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Off-Pump Coronary Bypass through Very Limited Sternotomy

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ABSTRACT

Objective: This study was designed to evaluate the feasibility of beating heart coronary bypass operations on the anterior vessels of the heart through very limited sternotomy (VLS).

Methods: Between February 1, 2000, and October 1, 2001, 76 patients with stenosis of the left anterior descending artery (LAD) and right coronary artery (RCA) underwent coronary bypass grafting through 6- to 7-cm T-shaped VLS. Mean age of the patients was 56 ± 4.7 years. Fourteen patients were women. Nine (12%) of the patients had a left ventricular ejection fraction of less than 35%. Forty-three patients had single-vessel disease, and the others had 2-vessel disease. Patients who needed emergency operations were excluded from the study.

Results: In 7 patients the operation was converted to full sternotomy with or without cardiopulmonary bypass. This outcome accounted for an over all failure rate of 9%. The internal mammary artery/arteries were the inflow vessels in all cases. Various types of composite grafts were created with the saphenous vein and radial artery. Thirty-five (46%) of the patients received a single graft to the LAD, 12 (16%) received 2 grafts to the LAD and RCA, 8 (11%) received 2 grafts to the LAD and a diagonal artery, and 21 (27%) received 3 grafts to the LAD, RCA, and a diagonal artery. Average graft number was 1.8 per patient. Mean operation time was 97 ± 26 minutes (range, 41-177 minutes). Mean anastomosis time for each graft was 16.0 ± 2.6 minutes in the first 26 patients and 9.0 ± 1.7 minutes in the rest. Mean intubation time, intensive care unit, and in-hospital stays were 4.1 ± 1.6 hours, 17.6 ± 3.4 hours, and 4.1 ± 0.8 days, respectively. One (1%) of the patients had perioperative myocardial infarction, and 1 (1%) had right lung laceration and prolonged air leakage. There were no cases of cerebrovascular accident, pulmonary insufficiency, deep wound infection, or renal failure. There was no hospital mortality. The mean follow-up period was 26. 8 ± 3.5 months. Thirty-nine (51%) of the patients underwent coronary angiography 1 year after the operation. Fifty-eight grafts were examined. There were 6 occluded grafts, with an overall patency rate of 90%. Three patients died in the follow-up period, 1 (1%) of these patients died of a cardiac cause.

Conclusion: Coronary bypass grafting on the LAD, the RCA, and their tributaries can be safely performed through VLS. Early and midterm results are comparable with those of classic methods of myocardial revascularization. Conversion to full sternotomy is quite easy and safe, should the necessity arise.

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INTRODUCTION

Coronary artery bypass grafting (CABG) can be considered the most widely studied and practiced surgical procedure in the history of medicine. The technology, application, and methods of CABG are continuously evolving [Cosgrove 1984]. Although CABG with cardiopulmonary bypass (CPB) is successful in the treatment of ischemic cardiac disease, it has long been recognized that the use of CPB has immediate and long-term deleterious effects on patients [Kirklin 1983, Eleftheriades 1997, Stump 1999, Newman 2001]. The ideal way to prevent these deleterious effects is to avoid them and conduct the operation on a beating heart. The advent of mechanical stabilizers facilitated revascularization of the coronary arteries, but the equipment is bulky and sometimes very costly. Use of smaller incisions to gain access to the heart and endoscopic graft procurement are other important topics in minimally invasive coronary surgery. Different types of small and less invasive incisions have been introduced to the practice of coronary surgery. Partial lower sternotomy in various configurations excluding the manubrium is one of these incisions.

The purpose of this study was to show the feasibility of off-pump CABG (OPCABG) through very limited partial lower sternotomy (VLS). Mechanical stabilizers were not used in the first 26 patients. This report describes the early and midterm clinical and angiographic results for 76 patients operated on with this technique.

MATERIALS AND METHODS

Patient Population and Indications

From February 2000 to October 2001, 817 patients underwent isolated CABG in our institution. In 305 (37%) of the patients, OPCABG was performed. Early in the study period only patients with absolute or relative contraindications to CPB underwent OPCABG. Later, OPCABG practically became the first choice of treatment in every isolated CABG procedure except those on patients with very dilated ischemic hearts, a deep intramural left anterior descending artery (LAD), or coronary arteries less than 1 mm in diameter.

In 76 (25%) of the 305 patients, OPCABG was performed through VLS. Of these 76 patients, 62 were men and 14 were women. The mean age was 56 ± 4.7 years (range, 32-76 years);

Table 1. Summary of Patient Characteristics

Variable	No. (%)
No. of patients	76 (100)
Sex	
Male	62 (82)
Female	14 (18)
Mean age, y	56.0 ± 4.7
Smoking	69 (91)
Pulmonary disease	42 (55)
Diabetes mellitus	35 (46)
Hyperlipidemia	17 (22)
Hypertension	58 (76)
Cerebrovascular disease	6 (8)
Peripheral vascular disease	9 (12)
Chronic renal failure	4 (5)
Prior myocardial infarction	37 (49)
Unstable angina pectoris	11 (14)
Prior cardiologic intervention	20 (26)
Ejection fraction <0.35	15 (20)
Congestive heart failure (class II or higher)	19 (25)

12 (16%) of the patients were older than 70 years. All patients had stenosis of the LAD alone or in combination with the right coronary artery (RCA). Patients with stenosis of the left main coronary artery, the lateral circumflex artery (CRX), or posterior descending artery were excluded from the study. No emergency operation was included in the study. Table 1 shows the preoperative characteristics of the study group.

Anesthesia Management

Cost-effectiveness and early recovery were the prime goals in design of the anesthetic protocol. The protocol had the following components:

1. Premedication with diazepam 10 mg intramuscularly
2. Induction with fentanyl 3 to 5 μg/kg, pancuronium 0.1 mg/kg, and thiopental sodium (Pentothal) 6 to 8 mg/kg intravenously (IV)
3. Maintenance with fentanyl and norcuronium as necessary
4. Maintenance of mean arterial pressure above 65 mm Hg by volume filling (no use of vasopressor drugs)
5. In the absence of mechanical stabilizers, maintenance of heart rate between 50 and 70 beats/min with pharmacologic agents and atrial pacing if necessary
6. Early extubation

Surgical Technique

A 10-cm skin incision was made in the lower part of the sternum beginning at the level of the third intercostal space down to the xiphoid process (Figure). A transverse incision in the sternum was made with a Gigli saw at the level of the third intercostal space. The VLS was made with an electrically powered sternum saw from the xiphoid process upward. The left internal mammary artery (LIMA) alone or in combination with the right internal mammary artery (RIMA) was prepared with electrocautery and scissors. A single-blade retractor attached to the side of the operating table facilitated exposure during harvest. Heparin 1.5 mg/kg IV was administered. A single-blade sternal retractor was used for visualization of the mediastinum. The pericardium was opened. A pericardial hiatus was created for the LIMA and/or RIMA, and the pericardial edges were tied to the sternal retractor with silk sutures. Several sponges behind the heart were used for visualization of the LAD and the diagonal branches. Upward traction on a thick epicardial silk suture was used for exposure of the RCA. The feasibility of continuing the operation via VLS was studied at this stage. Failure to properly visualize the coronary vessels and poor quality of the mammary arteries led to full sternotomy. The LIMA was always used for LAD revascularization with an end-to-side anastomosis (E-S). The RCA and the diagonal arteries were revascularized by various E-S and end-to-end anastomotic techniques mainly with the radial artery (RA). The saphenous vein (SV) was used early in the study and later when use of the RA was not feasible because of a positive result of an Allen test or because of chronic renal failure (serum creatinine level >1.5 mg/dL). When used as an inflow to the RCA, the RIMA was always extended with SV or RA.

Two 3-0 polypropylene sutures (Prolene; Ethicon, Somerville, NJ, USA) passed deeply around the vessel through a rubber protector proximal and distal to the vessel were used for control of bleeding. In the first 26 patients, mechanical stabilizers were not used, but stabilizers (Octopus II tissue stabilizer; Medtronic, Grand Rapids, MI, USA) were routinely used in the other patients. A test occlusion period of 2 to 5 minutes during which the composite grafts were created was applied to all vessels to be revascularized. Any

Skin incision, 10-cm in length, made in the lower part of the sternum beginning at the level of the third intercostal space down to the xiphoid process.

Table 2. Summary of Reasons for Conversion to Complete Sternotomy*

Inadequate exposure of the coronary artery	
Diagonal	1
Right coronary artery	1
Unsuitable coronary artery	
Intramural LAD	1
Calcified LAD	1
Hemodynamic instability	2
Refractory ventricular fibrillation	1

*LAD indicates left anterior descending artery.

manifestation of myocardial ischemia prompted use of an intracoronary shunt (Medtronic). A simple air blower helped in maintenance of a blood-free surgical field.

In the LAD domain, first the diagonal artery and then LAD were revascularized. Order of revascularization between LAD and RCA was such that first the vessel with the higher degree of stenosis was revascularized. E-S anastomosis between LIMA or RIMA and SV or RA was made in such a way that the previously created bypass could carry blood to the target vessel while the other anastomosis was made with the same inflow artery. This way, total ischemic time was minimized and de-airing of the graft for the last anastomosis became much easier.

The coronary anastomosis was completed with 8-0 polypropylene (Prolene) running suture, and heparin was reversed in a ratio of 1:2 with protamine.

Intensive Care Unit

In the intensive care unit (ICU), weaning was carried out as soon as possible. Electrocardiographic and creatine kinase–myocardial band (CK-MB) follow-up was performed in the ICU 30 minutes after the operation and every 6 hours thereafter.

Anticoagulation with heparin (5000 IU/6 h) was begun as soon as hourly bleeding was <50 mL. Patients were given oral aspirin immediately after extubation. Oral anticoagulation with warfarin was started on the first postoperative day and continued for 3 months to keep the international normalized ratio >2.0.

Follow-up

All patients were examined by us 1 month after the operation. All except 1 had no symptoms and were in Canadian Cardiac Society (CCS) stage I or II. The patient with symptoms had undergone previous percutaneous transluminal coronary angioplasty (PTCA) and stent implantation to the CRX. Control angiography showed in-stent restenosis. Successful PTCA was performed.

Six months postoperatively, 62 (81%) of the patients underwent treadmill exercise testing. Three (5%) of the patients had positive results. These patients underwent control angiography, which showed 2 occluded grafts (1 RCA, 1 diagonal artery) in 2 patients. The third patient had developed diffuse narrowing of the LIMA and LAD (string sign). The other patients were interviewed by telephone. All were symptom free and in CCS stage I or II.

Thirty-nine (51%) of the patients who had no symptoms underwent coronary angiography 14 to 21 months after the operation.

RESULTS

The procedures on 7 (9%) of the 82 patients scheduled for VLS operations were converted to full sternotomy with or without CPB. Table 2 summarizes the reasons for these conversions. None of the patients had any morbidity or mortality because of the conversion.

Mean operation time was 97 ± 26 minutes (range, 41-177 minutes). Mean anastomosis time for each graft was 16.0 ± 2.6 in the first 26 patients and 9.0 ± 1.7 minutes in the rest. In total, 138 vessels were revascularized. The LAD was revascularized by the LIMA in all cases. Table 3 summarizes the anastomosis types. Internal mammary arteries were the sole inflow vessels for coronary bypass grafts.

One (1.3%) of the patients developed electrocardiographic findings of perioperative myocardial infarction. He underwent immediate coronary angiography, which showed occlusion of an RIMA and SV composite graft to a diagonal artery. Hemodynamic status was stable, and further intervention was not performed. This patient was the only one who had a CK-MB level >50 U/L (153 U/L at the first postoperative hour). In 1 (1.3%) of the patients, the right lung was lacerated during transverse sternotomy, and the tear caused prolonged air leak. The patient recovered without surgical intervention. This patient was the only one who stayed in the hospital >10 days.

Mean intraoperative and postoperative bleeding amounts were 368 ± 70 mL and 230 ± 90 mL, respectively. Only 4 (5%) of the patients had more than 500 mL of bleeding. They were the only patients who needed blood transfusion. No reentry operation was necessary.

Table 3. Summary of Perioperative Findings

Operation time, min	97 ± 26
Mean follow-up period, mo	26.8 ± 3.5
Intraaortic balloon counterpulsation	3 (4%)
Intraoperative bleeding, mL	360 ± 70
Postoperative bleeding, mL	230 ± 90
Perioperative myocardial infarction, no. of cases	1 (1%)
Prolonged air leakage, no. of cases	1 (1%)
Stroke, no. of cases	0
Renal failure, no. of cases	0
Deep wound infection, no. of cases	0
Sternal dehiscence, no. of cases	1 (1%)
Postoperative creatine kinase–myocardial band value, U/L	
30 min	42.7 ± 10.3
6 h	27.9 ± 6.6
12 h	35.6 ± 3.1
Intubation time, h	4.1 ± 1.6
Intensive care unit stay, h	17.6 ± 3.4
Hospital length of stay, d	4.4 ± 0.8

Table 4. Distribution of Angiographically Occluded Grafts*

Diagonal-LIMA-SV (E-S)	2
Diagonal-RIMA-RA (E-E)	1
RCA-RIMA-RA (E-E)	1
RCA-LIMA-RA (E-S)	2

*LIMA indicates left internal mammary artery; SV, saphenous vein; E-S, end-to-side anastomosis; RIMA, right internal mammary artery; RA, radial artery; E-E, end-to-end anastomosis.

Three (4%) of the patients received intraaortic balloon counter pulsation in the immediate postoperative period, and 9 (12%) received inotropic support.

Mean intubation time, ICU stay, and in-hospital stay were 4.1 ± 1.6 hours, 17.6 ± 3.4 hours, and 4.6 ± 0.8 days, respectively.

The mean follow-up period was 26.8 ± 3.5 months. The postoperative follow-up rate was 100% at 1 month but 81% and 85% at 6 months and 1 year, respectively. One month postoperatively all but 1 of the patients (98.7%) were symptom free. Control angiography in that patient showed stenosis in a previously performed stent implantation site. At 6 months, results of a treadmill exercise test were positive in 3 (4%) of the patients. Control angiography in these patients confirmed the presence of 2 occluded grafts.

Thirty-nine (51%) of the patients underwent coronary angiography 14 to 21 months after the operation. Of a total of 58 grafts, 6 were either completely occluded or stenosed, for a patency rate of 90%. In 4 patients 1 graft and in 1 patient 2 grafts were occluded (Table 4). None of the occlusion occurred in an LAD. Only 1 patient had stenosis of a native RCA that had been bypassed previously, and this patient was treated by PTCA. It was surprising that closure or stenosis of the E-S anastomosis in the composite graft did not lead to deterioration of flow in the main graft.

DISCUSSION

Although CABG is the most widely performed and studied operation in the history of medicine, the techniques and methods are still being refined and improved in many ways [Loop 1998].

The deleterious effects of CPB have detracted from the efficacy of CABG. OPCABG has been developed and practiced for avoidance of the side effects of extracorporeal circulation and cardiac arrest from cross-clamping of the aorta. With OPCABG, the systemic inflammatory response to the pump apparatus and its aggravating effects on existing comorbid conditions such as chronic obstructive pulmonary disease, chronic renal failure, diabetes, and cirrhosis are reduced substantially.

Despite encouraging short-term results, long-term benefits of OPCABG still have to be evaluated [Moshkovitz 1995, Gundry 1998, Trachiotis 1998]. A constant criticism by opponents of OPCABG has been that the procedure fails to create an optimal anastomosis and complete revascularization. Although OPCABG on the anterior vessels of the heart without use of stabilizers has been reported, the advent of these devices has produced the luxury of anastomosis in a nearly still field [Naseri 2002]. By the mid-1990s different types of heart positioners made exposure and consequent revascularization of the CRX territory a reality [Novitzky 2002]. Beginning in 1997 we started doing OPCABG as the first choice of revascularization procedure in high-risk patients with comorbid states. After we completed the learning curve of this surgical procedure, all patients undergoing isolated CABG were given a chance to be operated on with off-pump technique. Hemodynamic instability, deep intramyocardial LAD, and coronary arteries less than 1 mm in diameter were the reasons for conversion to on-pump CABG.

Previous authors have advocated use of smaller incisions for decreasing surgical trauma and for improving cosmetic results, factors that have real impact on recovery of the patient [Moreno 1997, Lichtenberg 2000]. For patients with lesions of the LAD alone, limited anterior small thoracotomy (LAST) can be used for harvesting the LIMA and for anastomosis [Calafiore 1998]. Only the stenotic lesions of LAD can be tackled with this method. Because of this important shortcoming, various types of partial sternotomy incisions have come to the practice of CABG. We used a VLS similar to that described by others [Walerbusch 1998, Troise 2002]. The advantage over LAST are (1) easy takedown of both LIMA and RIMA, (2) access to the RCA, (3) easy conversion to full sternotomy should it become necessary, and (4) a much larger surgical field for easy creation of various T, Y, and I composite grafts. There was no mortality in our study group. The rate of perioperative myocardial infarction was comparable with that of on-pump CABG mentioned elsewhere.

The incidence of stroke after CABG is mainly related to atheroembolism from the aorta during either cannulation or creation of the proximal anastomosis with the use of an aortic side clamp. The complete aortic no-touch component of this method led to a lack of any cases of postoperative stroke.

The goal of this study was assessment of OPCABG with 1 or both mammary arteries in a subset of patients with 2-vessel disease operated on through median VLS. Total revascularization was performed in all patients. Although this group represented a small subset of our CABG cases, it combined the advantages of (1) OPCABG, (2) VLS, and (3) an aortic no-touch technique very favorable in atheroma of the ascending aorta. The procedure described completes the surgeon's alternatives in the field of CABG.

CONCLUSION

This study was limited in that it represented an observational retrospective analysis of the data and did not have a control group for direct comparison. Although the operative technique led to excellent early and satisfactory midterm results with comparable mortality and very low morbidity, the follow-up period was short and did not give an idea about the long-term effects of this modality. Further follow-up is required for evaluation of the long-term results of this treatment.

At the beginning, working in a small surgical field with a bulky mechanical stabilizer may seem cumbersome, but with

time and an increase in experience of the surgical team, OPCABG through VLS may become the procedure of choice for a selected group of patients with stenosis of the LAD and RCA.

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