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Coronary Endarterectomy with Beating Heart in Patients with Diffuse Atheromatous Coronary Artery Disease and Poor Ventricular Function: Early and Midterm Results

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ABSTRACT

Background: In this study, we retrospectively reviewed our experience with off-pump coronary artery bypass grafting and coronary artery endarterectomy in patients with severely reduced left ventricular function and diffuse atheromatous coronary artery disease to evaluate the early and midterm results.

Methods: Between July 1998 and March 2004, 42 patients underwent off-pump myocardial revascularization with coronary artery endarterectomy. The mean age (±SD) for the 28 male and 14 female patients was 59 ± 10.2 years. Twenty-seven patients (64.2%) had experienced a previous myocardial infarction, and 11 (26.2%) had undergone an operation on an emergency basis. All patients had an ejection fraction of less than 30%. The left anterior descending coronary artery was the most endarterectomized vessel (75% of patients).

Results: There were 5 early deaths (11%). Twenty-five (67.6%) of the surviving patients were symptom free, and 8 were in Canadian Cardiovascular Society classes II to IV. The ejection fraction improved after the operation in the 30 patients (71.42%) who underwent echocardiographic control and coronary angiography. The 28.4-month patency rate of the endarterectomized coronary arteries was 89%. The patency rates were 93.3% for the left internal thoracic artery-left anterior descending coronary artery and 88.8% for the right coronary artery.

Conclusion: The results of this study show increased operative mortality and morbidity in patients requiring coronary artery endarterectomy. However, the early results and particularly the midterm survival rates, clinical status, and continued graft patency justify off-pump coronary artery endarterectomy in patients with severely depressed left ventricular function and diffuse coronary artery disease. Many of these patients have disease that would otherwise be inoperable.

INTRODUCTION

Patients with diffuse atheromatous coronary artery disease and severely reduced left ventricular function may be candidates for cardiac transplantation. Ischemic cardiomyopathy is currently the most common indication for cardiac transplantation [Milano 1993]. Unfortunately, the very limited number of organs has resulted in a long waiting list and the exclusion of patients with comorbid disease or advanced age [Evans 1986]. The authors of many studies have concluded that the more severe the preoperative ventricular dysfunction, the greater the long-term benefits of surgical versus medical therapy [Christakis 1992]. The operative mortality rate after coronary artery bypass grafting (CABG) surgery in high-risk patients with severe ventricular dysfunction varies between 1.6% and 50% [Cosgrove 1984, Christakis 1989].

Coronary artery endarterectomy (CAE) has been an accepted procedure in several institutions for more than 50 years. Since the development of cardiopulmonary bypass (CPB) and cardioplegia, CABG has been performed consistently worldwide for decades with few enduring technical modifications [CASS 1983, Wright 1987, Bell 1992]. Recently, technologic advances have enabled beating-heart alternative approaches to the time-honored standard CABG procedure and provided opportunities for decreased morbidity and mortality [Eryılmaz 2003]. Although working on a beating heart is difficult work, off-pump bypass surgery has important benefits. Especially, it does not have the inflammatory, neurologic, and renal effects of CPB. The requirement of blood transfusion and extended ventilator support are less with this technique, so the related complications are fewer. As individual and institutional experience develops, the appropriate procedure selected for a given patient will, and should, change accordingly. The selection of the best operative approach and the appropriate combination of available techniques for each patient is a dynamic process, from the initial

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evaluation of the patient through the completion of the revascularization procedure [Christakis 1989, Bell 1992, Djalilian 1995].

The aim of this study was to assess retrospectively our early and midterm results of CAE without CPB in patients with poor ventricular function and diffuse atheromatous coronary artery disease.

MATERIALS AND METHODS

Patients' Profiles

Between July 1998 and June 2004, 1986 patients underwent isolated CABG, 453 of them off-pump. CAE was carried out in 42 patients aged between 34 and 78 years (mean ± SD, 59.0 ± 10.5 years). Twenty-eight patients (67%) were male, and 14 (33%) were female. Twenty-four patients (57%) required the procedure for 1 coronary artery, and the rest (43%) underwent the operation for multiple arteries. Thirty-five patients (83%) had a previous history of smoking, 19 (45%) had hypertension, 9 (21%) had diabetes mellitus, and the other 27 patients (64%) had experienced previous myocardial infarction. Fourteen patients (33%) had a history of unstable angina, and 11 (26%) underwent operation emergently because of the onset of angina following the standard coronary angiographic evaluation. All of the patients had diffuse segmentary wall motion abnormalities detected by echocardiography. The mean ejection fraction of the patients was 29.7% ± 2.6% (range, 25%-30%) (Table 1). All of the patients with signs of ischemia underwent myocardial perfusion scintigraphy to identify scarring tissue.

Table 1. Demographic Characteristics of the Patients (N = 42)*

Age, y	59.2 ± 10.5
Ejection fraction, %	29.7 ± 2.6
Sex, n (%)	
Male	28 (67)
Female	14 (33)
Hypertension, n (%)	19 (45)
Smoking, n (%)	35 (83)
Diabetes, n (%)	9 (21)
Previous MI, n (%)	27 (64)
No. of diseased vessels, n (%)	
2 Vessels	9 (21)
3 Vessels	33 (79)
NYHA class, n (%)	
II	12 (29)
III	30 (71)
CCS class IV, n (%)	42 (100)
Status, n (%)	
Elective	31 (74)
Emergency	11 (26)

*Age and ejection fraction data are presented as the mean ± SD. MI indicates myocardial infarction; NYHA, New York Heart Association; CCS, Canadian Cardiovascular Society.

Operative Technique

All procedures were performed with the beating-heart technique. Left internal thoracic artery (LITA) and saphenous vein grafts were harvested for grafting. The patients were administered heparin at a dose of 100 U/kg. Neither a heart stabilizer nor intraluminal shunts were used. Silicone snare sutures were placed proximally and distally to the anastomosis to provide a bloodless and stable field of epicardium. After coronary arteriotomy, a closed CAE was performed as much as possible on the occluded coronary artery detected in the preoperative coronary angiographic evaluation. Following the procedure, the margins (mean, 4.7 ± 3.2 cm; range, 2-10 cm) of the endarterectomy specimens were examined to avoid any tapering or feathering in the distal end. It has frequently been possible to remove all distal atheroma from the right coronary artery (RCA) and the left anterior descending artery (LAD) along the length of a 0.8-cm coronary arteriotomy. If residual plaque was thought to remain in the distal vessel, the coronary arteriotomy was extended as much as necessary to allow the complete removal of the plaque. The endarterectomized vessels were flushed with heparinized solution to remove small residual particles. When a CAE was performed on the LAD, a LITA graft was used. A saphenous vein graft was used as a conduit to the coronary arteriectomy site in the other vessels. The procedure was performed on the RCA in 9 patients, on the left coronary artery in 15 patients, and on the RCA plus LAD in 18 patients. The LITA-LAD anastomosis was done with no coronary endarterectomy for the patients who had undergone the procedure on the RCA. Although 12 patients had stenosis in the circumflex artery, there were no indications for an anastomosis because the vessel had a very small diameter (<1 mm). The rest of the patients had plaque in the circumflex artery. The mean number of grafts per patient was 1.93 ± 0.7. The mean time for CAE and coronary artery anastomosis was 20.9 ± 7.9 minutes per patient, and the mean total procedure time was 64.7 ± 5.9 minutes (Table 2).

Postoperatively, heparin administration was initiated in the intensive care unit in the 2 hours following the proce-

Table 2. Operative and Postoperative Characteristics (N = 42)*

Anastomosis time, min	20.9 ± 7.9
Operation time, min	64.7 ± 5.9
No. of anastomoses	1.93 ± 0.7
Grafts, n (%)	69 (100)
LITA	42 (61)
Saphenous vein	27 (39)
Inotrope requirement, n (%)	15 (36)
IABP requirement, n (%)	6 (14)
Coronary artery endarterectomy, n (%)	
LAD	15 (36)
RCA	9 (21)
LAD + RCA	18 (43)

*Data are presented as the mean ± SD where appropriate. LITA indicates left internal thoracic artery; IABP, intra-aortic balloon pump; LAD, left anterior descending artery; RCA, right coronary artery.

dure. All patients underwent anticoagulation treatment with warfarin sodium for the following 12 months to maintain an international normalized ratio of 2.0 to 2.5, and aspirin treatment was initiated.

Data Analysis and Follow-up

Preoperative and postoperative clinical evaluation was done by the same physician in accordance with the New York Heart Association (NYHA) and Canadian Cardiovascular Society (CCS) classifications. The data collected included demographics, comorbidity risk factors, operative data, mortality data, and postoperative complications, defined as myocardial infarction, low cardiac output, malignant ventricular arrhythmias, bleeding requiring a rethoracotomy, stroke, respiratory insufficiency, renal failure requiring dialysis, and mediastinal infection.

All patients were reexamined during the second and sixth postoperative months, and they were seen yearly thereafter. Echocardiography to measure ejection fraction, scintigraphy to examine myocardial perfusion, and coronary artery angiography were carried out with all patients who were alive at the end of the first year.

Statistical Analysis

Data were analyzed by means of chi-square and Student *t* tests. Survival data were analyzed by using the standard Kaplan-Meier actuarial technique for estimating survival probabilities.

RESULTS

Early Results

Five patients (12%) died during hospitalization from ventricular fibrillation (n = 2) or low cardiac output (n = 3). Four patients underwent operation emergently because of unstable angina. The following factors had an influence on hospital mortality: advanced age, a history of smoking, unstable angina, a prolonged coronary anastomosis time, postoperative hemodynamic instability, postoperative respiratory insufficiency, and ventricular fibrillation. Postoperative myocardial infarction occurred in 4 patients (10%) with elevations in enzyme levels (creatine kinase MB isoenzyme, troponin I) and electrocardiographic changes (ST elevation). Three of these patients had undergone an RCA endarterectomy, and the other had had a LAD endarterectomy. Postoperative hemodynamic instability was observed in 15 patients (36%), and insertion of an intra-aortic balloon pump was required in 6 patients (14%). Ventricular fibrillation occurred in 7 patients (17%) and caused death in 2 (4%). Other postoperative complications were atrial fibrillation, acute respiratory failure, and bleeding (Table 3).

Midterm Results

Follow-up was completed for 94.5% of the patients. The follow-up period ranged from 3 to 84 months (mean, 32.06 ± 16.5 months). There were 4 deaths: 3 patients died from primary cardiac failure, and 1 patient died for a cerebrovascular reason. Twenty-five patients (68%) were angina free, and 8 had angina (5 patients were in CCS class II, 1 was in class III, and 2 were in class IV). At the end of first year, 32 patients were assigned to NYHA class II, 5 to NYHA class III, and 1 to NYHA class IV. All patients underwent echocardiographic control evaluations, which showed improvements in ejection fraction after surgical intervention. The mean preoperative and postoperative ejection fractions were 29.7% ± 2.6% and 34.6% ± 5.3% respectively. The patients underwent coronary angiographic control evaluation at a mean period of 22.4 ± 11.5 months after surgical intervention, and the patency rate for the endarterectomized coronary arteries was 89%. The patency rates were 93% for the LITA-LAD and 89% for the RCA (saphenous vein graft) (Table 4).

Table 3. Early Postoperative Complications (N = 42)*

Variables	Patients, n (%)
Mortality	5 (12)
Ventricular fibrillation	2 (5)
Low cardiac output	3 (7)
Preoperative MI	4 (10)
Rhythm disturbances	13 (31)
Postoperative VF	7 (17)
Postoperative AF	6 (14)
Rethoracotomy	1 (2)
Respiratory insufficiency	1 (2)

*MI indicates myocardial infarction; VF, ventricular fibrillation; AF, atrial fibrillation.

DISCUSSION

The operative mortality and long-term survival rates for patients who undergo CABG have repeatedly been shown to

Table 4. Late Results (n = 37)*

Variables	Patients, n (%)
Mortality	4 (10)
Primary cardiac failure	3 (7)
Cerebrovascular	1 (2)
Angina free	25 (68)
CCS class	
II	34 (92)
III	1 (3)
IV	2 (5)
NYHA class	
II	32 (76)
III	4 (10)
IV	1 (2)
Angiographic control	37 (100)
LAD patency	14 (93)
RCA patency	8 (89)
LAD + RCA patency	11 (61)

*CCS indicates Canadian Cardiovascular Society; NYHA, New York Heart Association; LAD; left anterior descending artery; RCA, right coronary artery.

be influenced not only by the operative techniques but also by preoperative patient characteristics. Age, female sex, repeat coronary artery bypass operation, depressed left ventricular function, degree of stenosis of the native coronary artery, the severity of preoperative symptoms, and the presence of associated illnesses all play a major role in determining early and late mortality rates [Schaff 1983, McCormick 1985, Wright 1987]. In addition, an incomplete surgical revascularization markedly reduces long-term survival and the relief of symptoms [Cukingnan 1980, Lawrie 1982, Schaff 1983]. Patients who required multiple coronary endarterectomies had a significantly increased early and late mortality rate [Brenowitz 1988].

Diffuse coronary artery disease is commonly cited as a contraindication to bypass grafting. The best estimate of prevalence has been reported from the Coronary Artery Surgery Study (CASS), in which 4.9% of the patients characterized were said to have had no graftable arteries [CASS 1983]. The currently available therapeutic options for patients with end-stage coronary atherosclerosis include transmyocardial laser revascularization (TMLR) and a CABG procedure combined with CAE [Livesay 1986, Keon 1988, Minale 1989, Eryılmaz 2003, Quigley 2004]. Of these options, a few authors have revealed successful results with TMLR [Quigley 2004]. Considering the use of CABG for small distal vessels, CAE could be an adjunctive tool because bypassing to such arteries would not provide satisfactory complete revascularization. However, CAE has been reported to be a time-consuming and challenging procedure, and its beneficial effect has been questioned because of an increased risk of perioperative mortality and morbidity, especially when CAE is performed on the LAD [Livesay 1986, Minale 1989]. Lower patency and higher morbidity rates after CAE limit its use to arteries that are inoperable by conventional bypass techniques [Livesay 1986, Brenowitz 1988, Keon 1988, Minale 1989]. We confine this procedure to a small group of patients (2.11%) with severely depressed left ventricular function and diffuse atheromatous coronary artery disease. Because of the lack of endothelium, all of the subendothelial material that can trigger the coagulation cascade is exposed to blood flow. The absence of substances released from the endothelium, such as prostacyclin and nitric oxide, that prevent platelet adhesion and aggregation may further contribute to early occlusion. In spite of these problems, we performed both open and closed CAE on the LAD and the RCA in this group of patients. An off-pump technique seems more logical for patients with a poor ventricle or in some other instances, and CPB, hypothermia, or cannulation is not desirable. Most of the effects of these actions are reversible in the patients normally encountered, but CPB may have irreversible and even fatal results in patients who have a reduced ejection fraction. Off-pump bypass surgery has become the first choice in our clinic for coronary artery bypass operation in high-risk patients.

There is a wide variation in the results reported for CAE in conjunction with on-pump CABG, but there are few reports of endarterectomies performed in off-pump bypass operations [Eryılmaz 2003]. Eryılmaz and associates reported the use of CAE without CPB in 11 patients and reported no 30-day mortality in their series [Eryılmaz 2003].

Hospital mortality rates after on-pump CABG with CAE have varied from 4% to 15% and have been reported to be higher than the rates for conventional bypass techniques [Livesay 1986, Brenowitz 1988, Keon 1988]. For this reason, we prefer off-pump coronary artery surgery with CAE in patients with diffuse coronary artery disease. In our series, 5 deaths (12%) occurred in the hospital. Four of these patients had been in critical condition preoperatively and had undergone operation on an emergency basis. We performed 1 CAE in of the 3 patients and 2 CAE procedures in the other 2 patients. The most frequently endarterectomized vessel was the left coronary artery (70%). Initially, endarterectomy of the right system was preferred because of its technical simplicity and a lower risk. Considering postoperative morbidity and mortality, myocardial infarction resulting from thrombosis or residual obstruction of the vessel has been reported as the main cause. Postoperative myocardial infarction rates reported in the literature range from 5% to 25% [Jones 1983, Bell 1992]. In our experience, 4 postoperative myocardial infarctions occurred, and the rate was 9.5%.

Severe left ventricular dysfunction was a significant predictor of late mortality in all patient groups. Patients who required multiple CAE procedures and who had normal left ventricular function or mild left ventricular dysfunction had a 5-year survival rate of 78.8%. The survival rate was 47.4% for patients with multiple CAE procedures and severe left ventricular dysfunction [Brenowitz 1988]. Lawrie and associates [Lawrie 1982] studied 1274 men with double- and triple-vessel disease who underwent coronary artery bypass. One of the significant predictors of late mortality was the number of diseased but ungrafted arteries. The presence of residual lesions in the LAD was the most important predictor of late cardiac death in their series. In our series, 4 midterm deaths (10%) occurred, and all of the patients had severe left ventricular dysfunction. The mean ejection fraction was very low (<30%). The 5-year survival rate was 79% in our series, and this rate compares favorably with the rate found in other studies. Actuarial survival rates after on-pump CABG with left CAE was reported to vary between 47% and 93% at 5 years, depending on risk factors [Brenowitz 1988].

Clinically, 68% of our survivors were angina free at an average interval of 34 ± 11 months after surgical intervention. An improvement in myocardial contractility following the surgical intervention was also shown by means of echocardiographic control evaluation. The coronary angiographic examination revealed the patency rate of the grafts anastomosed to the endarterectomized vessels to be similar to the patency rates seen in previously published studies [Minale 1989, Djalilian 1995, Gill 1998].

In conclusion, the early results, the midterm survival results, the persistent relief of angina, and the long-term graft-patency data all confirm that our techniques of off-pump CAE in patients with a severely depressed left ventricle provide long-lasting relief to patients with diffuse coronary artery disease. In addition, this study suggests that CAE with off-pump coronary artery surgery is beneficial in patients with severe left ventricular dysfunction.

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