

Myocardial Revascularization with Coronary Endarterectomy. Stratification of Risk Factors for Early Mortality

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Objective - To determine the risk factors for mortality related to myocardial revascularization when performed in association with coronary endarterectomy.

Methods - We assessed retrospectively 353 patients who underwent 373 coronary endarterectomies between January '89 and November '98, representing 3.73% of the myocardial revascularizations in this period of time. The arteries involved were as follows: right coronary artery in 218 patients (58.45%); left anterior descending in 102 patients (27.35%); circumflex artery in 39 patients (10.46%); and diagonal artery in 14 patients (3.74%). We used 320 (85.79%) venous grafts and 53 (14.21%) arterial grafts.

Results - In-hospital mortality among our patients was 9.3% as compared with 5.7% in patients with myocardial revascularizations without endarterectomy ($p=0.003$). Cause of death was related to acute myocardial infarction in 18 (54.55%) patients. The most significant risk factors for mortality identified were as follows: diabetes mellitus ($p=0.001$; odds ratio = 7.168), left main disease (<0.001 ; 9.283), female sex (0.01; 3.111), acute myocardial infarction (0.02; 3.546), ejection fraction $<35\%$ (<0.001 ; 5.89), and previous myocardial revascularization (<0.001 ; 4.295).

Conclusion - Coronary endarterectomy is related to higher mortality, and the risk factors involved are important elements of a poor outcome.

Key words - coronary endarterectomy, myocardial revascularization, atherosclerosis

Coronary endarterectomy as proposed by Bailey et al¹ has been used since 1957 as a form of myocardial revascularization. Currently, marked technological developments have changed cardiac surgery and have reduced the unsuccessful indices of myocardial revascularization discarding coronary endarterectomy as a possible treatment for coronary heart disease for some decades, because of its high morbidity and mortality.

On the other hand, a great increase in surgical indications has occurred for individuals of more advanced ages with diffuse coronary heart disease, whose lesions were frequently considered inoperable through conventional methods. The need for complete myocardial revascularization in these patients has justified the resurgence of coronary endarterectomy².

Because of the difficulty in defining precisely the ideal patients to undergo coronary endarterectomy, which results in a variability of indications and occasionally in its indiscriminate use, coronary endarterectomy has been characterized as a risk factor of mortality associated with myocardial revascularization³, mainly related to perioperative acute myocardial infarction. Therefore, the use of coronary endarterectomy is still a matter of controversy and its results are highly variable due to lack of uniformity.

The objective of this study is to assess the in-hospital evolution of patients undergoing this procedure and to determine the risk factors related to its morbidity and mortality.

Methods

We assessed retrospectively 353 patients who had undergone coronary endarterectomy during the period from 1989 to 1998 at the Instituto do Coração de Hospital das Clínicas, School of Medicine, University of São Paulo, corresponding to 3.73% of the 9,429 surgeries for myocardial revascularization performed at this institution during that

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period. Ages of the patients ranged from 29 to 84 years (mean of 59.8 years), and 276 (78.19%) patients were males.

Of all patients, 171 (48.44%) had 3 or more risk factors for coronary heart disease and 138 (39.09%) were diabetic patients. Surgical indication resulted from unstable angina in 190 (53.82%) patients, and 197 (55.81%) patients were in functional class III or IV of the Canadian Cardiovascular Society. Fifty-seven (16.15%) patients were operated on during the acute phase of acute myocardial infarction.

Twenty-four (6.8%) patients were operated upon on an emergency basis. Previous acute myocardial infarction and myocardial revascularization occurred, respectively, in 179 (50.71%) and 27 (7.6%) patients. Triple vessel involvement occurred in 323 (91.5%) patients, and 47 (13.31%) patients had left main disease. Ventricular function was significantly impaired (ejection fraction <35%) in 51 (14.45%) patients.

All patients underwent surgery with extracorporeal circulation. The methods of cardiac protection used were intermittent aortic clamping with mild hypothermia in 204 (57.8%) patients and cold blood cardioplegia in the remaining patients. The manual technique of endarterectomy was adopted through a wide arteriotomy and removal of thrombi proximal and distal to the opening. In cases of arteriotomies larger than 3 cm, reconstruction was performed through wide venous anastomoses or through arterioplasty with the saphenous vein followed by an anastomosis with arterial graft at the center of the venous fragment.

We performed 373 endarterectomies, and the procedure was performed twice in 20 patients. The arteries operated upon were the following: right coronary artery in 218 (58.45%) patients; left anterior descending artery in 102 (27.35%) patients; circumflex artery and its branches in 39 (10.46%) patients; and diagonal artery in 14 (3.74%) patients. We used the saphenous vein graft in 320 (85.79%) patients, the left internal thoracic artery graft in 39 (10.46%) patients, the right internal thoracic artery graft in 11 (2.95%) patients, the right gastroepiploic artery graft in 2 (0.55%) patients, and the radial artery graft in one (0.26%) patient.

We performed a mean of 3.32 anastomoses per patient. The mean durations of extracorporeal circulation and anoxia were, respectively, 116.27 and 71.95 minutes.

The most frequently associated procedure was left ventricular aneurysmectomy in 21 patients, and we added thrombectomy in 11 patients. The other procedures associated were left ventricular thrombectomy in 9 patients, mitral valvoplasty in 5 patients, aortic valve replacement in 4 patients, mitral valve replacement in 3 patients, carotid endarterectomy in 2 patients, replacement of the ascending aorta in 2 patients, correction of a fistula between the right coronary artery and the pulmonary artery in one patient, and pulmonary lobectomy in one patient.

In the postoperative period, characterization of acute myocardial infarction followed basically electrocardiographic criteria, such as new Q waves, persistent intraventricular conduction defects, and poor of progression of the R wave in precordial leads. In addition, changes in regional contraction on the two-dimensional echocardiogram that

did not exist in the preoperative period were also considered. Measurement of MB fraction of the creatine phosphokinase, even though a routine procedure in the immediate postoperative period, did not constitute an absolute criterion for acute myocardial infarction, acting as a guide for this diagnosis when its value was 10% greater than that of total creatine kinase.

From the first postoperative day on, all patients received 200mg/day of acetylsalicylic acid until hospital discharge. Patients receiving arterial grafts were treated with calcium channel blockers (diltiazem – 180mg/day) from the first postoperative day on.

We tried to study the possible predictive factors of in-hospital death initially through a univariate analysis using the following tests: chi-square test, Pearson's test, Fisher's exact test, Student's *t* test, and Wilcoxon test. To estimate the probability of in-hospital death considering the variables selected in the univariate analysis, through a multivariate model, we used the logistic regression technique. The significance level established was 0.05.

Results

In-hospital mortality was 9.35% (33 patients) as compared with 5.66% of the remaining myocardial revascularizations ($p=0.003$). The cause of death was related to perioperative acute myocardial infarction with cardiogenic shock in 18 (54.55%) patients. Intraaortic balloon was used in 46 (13.03%) patients. Acute myocardial infarction and arrhythmias in the postoperative period occurred in 48 (13.6%) and 100 (28.33%) patients, respectively. Twenty-three (6.52%) patients had to be reoperated upon and the causes were as follows: mediastinal bleeding in 15 patients, 9 of whom also had associated cardiac tamponade; acute myocardial infarction in 3 patients; cardiopulmonary arrest in 2 patients; and mediastinitis in the 3 remaining patients.

To define the risk factors for mortality, the patients were divided into 2 groups as follows: group 1 - comprising 320 patients who survived the surgical procedure and were discharged from the hospital; group 2 - comprising 33 patients who evolved to in-hospital death.

The univariate analysis of the risk factors for mortality (Table I) identified the following characteristics as statistically significant: female gender ($p=0.01$), diabetes mellitus ($p=0.001$), previous myocardial infarction ($p=0.022$), previous myocardial revascularization ($p<0.001$), surgeries performed during the acute phase of myocardial infarction ($p=0.02$), left main disease ($p<0.001$), ejection fraction <35% ($p<0.001$), and a longer extracorporeal circulation ($p=0.005$). In the postoperative period, the following risk factors for mortality were identified: use of intraaortic balloon ($p<0.001$), presence of arrhythmias ($p=0.001$), perioperative acute myocardial infarction ($p<0.001$), acute renal failure ($p<0.001$), reoperation ($p<0.001$), and a shorter hospitalization ($p=0.001$).

Other variables, such as age, the presence of three or more risk factors for coronary heart disease, triple vessel lesions, number of grafts used in revascularization, double endarterectomy, emergency operation, associated proce-

Table I – Risk factors for preoperative mortality related to coronary endarterectomy through univariate analysis

Variable	Group 1	Group 2	P
N	320	33	—
Age (years)	59.75	60.7	0.587
Female sex	64 (20)	13 (39.39)	0.010 *
Diabetes mellitus	116 (36.25)	22 (66.67)	0.001 *
Risk factors **	151 (47.19)	20 (60.61)	0.142
Previous AMI	156 (48.75)	23 (69.7)	0.022 *
Previous MR	20 (6.25)	7 (21.21)	<0.001 *
AMI	47 (14.69)	10 (30.3)	0.020 *
Triple vessel	259 (80.94)	27 (81.82)	0.902
LM	37 (11.56)	10 (30.3)	<0.001 *
EF < 35%	37 (11.56)	14 (42.42)	<0.001 *
Emergency	21 (6.56)	3 (9.1)	0.583

Data between parentheses are percentages; * - statistically significant data; ** - three or more risk factors for coronary heart disease; AMI- acute myocardial infarction; MR- myocardial revascularization; LM left main disease; EF- ejection fraction.

Table III - Risk factors for mortality related to coronary endarterectomy through multivariate analysis with estimation of odds ratio

Variables	Odds ratio
Female sex	3.111
Diabetes mellitus	3.482
Left main disease	3.767
Acute myocardial infarction	3.546
Previous revascularization	4.295
Ejection fraction 35%	5.890

dures, duration of anoxia, and duration of the intensive care unit stay were also studied in the univariate analysis, but they did not reach statistical significance (Table II).

To select the most important variables for assessing the probability of death, we used multivariate analysis, which identified the following preoperative risk factors (Table III): female gender, diabetes mellitus, disease left main, patients undergoing surgery in the acute phase of myocardial infarction, previous myocardial revascularization, and ejection fraction <35%.

No statistically significant relation was found between the artery undergoing endarterectomy and the use of the intraaortic balloon pump the presence of arrhythmias, perioperative acute myocardial infarction, and death (Table IV). We also found no relation between the type of graft used in the artery undergoing endarterectomy and the above-cited variables (Table V).

Table IV - Relation between the site of endarterectomy and morbidity and mortality

Arteries	RC	AIVB	Cx	Di	p
IAoB	22 (11)	13 (14.61)	8 (23.53)	3 (27.27)	0.092
Arrhythmia	57 (28.5)	31 (34.83)	17 (50)	5 (45.45)	0.066
AMI	27 (13.5)	12 (13.48)	7 (20.59)	1 (9.09)	0.715
Death	18 (9)	7 (7.87)	5 (14.71)	1 (9.09)	0.631
Total	200	89	34	11	-

Data between parentheses are percentages; RC- right coronary artery; AIVB- anterior interventricular branch of the left coronary artery; Cx- circumflex artery; Di- diagonal artery; IaoB- intraaortic balloon; AMI- perioperative acute myocardial infarction.

Table II – Operative and postoperative risk factors for mortality related to coronary endarterectomy through univariate analysis

Variable	Group 1	Group 2	P
Number of grafts/pt	3.33	3.18	0.531
Double CE	18 (5.63)	2 (6.06)	0.695
Associated procedure	42 (13.13)	6 (18.18)	0.420
ECC duration (min)	114.25	135.85	0.005 *
Duration of anoxia (min)	71.53	75.97	0.209
Intraaortic balloon	24 (7.5)	24 (72.73)	<0.001 *
Arrhythmias	88 (27.5)	29 (87.88)	0.001 *
Perioperative AMI	32 (10)	18 (54.55)	<0.001 *
ARF	20 (6.25)	15 (45.45)	<0.001 *
Reoperation	11 (3.44)	12 (36.36)	<0.001 *
Hospitalization (days)	9	4	0.001 *
ICU stay (days)	4.35	11.39	0.257

Data between parentheses are percentages; * - statistically significant data; pt- patient; CE- coronary endarterectomy; ECC- extracorporeal circulation; AMI- acute myocardial infarction; ARF- acute renal failure; ICU- intensive care unit.

Discussion

The era of direct operations on coronary arteries for the treatment of coronary heart disease⁴ started in 1957 with the performance of direct endarterectomy by Bailey et al¹. With the appearance of extracorporeal circulation and spread of myocardial revascularization through venous grafts, the technique of direct endarterectomy remained out of use for several years.

The concept of complete myocardial revascularization gained strength in cardiology because of the higher incidence of late deaths, recurrence of angina, myocardial infarction, and reoperations in patients treated incompletely^{5,6}. Improvement in the results of myocardial revascularization caused by a larger experience, by the development of methods of myocardial protection, and by the use of the internal thoracic artery has allowed its application in patients

Table V – Relation between the type of graft used in myocardial revascularization associated with coronary endarterectomy and morbidity and mortality

Graft	Venous	Arterial	p
IAoB	43 (14.93)	4 (8.33)	0.222
Arrhythmia	98 (34.03)	13 (27.08)	0.344
AMI	41 (14.24)	6 (12.5)	0.748
Death	30 (10.42)	1 (2.08)	0.100
Total	288	48	-

Data between parentheses are percentages; IAoB- intraaortic balloon; AMI- perioperative acute myocardial infarction.

with diffuse coronary heart disease, which was earlier considered a surgical contraindication. In addition, technological development has contributed to delay in operative indication because of pharmacological or percutaneous treatment, or both. Therefore, the presence of patients with advanced atherosclerotic disease with a still viable myocardium is increasingly more frequent, in whom the only way of effectively preserving function is through removal of the atheromatous plaque, followed by revascularization with venous or arterial grafts, or both.

The use of coronary endarterectomy, however, is still controversial mainly because of lack of uniformity in its indications and controversial results, according to studies in the literature, most of which are retrospective. A first issue to be approached is the definition of the ideal patient and the concept of diffuse atherosclerotic disease of coronary arteries. Livesay et al³ have considered necessary the presence of occluded arteries with multiple stenoses and diffuse distal involvement. Christakis et al⁷ have added the presence of arteries perfusing viable myocardium with reversible ischemia, documented by scintigraphy with thallium or analysis of regional contraction on echocardiogram, or both. The contraindications for the procedure consisted of arteries with diameter smaller than 1 mm irrigating myocardial areas of fibrosis secondary to previous infarcts and extremely calcified vessels^{8,9}. Souza et al¹⁰ divide the indications of coronary endarterectomies into planned, when the procedure may be planned through preoperative coronary angiography, and necessary, when during operation the surgeon finds a previously attractive artery for myocardial revascularization but only coronary endarterectomy makes the procedure feasible.

The frequency of coronary endarterectomy varies with the medical center. Some groups perform it in a liberal manner without a careful analysis of each case, where it may represent up to 42% of the myocardial revascularizations performed¹¹. Our incidence of 3.73% reflects our conservative trend in regard to the procedure.

Another relevant issue is the importance of cardiac risk factors for the disease that affects millions of people in the entire world, but in this case it seems to manifest in a much more intense manner with significant repercussions when clinically or surgically treated¹². When comparing conventional myocardial revascularization with that associated with coronary endarterectomy, Livesay et al³ identified in the latter group a higher incidence of male patients, of patients with diabetes mellitus, with ventricular dysfunction, and a higher number of arteries undergoing revascularization per patient. The higher incidence of postoperative acute myocardial infarction was related to incomplete obstruction (stenosis <90%) of the coronary artery undergoing endarterectomy¹³.

Brenowitz et al¹² have defined the following as risk factors for multiple endarterectomy: age >70 years, reoperation, insulin-dependent diabetes mellitus, female sex, and severe ventricular dysfunction. They also established a relation between the higher number of these factors and mortality. In patients undergoing multiple coronary endarterectomy and in the presence of 2 or more of these factors, the

index was 26.9%, and in those with no risk factor it was 1.7%. The application of this index was reproduced by Salerno et al⁸, but not by other authors¹⁴.

Therefore, determination of the risk factors related to mortality of myocardial revascularization associated with coronary endarterectomy is extremely important to establish the most favorable cases. In our study, we identified as risk factors for in-hospital mortality the following: female gender, diabetes mellitus, left main disease, acute myocardial infarction, previous myocardial revascularization, and ejection fraction <35%. We found a relation between a higher number of these risk factors and the chance of in-hospital death.

From the technical point of view, endarterectomy may be manual or with the aid of carbon dioxide to detach the atheromatous plaque, but the latter has been currently abandoned. The procedure should be complete, and therefore it is more difficult to perform in the left coronary artery because of its great number of branches and because of its smaller diameter. Arteriotomy size varies according to the facility of plaque detachment and may extend distally. Serial incisions may be performed to avoid blind tractions and intimal lesions. Therefore, because of the difficulty in accessing the branches of the left coronary artery, the resulting arteriotomy may be very long¹⁴.

The methods of reconstruction of the wide arteriotomy comprise the following: primary suture, wide anastomosis with venous grafts, and arterioplasty with fragments of the saphenous vein isolated or followed by myocardial revascularization with arterial grafts^{15,16}.

More frequently, coronary endarterectomy is performed in a single manner, but some authors¹⁷ report its performance in two, three, and even seven arteries. Other authors believe a relation exists between the number of endarterectomies and the greatest morbidity and mortality, but this could not be reproduced in our study nor in others^{7,13,17}.

The procedure usually requires a greater period of extracorporeal circulation and anoxia⁷. Therefore, myocardial protection is mandatory. The method to be employed is, however, another point of controversy. Most authors prefer blood cardioplegia².

The site of endarterectomy, morbidity, and mortality is a controversial point. The right coronary artery was the first and is still the most frequently used artery because of the greater technical simplicity of the procedure in this artery and the relatively low risk. Brenowitz et al¹² introduced the use in the left anterior descending artery, but they reported a higher immediate mortality, as did others^{3,11,13}. These data could not be reproduced by Minale et al¹⁸ or by us, where a similar incidence was shown. We believe that the risk factors and performance of complete myocardial revascularization are more important than simply the site where coronary endarterectomy is performed.

Likewise, the type of graft used in coronary endarterectomy is a matter of controversy. The use of venous grafts is historical and few reports^{15,19} have shown experience with arterial grafts. Beretta et al²⁰ in a comparative analysis between the saphenous vein and the internal thoracic artery

found in the latter group lower mortality and incidence of acute myocardial infarction, a higher permeability of grafts at short- and long-term follow-up, and a higher symptomatic relief in the late follow-up. In our experience, despite the predominant use of venous grafts, we did not find significant differences between the type of graft used and immediate morbidity and mortality.

The main cause of failure in the postoperative period of coronary endarterectomy is acute myocardial infarction, which is directly related to thrombosis in the site of endarterectomy. This is the reason why some groups have routinely used platelet antiaggregating agents and anticoagulants, with significant changes in the prognosis²¹. Other causes of early occlusion of grafts are the incomplete removal of atheromatous plaques, intimal flap obstructing tributary vessels, conditions of low cardiac output, technical problems of the anastomosis, and inadequate myocardial protection. Postoperative frequency of acute myocardial infarction has ranged from 5 to 25%, with an associated mortality ranging from 0 to 15%. In our experience, these values were 13.6% and 5%, respectively.

The short-term results of coronary endarterectomy vary according to the study, reflecting variability in indications and operative techniques, as more recent studies^{7,13,17} have shown a significant improvement in results. Most studies, however, show a higher incidence of acute myocardial infarction, immediate mortality⁸, and a lower patency of the grafts performed in arteries undergoing endarterectomy, in relation to those where this resource was not used. The study by Livesay et al³ has analyzed the early and late evolution of 3,369 patients undergoing coronary endarterectomy, as compared with another group of 27,095 patients, in whom myocardial revascularization was not associated with coronary endarterectomy, during a period of 14 years. These authors have found a higher mortality (4.4%), a higher incidence of postoperative acute myocardial infarction (5.4%), and a higher incidence of cardiac arrest (3.5%) in the group undergoing coronary endarterectomy as compared with that undergoing only myocardial revascularization.

Some authors^{7,14,17,22-24}, however, report in-hospital mortality and patency of venous grafts similar for both groups. Larock et al²², with some differences in group homogeneity, have found a higher incidence of perioperative acute myocardial infarction, including impairment of the segmentary contractility assessed by myocardial scintigraphy with thallium. Christakis et al⁷, adopting strict criteria for indication, have prospectively studied 317 patients undergoing coronary endarterectomy as compared with 911 patients undergoing conventional myocardial revascularization with documented homogeneity between both groups. They have found a similar incidence of in-hospital deaths (3.2% and 3.8%), acute myocardial infarction (6% and 5.5%), low cardiac output syndrome (15.1% and 12.6%), and use of intraaortic balloon (4.5% and 6%). The authors have attributed these results to the strict se-

lection of patients and the large experience with the technique.

Late survival ranges from 71%^{13,17} to 90% after 5 years⁷, being comparable to that of the group undergoing conventional myocardial revascularization. Higher late mortality was observed in patients with acute myocardial infarction prior to surgery¹³, and also with advanced age and ventricular dysfunction¹², reflecting the more aggressive nature of the disease.

Sequential anatomicopathological studies have demonstrated that, in cases of failure after endarterectomy, an accelerated process of myointimal proliferation occurs followed by atherosclerosis in a second plane^{25,26}.

Livesay et al³ have found a small increase in the risk of mortality (2.9% per year) and in late complications in the long-term. The clinical evolution and prognosis, however, were similar to those of patients undergoing only myocardial revascularization. Patency of the grafts did not differ from that of coronary endarterectomy, being around 75% in 29 months. These data were reproduced by Goldstein et al⁹, who have found late permeability of 64% in 19 months.

On the other hand, Minale et al¹⁸ found different results when studying patency and changes in segmentary contractility after performing 728 coronary endarterectomies. Patency of the arteries undergoing endarterectomy was much lower than that of the arteries where this procedure was not used (45% versus 73.8%). These data agreed with maintenance of anginal symptoms and worsening in functional class. Segmentary contractility improved in 35% to 45% of the previously hypokinetic and akinetic areas, and worsening of segmentary contractility happened in 24% of the normal areas, reflecting a greater risk of contractile deterioration and a certain degree of subclinical perioperative acute myocardial infarction. Therefore, they postulate that this procedure should be limited to patients with unstable, critical, irresponsible clinical findings, limited to arteries that irrigate the left ventricular posterior wall with mild ventricular dysfunction.

In conclusion, resurgence of coronary endarterectomy as an adjunctive of myocardial revascularization is a strong concept that has gained impetus through the technological development related to cardiac surgery, providing a significant improvement in its results, comparable to those of conventional myocardial revascularization. When performed in an indiscriminate manner in diffuse atherosclerotic disease, a higher in-hospital mortality occurs, related to perioperative acute myocardial infarction. The risk factors identified in this study are important components related to a poorer evolution and should be considered in surgical indication. Coronary endarterectomy should be used whenever possible in selected patients in a programmed manner to promote myocardial revascularization.

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