Surgical restoration of the left ventricle for postinfarction aneurysm

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Aneurysm; Cardiomyopathies/ Myocardial diseases; Congestive heart failure; Coronary artery surgery; Ventricular remodeling.

Background. **Surgical left ventricular reduction is under investigation as an alternative to, or a bridge for, heart transplantation in patients with a left ventricular aneurysm. In fact, acute myocardial infarction can result in the development of a dyskinetic or akinetic left ventricular aneurysm which may in turn cause congestive heart failure, ventricular arrhythmias, and the formation of mural thrombi. The aim of this study was to evaluate the current operative risk of surgical restoration of the left ventricle and the early and late clinical results.**

Methods. **From January 1997 to December 2001, 94 patients (84 males and 10 females) presenting with a postinfarction aneurysm were submitted to surgical restoration of the left ventricle. All patients presented with symptoms of heart failure and/or angina. The preoperative NYHA functional class was: I in 6 patients, II in 22 patients, and III in 66 patients. No patient was in NYHA class IV at the time of surgery. The preoperative ejection fraction was 30 ± 7.9%. In 25 patients mural thrombi were identified and surgically removed. In patients with preoperative evidence of ventricular arrhythmias the Harken procedure was performed intraoperatively. The ventricular preoperative and postoperative performances were also studied in 10 patients using P-V loops obtained through a conductance catheter.**

Results. **The in-hospital mortality was 3.2%. The mean length of hospitalization was 7 ± 2.9 days. At follow-up (mean 26 ± 14.8 months) we observed an early improvement in the ejection fraction (30 ± 7.9 vs 48 ± 8.0%) and a decrease in the end-diastolic and end-systolic volumes and mean pulmonary pressure (139 ± 37 vs 84 ± 17 ml/m^2, 105 ± 39 vs 52 ± 20 ml/m^2, 35 ± 8.4 vs 23 ± 4.3 mmHg).**

Conclusions. **These results suggest that ventricular restoration is indicated in all patients with a postinfarction dyskinetic or akinetic aneurysm. The operation, if performed appropriately, is associated with a low in-hospital mortality and morbidity. A postoperative improvement in the early and long-term cardiac functions was demonstrated. An improvement in symptoms and quality of life was documented, increasing our expectations of an increased long-term survival.**

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Introduction

Acute myocardial infarction can result in the development of a dyskinetic or akinetic left ventricular aneurysm which may in turn cause congestive heart failure, ventricular arrhythmias, and the formation of mural thrombi[1-3].

Left ventricular aneurysmectomy has been performed since 1958 with favorable results in terms of an improvement in symptoms and quality of life[4-6]. The operative risk, however, was not negligible in the past, and the long-term survival was often reported as being rather suboptimal[7-9].

Two surgical techniques are mostly utilized: the linear suture aneurysmectomy, first described by Cooley et al.[5], and the endoventricular patch aneurysmectomy initially proposed by Jatene[10] and subsequently modified by Dor et al.[11] and Cooley[12].

Both techniques are performed with the aim of restoring the morphology of the left ventricular cavity. The choice of the procedure depends partly on the preference of the individual surgeon and partly on the anatomical situation, particularly on the extension and location of the aneurysm.

The purpose of this study was to evaluate the current operative risk of surgical restoration of the left ventricle and the early and long-term clinical results. Moreover, the acute hemodynamic changes induced by the operation have been assessed in a subset of patients included in the series herein reported.

Methods

Clinical material. From January 1997 to December 2001, surgical restoration of the left ventricle was performed in 94 consecutive patients (84 males, 10 females, mean age 62 ± 8.6 years).

The time elapsing from the acute myocardial infarction responsible for the aneurysm to the operation ranged from 4 to 43 months (mean 9 ± 7.0 months).

The left ventricular aneurysm was defined by ventriculography as dyskinetic when paradoxical systolic motion was present (84 patients), or as akinetic when a large non-contractile area, well delimited from the surrounding moving silhouette, was identified (10 patients).

The mean ejection fraction was 30 ± 7.9%.

All patients presented with symptoms of congestive heart failure and/or angina. In only 8 patients was angina the prevalent symptom, while the remaining patients predominantly presented with signs and symptoms of congestive heart failure. Although quite a number of patients had experienced episodes of pulmonary edema and had been, following the myocardial infarction, classified in NYHA functional class IV, optimization of the medical therapy in all patients resulted in a remarkable improvement of symptoms, so that at the time of surgery these patients were included in either NYHA class I (6 patients) or II (22 patients) or III (66 patients).

The history of 11 patients included episodes of malignant ventricular arrhythmias. In all these patients, a preoperative electrophysiological study demonstrating the inducibility of ventricular tachycardia was performed.

In 25 patients left ventricular mural thrombi were identified at echocardiography, but no preoperative cerebrovascular accident was recorded.

In the great majority of the patients (n = 87), the aneurysm was located in the territory of the left anterior descending coronary artery, while in only 7 patients was the site of the aneurysm inferior or postero-lateral (territory of the right or distal circumflex coronary artery).

Surgical procedure. Prophylactic intra-aortic balloon counterpulsation was instituted soon after induction of anesthesia in those patients with more pronounced preoperative signs of congestive heart failure (approximately one fourth of the entire population). We decided to use intra-aortic balloon counterpulsation preoperatively in patients with a severely low preoperative ejection fraction so as to achieve hemodynamic stability during the early phases of the surgical procedure and to avoid the risks associated with a low postoperative cardiac output.

All patients were operated upon using cardiopulmonary bypass in normothermia. During aortic cross-clamping, myocardial protection was obtained with a cold blood cardioplegic solution intermittently delivered anterogradely and retrogradely. The cardiopulmonary bypass time was 82 ± 27.4 min and the aortic occlusion time was 61 ± 22.4 min.

In 23 patients an aneurysmectomy followed by a linear suture left ventricular reconstruction was carried out, while in the rest of the patients the left ventricular cavity was restored using an endoventricular dacron patch. The patch (mostly oval in shape and approximately 2.5 × 3.5 cm in size) was sutured circumferentially at the border zone running between the scar tissue and viable myocardium. The use of these different techniques was related to the extent and location of the scarred tissue; when the scar involved the septum, the endoventricular patch was preferred while the linear resection technique was used in case of an aneurysm exclusively involving the wall.

Mural thrombi, when present, were carefully removed soon after having incised the aneurysm.

In patients with ventricular arrhythmias, an extensive circumferential endocardial resection according to Harken[13,14] was performed without intraoperative mapping.

Concomitant coronary artery bypass grafting was performed in 65% of the patients, and in 8 cases a severe mitral insufficiency with a centrally located regurgitant jet was repaired according to the Alfieri repair technique performed through the ventricular approach.

Ten patients, all with a severely depressed left ventricular function, were studied in the perioperative period with a conductance catheter introduced through the right upper pulmonary vein into the left ventricular cavity, in order to obtain pressure-volume loops and other hemodynamic data, using the methods previously described[15,16].

Follow-up. Information regarding follow-up was obtained for all hospital survivors and was 100% complete. The mean period of follow-up was 26 ± 14.8 months (range 1 to 49 months).

Data were collected either during follow-up clinical evaluation or by telephone interview with the patient or the referring physician. In addition, an echocardiographic examination was requested in all the survivors in order to obtain information regarding the ventricular performance and mitral valve function.

Statistical analysis. Variables are reported as means ± SD. The baseline characteristics and outcomes were compared using χ^2 analysis for categorical data and Student's t-tests for continuous variables. Differences were considered significant only when the p value was < 0.05. Survival was analyzed using the Kaplan-Meier actuarial methods (product-limit method).

Results

Hospital mortality and morbidity. Three (3.2%) in-hospital deaths occurred within the first postoperative month. In 2 cases, the cause of death was multiple organ failure. These patients were known to have widespread atherosclerotic vascular disease, severe long-lasting hypertension and chronic renal insufficiency. The other patient who died had severe left ventricular dysfunction associated with relevant mitral regurgitation which was successfully corrected. He developed a low cardiac output syndrome which was non-responsive to optimal pharmacologic support and intra-aortic balloon counterpulsation.

The great majority of patients had a rather smooth postoperative course (mean hospitalization 7 ± 2.9 days), although, as reported in table I, a number of non-fatal complications did occur.

Delayed outcome. Two patients (2.2%) died after hospital discharge, one suddenly (1 month later, probably of a ventricular arrhythmia) and the other of malignant neoplasm (8 months later). Using the actuarial method, the probability of surviving for 3 years after surgery was calculated at 94.7% (Fig. 1), with 95% confidence limits of 90-99%.

At the time of follow-up, the mean NYHA class was 1.4 ± 0.61 while the preoperative NYHA class was 2.7 ± 0.42 ($p < 0.001$). The distribution of the pre- and post-operative (at the last follow-up visit) functional classes is presented in figure 2.

The preoperative and postoperative ejection fractions, as determined at echocardiography, are shown in figure 3 for each patient. The mean ejection fraction increased from 30 ± 7.9 to 48 ± 8.0% ($p < 0.001$).

Table I. Postoperative non-fatal complications.

Atrial fibrillation	15 (15.9%)
Re-exploration for bleeding	10 (10.6%)
Prolonged ventilatory support	10 (10.6%)
Neurological problems	4 (4.2%)
Transient ischemic attack	3 (3.2%)
Stroke	1 (1.0%)
Pneumothorax	2 (2.1%)
Wound infection	1 (1.20%)

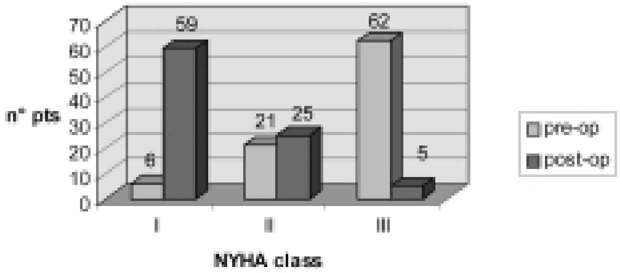

Figure 2. *Preoperative and postoperative NYHA functional classes at the last follow-up.*

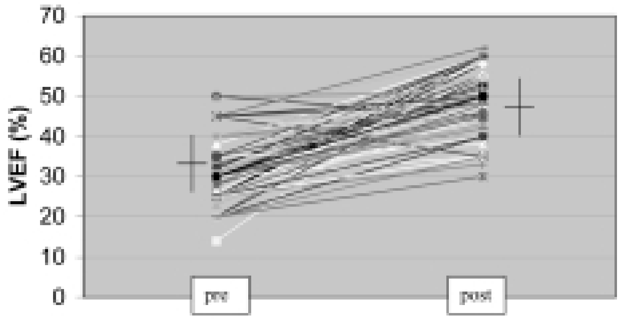

Figure 3. *Preoperative and postoperative left ventricular ejection fraction (LVEF).*

No mitral insufficiency was echocardiographically documented in patients in whom mitral valve repair was also performed.

In no case did episodes of congestive heart failure, angina, arrhythmias or neurological disorders necessitating hospitalization occur during follow-up.

Functional evaluation. Using a conductance catheter, the acute effects of the surgical restoration of the left ventricle have been studied in 10 patients of the series.

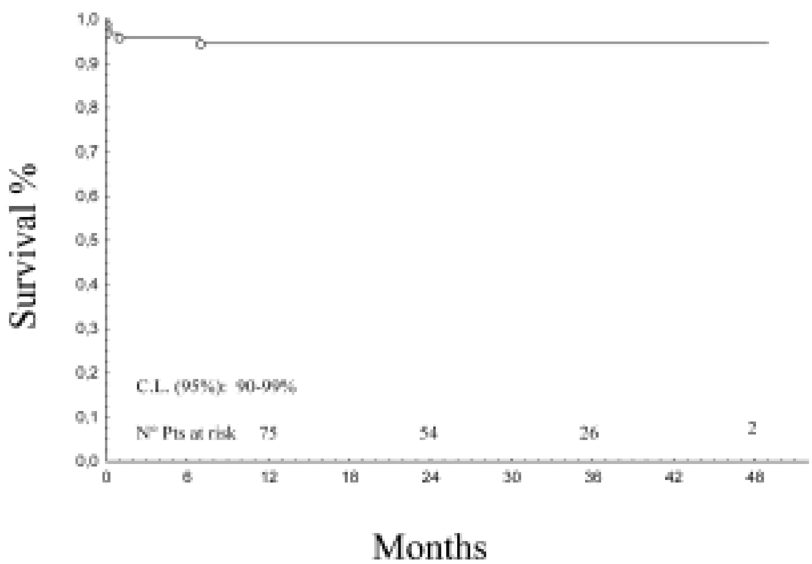

Figure 1. *Actuarial survival of the patients submitted to surgical restoration of the left ventricle. CL = confidence limit.*

These patients had presented with a huge aneurysm in the territory of the left anterior descending coronary artery and a mean ejection fraction of 23 ± 11%.

Following the procedure, the pressure-volume loops were consistently displaced leftwards as a result of the reduction in the end-diastolic and end-systolic volumes.

The cardiac index and stroke volume were not significantly modified. All significant hemodynamic changes which occurred after the operation are listed in table II.

Discussion

Owing to the introduction of thrombolysis and primary angioplasty for the treatment of acute myocardial infarction, the occurrence of left ventricular aneurysms is nowadays less common than in the past.

A considerable number of patients, however, can still be candidates for a surgical procedure the aim of which is to restore the morphology of the left ventricular cavity after an acute myocardial infarction. Surgery should be indicated even in patients without important symptoms when a large dyskinetic or akinetic area is diagnosed. The anatomical and functional changes resulting from necrosis may trigger the process of left ventricular remodeling which is progressive and ultimately leads to severe global left ventricular dysfunction. Di Donato et al.[17] have been able to detect important contraction and relaxation abnormalities even in non-ischemic zones, remote from the aneurysm. In view of these findings, an attempt to restore the left ventricular morphology during the early phases of the remodeling process seems to be justified.

Obviously, an appropriate concomitant medical treatment is advocated so as to maintain and even enhance the beneficial effects of surgery.

The low operative mortality and the low rate of postoperative complications in our series are relevant arguments in favor of an aggressive surgical approach. Due to the very small number of hospital deaths, a statistical analysis for the identification of the incremental risk factors associated with the procedure was considered meaningless and was therefore not carried out.

We can immediately notice however that the patients who did not survive presented with important comorbidities and severe left ventricular dysfunction. On the contrary, the operative risk seems to be negligible in those patients who do not present with an excessively compromised global ventricular function and/or relevant comorbidities.

In a limited number of patients we have been able to quantify the hemodynamic changes occurring immediately after surgical restoration of the left ventricle.

In association with the volume reduction, a dramatic improvement in the ejection fraction was documented. On the basis of the long-term clinical results and echocardiographic findings, it may be assumed that all these beneficial effects have persisted during the follow-up period.

With regard to the surgical technique, the use of an endoventricular patch is, in our opinion, mandatory when the scar tissue involves large areas of the interventricular septum. On the contrary, when the aneurysm does not involve the septum a linear suture aneurysmectomy can be equally effective.

Concomitant coronary artery bypass grafting is indicated only when ischemia or hibernation is demonstrated. The occurrence of variable degrees of mitral regurgitation is not uncommon when the heart is dilated and the ventricular cavity deformed. In order to abolish the volume overload, correction of hemodynamically significant mitral incompetence should always be considered in conjunction with restoration of the left ventricular morphology.

A certain proportion of patients with a postinfarction aneurysm are symptomatic for malignant ventricular arrhythmias. Under these circumstances, an endocardial resection performed circumferentially in the border zone running between the scar tissue and viable myocardium (where the reentry circuits responsible for the arrhythmias are supposed to originate) is indicated. This procedure has been effective in our experience as well as in the experience of others[18,19].

In conclusion, surgical restoration of the left ventricle is indicated in all patients who present with a dyskinetic or akinetic postinfarction aneurysm causing significant dilation and deformation of the ventricular cavity. The operation, if performed appropriately, is associated with a low in-hospital mortality and morbidity.

The results of the present study are suggestive of the occurrence of favorable hemodynamic changes and of reverse remodeling. Furthermore, a positive impact on symptoms and quality of life has been documented. A substantial improvement in the long-term prognosis may be expected.

Table II. Hemodynamic changes following surgical restoration of the left ventricle in 10 patients.

	Preoperative	Postoperative	p
Mean pulmonary pressure (mmHg)	35 ± 8.4	23 ± 4.3	< 0.01
End-diastolic pressure (mmHg)	8.6 ± 4.2	14 ± 3.5	< 0.05
End-diastolic volume (ml/m^2)	139 ± 37	84 ± 17	< 0.001
End-systolic volume (ml/m^2)	105 ± 39	52 ± 20	< 0.001
Ejection fraction (%)	23 ± 11	37 ± 14	< 0.001

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