Left ventricular aneurysm repair: early survival

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Aneurysm; Myocardial remodeling; Myocardial revascularization.

Background. **The aim of this study was to evaluate the early survival in patients submitted to left ventricular (LV) repair and concomitant myocardial revascularization.**

Methods. **We retrospectively reviewed the records of 51 patients who were submitted to LV repair and concomitant myocardial revascularization between January 1998 and June 2003. Of 51 patients (44 males with a mean age of 60 ± 9.2 years, and 7 females with a mean age of 61 ± 6.5 years), 29 (56.9%) were submitted to the McCarthy technique, 16 (31.3%) to the technique that was described by Jatene and modified by Dor, and 6 (11.8%) to the Cooley technique (linear repair). The mean preoperative LV ejection fraction was 36.5 ± 7.7%, the mean preoperative LV end-diastolic diameter was 61.8 ± 3.9 mm, the mean preoperative LV end-systolic diameter was 49.9 ± 5.1 mm, the mean preoperative interventricular septal thickness was 9.7 ± 1.7 mm, and finally, the mean posterior wall thickness was 8.9 ± 1 mm. The mean follow-up was 30.7 ± 23.4 months (range 11-82 months).**

Results. **One patient died during surgery (1.9%) and one early postoperatively (1.9%). The causes of death were respectively irreversible ventricular fibrillation and low cardiac output syndrome. The overall survival at follow-up was 98% (49 patients). One patient died during follow-up of myocardial infarction. At follow-up, all patients presented with improved clinical symptoms, and had a better mean NYHA functional class with respect to the preoperative value (3.3 ± 0.3 vs 2.0 ± 0.5, p < 0.05). Besides, the mean CCS angina class decreased in all patients (3.4 ± 0.2 vs 1.9 ± 0.3, p < 0.05). The average LV ejection fraction increased from 36.3 ± 7.7 to 44.3 ± 4.9% (p < 0.001), the average LV end-diastolic diameter decreased from 61.7 ± 3.9 to 55.5 ± 5.6 mm (p < 0.001), and the average LV end-systolic diameter decreased from 49.9 ± 5.1 to 40.4 ± 5.1 mm (p < 0.001). No statistically significant difference was found between the preoperative and postoperative data regarding the interventricular septal thickness (9.7 ± 1.7 vs 10.3 ± 1.6 mm, p = NS), and the posterior wall thickness (9.7 ± 1 vs 8.8 ± 1.3 mm, p = NS).**

Conclusions. **LV aneurysm repair and concomitant myocardial revascularization may be performed with an acceptable surgical risk and a good early survival.**

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Introduction

Left ventricular (LV) remodeling is characterized by progressive LV dilation, rearrangement of the wall structure, myocyte hypertrophy, and an increasing muscle mass without an increase in wall thickness[1].

LV dilation may play an important and active role in the development of chronic heart failure[2], and LV volume is the most powerful predictor of survival in patients with coronary heart disease[3]. Progressive LV dysfunction is also an important risk factor for early mortality and life-threatening ventricular arrhythmias after acute myocardial infarction (MI)[4].

Because LV remodeling strongly influences the prognosis of patients with MI[1], it is currently a subject of intense investigation. It has long been believed that LV aneurysm is an illness to be treated surgically only when medical therapy is no longer sufficient to keep the patient's symptoms in check; today however, the increased knowledge of the pathophysiology of LV aneurysm has changed the indications to surgery. Although intensive medical management reduces symptoms and improves survival, surgery may still be necessary.

Recently, various surgical approaches have been designed to abort and reverse remodeling, diminish heart failure, and improve survival.

The purpose of this study was to ascertain whether the decrease in LV dimensions, cardiac function, and quality of life may improve in patients with LV repair and concomitant myocardial revascularization. In this study, LV repair was performed by means of three operative techniques.

Methods

Retrospective studies of patients with a LV aneurysm and treated in our center were performed. Between January 1998 and June 2003, 52 consecutive patients were submitted to LV reduction surgery.

Myocardial revascularization by means of coronary artery bypass grafting and concomitant LV reduction was performed in 51 patients (99%). In 1 patient (1%) LV reduction was performed alone because a post-traumatic aneurysm was found; this patient was excluded from the study.

Patients with LV dysfunction and predominant mitral valve insufficiency were not included in this study. Of 51 patients (44 males with a mean age of 60 ± 9.2 years, and 7 females with a mean age of 61 ± 6.5 years), 29 (56.9%) were submitted to the McCarthy technique[5], 16 (31.3%) to the technique described by Jatene[6] and modified by Dor[7], and finally, 6 (11.8%) to the Cooley technique (linear repair)[8]. In only 1 patient (1.9%) was a redo procedure necessary. This patient had been submitted to the Jatene technique and concomitant myocardial revascularization performed by anastomosing a saphenous vein graft to the left anterior descending coronary artery (LAD) and another saphenous vein graft to the obtuse marginal artery 10 years previously. He later presented with angina and dyspnea. A voluminous pseudoaneurysm at the site of the previous aneurysmectomy was diagnosed and it was decided to submit the patient to redo surgery. The previous patch was removed and the left ventricle was reconstructed using the McCarthy technique. Concomitant myocardial revascularization was achieved by anastomosing the left internal mammary artery (LIMA) to the LAD.

All patients (100%) had a history of an anterior MI, 18 (35.3%) were diabetic, and 22 (43.1%) were hypertensive. We reviewed these patients with regard to five preoperative variables: age, sex, CCS angina class, LV failure according to the NYHA functional class, and indication for surgery.

All patients had been submitted to hemodynamic and echocardiographic evaluation prior to surgery. The hemodynamic data included: the number of diseased coronary vessels including left main disease, the site of the aneurysm, and the global LV ejection fraction. Patients were categorized as having single-, two- or three-vessel disease when ≥ 50% luminal narrowing was found in one or more coronary arteries or a major branch, or both. Patients were classified as having proximal LAD disease when ≥ 50% stenosis was observed before the first septal branch. Twenty-six patients (50.9%) had three-vessel disease, 20 (39.2%) two-vessel disease, and 5 (9.8%) had single-vessel LAD disease (Table I). Significant LAD disease (defined as ≥ 50% narrowing of the luminal diameter of a major coronary segment) was present in all patients (100%). The echocardiographic data were recorded and analyzed by an experienced cardiac ultrasonographer using an Acuson Sequoia 512 (Acuson, Mountain View, CA, USA) instrument. The echocardiographic data included: global LV ejection fraction, LV end-systolic (LVESD) and end-diastolic (LVEDD) diameters, and interventricular septal (IVS) and posterior wall (PW) thicknesses.

Table I. Coronary artery diseases and indications for surgery.

Coronary artery disease	No. patients
3-vessel disease	26 (50.9%)
2-vessel disease	20 (39.3%)
1-vessel disease	5 (9.8%)
Left anterior descending coronary artery	51 (100%)
Indications for surgery	
Angina	26 (51%)
Dyspnea (NYHA class III-IV)	22 (43.1%)
Recurrent ventricular tachycardia	3 (5.9%)

The mean preoperative ejection fraction was 36.5 ± 7.7%, the mean preoperative LVEDD was 61.8 ± 3.9 mm, the mean preoperative LVESD was 49.9 ± 5.1 mm, the mean preoperative IVS thickness was 9.7 ± 1.7 mm, and finally, the mean PW thickness was 8.9 ± 1 mm. Patients presenting with a history of episodes of ventricular arrhythmias were submitted to dynamic electrocardiographic study (Holter ECG).

The indications for surgery were: angina in 26 patients (51%), dyspnea in 22 patients (43.1%, NYHA class III-IV), and recurrent episodes of ventricular tachycardia refractory to medical therapy in 3 patients (5.9%) (Table I).

Treatment in the intensive care unit was as per protocol and was similar in all patients with regard to weaning from mechanical ventilation, the use of inotropic vasodilator and antiarrhythmic drugs and the indications to intra-aortic balloon pump (IABP). Infusion of antiarrhythmic drugs was started in theater in 37 patients (72.5%) and in 10 patients (19.6%) it was started in the intensive care unit at the very first signs of ventricular arrhythmia.

Survivors were contacted by phone and were invited to undergo follow-up clinical and echocardiographic examination. Postoperative controls were carried out in our institution.

The mean follow-up was 30.7 ± 23.4 months (range 11-82 months). The follow-up data were compared with the preoperative findings and the differences between the preoperative and postoperative data (follow-up) were analyzed.

Definitions. A LV aneurysm was defined at ventriculography as a zone of paradoxical systolic expansion (dyskinetic) or as an akinetic myocardial zone well delimited from the rest of the cardiac silhouette. In agreement with the Coronary Artery Surgery Study protocol[9], a LV aneurysm was considered to be present if all of the following three criteria were found: a) protrusion of the involved segment, b) absence of trabeculations in the involved segment, and c) well-defined demarcation of the infarct segment. A low cardiac output syndrome was clinically defined as the presence of persistent obtundation, cyanosis, cold extremities, tachycardia, oliguria, and hypotension not responsive to maximal inotropic support.

Perioperative MI was defined as either a new Q wave MI or as the elevation of the myocardial fraction of creatine kinase associated with persistent ST-segment or new conduction abnormalities.

Stroke was defined as any neurological deficit lasting > 24 hours, even if the deficit resolved before hospital discharge.

Operative mortality was any death occurring within 30 days of surgery.

Surgical procedures. A median sternotomy was performed in all patients. The ascending aorta was cannulated in first-time operation. Venous cannulation was accomplished using a double-staged atrial cannula. The femoral artery and vein were prepared if the patient had been previously submitted to sternotomy. The procedure was performed using cardiopulmonary bypass and moderate systemic hypothermia (33-35°C). Blood pressure was maintained at 60 to 80 mmHg. A ventricular vent was not inserted until the aneurysm had been opened and all clots carefully removed. The type of procedure to perform was selected on the basis of the extent of endocardial disease. The goal was to restore an elliptical LV cavity and a cone-shaped apex. Resection of the aneurysm and LV volume restoration were performed using three methods: the "linear suture technique" introduced by Cooley in 1958, "endoventricular patch aneurysmectomy" introduced by Jatene in 1984 and subsequently modified by Dor, and "no-patch repair" introduced by McCarthy in 2001. Details of the surgical techniques are described elsewhere[5-8].

Statistical analysis. The distribution of all relevant variables was expressed either as a percentage or as the mean ± SD with the 95% confidence intervals and compared using a two-tailed Student's t-test (paired or unpaired as appropriate). A p value < 0.05 was considered as statistically significant.

Results

All patients (100%) received concomitant coronary artery bypass, and complete myocardial revascularization was performed in 47 patients (92.1%). The LAD was bypassed in all cases: in 43 patients (84.3%) the LIMA was used whereas in 8 patients (15.7%) saphenous vein segments were anastomosed. All patients received coronary artery bypass grafting with an average of 2.9 ± 1.0 grafts per patient (range 1-4). Additional procedures included endarterectomy of the left internal carotid artery in 1 patient. Cardiopulmonary bypass was used in all 51 patients (100%); during aortic cross-clamping myocardial protection was performed using antegrade warm-blood cardioplegia every 20 min in 25 patients (49%), and by means of antegrade and retrograde cardioplegia using Buckberg solution every 20 min in 26 patients (51%). All distal anastomoses were performed before LV remodeling surgery. In 44 patients (86%) LV remodeling and construction of all distal and proximal anastomoses were performed during cardioplegic cardiac arrest whereas in 7 patients (14%), only LV aneurysmectomy was performed on the beating heart, while construction of all distal and proximal anastomoses was performed during cardioplegic cardiac arrest. The average cross-clamping time was 98.2 ± 21.2 min (range 50-145 min), and the average pump time was 131 ± 25.7 min (range 75-177 min). The type of surgical technique, the pump time and the cross-clamping time are shown in table II. Fifty patients (98.1%) were successfully weaned from bypass, but 2 patients (3.9%) required an IABP and 12 patients (23.5%) required inotropic support (adrenaline ≥ 0.03 γ/kg/min in 4 patients, and dopamine ≥ 5 γ/kg/min in 8 patients). Antiarrhythmic drugs infused in theater included amiodarone in 25 patients (49%) and xylocaine in 12 patients (23.5%). Only 1 patient (1.9%) required reoperation for bleeding. Other perioperative complications included: respiratory insufficiency and stroke in 1 patient (2%) manifesting on the second postoperative day, and melena in 1 patient (2%) manifesting on the

Table II. Operative data.

	McCarthy	Jatene-Dor	Cooley	All patients
Aneurysmectomy + CABG	29 patients (100%)	16 patients (100%)	6 patients (100%)	51 (100%)
LIMA → LAD	27 patients (93.1%)	12 patients (75%)	4 patients (66.6%)	47 (92.1%)
Aortic cross-clamping time (min)	95.6 ± 20.2	110 ± 18.7	77 ± 19.8	98.2 ± 21.2
Cardiopulmonary bypass time (min)	131 ± 24	139 ± 21	92 ± 24	131 ± 25.7
Age (years)	63 ± 6.6	57 ± 7.5	53 ± 13.5	60.4 ± 7.8

CABG = coronary artery bypass graft; LAD = left anterior descending coronary artery; LIMA = left internal mammary artery.

fourth postoperative day. The average length of stay in the intensive care unit was 2.8 ± 1.5 days, while, the average length of hospital stay was 17.6 ± 5.7 days. One patient died during surgery (1.9%); this patient could not be weaned from cardiopulmonary bypass despite the use of inotropic drugs and IABP support. This patient had been submitted to aneurysmectomy using the linear repair technique. Independent risk factors for intraoperative mortality were emergency surgery for cardiogenic shock (systolic blood pressure < 70 mmHg), LV ejection fraction < 20% and a history of ventricular arrhythmia. One patient (1.9%) died within 30 days of surgery. He had been submitted to LV aneurysmectomy using the linear repair technique. The causes of mortality were irreversible ventricular fibrillation and low cardiac output syndrome. Classification of the site of the aneurysm showed that the majority of aneurysms were located in the antero-apical-lateral region in 29 patients (56.9%). The remaining LV aneurysms were identified in the antero-apical region in 16 patients (31.4%), and in the apical region in 6 patients (11.7%). Four patients (7.8%) were found to have an endoventricular thrombus.

The mean follow-up was 30.7 ± 23.4 months. The overall survival at follow-up was 98% (49 patients). During follow-up 1 patient died of acute MI. Following surgery, all patients presented with improved clinical symptoms and mean NYHA functional class with respect to their preoperative status (3.3 ± 0.3 vs 2.0 ± 0.5, $p < 0.05$). Besides, all patients also presented with an improved mean CCS angina class (3.4 ± 0.2 vs 1.9 ± 0.3, $p < 0.05$). Therefore, 96% of patients were asymptomatic; 1 patient (4%) presented with moderate effort dyspnea (NYHA class III-IV) and 1 patient required an automatic implantable cardioverter-defibrillator. The preoperative and postoperative LV morphology, functional changes and hemodynamic measurements of all patients are shown in table III. Preoperatively, no intertechnique differences were found with regard to all the echocardiographic variables considered. Table IV shows the comparison of the echocardiographic data between different techniques before and after surgery. In this comparison, LV ejection fraction was found to have improved only in patients submitted to the McCarthy technique; on the other hand, no statistically significant differences were observed for the other techniques. Moreover, LVEDD and LVESD decreases were in two groups of patients (Table IV). Analysis of the differences between the preoperative and postoperative data regarding LVEDD and LVESD in patients submitted to the Cooley procedure did not reveal any statistically significant differences (Table IV). Ninety-six percent of the patients adhere to the medical therapy they were prescribed during follow-up and also attend to periodic clinical and instrumental postoperative check-ups.

Table III. Comparison between the preoperative and postoperative (follow-up) echocardiographic parameters, NYHA class, and CCS class.

	Pre	Follow-up	p
LVEF (%)	36.3 ± 7.7	44.3 ± 4.9	< 0.001
LVEDD (mm)	61.7 ± 3.9	55.5 ± 5.6	< 0.001
LVESD (mm)	49.9 ± 5.1	40.4 ± 5.1	< 0.001
IVS (mm)	9.7 ± 1.7	10.3 ± 1.6	NS
PW (mm)	9.7 ± 1	8.8 ± 1.3	NS
NYHA class	3.3 ± 0.3	2.0 ± 0.5	< 0.05
CCS class	3.4 ± 0.2	1.9 ± 0.3	< 0.05

IVS = interventricular septum; LVEDD = left ventricular end-diastolic diameter; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic diameter; PW = posterior wall.

Table IV. Comparison between the preoperative and postoperative (follow-up) echocardiographic parameters (surgical techniques).

	McCarthy	Jatene-Dor	Cooley
LVEF (%)	37.3 ± 6.9 vs 44.9 ± 3.9 p < 0.001	44.3 ± 7.7 vs 43.7 ± 6.9 NS	32.5 ± 10.6 vs 41.5 ± 2.1 NS
LVEDD (mm)	61 ± 4.3 vs 55.1 ± 5.1 p < 0.001	60.6 ± 3.8 vs 53.5 ± 5.1 p < 0.001	65.5 ± 3.6 vs 61 ± 4.9 NS
LVESD (mm)	51.6 ± 4.2 vs 41.2 ± 5.4 p < 0.001	47.4 ± 4.4 vs 40.5 ± 3.1 p < 0.001	49 ± 1.4 vs 44 ± 5.6 NS
IVS (mm)	9.7 ± 2.1 vs 8.5 ± 1.7 NS	9.5 ± 1 vs 10.3 ± 1.2 NS	10 ± 0.5 vs 8.5 ± 0.7 NS
PW (mm)	9.3 ± 1.1 vs 9 ± 1.4 NS	8.6 ± 0.7 vs 8.5 ± 1.2 NS	8 ± 0.5 vs 9 ± 1.4 NS

IVS = interventricular septum; LVEDD = left ventricular end-diastolic diameter; LVEF = left ventricular ejection fraction; LVESD = left ventricular end-systolic diameter; PW = posterior wall.

Discussion

LV remodeling is a natural consequence of MI. It is a process in which the ventricular size, shape, and function are regulated by mechanical, neurohormonal, and genetic factors[1,10].

Aneurysms may remain clinically asymptomatic independently of their size; by the time they become symptomatic the left ventricle may be very expanded and its contractile function irreversibly deteriorated. For this reason, patients with a transmural MI must be monitored periodically, and just as Mickleborough et al.[11], we suggest that patients in whom akinetic or dyskinetic areas develop after an infarction should be followed up closely and considered for surgical treatment when signs of decompensation such as worsening symptoms in spite of optimal medical management first occur or in asymptomatic patients if there is evidence of an increasing ventricular volume or mitral insufficiency. If repair is delayed, the contractile function of the residual viable muscle may deteriorate with a progressive decrease in ejection fraction and chamber dilation, both of which are associated with a less satisfactory surgical result.

In the last years, there has been a considerable improvement in the prognosis of these patients, thanks to the increased attention and timeliness dedicated to the care of these subjects. In fact, early perfusion procedures, thrombolysis or angioplasty, have changed the natural history of MI, reducing the incidence of transmural MI and the development of LV aneurysms. The results of the present study confirm this trend.

In spite of this, surgical procedures are still necessary since it is possible to excise non-contractile areas and perform LV remodeling and myocardial revascularization only at surgery.

The reduction in LV volume has two important effects: first, based on "La Place's law" which relates the wall stress inversely to the wall thickness and directly to the chamber radius, volume reduction diminishes wall stress and thereby reduces myocardial oxygen consumption, and second, the reduction in the wall stress as a critical determinant of afterload, enhances the contractile performance of the ventricle by increasing the extent and velocity of systolic fiber shortening.

Myocardial revascularization, by improving heart muscle perfusion, reduces or prevents angina pectoris, and an internal mammary artery graft to the LAD may be particularly important to revascularize the viable interventricular septum and control ventricular arrhythmias.

Various studies have shown that LV aneurysmectomy with concomitant myocardial revascularization change the natural history of the aneurysm with an improvement in the quality of life and patient outcome[12,13].

In a previous work of our Institute[14], in which two surgical procedures have been compared (the linear repair Cooley technique and the Jatene-Dor technique), it was found that endoventricular patch plasty associated with myocardial revascularization performed by anastomosing the LIMA to the LAD was associated with better early and late results.

The positive outcome reported in many studies[6,14] is also confirmed in this work. In this study, only 1 patient (1.9%) died during surgery. The early postoperative mortality rate (30 days) was 1.9%; this is lower than that reported in other studies. Elefteriades et al.[15], using a linear repair technique, reported a mortality of 6.7%. Jatene[6] and Dor et al.[7] reported an operative mortality rate of 5 and 6.2% respectively. Finally, Bolooki et al.[16], and Lundblad et al.[17] reported operative mortality rates of 16 and 8.7% respectively.

In this series there were few postoperative complications and only 5.8% of patients required IABP support.

There was only one perioperative stroke. We believe that removing any endocardial thrombus before insertion of a LV vent may have contributed to the low perioperative stroke rate.

The decrease in LVEDD and LVESD with an increase in LV ejection fraction is also significant (Table III).

However, when analyzing these data we have found some differences between techniques. Despite the fact that the Cooley technique and the Jatene-Dor technique were associated with a decrease in LVEDD and LVESD, and with improved clinical symptoms and a good survival at follow-up, the LV ejection fraction was not found to have significantly increased.

Mickleborough et al.[18] showed the validity of the "linear repair" technique, Dor et al.[19], Menicanti and DiDonato[20] and Bolooki et al.[16], that of endoventricular patch plasty.

A statistically significant improvement in LV ejection fraction, beyond what would have been expected on the basis of the ventricular diameters, has been found for the McCarthy technique (37.3 vs 44.9%, $p < 0.001$).

The contractile dysfunction observed following the Cooley technique may be due to the fact that in this conventional repair the lateral and the medial (septal) walls of the left ventricle are sutured together at a point where they would naturally lie several centimeters apart, thereby significantly decreasing the functional LV cavity size and distorting the natural LV geometry; in this technique the septal paradox is not excluded when the septal area is significantly involved[21].

It has been proposed that the use of an endoventricular patch as described by Jatene and Dor a) may eliminate a larger segment of dyskinetic septum from the residual effective ventricular cavity with a consequent greater exclusion of the aneurysmal zone without an excessive reduction of the residual cavity dimensions, and b) determines a better reorientation of the myocardial fibers.

A better postoperative myocardial function could be the consequence of this. However, Nicolosi et al.[22] did not find any differences in the postoperative LV function in animal models.

Moreover, in agreement with the hypothesis of McCarthy[23], replacing a dyskinetic aneurysm with an akinetic patch could limit the global ventricular global function in spite of the benefits of myocardial revascularization. In small aneurysms that do not involve the septum, the theoretical advantages of endoventricular patch repair are less convincing.

However, it is possible that the symptomatic improvement related to the decreased ischemia may not be reflected in concomitant changes in the LV function.

Tikiz et al.[24], in their work, suggest that single-vessel disease, the absence of previous angina, total LAD occlusion, and female gender were important determinants in the formation of a LV aneurysm after an anterior MI. In our series, only proximal and total LAD occlusions were shown to be a significant determinant of LV aneurysm formation, and was present in 100% of patients.

Our study shows that the early survival (mean follow-up 30.7 ± 23.4 months) is excellent (98%). Athanasuleas et al.[25], reported an overall early survival (at 18 months) of 84%.

Finally, Jatene[6] reported that the impairment in cardiac function partially depends on the degree of distension but mainly on the amount of infarcted muscle. A relatively small infarct may result in a large distension with a very large aneurysm but with only limited involvement of the myocardium and, consequently, of ventricular function. A large infarct with a small distension impairs the ventricular function to a much greater degree even if the heart is relatively small. For this reason, classifying aneurysms as small, medium, and large is of little use. We think that the size of LV aneurysms may be relevant for the success of surgical procedures, but that the most important factor is probably the extent of calcification of the surrounding wall.

Further randomized study may be needed to explain which surgical procedure would yield the most benefit. In spite of the availability of several surgical procedures, these data confirm the importance of LV repair and concomitant myocardial revascularization to improve the patient outcome. The role of aneurysmectomy and LV remodeling surgery as an adjunct to coronary artery bypass grafting is currently being investigated as one arm of a National Institutes of Health-sponsored multicenter study (STICH trial)[26]. The information gleaned from the STICH trial will guide future therapy.

In conclusion, we think that LV aneurysm repair and concomitant myocardial revascularization may be performed with an acceptable surgical risk and a good early survival.

Study limitations. The study has a number of limitations. It is not a randomized study and it is retrospective. The relatively small number of patients and the inhomogeneous distribution of the population may have influenced the results. The echocardiographic examinations were performed by two echocardiographers but the interobserver variability was not quantified. The present study refers to a single institution experience. Dyskinetic aneurysms may have a thick LV wall, consisting of a mixture of scar and viable myocardium. Finally, a certain number of patients will benefit most from revascularization alone and not aneurysmectomy.

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