Surgical treatment of left ventricular post-infarction aneurysm with endoventriculoplasty: late clinical and functional results

Daniel Giorgio Di Mattia*, Pietro Di Biasi, Maurizio Salati, Andrea Mangini, Pino Fundaro, Carmine Santoli

Department of Thoracic and Cardiovascular Surgery, Luigi Sacco Hospital, Via G.B. Grassi, 74 20137 Milan, Italy

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Abstract

Objective: The temporal response to endoventriculoplasty (EVP) has not been well defined. We have evaluated the long-term clinical and functional results of this technique. Methods: From 1988 to 1997, 121 patients underwent aneurysmectomy by EVP associated with myocardial revascularization for anteroapical left ventricular postinfarction aneurysm. Among these, 39 patients (43%) underwent early post-operative cardiac catheterization (within 3 months maximum), and were available to be revaluated after a mean follow-up time of 56 ± 28 months, by means of a new hemodynamic study. Left ventricular silhouettes were analyzed by means of a special software. Results: The mean New York Heart Association functional class decreased from 2.5 ± 0.9 to 1.6 ± 0.8 (P < 0.001) late postoperatively. The global ejection fraction improved early postoperatively from 43 ± 13 to 61 ± 13% (P < 0.001), and late postoperatively slightly decreased to 42 ± 13% (ns) versus preoperative values. Left ventricular end diastolic pressure early postoperatively fell from 16.8 ± 7.0 to 15.7 ± 6.7 (ns), and late postoperatively increased to 21.6 ± 8.8 (ns) versus preoperative values. Pulmonary artery pressure rose early postoperatively from 31.5 ± 6.4 to 32.1 ± 6.7 (ns), and late postoperatively to 34.9 ± 8.9 (ns). The global contractility score decreased early postoperatively from 42.3 ± 9.6 to 28.4 ± 13.6 (P < 0.001), the global late postoperative contractility was 35 ± 14 (ns) versus preoperative values. Patients who benefit most from the operation were those with a normal postoperative contraction pattern, where ejection fraction improved respectively early postoperatively from 43 ± 13 to 63 ± 11% (P < 0.001), and late postoperatively to 49 ± 10% (P < 0.001) versus preoperative values. Occlusion or critical stenosis of bypass grafts occurred in 10 patients (25.6%). There were no significant differences in hemodynamic data and hypokinesis score changes between patients with patent or occluded bypass graft, and between patients with mono or multivessel disease. The operative mortality was 6.3%, and 8.8% needed intraaortic balloon counterpulsation. The actuarial survival rates at 5 and 7 years were 73 ± 6 and 61 ± 6%. The mean follow-up period was 68 months (with 112 months maximum). Conclusions: We conclude that, in our patients group, EVP of left ventricular aneurysm associated with coronary grafting improves clinical status after operation. We registered a trend for a mild hemodynamic worsening, irrespective of coronary artery disease except in those patients who had shown a normal postoperative contraction pattern. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Left ventricular aneurysm; Endoventriculoplasty; Left ventricular geometry; Long-term results

1. Introduction

Since 1985 when Jatene [1] described an alternative approach to the conventional surgical treatment performed with the linear suture of left ventricular aneurysm, circular reconstruction of the left ventricle has become the gold standard. Successively Dor et al. [2] modified this technique by means of an implanted patch inside the left ventricle, excluding the akinetic portion of the left ventricular septum.

However very few data concerning late functional and hemodynamic status after this surgical procedure are available in the medical literature.

Nevertheless these are important criteria for evaluation
because these outcomes should strongly influence the clinical decision for operative procedure.

Here we report our clinical, echocardiographic and hemodynamic results with endoventriculoplasty (EVP) using the Dor et al. [2] technique in patients who had been operated on and who gave their consent to a second and a third hemodynamic study.

2. Material and methods

The study group consisted of 39 patients among 121 consecutive patients who were subjected in our institution to left ventricular (LV) patch repair for postinfarction LV aneurysm by the same surgical team from November 1988 to December 1997. The patients gave informed consent, and our institutional committee on human research approved the study protocol. Angiographic diagnosis of LV aneurysm was based on the CASS definition (segment of the left ventricular wall protruding from the expected outline of the ventricular chamber and displaying either akinesis or dyskinesis).

2.1. Clinical characteristics

There were 32 men and seven women with a mean age of 60±8 years (range, 43–78 years). Surgical intervention had been recommended because of angina in 33 patients and congestive heart failure in six patients. Only one patient had atrial fibrillation; normal sinus rhythm was present in the others. Four patients (11.8%) had complex ventricular arrhythmias on 24-h electrocardiographic examination. One patient had a history of systemic embolization. Two patients underwent an emergency cardiac procedure because of hemodynamic deterioration. One required moderate inotropic support before operation, the other inotropic support and intraaortic balloon counterpulsation before operation.

All operations were done with cardiopulmonary bypass and aortic cross-clamping. Moderate systemic hypothermia (26–28°C), cold antegrade cardioplegia (St. Thomas’ Hospital solution), and topical (endocardial and epicardial) cooling were used. Intracardiac repair and myocardial revascularization were done during the same period of aortic cross-clamping. Left ventriculotomy was begun at the ‘dimpling’ point of the aneurysmal scar and was extended after taking into account the endocardial fibrosis and the presence of muscular tissue. In patients with a large aneurysm, a preliminary circumferential suture was used to reduce the mouth of the LV aneurysm. An autologous glutaraldehyde-tanned pericardial patch was inserted following the junction between scarred and normal endocardium. The patch was oval with a major width of 3–4 cm. The aneurysmal wall was sutured over the patch by means of over-and-over suturing. Biologic glue was applied generously to fill the excluded cavity and to ensure perfect hemostasis.

2.2. Operative technique

All operations were done with cardiopulmonary bypass and aortic cross-clamping. Moderate systemic hypothermia (26–28°C), cold antegrade cardioplegia (St. Thomas’ Hospital solution), and topical (endocardial and epicardial) cooling were used. Intracardiac repair and myocardial revascularization were done during the same period of aortic cross-clamping. Left ventriculotomy was begun at the ‘dimpling’ point of the aneurysmal scar and was extended after taking into account the endocardial fibrosis and the presence of muscular tissue. In patients with a large aneurysm, a preliminary circumferential suture was used to reduce the mouth of the LV aneurysm. An autologous glutaraldehyde-tanned pericardial patch was inserted following the junction between scarred and normal endocardium. The patch was oval with a major width of 3–4 cm. The aneurysmal wall was sutured over the patch by means of over-and-over suturing. Biologic glue was applied generously to fill the excluded cavity and to ensure perfect hemostasis.

Myocardial revascularization was accomplished after ventriculotomy and before implantation of the patch. All patients underwent complete myocardial revascularization with coronary artery bypass grafting of one vessel in seven patients, two vessels in 11, three vessels in 20, and four vessels in one patients. The left internal thoracic artery was grafted in 34 patients (87.2%) on LAD. Open endarterectomy of the LAD was performed in two patients. No mitral valve procedure was done. All patient had LV aneurysm repair with autologous glutaraldehyde-tanned pericardial patch.

2.3. Echocardiography

M-mode and two-dimensional echocardiography and pulsed continuos and color Doppler examinations were performed preoperatively in all patients. The studies were repeated at discharge and on a yearly basis thereafter during the follow-up. Left ventricular chamber sizes were obtained from M-mode findings at the basal level. Left ventricular volumes and ejection fractions were calculated using Simpson’s model [3] unless good images could not obtained, in which case the model of Teicholz [4] was used.

Mitral regurgitation was quantified by the usual grading from 0+ to 3+. Preoperatively, 36 patients (92%) had slight

![Table 1](https://academic.oup.com/ejcts/article-abstract/15/4/413/523281)

<table>
<thead>
<tr>
<th>NYHA functional class</th>
<th>Class I</th>
<th>Class II</th>
<th>Class III</th>
<th>Class IV</th>
<th>EF (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8</td>
<td>11</td>
<td>14</td>
<td>6</td>
<td>43.2 ± 13.5</td>
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<tr>
<td>LVEDP (mmHg)</td>
<td>16.8 ± 7</td>
<td>16.8 ± 7</td>
<td>16.8 ± 7</td>
<td>16.8 ± 7</td>
<td>16.8 ± 7</td>
</tr>
<tr>
<td>PAP (mmHg)</td>
<td>31.5 ± 6.4</td>
<td>31.5 ± 6.4</td>
<td>31.5 ± 6.4</td>
<td>31.5 ± 6.4</td>
<td>31.5 ± 6.4</td>
</tr>
<tr>
<td>CI (ml/min per m²)</td>
<td>2.7 ± 0.1</td>
<td>2.7 ± 0.1</td>
<td>2.7 ± 0.1</td>
<td>2.7 ± 0.1</td>
<td>2.7 ± 0.1</td>
</tr>
<tr>
<td>EDD (mm)</td>
<td>60.5 ± 11.4</td>
<td>60.5 ± 11.4</td>
<td>60.5 ± 11.4</td>
<td>60.5 ± 11.4</td>
<td>60.5 ± 11.4</td>
</tr>
<tr>
<td>Score (points)</td>
<td>42.3 ± 9.6</td>
<td>42.3 ± 9.6</td>
<td>42.3 ± 9.6</td>
<td>42.3 ± 9.6</td>
<td>42.3 ± 9.6</td>
</tr>
<tr>
<td>Site of MI</td>
<td>Anterior</td>
<td>Anterior</td>
<td>Anterior</td>
<td>Anterior</td>
<td>Anterior</td>
</tr>
<tr>
<td>Anteroseptal</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

NYHA, New York Heart Association; EF, ejection fraction; LVEDP, left ventricular end-diastolic pressure; PAP, mean pulmonary artery pressure; CI, cardiac index; EDD, end-diastolic diameter; MI, myocardial infarction.
or no mitral regurgitation, two (5.1%) had mild, and one (2.6%) had moderate mitral regurgitation.

2.4. Angiography and computerized analysis

All patients had ventriculography before operation. Two postoperative study were performed after operation, the first within 3 months and the second later, in a time included from 9 and 98 months after surgery.

Wall motion was assessed by means of a computerized analysis method [5]. This analysis system achieves a semi-objective evaluation of left ventricular kinesis. A calculation that uses end-diastolic and end-systolic ventricular silhouettes generates, by a specific algorithm, a left ventricular contraction for the right anterior oblique projection. Ventricular silhouettes were divided into five segments: anterobasal, anterolateral, apical, diaphragmatic and posterobasal. Each of these segments were further divided into four subsegments. Twenty areas were obtained by dividing the longitudinal axis of the silhouettes by 10 equidistant orthogonal coordinates (Fig. 1). The systolic percent reduction of each area (subsegmental ejection fraction) was obtained to display a contraction curve. This curve was compared with a reference contraction curve obtained from a normal population (n = 30).

After the formation of the contraction curve, the analysis system computed a score for each subsegment: 0 = normal wall motion, 1 = moderate hypokinesis, 3 = severe hypokinesis, 4 = akinesis, 5 = diskinesis. A normal wall segment would receive a score of 0 whereas a fully diskinetic segment would receive a score of 20 (five × four subsegments). The global hypokinetic score was the sum of the score of all segments.

The aneurysm score was made up of the anterolateral and apical scores. The nonaneurysm score was the sum of the anterobasal, diaphragmatic and posterobasal scores.

A morphologic observation of the curve was performed. If the curve resembled that of the healthy population (irrespective of the absolute amount of contraction), it was considered satisfactory (well-restored geometry). The curve was considered unsatisfactory when residual akinesis extended for at least one segment. An analysis system overestimated the ejection fraction, the normal values being 0.79 ± 0.05.

Coronary arteriography was performed in all patients who underwent further study.

2.5. Follow-up

Follow-up consisted of clinical, echocardiographic, angiographic examinations and computerized analysis. Follow-up ranged from 9 to 98 months with a mean follow-up of 56 ± 28 months.

2.6. Statistical analysis

All values are expressed as the mean ± the standard deviation with the exception of actuarial survival rates that are expressed as rate ± the standard error. The comparisons between preoperative and postoperative data were done with paired Student’s test. Univariate analysis was performed for discrete variables using contingency tables. Survival and event-free curves were obtained by the life-table method. Significance was achieved at a P-value of less than 0.05.

3. Results

The mean number of bypass grafts was 2.4 ± 0.8. Two patients (5.1%) required intraaortic ballon counterpulsation for hemodynamic stabilization. Postoperative myocardial infarction occurred in one patient (2.6%). In this patient, early postoperative angiography revealed an occluded right coronary artery saphenous graft. Mild to moderate inotropic support was required in 11 patients (28.2%). Mechanical ventilation was not required in any patient for longer than 96 h.

3.1. Follow-up

Twenty-eight patients (71.8%) were angina free. Twenty-three patients were classified in New York Heart Association class I (59%), 11 in class II (28.2%), four in class III (10.3%), and one in class IV (2.6%). The mean New York Heart Association functional class decreased from 2.5 ± 0.9 to 1.6 ± 0.8 (P < 0.001) late postoperatively. The four patients with preoperative complex arrhythmias had no clinical complications during follow-up. Three patients discontinued antiarrhythmic therapy after serial 24-h electrocardiograms. The other was on a regimen of amiodarone, which provided satisfactory control.

![Fig. 1. Regional wall functional analysis. The end-diastolic (solid line) and end-systolic (broken line) ventricular silhouettes are divided into 20 subsegmental areas. A computer calculated the systolic change for each area (subsegmental ejection fraction).](image-url)
3.2. Angiographic results

The mean ejection fraction improved early postoperatively from 43 ± 13 to 61 ± 13% (P < 0.001), and late postoperatively slightly decreased to 42 ± 13% (ns) versus preoperative values (Fig. 2).

Left ventricular end diastolic pressure early postoperatively fell from 16.8 ± 7 to 15.7 ± 6.7 (ns), and late postoperatively increased to 21.6 ± 8.8 (ns) versus preoperative values. Pulmonary artery pressure rose early postoperatively from 31.5 ± 6.4 to 32.1 ± 6.7 (ns), and late postoperatively to 34.9 ± 8.9 (ns) versus preoperative values. The global contractility score decreased early postoperatively from 42 ± 9.6 to 28.4 ± 13.6 (P < 0.001); the global late postoperative contractility was 35 ± 14 (ns) versus preoperative values. Global and regional contractility changes are shown in Table 2 and Figs. 3 and 4.

Analysis of the individual contractility curves showed well-restored geometry (Fig. 5A) in 26 patients (66.7%) and impaired geometry in 13 (33.3%) (Fig. 5B).

In the group with a normal pattern, mean ejection fraction improved, respectively early postoperatively from 43 ± 13 to 63 ± 11% (P < 0.001), and late postoperatively to 49 ± 10% (P < 0.001) versus preoperative values. Whereas the group with an abnormal pattern showed an improvement early postoperatively from 43 ± 14 to 57 ± 16% (P < 0.001), but late postoperatively the mean ejection fraction decreased to 30 ± 8.7% (P < 0.001) versus preoperative values. Preoperative functional characteristics of these two groups are presented in Table 3.

Oclusion or critical stenosis of bypass grafts occurred in 10 patients (25.6%). There were no significant differences in hemodynamic data and hypokinesis score changes between patients with patent or occluded bypass graft, and between patients with mono or multivessel disease.

3.3. Echocardiographic results

End-diastolic left ventricular diameter (basal level) did not change early and late postoperatively (early from 60.5 ± 11.4 to 57.2 ± 10.3 mm, late to 61.8 ± 9.6 mm).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preoperative (points)</th>
<th>Early postoperative (points)</th>
<th>Late postoperative (points)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global score</td>
<td>42.3 ± 9.6</td>
<td>29.3 ± 11.9</td>
<td>33.8 ± 16.1</td>
</tr>
<tr>
<td>Subsegment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterobasal</td>
<td>4.8 ± 3.1</td>
<td>3.2 ± 4.8</td>
<td>3.2 ± 3.2</td>
</tr>
<tr>
<td>Anterolateral</td>
<td>13 ± 3.7</td>
<td>7.2 ± 4.4</td>
<td>8 ± 4.2</td>
</tr>
<tr>
<td>Apical</td>
<td>13.9 ± 3.7</td>
<td>8.3 ± 5.9</td>
<td>12.2 ± 5.1</td>
</tr>
<tr>
<td>Diaphragmatic</td>
<td>8 ± 4.5</td>
<td>6.6 ± 6</td>
<td>6.6 ± 3.8</td>
</tr>
<tr>
<td>Postero basal</td>
<td>3.1 ± 4.8</td>
<td>2 ± 2.8</td>
<td>4.9 ± 4.3</td>
</tr>
</tbody>
</table>

Mitrail regurgitation increased early postoperatively (from 1+ to 2+) in one patients, and increased late postoperatively (from 1+ to 2+) in four patients. In two patients, mitral regurgitation decreased early postoperatively (from 2+ to 1+), and decreased late postoperatively (from 2+ to 1+) versus preoperative values in two patients.

Mean ejection fraction was preoperatively 47 ± 11%, early postoperatively 42 ± 10%, late postoperatively 34 ± 8.3%.

4. Discussion

The circular reconstruction for LV aneurysm has gained wide popularity for its innovative concept of a restored ventricular geometry [1,2,6,7].

This operation seems to overcome the problems related to the standard linear suture excluding the septal extension of the fibrotic process from the ventricular chamber, diverting myocardial fibers toward the apex, decreasing the tension on the transitional zone, and aiding the revascularization of the LAD. Nevertheless, hemodynamic improvements after standard aneurysmectomy remains controversial, and clinical results are debated.

Some authors [8–13] report an increase in clinical and hemodynamic variables after aneurysmectomy, others [14–18] record no improvements, nevertheless, none of these studies present a long-term follow-up.
Dor et al. [19] have published a study that prospectively evaluates a large series of patients subjected to patch repair of an LV aneurysm in whom preoperative and postoperative hemodynamic studies have been performed. In these patients, LV pump function and clinical status improved 1 year after the operation.

Shapira et al. [20] in 1997 have demonstrated that clinical results of endoaneurysmorrhaphy versus linear repair up to 5 years after the operation, resulted in a greater increase in postoperative left ventricular ejection fraction and a substantially improved long-term clinical outcome.

Our data show that in our study, global pump function is objectively improved early after surgery, but in the long-term it remains invariable.

Functional status is improved in the vast majority of patients in the long-term follow-up. Only five patients (12.8%) were still in New York Heart association class III or IV, and only 11 patients (28.2%) had angina.

There were no significant differences in hemodynamic data and hypokinesis score changes between the patients with patent graft and the 10 patients (25.6%) with occluded bypass graft, and between seven patients (17.9%) with mono or multivessel disease.

Patients who benefit most from the operation were those with a normal postoperative contraction pattern, where ejection fraction improved, respectively, early postoperatively from 43 ± 13 to 63 ± 11% (P < 0.001), and late postoperatively to 49 ± 10% (P < 0.001) versus preoperative values.

In conclusion, in our series of patients, who were studied hemodynamically both before and after surgery, endoventriculoplasty of LV aneurysm associated with coronary grafting improves clinical status late after operation. These patients present a satisfactory survival and quality of life up to 7 years after surgery. We registered a trend for a mild hemodynamic worsening, irrespective of coronary artery disease status, except in those patients who had shown a normal postoperative contraction pattern. These data suggest postoperative symmetrical contraction pattern to be prognostic for a better hemodynamic trend in the long-term follow-up.

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**Table 3**

Preoperative functional status and operative data of patients with restored or impaired systolic geometry

<table>
<thead>
<tr>
<th>Variable</th>
<th>Systolic geometry (n = 26)</th>
<th>Impaired (n = 13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF (%)</td>
<td>43 ± 13.4</td>
<td>43 ± 14.7</td>
</tr>
<tr>
<td>LVEDP (mmHg)</td>
<td>18.6 ± 7.1</td>
<td>14.9 ± 7.1</td>
</tr>
<tr>
<td>Global Score (points)*</td>
<td>42.8 ± 9.6</td>
<td>41.3 ± 10.1</td>
</tr>
<tr>
<td>EDD (mm)</td>
<td>60.4 ± 12.2</td>
<td>60.7 ± 9.7</td>
</tr>
<tr>
<td>No. of grafts/patient</td>
<td>2.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

*For scoring system, see Section 2.4. There were no significant differences between groups: EF, ejection fraction; LVEDP, left ventricular end-diastolic pressure; EDD, end-diastolic diameter.
References

[10] Dr F. Mohr (Leipzig, Germany): May I ask you a provocative question? These isometric contraction failures, are they from the beginning and can you diagnose them. Should we ask whether the endoventriculoplasty is the right procedure or should we consider the Batista procedure for those patients?
[11] Dr Di Mattia: I think that the endoventriculoplasty is the right procedure. This kind of analysis may be considered for the Batista procedure, but we have not yet operated on a patient with the Batista procedure in this case.

Appendix A. Conference discussion