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Impact of surgical ventricular restoration on early and long-term outcomes of patients with left ventricular aneurysm

A single-center experience

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Abstract

Left ventricular aneurysm (LVA) is a common complication of myocardial infarction. However, the optimal treatment for LVA remains controversial.

In this retrospective study, we analyzed the early and long-term clinical consequences of surgical ventricular restoration on 102 patients who had undergone repair between January, 2005 and January, 2015. The LVA repair approaches comprised of patch plasty (n=28), linear repair (n=40), and plication repair (n=34).

Patient demographics were 60.8% male, and the mean age was 60.5±7.2 years. The in-hospital mortality rate was 7.8% (8/102), including 6 patients who died from low cardiac output and 2 from multiorgan failure. During the early postoperative period, left ventricular sizes significantly decreased in the patch plasty and linear repair groups compared with the plication group. In addition, all 3 repair techniques greatly ameliorated left ventricular ejection fraction ($P<.05$), and there was no significant difference in survival rate between groups ($P=.25$).

Surgical ventricular restoration (linear repair, plication repair, and patch plasty) obtained equivalently appreciable outcomes for cardiac function improvement, perioperative mortality, and survival. Selection of a surgical technique for LVA patients should be optimized to individual patient conditions including the morphological characteristics of the aneurysm and ischemic scar.

Abbreviations: CABG = coronary artery bypass graft, IABP = intra-aortic balloon pump, LAD = left of anterior descending artery, LCO = low cardiac output, LV = left ventricular, LVA = left ventricular aneurysm, LVEF = left ventricular ejection fraction, MI = myocardial infarction, MR = mitral regurgitation, SVR = surgical ventricular restoration.

Keywords: left ventricular aneurysm, linear repair, myocardial infarction, patch plasty repair, plication repair, surgical ventricular restoration

1. Introduction

Left ventricular aneurysm (LVA) is a severe complication resulting from myocardial infarction (MI), which is linked to high mortality and morbidity.[1] Pathophysiologically, the part of the ventricle affected by the aneurysm becomes dyskinetic or akinetic, leading to impaired contractile and filling capacities.[2] Moreover, inconsistent movement of the aneurysm decreases left ventricular (LV) output and may eventually cause heart failure.[3] In addition, due to the electrophysiological differences at the border of the functional and infarcted tissues, ventricular arrhythmias may occur, consequently resulting in angina and/or sudden death.[4] Other LVA consequences include thromboembolic complications due to aneurysmal mural thrombi.[5] Given the clinical importance of LVA, it is imperative to develop strategies for its effective management in order to reduce LVA-related mortality.

Currently, surgical ventricular restoration (SVR) is recognized as the mainstay treatment for LVA patients, as it is proven to efficiently ameliorate cardiac function and decrease mortality in patients with postinfarction LVA. Likoff and Bailey[6] first performed surgical repair of LVA, and Cooley[7] first performed the resection under cardiopulmonary bypass. Further, Dor[8] treated patients with ischemic cardiomyopathy after a large anteroseptal MI with endoventricular circular patch plasty. Since then, modifications of SVR have been proposed and several large-scale studies have demonstrated efficacy and safety of SVR with regards to LV functional recovery and survival.[9,10] Currently, SVR includes 3 surgical techniques: patch plasty, linear repair, and plication repair. Previously, several studies compared the clinical outcomes of 2 of these techniques, but obtained inconsistent findings. For instance, Vural et al[11] reported that the patch repair was superior to the linear repair in regard to LV geometry and long-term clinical results. However, Mukaddirov et al[12] compared the outcomes of LVA patients who underwent linear closure with patients who underwent patch plasty repair, and reported no significant differences between these approaches at both short and long-term follow-up. In a retrospective study, Antunes et al[2] found that the results of LVA repair obtained with patch plasty or linear repair were comparable in terms of

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perioperative mortality, late cardiac function, and survival. Few studies compared all 3 of these techniques in 1 study.

In this retrospective study, we compared the efficacy and safety of patch plasty, linear repair, and plication repair in patients with LVA, and we present the early and long-term clinical outcomes.

2. Methods

2.1. Patients and protocols

Between January, 2005 and December, 2015, 146 consecutive patients underwent SVR with concomitant coronary artery bypass graft (CABG) surgery at the Department of Cardiovascular Surgery, Second Affiliated Hospital of Harbin Medical University, Harbin, China. Patients without LV shape classification and LV volume measurement before operation were excluded from analyses. Therefore, 102 patients were included in this study. Demographic and surgical data were obtained from medical charts, and all patients were followed up concerning their in-hospital and long-term outcomes. As a retrospective study, data analysis was performed anonymously. The study protocol was approved by the ethics committee at Harbin Medical University.

2.2. Definitions and surgical techniques

Left ventricular aneurysm was preoperatively identified using transthoracic echocardiography and coronary angiography in all patients, and cineangiography was additionally performed in 82 (80.4%) patients. The diagnosis of LVA was made preoperatively and confirmed intraoperatively. Cardiac function was evaluated with transthoracic echography (TTE) (Simpson method). During the study period, SVR was performed using the plication repair technique in 34 (33.3%) patients, linear repair in 40 (39.2%) patients, and endoventricular circular patch plasty in 28 (27.5%) patients. The procedures were conducted under cardiopulmonary bypass or off-pump beating heart for the aneurysm repair and for the revascularization. Diagnosis of LVA was further validated visually and by palpation of the thinned wall of the left ventricle. After the LV opening, the transition zone between viable myocardium and the fibrotic scar area was identified. A longitudinal ventricular incision was made in parallel and 2 to 3 cm lateral to the left of the anterior descending artery (LAD). Intraventricular clots were removed if applicable, and the ventricle was irrigated with saline. Based on the shape and size of the ventricular cavity, resection was performed to remove a portion of the thinned ventricular wall. For the linear repair technique, the edges were sutured directly by using 2 strips of Teflon. For patch plasty repair, a circular patch graft of woven Dacron fabric was prepared to replace the diseased area in the ventricular cavity. In addition, for small aneurysms, the plication technique without opening the aneurysm was performed. This procedure was reserved only for small aneurysms that did not contain mural thrombi. A 2-layer suture line was placed across the aneurysm using a strip of Teflon felt on either side. The suture line was oriented to reconstruct a relatively normal LV contour and did not exclude all the aneurysm tissues. Once the ventricular repair was accomplished, CABG was performed. If the mitral regurgitation (MR) reached a medium level, replacement of the mitral valve was also carried out.

2.3. Follow-up

Patients were followed up by either telephone interview or review of clinical records at our institution. The cardiac and noncardiac events of these participants were documented. Follow-up period ranged from 0 to 60 months, and 21.3% patients were lost to follow-up due to migration or an unknown cause, the latter of which included loss of contact, including phone number change, empty phone number, wrong phone number, and no one taking the phone call; long-distance visits; health issues, including severe pain, motion sickness, aging, being bedridden, inconvenience to move, hospitalization, or demise; lack of awareness of follow-up, including reluctance to visit, no need to revisit due to good outcome of surgery, no willingness to visit due to unexpected clinical events because of surgery; business reasons, including busy work and too many business trips; and local recheck. Inability to contact the patient was the primary reason for the loss to follow-up.

2.4. Statistical analyses

Continuous data are presented as mean ± standard deviation (SD) and categorical data as percentages and frequencies. The Wilcoxon signed-rank test was used to compare preoperative and postoperative data. The Kruskal–Wallis test was used for comparison of continuous data and the Fisher exact test for dichotomous data among the 3 groups. Following the Kruskal–Wallis test, the Mann–Whitney *U* test with Bonferroni correction was used as the post hoc test. Kaplan–Meier curves were used to establish the postoperative survival rate of each group, which was compared to the log-rank test. $P < .05$ was defined as statistically significant in all tests. SPSS for Windows 15.0 (IBM Corporation; Armonk, NY) was used for statistical analyses.

3. Results

3.1. Comparison of demographic and baseline clinical characteristics of patients in 3 groups

In all, 102 patients were enrolled in this study. These patients were divided into 3 groups: patch plasty group (n=28), linear repair group (n=40), and plication repair group (n=34). Table 1 shows the preoperative clinical data of all the participants and in each of the 3 groups. Males comprised 60.8% of the study groups, and the mean age was 60.5 ± 7.2 years. Sixty-six (64.7%) patients had hypertension and 33 (32.4%) had diabetes. Mean New York Heart Association class of the patients in the study was 2.5 ± 1.3. Ninety patients (88.2%) had 3-vessel coronary disease, 14 (22.6%) had left main disease, 7 (6.7%) had double-vessel coronary disease, and 5 (4.9%) had single-vessel coronary disease. The location of the majority of LVAs was in the anterior wall (92.2%). Sixty-one (59.8%) patients had MR. The mean left ventricular ejection fraction (LVEF) was 34.2 ± 6.2%. In addition, there were no significant differences between groups in all patient demographic and baseline clinical characteristics.

3.2. In-hospital outcomes

The in-hospital mortality rate after SVR was 7.8% (8/102); 4 patients were in the linear group and 4 in the patch plasty group, including 6 deaths from low cardiac output (LCO) and 2 from multiorgan failure. An intra-aortic balloon pump (IABP) was placed in 32 patients, of whom 28 were discharged and 4 died. In addition, 15 (14.7%) patients had concomitant mitral valve replacement, 12 (11.8%) had postoperative arrhythmias, and 16 (15.7%) had postoperative infection. All patients in these 3 groups had marked improvement in angina symptoms after the operation.

Table 1

Comparison of demographic and basal clinical characteristics of patients in 3 groups.

Variable*	All patients (n=102)	Plication (n=34)	Linear (n=40)	Patch plasty (n=28)
Age (y)	60.5±7.2	57.6±8.2	60.9±6.2	62.5±8.8
Sex, male	62 (60.8%)	20 (58.8%)	26 (65.0%)	16 (57.1%)
Diabetes mellitus	33 (32.4%)	9 (26.5%)	13 (32.5%)	11 (39.3%)
Hypertension	66 (64.7%)	20 (58.8%)	25 (62.5%)	21 (75.0%)
LVEF	36.2%±10.2%	38.9%±11.8%	36.8%±11.0%	32.6%±10.8%
Mean NYHA class	2.5±1.3	2.2±1.1	2.5±1.0	2.6±1.3
Extension of CAD				
1-vessel disease	5 (4.9%)	3 (8.8%)	2 (5.0%)	0 (0%)
2-vessel disease	7 (6.7%)	3 (8.8%)	3 (7.5%)	1 (3.6%)
3-vessel disease	90 (88.2%)	28 (82.4%)	35 (87.5%)	27 (96.4%)
Aneurysm mural thrombus	46 (45.1%)	3 (8.8%)	23 (57.5%)	20 (71.4%)
LVA location				
Anterior	94 (92.2%)	34 (100.0%)	37 (92.5%)	23 (82.1%)
Posterior	6 (5.9%)	0 (0%)	2 (5.0%)	4 (14.3%)
Anteroposterior	2 (2.0%)	0 (0%)	1 (2.5%)	1 (3.6%)
MR				
Mild	43 (41.2%)	10 (29.4%)	17 (42.5%)	16 (57.1%)
Moderate	7 (6.9%)	1 (2.9%)	3 (7.5%)	3 (10.7%)
Severe	11 (10.8%)	0 (0%)	5 (12.5%)	6 (21.4%)

CAD=coronary artery disease, LVA=left ventricular aneurysm, LVEF=left ventricular ejection fraction, MR=mitral regurgitation, NYHA=New York Heart Association.
* For continuous variables, mean±standard deviation (SD); for categorical variables, number (per cent).

LV size and systolic function of patients in each group are shown in Table 2. Preoperatively, the patients in the patch plasty group presented with the most severe LV dilatation among the 3 groups, and LV size was similar in the plication and linear groups. In addition, the patch plasty group had significantly lower LVEF than the plication repair group. Postoperatively, patients in the linear and patch plasty group, but not in the plication group, had significant decrease in LV sizes; however, all 3 groups showed improved LVEF after surgery ($P<.001$) (Table 3).

3.3. Long-term outcomes

All 94 discharged patients (92.2%) were followed up for a period of 3.86±1.92 years. Twenty (21.3%) patients were lost to follow-up, primarily due to migration. Cardiac death occurred in 18 (19.2%) patients: 10 in the patch plasty group, 2 in the plication group, and 6 in the linear group. Kaplan–Meier analysis showed no significant difference in the mortality rate among these 3 groups (log-rank $P=.25$) (Fig. 1).

4. Discussion

In the present study, we compared three SVR techniques for treatment of LVA patients after MI, and found these techniques had equivalent safety and efficacy with respect to cardiac functional amelioration and survival benefit.

Left ventricular aneurysm is a complication of MI, with an occurrence rate of 10% to 35%.[2,13,14] The presence of

Table 2

Perioperative LV sizes and functions.

	Plication	Linear	Patch plasty	P* (1 vs 2)	P* (1 vs 3)	P* (2 vs 3)
Preoperative values	(n=34)	(n=40)	(n=28)			
LVEDD (mm)	55.8±8.6	69.3±7.5	69.8±8.7	<.001	<.001	.28
LVESD (mm)	42.5±12.6	49.0±14.4	53.2±12.8	.04	<.001	.22
LVEF (%)	38.9±11.8	36.8±11.0	32.6±10.8	.43	.02	.11
Postoperative values	(n=34)	(n=36)	(n=24)			
LVEDD (mm)	54.4±8.1	55.5±8.7†	58.1±8.7†	.59	.06	.13
LVESD (mm)	41.5±13.2	42.3±17.7†	46.5±16.7†	.78	.18	.33
LVEF (%)	50.2±11.6†	46.9±11.8†	44.3±10.8†	.39	.02	.11

LVEDD=left ventricular end-diastolic diameter, LVEF=left ventricular ejection fraction, LVESD=left ventricular end-systolic diameter.
* Bonferroni corrected *P*.
† $P<.05$ compared with the preoperative value.

Table 3

Mitral valve replacement of patients in 3 groups.

Variable	All patients (n=102)	Plication (n=34)	Linear (n=40)	Patch plasty (n=28)
Mitral valve replacement	11 (10.8%)	0 (0%)	5 (12.5%)	6 (21.4%)

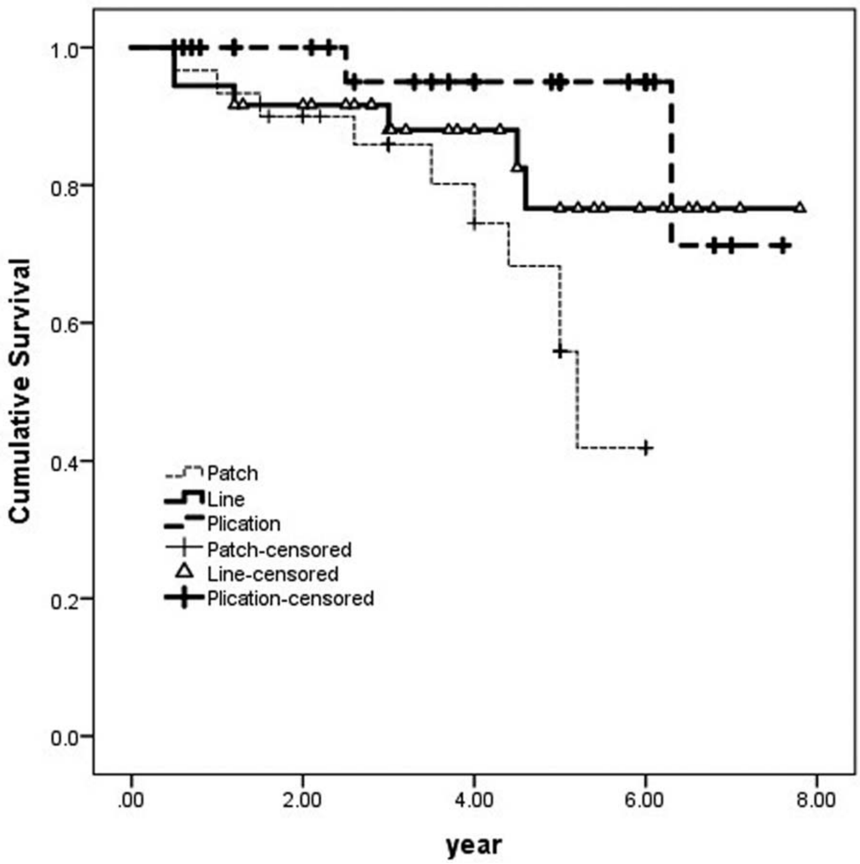

Figure 1. Comparison of survival rates between different surgical approaches.

aneurysm impairs LVEF and predisposes the heart to cardiac failure, and requires immediate surgical intervention.[15] Since Cooley[7] reported the first resection under cardiopulmonary bypass, the application of the traditional linear repair and a newer patch technique have been reported to achieve appreciable outcomes. In addition to these techniques, the endoventricular patch plasty was developed to treat LVA, leading to a further decrease in LV volume and more improvement in cardiac performance as measured by LVEF.[8] However, despite these advances, controversy still exists as to which technique is optimal for repairing MI-related LVA.[4,11,16] Because the LVEF of residual segments was the major factor influencing early and long-term outcomes,[17] we used LVEF to evaluate the cardiac function of patients after SVR. We found that all 3 SVR techniques significantly improved patient LVEF and had favorable early and long-term clinical outcomes in terms of mortality and cardiac functional recovery. Our findings were in agreement with a previous report showing equivalent efficacy of these techniques in the treatment of LVA.[17] Therefore, we believe that the selection of an LV repair technique should be optimized based on the physiological and pathological characteristics of the individual patient's heart.

In the present study, the overall in-hospital mortality rate was low (7.8%) among MI patients who underwent SVR, and the mortality rate was not significantly different between the 3 groups, although it was relatively high in the patch plasty and linear repair groups compared with the plication repair group. In addition, there were no significant differences in terms of long-term survival between the approaches. Because each of these techniques improved LV function in an equivalent manner, as evidenced by ameliorated end-diastolic and end-systolic dimensions and ejection fraction, it is conceivable that these techniques did not show any significant differences in the mortality and long-term survival benefit. In the present study, we chose the repair technique depending on several factors, including the dimension, size, and localization of the scar, and we demonstrated that LVA can be repaired equivalently by either linear, patch plasty, or plication.

Previously, several studies evaluated the outcomes of various approaches to LVA repair and found no significant difference in their ability to ameliorate cardiac dysfunction, reduce mortality rate, and improve long-term survival.[2,4,17] Consistent with these findings, in the present study, we found that there were no significant differences among patch plasty, linear, and plication repairs with regard to early and long-term clinical outcomes. Thus, it appears that each of these techniques may be safely used for repair of LVA, and we suggest that the selection of a particular technique should be based on the pathological properties of the diseased heart of each particular patient. Given that LVA is usually accompanied by the complete blockade of LAD and poor collateral supply, and that 75% of LVA patients were reported to exhibit multivessel disease,[18] we also suggest that SVR should be used together with revascularization to decrease or preclude the risk of angina pectoris and MI or deterioration of congestive heart failure. Another benefit of LAD revascularization is improvement of septal perfusion and suppression of ventricular arrhythmia.[19] In addition, LAD revascularization augments blood flow in the perianeurysmal regions of the lateral wall and septum, thereby improving LV function.[20] Vural et al[11]reported that CABG substantially reduced the incidence of postoperative LCO, although it did not affect postoperative mortality. Thus, if the functional myocardium remains present, the coronary artery should be able to be revascularized. Given that CABG attenuates myocardial ischemia and eliminates paradoxical movement linked to SVR, we suggest that ventricular reconstruction and revascularization should be performed in LAD patients with poor ventricular function.

Different SVR techniques have different advantages and applications. For instance, linear plasty can remove a large scar area and permit a linear closure of the LV opening within the scar, but also leaves some scar tissue. This technique should be performed in a heart with an intact interventricular septum, and is advantageous for anterolateral and anteroapical aneurysms.[21] For patch plasty, a patch is implanted inside the left ventricle, and thus eliminates the akinetic part of the LV septum, allowing reconstruction of LV geometry.[22] Dor plasty is good for large anteroseptal or posterobasal aneurysms, and can be applied in patients with more severe LV damage, in which a patch implantation shuns inadequate LV dimensions after the operation, while consequently promoting better reorganization of the myocardial fibers.[23] Indeed, Chen et al[24] showed that clinical outcomes of the linear and patch plasty repair techniques were similar except for LVEF, and they suggested that the selection of the repair technique for LVA should be customized for each individual patient, according to the aneurysm size and the extent of the scarring of the septum and the subvalvular mitral apparatus. In the present study, neither patch nor linear repair showed any significant differences in terms of cardiac functional improvement, perioperative mortality, and long-term survival.

Low cardiac output has been reported to occur in 20.9% to 67% of cases,[25,26] and is the most frequent postoperative complication linked to SVR, and also 1 of the major causes of early mortality after SVR. The requirement for temporary hemodynamic support with IABP, which is a significant and effective treatment for LCO, varied from 1.8% to 17.9%.[11,26] In the present study, we utilized IABP in 32 patients and achieved appreciable clinical outcomes. Another major cause of SVR-related early mortality was ventricular tachycardia.[26] Implantation of cardioverter-defibrillators can control ventricular tachycardia and significantly reduce mortality compared to drug therapy.[27]

Some limitations of this study need to be acknowledged. First, this study had a small sample size and was a single institute-sponsored study. Also, due to the nature of a retrospective study, sampling bias may exist in our study.

5. Conclusions

In the present study, we demonstrated that 3 SVR techniques—linear, plication, and patch plasty repairs—obtained favorable clinical outcomes in terms of cardiac functional improvement, perioperative mortality, and survival. The selection of an appropriate surgical technique should be optimized based on the condition of each individual patient, including the scar dimension, shape, and cavity size.

Author contributions

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