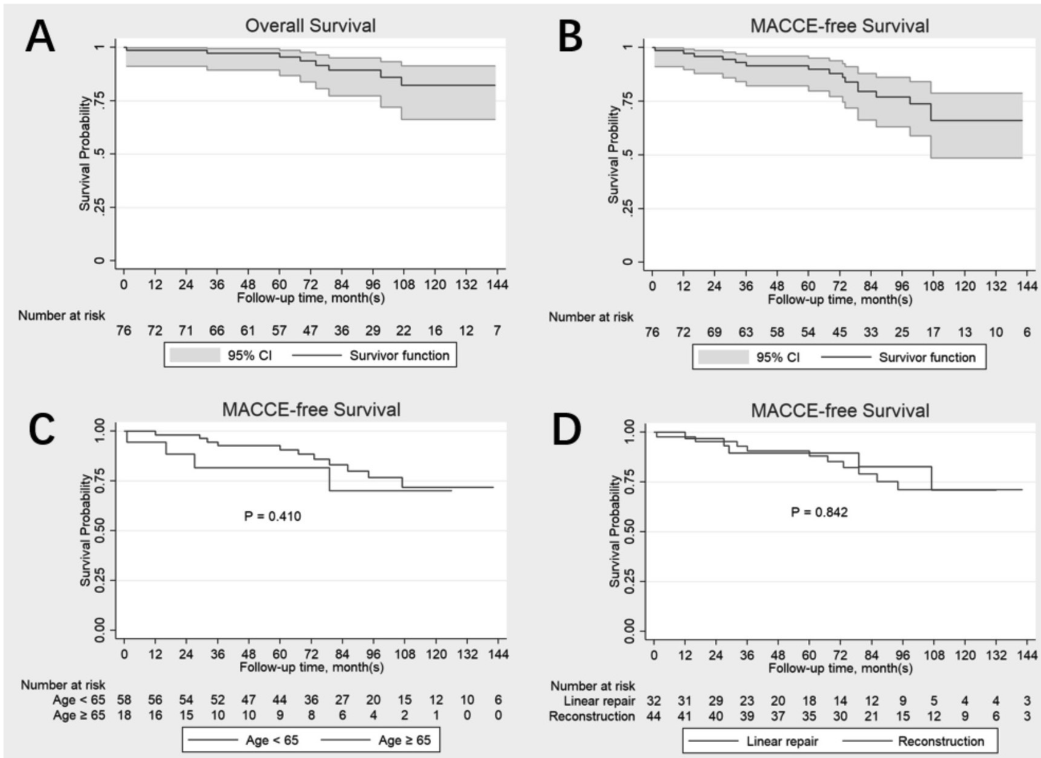

Figure 2. A) Kaplan–Meier estimates of overall survival; B) MACCE-free survival; C) according to different age; D) performance of ventriculoplasty. (MACCE, major adverse cardiovascular and cerebrovascular events; reconstruction group contains modified left ventricular reconstruction and endocardial patch reconstruction)

Table 4. Echocardiographic changes on preoperative, postoperative and follow up

Characteristic	Preoperative (*N* = 78)	Postoperative (*N* = 78)	*P*	Preoperative (*N* = 46)	Follow up (*N* = 46)	*P*
LVEF, %	41.1 ± 10.5	45.6 ± 7.9	<0.001	41.4 ± 10.9	50.2 ± 8.5	<0.001
LVEDD, mm	57.8 ± 6.6	52.0 ± 6.2	<0.001	57.1 ± 7.1	54.6 ± 8.1	0.021
Mitral regurgitation	-	-	0.004	-	-	0.261
None	39 (50.0%)	60 (76.9%)	-	21 (45.7%)	30 (65.2%)	
Trace	9 (11.5%)	4 (5.1)	-	7 (15.2%)	3 (6.5%)	
Mild	25 (32.1%)	13 (16.7%)	-	15 (32.6%)	11 (23.9%)	
Moderate	5 (6.4%)	1 (1.3%)	-	3 (6.5%)	2 (4.3%)	
Severe	0	0	-	0	0	

Values are mean ± SD or n (%). LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic dimension

triple vessel disease, advanced age, gender, BMI, smoking, hypertension, diabetes, hyperlipidemia, renal failure, previous PCI, atrial fibrillation, and flutter history, mild or moderate MR, NYHA functional class III or IV predicted MACCE ($P > 0.1$). The results indicated that ventricular septal defect closure ($P = 0.013$), ventricular thrombus ($P = 0.062$), and prior stroke ($P = 0.085$) was predictive of MACCE. (Table 6) In subsequent multivariable analysis, advanced age, different ways of ventriculoplasty, ventricular septal defect closure, ventricular thrombus, and prior stroke were analyzed. However, we found that none of these characteristics was an independent predictor of MACCE. (Table 7)

DISCUSSION

In this retrospective cohort study, we analyzed the clinical characteristics and long-term surgical outcomes of patients

Table 5. Comparison of baseline characteristics between subgroups

Characteristic	Advanced age (*N* = 18)	Non-advanced age (*N* = 60)	*P*	Ventriculoplasty, linear repair (*N* = 33)	Ventriculoplasty, reconstruction (*N* = 45)	*P*
Age (years)	70.4 ± 4.5	50.7 ± 8.6	<0.001	58.0 ± 12.6	53.3 ± 10.2	0.072
Female	11 (61.1%)	9 (15.0%)	<0.001	12 (36.4%)	8 (17.8%)	0.063
Smoking	8 (44.4%)	34 (56.7%)	0.362	17 (51.5%)	25 (55.6%)	0.724
Hypertension	7 (38.9%)	21 (35.0%)	0.763	14 (42.4%)	14 (31.1%)	0.303
Diabetes	6 (33.3%)	16 (26.7%)	0.581	9 (27.3%)	13 (28.9%)	0.875
Stroke	1 (5.6%)	8 (13.3%)	0.676	3 (9.1%)	6 (13.3%)	0.726
History of PCI	6 (33.3%)	12 (20.0%)	0.338	11 (33.3%)	7 (15.6%)	0.066
NYHA III or IV	12 (66.7%)	28 (51.9%)	0.273	20 (60.6%)	20 (51.3%)	0.428
Double or triple vessel disease	9 (50.0%)	19 (31.7%)	0.155	14 (42.4%)	14 (31.1%)	0.303
Ventricular thrombus	3 (16.7%)	26 (46.4%)	0.024	12 (36.4%)	17 (41.5%)	0.655
Body mass index (kg/m^2)	24.5 ± 3.8	24.7 ± 3.0	0.813	24.47 ± 3.37	24.78 ± 3.13	0.680
LVEF (%)	43.4 ± 11.7	40.4 ± 10.1	0.290	42.7 ± 10.7	40.0 ± 10.3	0.260
LVEDD (mm)	55.3 ± 5.7	58.5 ± 6.7	0.075	58.0 ± 7.0	57.6± 6.4	0.821

Values are mean ± SD or n (%). Advanced age is defined as age ≥ 65 years; PCI, percutaneous coronary intervention; NYHA, New York Heart Association heart failure class; Reconstruction group contains modified left ventricular reconstruction and endocardial patch reconstruction; LVEF, left ventricular ejection fraction; LVEDD, left ventricular end-diastolic dimension

with left ventricular aneurysms caused by CAD who were ineligible for concomitant revascularization. Our study showed that LVR could be a reliable approach for this special group of patients with improving cardiac function and achieving satisfactory early and long-term outcomes. Studies on the natural history of LVA report a 5-year survival of only 12% to 47% [Schlichter 1954; Grondin 1979]. Our study showed that the cumulative survival at 1, 5, and 10 years was 98.7%, 95.5%, and 82.3%, respectively, considerably improving the survival. In the past decades, different surgical techniques of LVA repair to restore left ventricular geometry proved to be valuable even in patients with severely impaired left ventricular function [Zheng 2009; Cooley 1989; Komeda 1992; Di Donato 1995]. In this subset of patients, modified left ventricular reconstruction and linear repair techniques were used to reconstruct the left ventricle in most patients (96.2%). The subgroup analyses indicated that neither advanced age nor the different ventriculoplasty affected the rate of MACCE occurrence. This result suggests that advanced age is not an absolute contraindication for this type of surgery and different ventriculoplasty can be chosen, depending on aneurysm size and the surgeons' personal preference. With the following risk factor analyses, we found that different procedures of ventriculoplasty did not predict MACCE. Although univariate Cox regression analysis indicated that ventricular septal defect closure, ventricular thrombus, and prior stroke were predictive of MACCE, further multivariable analysis showed that none of the baseline characteristics was an independent predictor of MACCE. This circumstance may be due to the limited sample size, which may reduce the power of tests.

Left ventricular wall tension increases with increasing left ventricular diameter, intracavitary pressure, and wall thinning. A large and thin-walled aneurysm has high wall tension, poor coronary perfusion, and further dilation. The LVR procedure can decrease left ventricular volume and restore the left ventricle to an elliptical shape. This relieves ischemia and reduces wall tension, particularly when myocardial stretch is known to be arrhythmogenic [Koilpillai 1996]. Although Dor and colleagues [Dor 1995] reported an approximately 10% improvement in LVEF after the LVR, our study found a more modest 4% improvement in LVEF. This kind of improvement continued to increase from 41.4% preoperatively to 50.2% on follow-up. Importantly, we also noted a steady decline in LVEDD after the LVR, and the grade of MR was significantly decreased. Apical and inferior-papillary-muscle displacement due to ischemic left-ventricular remodeling plays an important part in the generation of functional mitral regurgitation [Yiu 2000]. Furthermore, increasing the grade of MR after LVR is an important predictor for reintervention and was strongly associated with hospital readmission due to heart failure [Sartipy 2006]. During our follow-up period, we found that LVEDD was enlarged compared to postoperatively, which was synchronized with the aggravating grade of MR. The MR aggravation and left ventricular enlargement may be caused by ischemic left ventricular remodeling.

Although various authors [Komeda 1992; Barratt-Boyes 1984] underlined the importance of concomitant complete revascularization in patients with LVA, this subset of patients was ineligible for concomitant revascularization, due to a variety of reasons. Anatomic reasons which preclude

Table 6. Univariable analysis for potential baseline risk factors for major cardiovascular and cerebrovascular events

Characteristics	HR (lower, upper)	*P*
Advanced age	2.04 (0.71, 5.89)	0.188
Female	1.26 (0.40, 3.91)	0.694
Body mass index	1.10 (0.93, 1.29)	0.284
Smoking	1.22 (0.48, 3.11)	0.672
Hypertension	1.35 (0.53, 3.43)	0.531
Diabetes	1.85 (0.69, 4.98)	0.223
Stroke	3.15 (0.85, 11.63)	0.085
Hyperlipidemia	1.26 (0.47, 3.38)	0.651
Renal failure	2.01 (0.57, 7.11)	0.278
Previous PCI	1.47 (0.51, 4.23)	0.477
Atrial fibrillation and flutter history	1.94 (0.26, 14.75)	0.522
Left main disease	4.94 (0.61, 40.27)	0.135
Triple vessel disease	1.36 (0.31, 6.04)	0.689
Ventricular thrombus	0.34 (0.11, 1.06)	0.062
Mild or moderate MR	1.45 (0.54, 3.89)	0.469
NYHA III/IV	0.71 (0.26, 1.97)	0.516
Mitral valve intervention	0.04 (0.00, 183.65)	0.463
Ventriculoplasty		
Linear repair	1	
Reconstruction	0.95 (0.37, 2.45)	0.908
Ventricular septal defect closure	3.40 (1.29, 8.97)	0.013

PCI, percutaneous coronary intervention; MR, mitral regurgitation; NYHA, New York Heart Association heart failure class; mitral valve intervention includes mitral valve repair and mitral valve replacement; Reconstruction group contains modified left ventricular reconstruction and endocardial patch reconstruction

traditional revascularization include severe diffuse CAD, collateral-dependent myocardium, multiple coronary restenoses, chronic total coronary occlusions, degenerated saphenous vein grafts, poor distal targets, or lack of conduits due to prior CABG [Henry 2013; Jolicoeur 2012]. The most common reason precluding concomitant CABG in our study was severe diffuse CAD, other causes contained no suitable target vessel after PCI, deficiency of distal targets of the left anterior descending artery due to large ventricular aneurysm, chronic total occlusion of the distal target coronary. Povsic et al. indicated that predictors of mortality in patients with advanced CAD ineligible for additional revascularization included age, ejection fraction (EF), low body mass index, multivessel CAD, low heart rate, diabetes, diastolic blood pressure, history of coronary artery bypass graft surgery, cigarette smoking, history of congestive heart failure, and race [Povsic 2015]. However, we did not find a special independent predictor of MACCE in this special group of patients. Our results show that the overall survival and MACCE-free survival are satisfactory although without concomitant CABG. The feasible reasons may be that single-vessel disease was presented in a great amount of the patients (64.1%), and cardiac function was greatly improved after ventricular aneurysm surgery.

Table 7. Multivariable analysis for potential baseline risk factors for major cardiovascular and cerebrovascular events

Characteristics	HR (lower, upper)	*P*
Advanced age	1.29 (0.41, 4.09)	0.668
Stroke	1.97 (0.48, 8.19)	0.350
Ventricular thrombus	0.48 (0.14, 1.66)	0.249
Ventriculoplasty		
Linear repair	1	
Reconstruction	1.10 (0.38, 3.15)	0.862
Ventricular septal defect closure	2.38 (0.78, 7.24)	0.126

Reconstruction group contains modified left ventricular reconstruction and endocardial patch reconstruction

The limitation of this study relates to the fact that it involved non-randomized, retrospectively analyzed data from a single-center experience. In addition, the sample size was limited, which might reduce the power of tests. However, this study provides a contemporary review on the outcomes of LVR procedures for patients who are not eligible for CABG concurrently.

CONCLUSION

Patients with severe CAD and ineligible for concomitant CABG are in critical condition, LVR could be a reliable approach to improving cardiac function with satisfactory early and long-term outcomes.

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