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Comparison of Off-Pump and Conventional Coronary Endarterectomy

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ABSTRACT

Objective: This study was designed to compare the early and midterm results of off-pump coronary endarterectomy (OPCE) with those of conventional coronary endarterectomy (CCE) performed with cardiopulmonary bypass.

Methods: From April 1, 1999, until March 1, 2001, 332 patients underwent off-pump coronary artery bypass grafting at our institution. From this total, 44 (13%) of the patients underwent supplementary OPCE (group 1). The results were compared with those for a group of age-, sex-, and risk factor–matched patients undergoing CCE (group 2) at the same institution. The mean follow-up period was 16 months. The indications for operation in group 1 were angina in 16 (36%) of the cases, cardiac failure in 20 (45%), and prognosis in 8 (19%). In group 2 angina was the indication for operation in 11 (25%) of the cases, cardiac failure in 5 (11%), and prognosis in 30 (64%) of the cases.

Results: In group 1, 35 patients underwent single and 9 underwent double endarterectomy. The procedures included 32 right coronary artery, 12 left anterior descending artery, 2 lateral circumflex artery, and 7 diagonal branch operations. Three (6.8%) of the patients in group 1 and 2 (4.4%) of the patients in group 2 developed postoperative myocardial infarction ($P < .05$). One (2.2%) of the patients in group 1 and 2 (4.4%) of the patients in group 2 died in the postoperative period ($P < .05$). The numbers of patients with perioperative neurologic deficit in groups 1 and 2 were 0 and 7, respectively ($P < .001$). Although the rate of perioperative myocardial infarction was higher in group 1, mortality, occurrence of other morbid events, intubation time, intensive care stay, and hospital length of stay were less in group 1 than group 2.

Conclusion: OPCE can be performed safely with morbidity and mortality comparable with those of CCE.

INTRODUCTION

Coronary endarterectomy (CE) was first carried out by Bailey and colleagues without the use of cardiopulmonary bypass (CPB) [Bailey 1957]. Early studies reflecting experience with CE in stationary hearts in the 1960s and 1970s showed increased morbidity and mortality [Sabiston 1965, Sawyer 1967, Kaplitt 1971].

Before the era of CPB direct coronary revascularization (CABG) on a nonstationary heart was attempted by several pioneering cardiac surgeons on a small number of patients [Vineberg 1951, Kolesov 1965]. Introduction of the concept of CPB and refinement of the technique led to a rapid increase in the number of patients undergoing CABG, and many patients benefited from this procedure unless very severe dysfunction of one of the vital organs, including myocardium itself, prevented use of CPB. After reintroduction of off-pump coronary revascularization (OPCABG), the number of patients benefiting from this procedure increased steadily [Benetti 1985]. At the beginning, OPCABG was applied only to treatment of patients with absolute contraindications to CPB, but later, OPCABG practically became the standard mode of revascularization in many centers throughout the world. This technique prompted recovery of the patient, more rapid return to a productive life, and good midterm graft patency rates.

Although long-term patency of bypass grafts to endarterectomized coronary arteries has been shown to be less than that of bypass to nonendarterectomized vessels [Keon 1988, Johnson 1989, Ferraris 2000], endarterectomy is still carried out as an adjunctive treatment in a selected group of patients. We and others have performed CE without CPB with good early and midterm results [Naseri 1999, Bedi 2000].

MATERIALS AND METHODS

From April 1, 1999, to March 1, 2001, a total of 871 patients underwent CABG at our institution. In 332 patients, OPCABG was performed. From this number, 44 (13%) of the patients underwent off-pump CE (group 1). The indications for coronary revascularization were angina pectoris in 16 (36%) of the patients, heart failure in 20 (45%), and prognosis in 8 (19%). The indications for CE were insufficient distal arterial lumen in 41 (77%) of the patients, dislocated intimal atherosclerotic plaque in 2 (4%), and inability to pass sutures through the plaque in 10 (19%). All patients in group 1 were scheduled for preoperative OPCABG, but the indication for endarterectomy was found intraoperatively. In 3 (6%) of the patients, the operation started as OPCABG, but for varying reasons, the procedure was converted to conventional CPB. For prevention of statistical bias, none of these patients was included in this study. This group was compared with a group

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Table 1. Preoperative Findings in Groups 1 and 2

	Group 1	Group 2	*P*
Age, y	65.4 ± 4.8	63.4 ± 7.6	>.1
Male, %	61.4	55.8	>.5
Diabetes mellitus, %	84.0	79.5	>.5
Chronic obstructive pulmonary disease, %	27.8	22.6	>.1
Renal failure, %	3.2	2.1	>.1
Cerebrovascular disease, %	3.9	3.8	>.5
Preoperative atrial fibrillation, %	1.8	1.5	>.1
Unstable angina pectoris, %	23.4	25.3	>.1
Congestive heart failure, %	6.6	4.9	>.1
Severe left ventricular dysfunction, %	29.5	28.3	>.1

of 44 age-, sex-, and risk factor–matched patients who underwent CE with CPB (CCE) (group 2).

Preoperative data for both groups are summarized in Table 1. Careful evaluation of the preoperative data revealed a higher than normal frequency of unstable angina pectoris, diabetes mellitus, and chronic obstructive pulmonary disease (COPD) in both groups. COPD was defined as any spirometrically documented obstructive pattern of lung mechanics. Any patient with manifestations of heart failure or undergoing diuretic therapy was considered to have congestive heart failure. Severe left ventricular dysfunction was defined as an ejection fraction less than 30%. Preoperative renal failure was defined as any creatinine value more than 2 mg/dL or any need for dialysis. Postoperative renal failure was defined as a creatinine value more than 2 mg/dL or need for dialysis in a patient with previously normal renal function. Neurologic events were classified as transient ischemic attack (TIA), stroke, seizure, or delirium in the preoperative and postoperative periods.

Statistical Analysis

Data were expressed as mean ± SD. All statistical analyses were performed with the Student *t* test. In all cases significance was defined as $P < .05$.

Surgical Technique

OPCE (Group 1). After induction of anesthesia, the internal mammary arteries and the saphenous vein were harvested. After partial heparinization (1.5 mg/kg), activated clotting time (ACT) was noted, and if necessary, additional heparin was given to maintain ACT >300 seconds. Exposure of the left anterior descending artery (LAD) was achieved with retrocardiac sponges. The right coronary artery (RCA) was exposed by upward traction on a 0 silk suture passed around the RCA through the epicardial fat pad at the right atrioventricular groove. Lima stitches or a Starfish heart positioner (Medtronic, Grand Rapids, MI, USA) was used for exposure of the circumflex artery and posterior descending artery. Stabilization was carried out with the help of Octopus II and III devices (Medtronic). One proximal circular suture and 1 distal semicircular 3-0 polypropylene suture were used for control of bleeding. No intracoronary shunt was used. Two epicardial fine traction sutures helped in manipulation of the anastomosis without handling of the coronary arteries. No pharmacologic intervention was made to decrease heart rate. The endarterectomy was carried out manually with the use of a fine spatula. In the RCA blind closed traction endarterectomy was carried out, but open direct-vision endarterectomy was the method of choice in other vessels. Either a saphenous vein patch or the left internal mammary artery (LIMA) itself was used for LAD reconstruction.

CCE (Group 2). Standard aortic and 2-stage venous cannulation was done. Topical cold saline (4°C), mild to moderate systemic hypothermia, and tepid antegrade blood cardioplegia were used for myocardial preservation. Blood for cardioplegia was derived from the CPB circuit during cooling period at 32°C. Distal anastomoses were performed on a stationary heart. Partial aortic clamping was used for the proximal anastomoses after removal of the aortic cross clamp. CE was carried out manually with the use of a fine spatula. In the RCA blind closed traction endarterectomy was carried out, but open direct-vision endarterectomy was the method of choice in other vessels. Either a saphenous vein patch or the LIMA itself was used for LAD reconstruction.

All patients in groups 1 and 2 received anticoagulation with heparin (4 × 5000 units intravenously) after hourly bleeding was less than 50 mL. Aspirin (325 mg/d) was administered as soon as the patient was extubated, and aspirin therapy was continued indefinitely. Warfarin was started the day after the operation and continued for 3 months. Heparin administration was stopped as soon as the international normalized ratio was more than 2.0.

RESULTS

One (2.2%) of the patients in group 1 and 2 (4.4%) of those in group 2 died ($P < .05$). All 3 deaths had cardiac causes. Operative and postoperative data are summarized in Table 2. Total myocardial revascularization was achieved in all patients with a mean number of 2.1 ± 0.4 distal anastomoses in group 1 and 2.3 ± 0.9 anastomoses in group 2 ($P > .1$) Nine patients in group 1 and 11 patients in group 2 underwent double endarterectomy. The others underwent single-vessel endarterectomy. LIMA was the graft of choice for LAD revascularization. For

Table 2. Operative and Postoperative Findings in Groups 1 and 2

	Group 1	Group 2	*P*
Operation time, h	1.7 ± 0.4	1.8 ± 0.3	>.1
No. of grafts	2.1 ± 0.4	2.3 ± 0.9	>.1
Evolving myocardial infarction, %	6.8	4.4	>.05
Intraaortic balloon pulsation, %	4.5	20.4	<.001
Postoperative drainage, mL	370 ± 156	765 ± 440	<.01
Blood transfusion, units	0.8 ± 0.3	2.7 ± 1.6	<.01
New atrial fibrillation, %	13.0	6.8	<.05
Postoperative cerebrovascular accident, %	0.0	16.0	<.001
Postoperative renal failure, %	0.0	4.5	<.001
Intubation time, h	3.4 ± 1.4	9.8 ± 2.6	<.01
Intensive care unit stay, d	1.1 ± 0.6	2.1 ± 0.8	<.05
Hospital length of stay, d	4.2 ± 1.3	9.2 ± 2.8	<.05

different reasons, 1 (2.2%) of the patients in group 1 and 3 (6.8%) of those in group 2 did not receive LIMA grafts. Three (6.3%) of the procedures were converted from off-pump to conventional coronary revascularization. The difference in total operation time between the 2 groups was not significant ($P > .1$). Electrocardiographic and enzymatic criteria for postoperative myocardial infarction (MI) were the appearance of new Q waves, persistent intraventricular conduction defects, or loss of R-wave progression with a troponin I level >11.0 ng/mL. Three (6.8%) of the patients in group 1 and 2 (4.4%) of the patients in group 2 developed postoperative MI ($P < .05$). There was a higher frequency of perioperative intraaortic balloon pump support in group 2 ($P < .01$). Patients in group 1 had significantly less postoperative bleeding and received less blood transfusions than those in group 2 ($P < .01$ and $P < .01$, respectively). The incidence of postoperative atrial fibrillation was higher in group 1 than in group 2 (13% versus 6%). This result was statistically significant ($P < .05$). Mean intubation time was significantly longer in group 2 ($P < .001$). There were no neurologic complications in group 1, but there were 5 TIAs, 1 stroke, and 1 case of delirium in group 2 ($P < .001$). There was a significantly higher incidence of renal failure in group 2 ($P < .001$). None of the patients in either group developed deep sternal wound infection. Both intensive care unit (ICU) and hospital length of stay (LOS) were shorter for group 1.

Six months after the procedure, follow-up evaluation by physical examination, electrocardiogram, and treadmill exercise test showed all patients in New York Heart Association class I and II with no major adverse coronary events. Coronary angiography an average of 13 months after the procedure in a randomly selected group of 17 patients from group 1 and 15 patients from group 2 revealed that in group 1, 16 (73%) of 22 endarterectomized vessels were patent. This percentage was not statistically different from that in group 2, in which 13 (76%) of 17 endarterectomized vessels were patent ($P < .1$).

DISCUSSION

The aim of CABG is to revascularize the part of the coronary system distal to the stenotic segment. Sometimes revascularization cannot be achieved completely because of the extensive nature of the atherosclerotic process. In these cases CE completes the armamentarium of the cardiac surgeon [CASS 1983].

An important factor affecting late graft patency appears to be the rate of blood flow through the graft, and this flow rate depends directly on distal arterial vascular diameter.

With the introduction of the technology of CPB and extensive application of CABG, CE was used with good early results and acceptable mortality and morbidity in the treatment of a large number of patients. Evaluation of midterm and late results revealed a high incidence of graft stenosis in endarterectomized vessels. This finding led to a rapid decline in enthusiasm for CE, but the procedure continued to be used as an adjunct to CABG, mostly in cases in which there was insufficient arterial lumen and the suture could not be passed through the coronary artery [Djalilian 1995]. Keogh and coworkers used angioscopy to evaluate intravascular morphology after endarterectomy. Their study showed a surprisingly good intimal restructuring after the endarterectomy [Keogh 1991].

The 1990s witnessed a very rapid surge in the number of patients undergoing OPCABG. At the beginning only patients with stenosis of the LAD benefited from this modality of surgery. In time, however, and with development of more efficient stabilizers and heart positioning devices, patients with multivessel disease, including disease of vessels in the inferolateral aspect of the heart, were included. Nowadays, in some cardiac centers, OPCABG is the first choice of treatment for more than 95% of the patient population [Naseri 2002].

The concept of OPCE came to our minds first in the care of diabetic patients with a very high incidence of diffuse disease of the coronary arteries in which application of CABG seemed impossible without use of CE [Naseri 1999]. Endarterectomy of the RCA, which is the most common site of CE in most series, appears to be relatively safe and well tolerated, presumably in part because this vessel is very often nearly totally occluded and there are few side branches [Longmire 1958]. Unlike procedures on the RCA, endarterectomy of the LAD is considered a very risky procedure. In our series, LAD endarterectomy was carried out through a long arteriotomy (open endarterectomy). This technique is especially important for maintaining good and uninterrupted flow to the diagonal branches and septal perforators [Chang 1991]. Postoperative MI is the most dreaded early complication of CE. Although in our study there was a higher incidence of perioperative MI in OPCE than in CCE (6.8% and 4.4%, respectively), the incidence was still in an acceptable range.

There was a remarkable difference between the 2 groups in postoperative incidence of CVA (0.0% versus 16%). Evaluation of all other perioperative morbid events showed a significantly lower incidence of these events in group 1 than in group 2. Both ICU stay and LOS were significantly shorter for group 1.

Angiographic results of CE and patency rate have been studied by different groups [Dagenais 1998, Santini 2002]. In our study midterm control angiography showed a 73% patency rate in group 1 compared with 76% in group 2. The difference between the 2 groups was not statistically significant ($P < .1$).

The development of new technologies such as transmyocardial laser revascularization and, more recently, local delivery of angiogenic growth factors has refocused attention on the surgical management of diffuse coronary artery disease in patients with contraindications to application of CPB. In some cases, CE is technically feasible. To facilitate decision making among these options, we reviewed our experience with off-pump CE to determine the results to be expected with this approach.

Although the present study had the shortcomings of being retrospective early and midterm and having a small sample size, we concluded that CE on a beating heart can be done safely in a selected group of patients with impaired left ventricular function or severe dysfunction of a vital organ. Despite good early and midterm results, long-term clinical and angiographic benefits must be evaluated before a final

conclusion can be drawn. Long-term patency of these reconstructive vascular procedures depends on vigorous and aggressive control of risk factors.

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