CLINICAL SCIENCE

Efficacy of aneurysmectomy in patients with severe left ventricular dysfunction: favorable short- and long-term results in ischemic cardiomyopathy

Carlos Vicente Serrano Jr.,[I] José A. F. Ramires,[II] Alexandre de Matos Soeiro,[I] Luiz Antônio M. César,[II] Whady A. Hueb,[II] Luiz A. Dallan,[III] Fábio B. Jatene,[III] Noedir A. G. Stolff[III]

[I]Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, Unidade Clínica de Coronariopatias Agudas, São Paulo, SP, Brazil. [II]Instituto do Coração, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, Departamento de Cardiopneumologia, São Paulo, SP, Brazil. [III]Instituto do Coração, Hospital das Clínicas, Faculdade de Medicina, Universidade de São Paulo, Departamento de Cirurgia Cardíaca, São Paulo/SP, Brazil.

INTRODUCTION: The purpose of this study was to (1) identify the functional results after aneurysm surgery in patients with ischemic cardiomyopathy and (2) identify predictors of favorable outcomes.

METHODS AND MATERIAL: Patients (n = 169) with angiographic left ventricular ejection fraction of 22 ± 5% underwent aneurysm surgery and were prospectively followed for three years. Prior to surgery, 40% and 60% of the patients were in congestive heart failure NYHA class I/II and III/IV, respectively. Concomitant revascularization was performed on 95% of the patients.

RESULTS: Cumulative in-hospital and 36-month mortalities were 7% and 15%, respectively. These respective rates varied according to preoperative parameters: CHF class I-II, 4% and 13%; CHF class III-IV, 8% and 16%; LVEF<20%, 12% and 26%; LVEF 21-30%, 2% and 6%; gated LVEF exercise/rest >5%, <1% and 4%; and gated LVEF exercise/rest ≤5%, 17% and 38%. Higher LVEF ex/rest ratio ($p = 0.01$), male sex ($p = 0.05$), and a higher number of grafts ($p = 0.01$) were predictive of improvement in CHF class at follow-up based on the results of a multivariate analysis. After three years of follow-up, 84% of the patients were in class I/II, LVEF was 45 ± 7%, and gated LVEF ex/rest ratio was 13% higher ($p<0.01$) compared to the beginning of the study.

CONCLUSIONS: These data suggest that aneurysmectomy among patients with severe LV dysfunction result in short- and long-term favorable functional outcome and survival. Selection of appropriate surgical candidates may substantially improve survival rates among these patients.

KEYWORDS: Myocardial revascularization; Ventricular dysfunction; Ischemic cardiomyopathy; Cardiac surgery; Aneurysmectomy.

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E-mail: alexandre.soeiro@bol.com.br

Tel.: 55 11 3067-7427

INTRODUCTION

The term ischemic cardiomyopathy (ICM) is used to describe the clinical picture and pathological findings in patients with congestive heart failure secondary to ischemic heart disease. Manifestations of congestive heart failure are common in patients with coronary artery disease. They may be the dominant feature in those who have sustained prior myocardial infarctions with ischemic areas replaced by fibrous tissue, with disappearance or reduction of angina symptoms. The three most common causes of congestive heart failure in this setting are left ventricular aneurysm, mitral regurgitation due to dilatation of the mitral annulus and/or papillary muscle ischemic dysfunction, and an inadequate quantity of normally contracting myocardium.[1,2] ICM can also result from myocardial hibernation, which is characterized as a situation of reduced regional contractile function distal to a coronary artery stenosis from which the individual recovers after removal of the coronary stenosis.[3]

Patients who have untreated infarct-related ventricular aneurysms that compromise 20% to 25% of the left ventricular area develop progressive global ventricular dilatation. The rationale for congestive heart failure among ventricular aneurysms is that the fraction of blood that enters the region of the aneurysms causes an overload state, and severe global dilatation of the heart ensues over time.[3] The surgical treatment of left ventricular dysfunction has evolved gradually. Initially, it was demonstrated that patients with large ventricular aneurysms and severe cardiac failure improved with resection of the ventricular

aneurysm.[3] Surgical therapy of ventricular aneurysms evolved further with the intracavitary patch techniques of Jatene,[2] Dor,[1] and Cooley[4] that have yielded excellent surgical and functional results. However, the clinical and survival benefits of aneurysmectomy when severe left ventricular dysfunction is present remained controversial until the STICH trial in 2009, the results of which showed no reduction in the rate of death or hospitalization for cardiac causes in patients submitted to aneurysmectomy.[5] Therefore, the objective of this study was to describe the short- and long-term functional results after aneurysmectomy surgery in ICM and to identify predictors of a favorable outcome.

METHODS AND MATERIAL

Patient population. Between June 1992 and December 1995, 169 consecutive patients with ischemic heart disease underwent aneurysmectomy surgery at our institution. Prior to data collection, this study was approval by the ethics committee. Baseline clinical characteristics of patients are shown in Table 1. The three-year follow-up period was completed in 2001 by means of telephone contact or office visits. Follow-up consisted of obtaining information about the functional class of congestive heart failure (New York Heart Association), angina (Canadian Cardiovascular Society [CCS]), and survival data using a medical questionnaire.

Coronary angiography was conducted with all patients. In addition, the number of diseased coronary vessels (lumen narrowing $\geq$ 70%) was assessed. Global left ventricular ejection fraction (LVEF) was also measured by contrasted ventriculography. Left ventricular dysfunction was characterized by an ejection fraction $\leq$ 30%. Left ventricular aneurysm was defined as a zone of paradoxical systolic expansion (dyskinetic) or as an akinetic myocardial zone well delimited from the surrounding cardiac silhouette. Viability data were obtained by echocardiographic stress test or thallium scintigraphy for all patients. Baseline coronary angiography and ventriculography data are shown in Table 2. The indication for surgery was left ventricular failure, refractory to medical therapy, in the presence of an anatomic left ventricular aneurysm and concomitant coronary stenosis suitable for coronary artery bypass grafting (CABG).

Table 1 - Baseline clinical characteristics of the study population (n = 169).

Characteristic, n (percentage)	
Men	111 (66%)
Age (in years)	61 $\pm$ 9 (range: 31-78)
Arterial hypertension	76 (45%)
Smokers	75 (44%)
Total cholesterol > 240 mg/dL	64 (38%)
Diabetes	59 (35%)
Months since myocardial infarction	9.4 $\pm$ 6.2 (range; 1.5-32)
Functional class (CHF NYHA)[a]	
I	16 (9%)
II	53 (31%)
III	59 (35%)
IV	41 (25%)
Electrocardiographic Findings	
Sinus rhythm	135 (80%)
Atrial fibrillation	84 (20%)
Left anterior divisional block	81 (48%)
Left bundle branch block	53 (31%)
First degree atrioventricular block	38 (22%)
Third degree atrioventricular block	6 (4%)

[a]CHF NYHA, congestive heart failure according to the New York Heart Association.

Table 2 - Baseline angiographic data of the study population (n = 169).

Characteristic	
Lesion on left anterior descending artery (LADA) n(%)[a]	
Occlusion of LADA	87 (51%)
Critical stenosis of LADA (70-99%)	52 (31%)
< 70% stenosis of LADA	30 (18%)
Type of lesion n(%)[b]	
Uniarterial lesion	51 (30%)
Biarterial lesions	62 (37%)
Triarterial lesions	56 (33%)
Left ventricular ejection mean $\pm$ SD	22 $\pm$ 5% (range: 11-30)

[a]Between lesions on LADA: $p<0.0001$.
[b]Between types of lesion: $p = 0.58$.
Note: Left ventricular ejection fraction measured by contrasted ventriculography. Data expressed as number or percentage.

Operative procedures. With the patient supported on normothermic cardiopulmonary bypass, the heart was carefully examined to confirm the extension excise portion of a nonfunctioning wall previously analyzed by echocardiography or ventriculography. Once thinning of the nonfunctioning area was confirmed, a small incision was made. Any clot present was carefully removed. With the unloaded heart opened and beating, the surrounding wall was palpated, and its ability to contract (regional wall thickening) was reliably assessed. All thinned nonfunctioning portions of the wall were considered for resection.

Excision was planned to remove as much nonfunctioning wall as possible while restoring ventricular size and shape toward normal conditions as described by Jatene.[2] In many cases, the excised specimen was composed of a mixture of infarcted and viable muscle. In addition, repair sutures were often placed through relatively thick areas of myocardium. Sutures were positioned further apart on the tissue edges than on the felt strips so that the length of the incision was plicated in the closure to help to restore the shape of the ventricle toward normal conditions.

In most patients with an anterior aneurysm, scarring of the septum was observed. However, only in cases in which a major portion of the septum was both scarred and thinned was a septoplasty performed, as previously described. The anterior edge of the patch was incorporated into the ventricular closure. Once ventricular repair was completed, bypass grafting was carried out when indicated. Retrograde cardioplegia and antegrade cardioplegia or infusion down a right graft were utilized to protect the left and right ventricle, respectively. Complete revascularization was performed in all patients according to the noninvasive test performed.

In this study, a total of 290 grafts were accomplished, providing a grafts/patient ratio of 1.8 $\pm$ 0.4 (see Table 3). Nine patients with left anterior descending artery lesion did not receive any kind of graft. Intraoperative transesophageal echocardiography was conducted to confirm mitral insufficiency. If confirmed, both a left atriotomy and a left ventriculotomy through the aneurysm were performed. If the mitral valve was so severely diseased that it could not be repaired, a prosthetic mitral valve was implanted. After

Table 3 - Surgical treatment.

All grafts	290
Left internal thoracic artery	132
Right internal thoracic artery	46
Radial artery	32
Safena vein	80
Grafts/ patient	1.8 ± 0,4
Mitral valve replacement/repair	13

completion of the myocardial revascularization and mitral valve surgery, attention was directed toward the repair of the ventricular aneurysm. Mitral repair/replacement was done in 13 cases.

Statistical analysis. Spearman's rank test was used for correlations, whereas multiple regression analysis was utilized to assess the potential associations. The cumulative probability of events was determined using the Kaplan-Meier method, and differences in the distribution of events during the three-year study period were evaluated with the log-rank test. A p-value ≤ 0.05 was considered to be statistically significant.

RESULTS

Early post-operative care. Seven (4.1%) patients died in the hospital due to cardiac causes. Results of univariate analyses demonstrated that angina was associated with a decreased risk of hospital mortality ($p = 0.04$), whereas prolonged duration of cardiopulmonary bypass was associated with an increased risk of hospital mortality ($p = 0.03$). When entered into the multivariate analysis, none of the variables examined proved to be predictive. Specific features in the postoperative treatment in the intensive care unit are shown in Table 4. Significant differences occurred between patients who survived and patients who died during hospitalization.

Late clinical follow-up. Of the initial 169 patients, contrast ventriculography (for LVEF determination) was repeated on 133 (79%) patients at 6 months, 90 (53%) patients at 12 months, and 75 (44%) patients at 36 months. The initial LVEF of 22±5% increased significantly to 40±3% at 6 months and 45±6% and 45±7% at 12 and 36 months, respectively (see Figure 1). After three years of follow-up, we had information about 83% (140) of patients included in study. Ten (6.3%) late casualties were recorded during the follow-up period. Actuarial survival was 91.1%, 90.5%, and 89.2% at one, two, and three years, respectively

Table 4 - Post-surgical in-hospital data.

	Total (n = 169)	Survived (n = 158, 93%)	Died (n = 11, 7%)
Intensive care unit (in days)[a]	16±4	12±3	19±3
Hospital stay (in days)[a]	27±9	15±4	33±5
Need of vasoactive agents, n(%)[a] *	109 (64%)	98 (62%)	11 (100%)
Need of mechanical ventilation n(%)[b] *	3.4±2.1	0.8±0.2	4.8±0.5
Acute renal failure n(%)[a]	19 (11%)	8 (5%)	11 (100%)
Urinary or respiratory tract infection n(%)[c]	11 (7%)	31 (20%)	8 (73%)

Between patients who survived and patients who died during hospitalization: [a]$p<0.0001$, [b]$p<0.01$, [c]$p = 0.001$.* = more than 24 hours after surgery. Mean±SD.

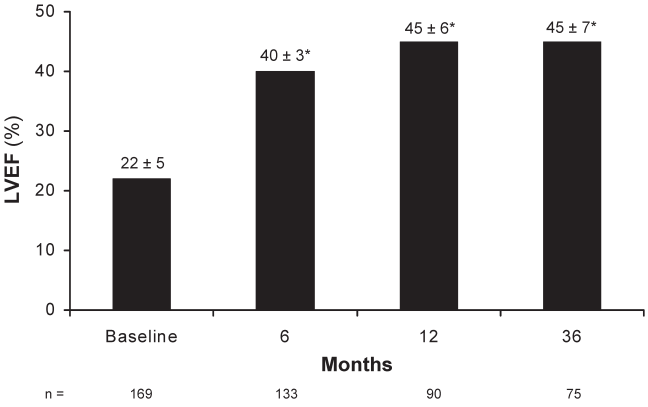

Figure 1 - Left ventricular ejection fraction (LVEF) determined by contrast ventriculogram.

(see Figure 2A). Actuarial survival rates based on baseline characteristics are shown in Figures 2B, 2C, and 2D.

There was a successful functional outcome of myocardial revascularization as evidenced by a significant improvement in congestive heart failure NYHA class, gated LVEF ex/rest ratio by radioisotopic ventriculography performed at 2 and 36 months, and contrast ventriculography. Congestive heart failure classes I, II, III, and IV were observed in 81 (56%), 42 (29%), 16 (10%), and 8 (5%) operative survivors at follow-up, respectively (see Figure 3). Angina classes (CCS) I/II and III/IV were observed in 54% and 16% of patients, respectively, at three-year follow-up. In 30% of patients, we did not observe angina.

Several variables were identified as correlates of recurrent heart failure. In particular, lower LVEF, presentation with congestive heart failure, and need for preoperative IABP were associated with a greater likelihood of recurrent heart failure, whereas higher LVEF ex/rest ratio ($p = 0.01$), male sex ($p = 0.055$), and higher number of grafts ($p = 0.01$) were predictive of improvement in congestive heart failure class at follow-up.

DISCUSSION

These data suggest that, among patients with severe left ventricular dysfunction, aneurysmectomy results in favorable short- and long-term functional and clinical outcomes, which lead to satisfactory survival rates. Selection of appropriate surgical candidates and extensive use of concomitant revascularization substantially improves survival rates. Currently, aneurysmectomy is considered to be a prominent surgical technique of left ventricular reconstruction for either dyskinetic or akinetic left ventricular segments in patients with ICM. Dyskinetic/akinetic left ventricular segments almost exclusively involve the left ventricle, most commonly the anterior or apical segments. For the detection of left ventricular dyskinetic/akinetic segments, biplane left ventriculography is a precise method that is available for outlining left ventricular segments, assessing septal motion, and determining the quantity of functioning residual myocardium.[4] Nevertheless, other noninvasive methods, such as magnetic resonance imaging, that were unavailable at the time of the study are gaining popularity. Aneurysmectomy associated with concomitant CABG improves ventricular function in patients with severe coronary artery disease and severe left ventricular dysfunction.

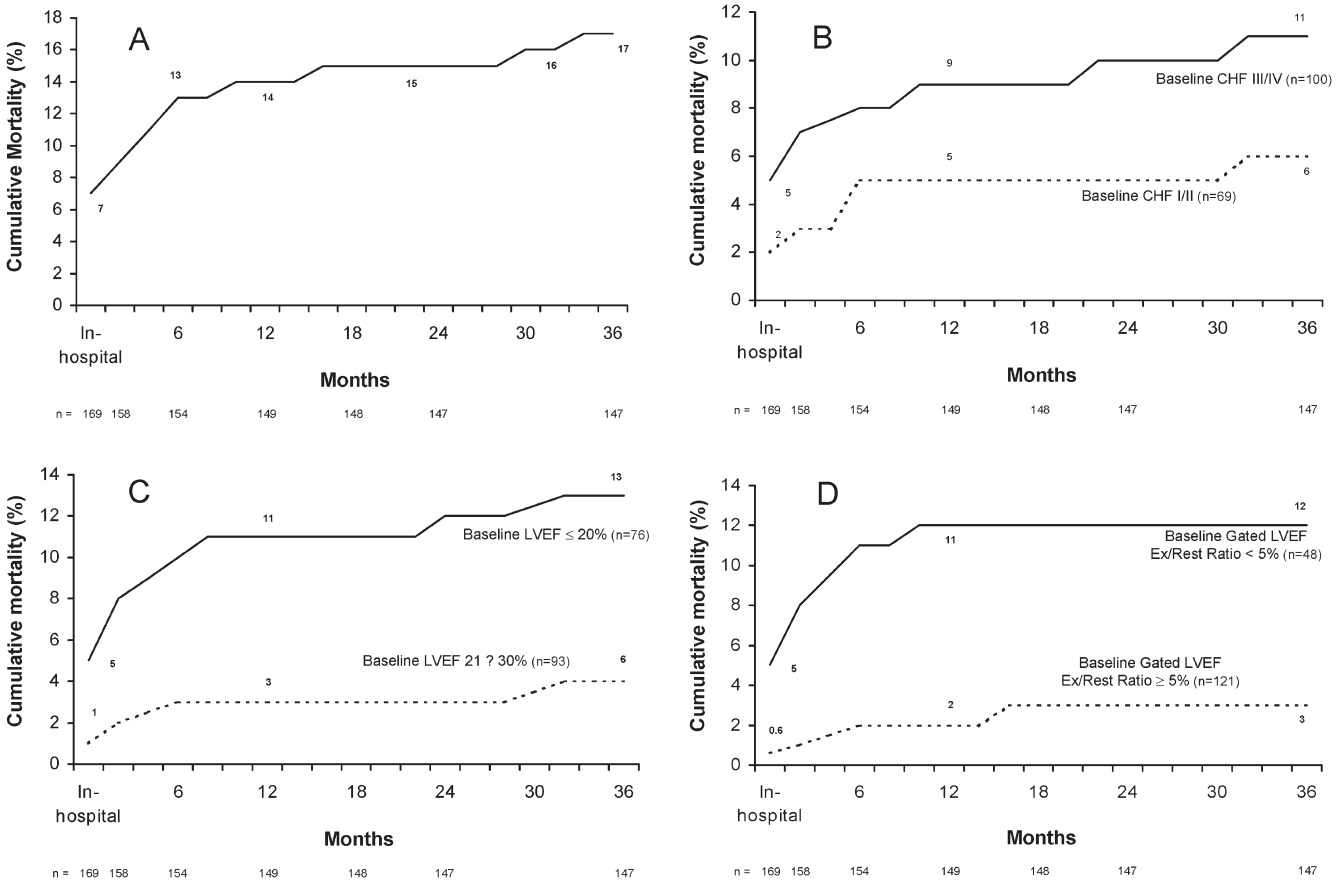

Figure 2 - Cumulative mortality: A, global; B, according to baseline congestive heart failure New York Heart Association classification (CHF NYHF); C, according to baseline left ventricular ejection fraction (LVEF); D, according to baseline gated left ventricular ejection fraction (LVEF) exercise (ex)/rest ratio.

Functional outcome. Few clinical series have focused on the functional outcome after myocardial revascularization in ICM. Most researchers have verified that short- and long-term survival rates after surgery are acceptable. The disclosure of short-term progress in left ventricular systolic performance has generally been viewed as an indicator of successful functional effect.[6,7] Contrary to this hypothesis, present evidence suggests that an increase in left ventricular ejection fraction is not accompanied by clinical improvement.[6] These findings have significant implications because clinical management of congestive heart failure has also produced significant progress in terms of both survival and

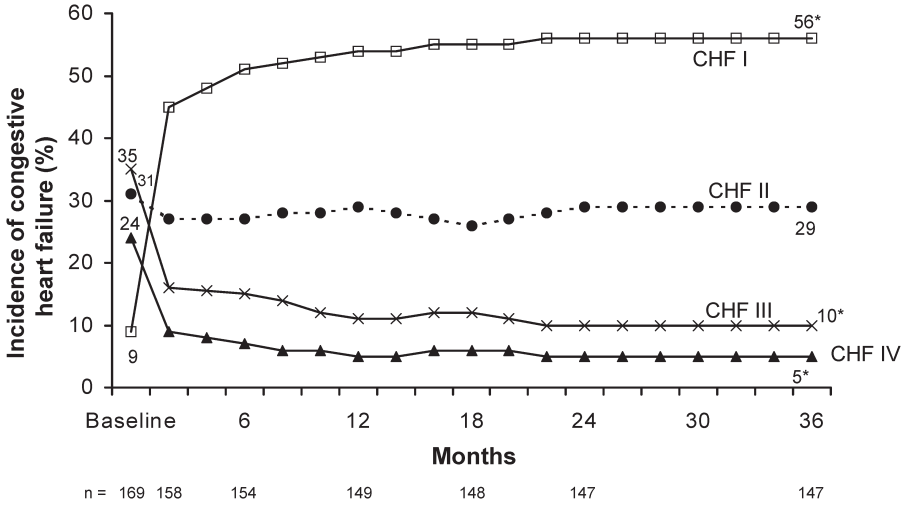

Figure 3 - Incidence of congestive heart failure after surgery according to functional class (New York Heart Association classification). *$p<0.01$ vs. baseline.

control of symptoms.[7] Thus, the preference of the most advantageous therapeutic modality for a specific patient with ischemic left ventricular dysfunction must be well thought out. Merely considering survival may be inadequate to distinguish among therapeutic options.

For the most part, congestive heart failure is accountable for the satisfactorily low occurrence of symptoms late after surgery. Estimates of recurrent heart failure are well described and differ broadly from other studies of patients with ICM, ranging from 28% to 63%.[7] The current findings are consistent with those of previous studies. It is possible that the cases of recurrent heart failure point to the unyielding development in the direction of left ventricular dysfunction.[7] Determination of left ventricular ejection fraction by echocardiogram is reasonable to reveal the relationship between left ventricular systolic function and congestive heart failure late after revascularization.

Predicting the recurrence or appearance of the symptoms of congestive heart failure has immeasurable relevance in terms of patient selection. The present study linked the greater possibility of heart failure at follow-up after aneurysmectomy with female sex, history of congestive heart failure, lower ejection fraction, and need for preoperative IABP support. In addition, history of angina, use of the left internal thoracic artery, and number of bypass grafts were inversely related to recurrence of congestive heart failure.

The importance of demographic characteristics before surgery is quite obvious, even though a relation with recurrent heart failure has not been previously described. In fact, lower ejection fraction has frequently been associated with unfavorable long-term outcomes after revascularization in ICM, as have history of congestive heart failure and female sex.[7] The requirement for preoperative IABP may predict which patients will have more severe left ventricular failure. Assessment of known evidence is problematic because not many researchers have investigated the recurrence of congestive heart failure in large clinical trials.

Whereas the clinical variables *per se* have an influence on patient selection, the operative variables examined in this study have applicable management connotations. Evidence suggests that more widespread exploitation of left internal thoracic artery grafts and complete myocardial revascularization can diminish the recurrence of congestive failure in the short- and long-term following surgery. This finding is consistent with inferences made by previous researchers regarding the overall revascularization patients.[7-20] Failure to previously demonstrate an association on ICM between the sort of graft for bypass and long-term coronary events by other investigators may be related to the decreased application of the left internal thoracic artery (i.e., between 20% and 35% when informed).[7] The rationale for not employing the left thoracic artery in the past in patients with ICM was due to apprehension about complications related to advanced age, urgency of revascularization, and reserved anxiety about long-term prognosis.[16] However, the findings of this study and other recent studies[16,17,19-23] suggest that there is little cause for concern. Thus, patients with ICM should be managed with a left internal thoracic artery graft when revascularization is selected therapy.[15]

Survival. Coronary artery bypass grafting has advanced into a secure therapy approach for selected patients with ischemic left ventricular failure. The present study demonstrated that myocardial revascularization can currently be accessible to patients with ICM at a low operative hazard (as low as 2%) and with a reasonable long-term follow-up. Assessment of survival estimates after coronary artery bypass grafting with previously published series presents some limitations.[15] In particular, patient selection principles are not consistent among the various clinical reports with regard to the values of left ventricular ejection fraction and the inclusion of patients with acute myocardial infarction, left ventricular aneurysm, or valve disease who require surgical management.[5] Despite these limitations, a surgical mortality rate varying from 2% to 10% has been reported for a considerable number of consecutive patients.[6,7,14,16,17,19,20,22]

Consistent with previously reported actuarial 5-year survival rates between 64% and 73%,[16,17,19,20,22] the long-term outcomes after myocardial revascularization were also satisfactory in the present study. Progress in perioperative management of patients with end-stage ischemic heart disease[6] has been instrumental in transitioning bypass grafting from a high-risk neglected alternative to transplantation[6,7] to a low-risk routine modality. However, the constant evolution throughout the last decade of time of patient selection criteria by means of prospective laboratory investigation and of retrospective risk stratification has played an even more important role in this transition.[6,22]

Consequently, reviews of large clinical series, such as the current one, have been conducted to isolate preoperative variables that may predict the outcome of revascularization. Analysis of previous studies shows that a sequence of patient characteristics, including advanced age, female sex, lower ejection fraction, comorbid conditions, urgency of operation, and reoperation, may be linked to increased operative risk.[6,18,24-32] In the present study, both late overall and late cardiac mortality were associated with lower ejection fraction, fewer bypass grafts, and longer duration of cardiopulmonary bypass.

The association between preoperative left ventricular function and short- and long-term survival is instinctive because it describes the severity of ischemic left ventricular failure.[14] The number of bypass grafts in the present series highlights the completeness of the revascularization because two thirds of patients had two- and three-vessel disease. Accordingly, the finding of an inverse relationship between the number of grafts and mortality is consistent with the results of Luciani and colleagues,[3] who reported that complete myocardial revascularization was inversely linked to mortality. Complete revascularization of the myocardium has vast prognostic implications for survival.[6] In addition, the role of the length of cardiopulmonary bypass in predicting morbi-mortality must also be considered. This additional aspect emphasizes the magnitude of ischemic heart disease, where prolonged circulatory assistance may be mandatory to wean a deteriorating heart from bypass.[3]

Recently, the Surgical Treatment for Isquemic Heart Failure (STICH) trial studied surgical ventricular reconstruction added to CABG in 1,000 patients with heart failure (LVEF of 35% or less) caused by coronary artery disease.[5] The patients were randomly selected to undergo CABG alone or CABG with surgical ventricular reconstruction; the median follow-up was 48 months. The findings of this study showed that adding surgical ventricular reconstruction to CABG reduced the left ventricular volume compared to CABG alone. However, this anatomical change was not associated with a greater improvement in symptoms or exercise tolerance or with a reduction in the rate of death or hospitalization for cardiac causes.[5]

Limitations. The present study was retrospective and not randomized, similar to previous studies of myocardial revascularization in patients with ICM. Modifying medical practice by increasing the period of cardioplegia, myocardial viability evaluation, and use of the left internal thoracic artery, might have had an influential role in our findings unlike previously published work. Late follow-up echocardiographic and coronary angiographic studies were not executed in all patients. It is difficult to determine if poor functional outcome is a result of complications related to myocardial revascularization and/or progressing ICM. This limitation is present in most of the previously published papers on this topic. Other colleagues have proposed the Specific Activity Scale, which has better consistency with exercise treadmill presentation than NYHA or CCS.[3,33] Nevertheless, NYHA and CCS continue to be the main scoring practices used, and their application is acceptable if clinical series are to be matched up to. All data were obtained before 2001, which may modify some results because of the development of new technologies and surgical methods after this period.

CONCLUSION

The findings of this study suggest that aneurysmectomy among patients with severe LV dysfunction results in short- and long-term favorable outcome function and survival. In addition to the enduring relief from angina, most of the patients experienced improvements in congestive heart failure at long-term follow-up. Selection of appropriate surgical candidates may substantially improve survival among these patients.

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