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Left ventricular aneurysms: early and long-term results of two types of repair☆

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Abstract

Objective: Controversy still exists regarding the optimal surgical technique for postinfarction left ventricular (LV) aneurysm repair. We analyze the efficacy of two established techniques, linear vs. patch remodeling, for repair of dyskinetic LV aneurysms. **Methods**: Between May 1988 and December 2001, 110 consecutive patients underwent repair of LV aneurysms. These represent 2.0% of a total group of 5429 patients who underwent isolated CABG during the period. Seventy-six (69.1%) patients were submitted to linear repair and 34 (30.9%) to patch remodelling. There were 94 (84.5%) men and 17 women, with a mean age of 59.2±9.2 years. Coronary surgery was performed in all patients (mean no. of grafts/patient, 2.7±0.8) and 14 (12.7%) had associated coronary endarterectomy. Forty-four (40.0%) patients had angina CCS class III/IV (linear 43.4%, patch 32.4%, NS) and the majority was in NYHA class I/II (88.2% in both groups). Left ventricular dysfunction (EF>40%) was present in 72 (65.5%) patients (linear 61.8%, patch 73.5%, NS). **Results**: There was no perioperative mortality, and major morbidity was not significantly different between linear repair and patch repair groups. During a mean follow-up of 7.3±3.4 years (range 4–182 months) 14 patients (14.3%) had died, 12 (85.7%) of possible cardiac-related cause. Actual global survival rate was 85.7%. Actuarial survival rates at 5, 10 and 15 years were 91.3, 81.4 and 74%, respectively. There was no significant difference in late survival between the patch and the linear groups. At late follow-up the mean angina and NYHA class were, 1.3 (preoperative 2.4, $P<0.001$) and 1.5 (preoperative 1.7, NS), respectively, with no difference between the groups. There was no significant difference in hospital readmissions for cardiac causes (linear 22.8% and patch 37.0%). **Conclusions**: The technique of repair of postinfarction dyskinetic LV aneurysms should be adapted in each patient to the cavity size and shape, and the dimension of the scar. Both techniques achieved good results with respect to perioperative mortality, late functional status and survival.

Keywords: Left ventricular aneurysm; Linear repair; Patch repair

1. Introduction

Left ventricular aneurysms (LV aneurysms) are a common complication of myocardial infarction. The scarred area becomes increasingly thin and dyskinetic. The aneurysm absorbs part of the LV ejection, eventually leading to cardiac failure which may be refractory to medical therapy and require surgical treatment.

Surgical methods to restore the volume and shape of the left ventricle have evolved over the years. Surgical repair of LV aneurysms was first performed by Charles Bailey [1]. The first resection under cardiopulmonary bypass was reported by Denton Cooley and associates [2]. During the following decades, besides the traditional linear repair, newer patch remodeling techniques were devised and reported in an effort to improve results [3–6]. Although aneurysmectomy has been performed for almost five decades, the most appropriate surgical approach to a patient with a dyskinetic LV aneurysm is still controversial.

In this retrospective study we assess the early and late results of patients undergoing surgery by two techniques of repair of postinfarction dyskinetic LV aneurysms, namely patch remodeling and linear repair.

2. Material and methods

2.1. Patient population

From May 1988 to December 2001, 5429 consecutive patients were subjected to CABG. Of these, 110 (2.0%) underwent surgical repair of postinfarction dyskinetic LV aneurysms. All patients had simultaneous coronary revascularization. Patients who had other associated procedures

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Table 1
Preoperative patient characteristics (values in % unless indicated otherwise)

Variable	All patients ($n=110$)	Linear ($n=76$)	Patch ($n=34$)	P value
Age (years)	59.2±9.2	59.5±9.3	58.6±8.9	0.627
Body surface area (cm^2)	172.1±14.4	172.2±16.3	171.7±14.5	0.894
Male sex	84.5	89.5	73.5	0.033
Diabetes mellitus	15.5	18.4	8.8	0.260
Hypertension	56.4	57.9	52.9	0.628
Peripheral vascular disease	9.1	11.4	6.5	0.720
CCS class III/IV	40.0	32.4	43.4	0.274
NYHA class I/II	88.2	88.2	88.2	1.000
Left main disease	14.5	17.1	8.8	0.382
Non-elective surgery	8.2	9.2	8.2	0.718
LV dysfunction (EF<0.4)	65.5	61.8	65.5	0.234
Three-vessel disease	75.0	75.0	76.5	0.868
Anterior aneurysm	77.3	78.9	73.5	0.625

(e.g. valve surgery) are not included, to avoid eventual confounding factors. Seventy-six (69.1%) patients were submitted to linear repair and 34 (30.9%) to pacth repair. The diagnosis of LV aneurysms was made preoperatively by the angiographic appearance (paradoxical motion), and confirmed intraoperatively. The indication for surgery in patients with normal or moderately impaired LV function and low functional NYHA class was based on their coronary artery disease and angina class. In these cases, LV scars that clearly contained little muscle and were of important size, encountered during surgery for coronary artery disease, were excised.

Demographic, clinical, operative and perioperative, and in-hospital outcome data were collected prospectively and entered into a computerized database especially designed for patients receiving coronary revascularization procedures in our department. The variables selected for analysis were the following:

(1) *preoperative*—age, sex, body surface area, cerebral vascular disease, peripheral vascular disease, diabetes mellitus, history of hypertension, angina class (CCS, Canadian Cardiovascular Society), functional status (NYHA, New York Heart Association), reoperation, recent myocardial infarction, surgical priority (elective, urgent or emergent), number of vessels diseased, left main disease, left ventricular function (assessed by ventriculography or echocardiography or both);
(2) *operative*—type of repair (linear or patch), cardiopulmonary bypass time, number of grafts, coronary endarterectomy, use of double internal thoracic artery (ITA);
(3) *postoperative*—perioperative mortality, use of inotropic agents, use of mechanical assist, reoperation for bleeding or sternal complications, respiratory failure, acute renal failure, myocardial infarction, cerebrovascular accident, and length of hospital stay.

The definitions of some of these variables are indicated in Appendix A.

2.2. Preoperative clinical and angiographic data

Perioperative, clinical and angiographic data are detailed in Table 1. There were 93 male (68 linear, 28 patch, $P<0.001$) and 17 women (eight linear, nine patch). The mean age was 59.2±9.2 years (range 37–75 years) with no difference between the two groups. Seventeen (15.5%) patients were diabetic, and 62 (56.4%) had hypertension. Forty-four patients (40%) were in Canadian Cardiovascular Society (CCS) class III or IV and 13 (11.8%) were in NYHA functional class III or IV. Three-vessel disease was present in 83 patients (79.0%), 27 patients (20.0%) had double-vessel coronary disease, and 16 (14.5%) had left main disease. There was only one case (in the linear group) of redo-CABG among these patients. All patients had had at least one myocardial infarction (MI) and only two patients had history of recent MI (one linear, one patch). Eighty-five (77.3%) aneurysms were anterior with no significant difference between the two groups. Left ventricular dysfunction (EF<40%) was present in 65.5% (47 linear, 25 patch, NS). The majority (91.8%) of patients were operated on electively. No patient in our series had experienced embolic episodes from the aneurysm and none had implantable cardioverter defibrillators (ICDs) preoperatively.

A comparative analysis of the preoperative characteristics of the other 5319 consecutive patients subjected to isolated CABG during the study period is shown in Table 2.

2.3. Operative technique

Cardiopulmonary bypass was instituted using a bubble or membrane oxygenator and non-pulsatile flow. Surgery

Table 2
Comparative analysis of the preoperative characteristics between LV aneurysm repair and isolated CABG (values in % unless indicated otherwise)

Variable	LV aneurysm repair ($n=110$)	Isolated CABG ($n=5319$)	P value
Age (years)	59.2±9.2	60.4±9.2	0.178
Male sex	84.5	88.4	0.215
Diabetes mellitus	15.5	21.9	0.105
Hypertension	56.4	55.4	0.841
Peripheral vascular disease	9.1	8.9	0.953
CCS class III/IV	40.0	41.9	0.688
Left main disease	14.5	15.6	0.754
Non-elective surgery	8.2	8.1	0.965
LV dysfunction (EF<0.4)	65.6	14.0	<0.001
Three-vessel disease	75.0	74.2	0.774

was conducted under ventricular fibrillation and moderate hypothermia (30–32 °C) for the aneurysm repair and for the construction of the distal anastomoses using a technique we have previously described [7,8]. Under cardiopulmonary bypass, the diagnosis of dyskinetic LV aneurysms was confirmed visually and by palpation of the thinned wall of the left ventricle. In these cases, to avoid displacement of an eventual clot, the left ventricular vent was placed through the right superior pulmonary vein only after ventricular fibrillation was induced. An incision was then made over the aneurysm and, if present, clots were removed.

Depending on the size and shape of the left ventricular cavity, a portion of the thinned wall was resected. For the linear repair, depending on the consistency of the LV wall, the edges were either sutured directly (overlaping technique) or with two strips of Teflon using a combination of continuous and mattress sutures. For patch repair, the aneurysm was opened and an elliptical or circunferential patch of Teflon, covered on the ventricular side by autologous pericardium, was sutured to the 'red/white' border zone of the ventricular wall and septum, using a continuous 4-0 polypropylene suture. The excess aneurysm wall was resected, leaving a residual portion that was closed over the patch using a continuous 3-0 polypropylene suture. Endocardial mapping was not performed.

Once ventricular repair was completed, bypass grafting was carried out. Revascularization, including the area of LV aneurysm repair, was performed whenever indicated and technically possible.

2.4. Follow-up

Follow-up data were obtained directly from the patients and/or their general practitioners by telephone call or a written questionnaire. Data obtained included survival, functional status (NYHA) and angina class (CCS), and cardiac-related hospital readmission. Twelve patients (10.9%) were lost to follow-up because of migration or unknown reasons.

2.5. Statistical analysis

Data were retrieved from the database and were retrospectively analyzed with assistance of the Systat© statistical software. Continuous variables are expressed as mean ± SD. Categorical variables are presented as percentages. Groups were compared with use of Fischer's exact test, Student's *t*-test or the Mann–Whitney *U*-test, as appropriate. Survival curves were calculated according to the method of Kaplan and Meier and subgroups were compared using the Log-rank test (method of Breslow–Ghean).

3. Results

3.1. Intraoperative data (Table 3)

The mean cardiopulmonary bypass time was 82.7 ± 33.9 min with no significant difference between the two groups. Concomitant myocardial revascularization was performed in all patients. The left anterior descending artery was revascularized in 102 (93%) patients, predominantly (92.2%) with ITA (91 left, 3 right). ITA grafts were used in 105 (95.5%) patients for a mean of 1.2 ± 0.6 arterial anastomoses per patient (1.3 ± 0.6 linear, 1.0 ± 0.5 patch, $P=0.011$). The left ITA was used in 105 patients (99% linear, 88% patch, $P=0.015$). In 26 patients (23.6%) both left and right ITAs were used (29% linear, 6% patch, $P=0.050$). Additionally, a mean of 1.5 ± 0.8 venous anastomoses per patient were constructed. Endarterectomies were performed in 14 cases (12.7%).

3.2. Early results

There was no perioperative mortality (the mortality for isolated CABG during the period was 1.2%) and no significant difference was found in morbidity between the linear and patch groups (Table 4). Twenty-three patients (20.9%) required inotropic support, but only 6 (5.5%) for periods longer than 24 h. Mechanical support (intra-aortic balloon pump) was used in two patients (1.8%). Six patients (5.5%) developed acute renal failure, but none required dialysis and four patients (3.6%) had a myocardial infarction. Supraventricular arrhythmias, mainly atrial fibrillation, necessitating medical and/or electrical treatment occurred in 25 patients (22.7%). Five patients (4.5%) had an episode of ventricular fibrillation or tachycardia requiring electrical treatment. Five patients (4.5%) required re-exploration because of haemorrhage and one (0.9%) was reoperated for sternal dehiscence without mediastinitis. Six patients (5.5%) had a stroke, all with at least partial recovery. This is about double of that observed in non-aneurysm patients. The mean length of hospital stay was 8.9 ± 6.8 days.

3.3. Long-term results

Twelve patients were lost to follow-up. The mean follow-up time of the other 98 survivors was 7.3 ± 3.4 years (range 4–182 months), with no significant differences ($P=0.134$) between the pacth and the linear groups (8.1 ± 3.3 and

Table 3
Operative data (values in % unless indicated otherwise)

Variable	All patients ($n=110$)	Linear ($n=76$)	Patch ($n=34$)	*P* value
No. of grafts (mean/pt)	2.7 ± 0.8	2.8 ± 0.7	2.7 ± 0.8	0.401
No. of arterial grafts (mean/pt)	1.2 ± 0.6	1.3 ± 0.6	1.0 ± 0.5	0.011
Left ITA	95.5	98.7	88.2	0.015
Double ITA	23.6	11.8	28.9	0.050
Coronary endarterectomy	12.7	14.5	8.8	0.543
Mean CPB time (min)	82.7 ± 33.9	80.2 ± 37.6	88.4 ± 23.4	0.169

Table 4
Early outcome results

Variable	All patients ($n=110$)	Linear ($n=76$)	Patch ($n=34$)	*P* value
Mortality	0	0	0	
Inotropic support	20.9	22.4	16.6	0.574
Mechanical support	1.8	0	5.6	0.094
Low cardiac output syndrome	20.9	22.4	17.6	0.574
Stroke	5.5	5.3	5.9	1.000
Ventricular fibrillation or tachycardia	4.5	2.6	8.8	0.170
Reoperation for bleeding	4.5	5.3	2.9	1.000
Hospital stay (mean days)	8.9 ± 6.8	8.4 ± 3.3	10.1 ± 10.3	0.335

Univariate comparative analysis between the linear and patch groups (values in % unless indicated otherwise).

7.0 ± 3.5 years, respectively). Fourteen patients (14.3%) had died, 12 (85.7%) of possible cardiac-related cause.

The cumulative survival for the entire group is shown in Fig. 1. Actual global survival rate was 85.7%. Actuarial survival rates at 5, 10 and 15 years were 91.3, 81.4 and 74%, respectively. Ten-year survival was 84.6% in the pacth group and 79.7% in the linear group. However, comparison of survival curves between the two groups revealed no significant difference (Fig. 2).

The NYHA functional class for the entire group changed from 1.7 ± 0.7 preoperatively to 1.5 ± 0.8 at the last follow-up ($P=0.783$). There was also no significant difference between the groups (patch from 1.8 ± 0.7 to 1.6 ± 0.9, linear from 1.6 ± 0.7 to 1.5 ± 0.7). On the other hand, the CCS angina class improved significantly ($P>0.001$) for the entire group from 2.4 ± 1.3 preoperatively to 1.3 ± 0.7 at follow-up, and there was also a significant difference ($P<0.001$) between the two groups (patch from 2.3 ± 0.6 to 1.5 ± 0.8, linear from 2.4 ± 0.8 to 1.2 ± 0.6) (Table 5).

The incidence of hospital readmission for cardiac causes was 27.4% (23 patients) without significant difference ($P=0.172$) between the two groups (linear, 22.8%; patch, 37.0%).

4. Discussion

Repair of postischemic left ventricular aneurysms goes back to 1954 when Bailey successfully performed the first left ventricular aneurysmectomy with the help of a partially occluding, side-biting clamp on a beating heart [1]. In 1958,

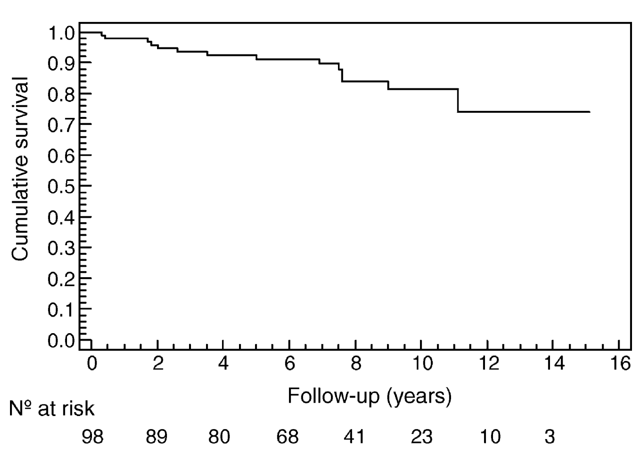

Fig. 1. Cumulative survival for the entire group of patients.

Cooley [2] first performed left ventricular aneurysmectomy by plication and linear closure under extracorporeal circulation. Subsequently, the philosophy of regaining the normal left ventricular geometry led to surgical methods aimed at restoration of the elliptical shape of the left ventricle. These include excision, plication, septoplasty/plication, and overlap techniques, grossly classified as linear repair, or patch repair methods.

In the linear repair the usual technique is direct suture of the two edges. When reconstruction is performed with this technique, a line of closure is selected that will least distort the LV. The edges are either sutured directly or supported by two strips of Teflon. Alternatively, the aneurysm can be repaired using an overlap technique or by a modified linear technique, eventually combined with septoplasty.

As for the patch repair there are two main techniques: the circular patch and the endoventricular patch. Identical versions of the latter have been termed *endoaneurysmorrhaphy* by Cooley [5] or *endoventricular circular pacth plasty repair* by Dor [4]. The rationale for endoventricular pacth is in part based on the fact that the area of septal scarring can be excluded from the reconstructed LV which is also remodeled and/or resized appropriately.

Although these and other surgical methods have evolved over last decade and a half, the most appropriate surgical approach to the treatment of dyskinetic LV aneurysms is still controversial. On purely theoretic considerations [9-11], patch remodeling of postinfarction LV aneurysms improves

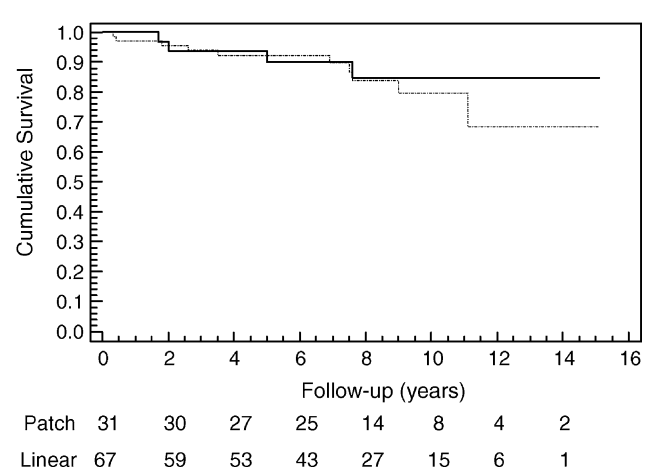

Fig. 2. Cumulative survival for patients with pacth (dashed line) or linear repair (continuous line), showing no significant difference ($P=0.6$) between the two groups (Log-rank test). Numbers of patients at risk for each time-interval are indicated at the bottom.

Table 5
Follow-up results (values in % unless indicated otherwise)

	All patients ($n=84$)	Linear ($n=57$)	Patch ($n=27$)
NYHA (mean)	1.5±0.8	1.5±0.7	1.6±0.9
Angina CCS class (mean)	1.3±0.7	1.2±0.5	1.5±0.8
Hospital readmission	27.4	22.8	37.0

P, NS.

ventricular geometry, thus contributing to better early and late outcome [12-14]. But some retrospective clinical studies failed to demonstrate any difference between linear and patch repairs [15-20].

In this study, we compared the early and late results of 110 consecutive patients undergoing repair of postinfarction dyskinetic LV aneurysms non-randomly assigned to either linear or patch repair. All procedures were performed by the same surgeon and there was no difference in the intraoperative management with regard to the myocardial protection strategy. Another limitation for this comparison lies in the fact that the preoperative cardiac status of the two groups was not identical. Generally, the choice of the repair technique depended on factors such as localization, size and extension of the scar. An extensive and clearly defined fibrotic globoid aneurysm sac with a well formed neck, especially when located in the or near the apical area, generally led to patch repair, while in a wide-based dyskinetic segment imprecisely separated from the surrounding viable myocardium a linear repair was usually preferred. Hence, it can be speculated that patients operated on by the linear technique could be expected to have better preoperative cardiac status and, thus, a better immediate outcome and late survival should have been expected in this group. Therefore, the following comments must be considered with this in mind.

In this study there was no perioperative mortality. This result, that compares favorably with other recently published studies [12-14,16-21], where the reported hospital mortality ranged from 2 to 8%, could be attributed, at least in part, to differences between patient populations. In fact, some of those studies include patients in more advanced NHYA class and LV dysfunction and cases with concomitant mitral valve surgery. All these constitute established risk factors for hospital mortality. It is precisely for this reason that in the last decade we followed a strict policy of preoperative modulation of modifiable risk factors, such as functional class. Even LV function can be clearly bettered by aggressive anti-failure therapy. We feel very confident that this policy became life-saving for many patients. For argument sake, the mortality for isolated CABG during this period was 1.2%.

The most common in-hospital complications found in this study were low cardiac output (20.9%), ventricular arrhythmias (4.5%), stroke (5.5%) and bleeding (4.5%), and there were not significant differences between the linear and patch groups. These results are comparable to those reported by other authors [16,17,22].

The 5-year survival in our patients (91.3%) also compares favourably with those reported in recent series, between 73 and 90% [12-21]. Again, as was the case with early results, the late results are variable, and largely dependent on the differences in patient populations.

As others have found [13,16,17,19,21,23], we have demonstrated a significant improvement in the angina class after operation (from 2.4 to 1.3). By other hand the mean NYHA class remained basically unaltered as we could find only a small change (from 1.7 to 1.5).

In conclusion, the controversy regarding whether patch repair provides results superior to those achieved with the more classical linear closures is likely to remain unanswered. We are unaware of any prospective studies comparing the results of the two procedures, but several studies [12-14] showed improved early and/or late results with patch techniques, while others [15-20] reported no differences between linear and patch repairs. In our experience, we could not demonstrate significant differences either in the early or in the late results between the two techniques, possibly also because the groups are different and the patients were not really the sickest ones, especially with regard to the condition of the remote myocardium.

We believe that the technique of repair of postinfarction dyskinetic LV aneurysms should be adapted in each patient to the cavity size and shape, and the dimension of the scar. Although this study is retrospective and the patients in the two groups were not entirely similar, both patch and linear repair achieved good results with respect to perioperative mortality, late functional status and survival.

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Appendix A

Variables	Definitions
Diabetes mellitus	History of diabetes treated with oral agents or insulin
Hypertension	Blood pressure exceeding 140/90 mmHg, or a history of high blood pressure, or the need for antihypertensive medications
Peripheral vascular disease	Manifested by one or more of: exertional claudication and/or rest pain, prior revascularization procedure to the lower limbs, absent or diminished pulses in the legs, angiographic evidence of non-iatrogenic peripheral arterial obstruction of $\geq$50% of the luminal diameter
Cerebrovascular disease	Previous stroke and/or transient ischemic attack
Recent AMI	Evidence of AMI in the last 30 days before surgery
Unstable angina	Use of intravenous nitrates within 48 h of surgery
Left main disease	Stenosis of 50% or greater
Left ventricular function	Assessed by ventriculography and/or echocardiography
Reoperation	History of prior CABG
Perioperative mortality	Death occurring within 30 days of the operation or during the same hospitalisation
Inotropic support	Use of any inotropic agent after the patient left the operating room, for any period of time
Mechanical support	Intra-aortic balloon and/or left ventricular assist device
Acute renal failure	Postoperative creatinine serum level $\geq$2.5 mg/dl in patients with preoperative levels $\leq$2.0 mg/dl
Cerebrovascular event	Transient ischemic attack or stroke
Low cardiac output syndrome	Need for postoperative inotropic support, for any length of time, and/or mechanical support in the intensive care unit

Appendix B. Conference discussion

Dr O. Oto (*Izmir, Turkey*): I have got around 30 cases of Dor operations so far with zero mortality, which is similar to your results, but I am amazed with your results with linear ones. In linear aneurysmectomy that I have done two to five years ago I have got around 4–5% mortality. I strongly suggest to perform the Dor operation because of very low mortality, zero mortality so far, similar to yours, but can you comment on your linear type of aneurysmectomy, why you don't have any mortality there?

Dr Antunes: I stress two points. First, the global mortality for the more tan 4000 patients who had isolated coronary surgery during this period was 1.0. So the fact that we had zero mortality in this case, it is just a statistical fact. But on the other hand, it is important, and I didn't stress that well enough, this study excludes all patients who had all other types of pathology; no valves, no valve involvement, no valve repairs. These were just patients whose only factor was the presence of an aneurysm.

Dr R. Deac (*Mures, Romania*): For years we were looking for a technique to repair a left ventricular aneurysm. My question is what were the criteria by which you assigned patient to linear or to patch reconstruction in your study?

Dr Antunes: All these operations were done by the same surgeon, that is myself, and basically it is a decision of the moment. The feeling is that if the aneurysm is more apical, therefore the longitudinal diameter of the ventricle is longer, then a patch repair is probably more likely to restore the shape of the ventricle.

If, on the other hand, you have either a lateral or a posterior aneurysm, then the linear repair appears to be more logical, and that is what we did. That is, we do not have a specific rule of thumb to decide when to do one or the other. And this was a conclusion that was surprising to me because I tended to believe that we should do more and more the Dor type procedure, and these results do not lead to that conclusion.

Dr J. Dinkhuysen (*San Paulo, Brazil*): I would like to know if you revascularized the artery of the infarct which promoted the aneurysm of the ventricle?

Dr Antunes: We tended not to, except for the anterior descending artery. That artery, if it is still patent, we will do our best to revascularize. That is exactly the opposite for the posterior descending artery. Usually, it is a fibrous cord and then we tend not to complicate the procedure by doing the graft of that artery.

Dr T. Wahlers (*Jena, Germany*): Don't you think that the assessment by echo determining endsystolic volume after remodeling might help you in the future to assess whether this or that procedure might be more advantageous in the specific patient?

Dr Antunes: You must realize that this was just a retrospective observational study on prospectively collected data. The results surprised us, and we will have to re-analyze each individual patient and see whether we can find any anatomical factor that in fact influences these results. It is a matter for thought in the near future in our unit.