Original Article

Individualized Off-Pump All Internal Thoracic Artery Revascularization

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Objective: We developed an individualized off-pump approach in an all internal thoracic artery (AITA) composite graft revascularization (AITACR) program to minimize postoperative neurological complications and to obtain the best long-term results possible. Early results of the individualized approach are reported.

Patients and Methods: The operative method (on-pump or off-pump) was determined based on institutional selection criteria. Early neurological outcomes were evaluated in 157 men and 42 women; the mean age was 67.3 ± 9.3 years.

Results: Fifty-nine underwent off-pump procedures and 140 on-pump. The off-pump patients were older than the on-pump patients. The prevalence of diabetes mellitus, history of previous cerebral infarction, and atherosclerotic disease in the ascending aorta was more frequent in the off-pump group than in the on-pump group. The total number of distal anastomoses was 3.2 ± 0.9 per patient. There was no operative mortality. Three patients (1 in the off-pump group and 2 in the on-pump group) had postoperative cerebral infarctions possibly related to postoperative atrial fibrillation.

Conclusions: When patients were allocated to the on-pump group or the off-pump group based on our criteria, excellent results were achieved with acceptable morbidity. An individualized off-pump approach in an AITACR program appears reasonable and safe with excellent early neurological outcomes. (Ann Thorac Cardiovasc Surg 2009; 15: 155–159)

Key words: coronary artery bypass grafting, neurological complication, off-pump coronary artery bypass grafting, individualized approach, all internal thoracic artery composite graft revascularization

Introduction

Avoiding the dreaded complication of stroke after coronary artery bypass grafting (CABG) is a vital problem. Off-pump coronary artery bypass grafting (OPCABG) is now widely accepted in the medical community as a minimally invasive procedure with minimal risks of stroke complications.[1)] However, there are no clinical reports of consistent stroke-free outcomes after OPCABG, and there is no definitive agreement on which patients should undergo this procedure to avoid perioperative stroke. The aorta-no-touch technique has been reported as useful in minimizing this neurological perioperative complication.[2,3)]

The priority in performing coronary revascularization should focus on long-term results, such as angina-free rate or survival rate. In selecting the bypass graft and its design during CABG, the Tector group has developed an approach to obtain the best possible long-term outcomes.[4)]

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The exclusive use of internal thoracic arterial (ITA) conduits with a composite graft (all ITA composite graft revascularization [AITACR]) was introduced to treat patients with triple-vessel disease.[4] In 2000, we developed a CABG program to obtain the best possible short- and long-term and stroke-free results possible by individually selecting the OPCABG procedure and by maximally avoiding aorta-touching procedures with the use of AITACR.

In this study, patients were individually allocated to either on-pump CABG (ONCABG) or OPCABG based on the results of chest computed tomography (CT) and magnetic resonance angiography (MRA) of the neck and intracranial vessels. Selection criteria for OPCABG are clarified in the *Patients and Methods* section. We reviewed the immediate postoperative results retrospectively in CABG patients undergoing AITACR to clarify risks of the perioperative neurological complications rate after individualized AITACR procedures. At present, there is little evidence documenting the immediate operative outcomes in a patient population undergoing CABG with AITACR after individualized allocation to the ONCABG or OPCABG procedure.

Patients and Methods

We started the AITACR program in January 2000 for patients undergoing CABG. From that month through July 2002, a total of 294 CABG procedures were performed at the Iwate Medical University Memorial Heart Center. Patients undergoing CABG procedures with concomitant valve, congenital cardiac, or aortic surgery were excluded from this study, along with patients undergoing procedures for single distal anastomosis or bilateral in situ ITA anastomoses. Therefore 199 patients were included in the present study, comprising 157 men and 42 women with a mean age of 67.3 ± 9.3 years. They were consecutive patients who underwent isolated CABG with the use of all ITA composite grafts (with no radial and no gastroepiploic artery grafts), and no patient was excluded because of poor left ventricular function, female sex, older age, diffuse disease, or increased operative risk. Informed consent was obtained from every patient in this study after they fully understood the procedure and the allocation status. In all patients, the revascularization was complete technically. All operations were performed by one of two of the authors, either KK or HI, as the surgeon, depending on the surgery schedule.

ITA harvest

Most of the ITA grafts were harvested as in situ, skeletonized grafts with the use of an electrocautery or ultrasonic scalpel. Drug-soaked (papaverine or olprinone hydrochloride)[5] sponges were used to wrap the grafts until anastomosis. Composite grafts were constructed before the cardiopulmonary bypass. All distal anastomoses were performed with a cardiopulmonary bypass, aortic cross clamp, and cardioplegic arrest in patients undergoing ONCABG. At the end of the procedure, blood flow in the main left ITA stem was measured using a 2.0- or 3.0-mm transit time Doppler flow probe (Medi-Stim AS, Oslo, Norway).

Selection for OPCABG

Allocation to the OPCABG group was individually indicated according to our criteria. Candidates included (1) patients with severe carotid or intracranial cerebral artery disease screened by both the head and neck MRA, followed individually by brain-stress ^{133}Xe single-photon emission CT[6]; (2) patients having severe ascending aortic disease with calcification or atheromatous debris screened by chest contrast CT; (3) patients with untreated malignancy; and (4) patients with impaired renal function (serum creatinine > 1.5 mg/dl) or ongoing hemodialysis.

The percentage of stenosis was calculated by dividing the luminal diameter of the narrowest part of the artery by that of a part distal to the lesion. The following MRA findings defined severe stenosis: ≥ 60% stenosis or total occlusion of the common carotid artery; 60% stenosis or total occlusion of the internal carotid artery; 60% stenosis of the dominant vertebral artery or total occlusion of both vertebral arteries; 60% stenosis or total occlusion of the basilar artery; stenosis accompanied by poor peripheral blood perfusion or total occlusion of the anterior, middle, and posterior cerebral arteries.

Early operative outcomes (mortality, morbidity, neurological complications) and duration of intensive care unit (ICU) stay were noted and compared between the ONCABG and OPCABG groups.

All data are expressed as mean ± standard deviation, after processing using a statistical software package (StatView 5.0 for Windows, SAS Institute, Cary, NC, USA). The chi-square test and Fisher's exact test were used for categorical data, and Student's *t*-test was used for numerical data. Statistical significance was set at $p < 0.05$.

Table 1. Clinical profiles of patients

	Overall	ONCABG	OPCABG	P value
Age (years)	67.3 ± 9.3	65.7 ± 9.5	71.2 ± 7.9	0.0001
Gender (f/m)	42/157	33/107	9/50	
Unstable AP (%)	46 (22.6)	28 (21.2)	18 (30.5)	
Preop. IABP (%)	15 (7.5)	12 (6.8)	3 (5.1)	
LVEF (%)	56.2	54.2 ± 14.9	60.8 ± 13.3	0.0039

f, female; m, male; AP, angina pectoris; preop., preoperative; IABP, intra-aortic balloon pumping; LVEF, left ventricular ejection fraction; ONCABG, on-pump coronary bypass grafting; OPCABG, off-pump coronary artery bypass grafting.

Table 2. Number of diseased vessels in the two groups

	Overall (190/191)	ONCABG (131/132)	OPCABG (59/59)
SVD (%)	7 (3.7)	4 (3.0)	3 (5.1)
DVD (%)	84 (44.0)	51 (38.6)	33 (55.9)
TVD (%)	99 (51.8)	76 (57.6)	23 (38.9)

SVD, single-vessel disease; DVD, double-vessel disease; TVD, triple-vessel disease; ONCABG, on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting.

Results

Operative method

Sixty patients underwent OPCABG after the allocation process. One patient in this group was converted to ONCABG because of hemodynamic instability; therefore 141 patients underwent ONCABG (59 OPCABG and 140 ONCABG patients). Mean age at surgery was 65.7 ± 9.5 years in the ONCABG group, whereas that in the OPCABG group was 71.2 ± 7.9 years ($p < 0.0001$). There were 107 men (74.2%) and 33 women (25.8%) in the ONCABG group, and 50 men (84.7%) and 9 women (15.3%) comprised the OPCABG group. Table 1 shows preoperative patient profiles.

The mean cross-clamp time for the ONCABG patients was 73.9 ± 26.7 min. Preoperative left ventricular ejection fraction (LVEF) in the ONCABG patients was worse than in the OPCABG patients ($p < 0.0039$). The prevalence of diabetes mellitus, the history of previous cerebral infarction, and atherosclerotic disease in the ascending aorta were more frequent in the OPCABG than in the ONCABG group. Table 2 shows the analysis of the number of diseased vessels between the two groups. One ONCABG patient had pure left main disease. The difference in the number of diseased vessels between the groups did not reach statistical significance.

The total number of distal anastomoses was 3.2 ± 0.9 per patient. It was greater in the ONCABG group (3.4 ± 0.8 per patient) than in the OPCABG group (2.8 ± 0.8 per patient) ($p < 0.0001$). Detailed information on the anastomoses is listed in Table 3. Total flow through the left ITA stem was 84.9 ± 35.9 ml/min: 88.6 ± 37.8 ml/min in the ONCABG group and 77.0 ± 30.3 ml/min in the OPCABG group ($p < 0.0401$) (Table 3).

Major morbidity and mortality

There was no operative mortality. The ONCABG group contained 1 case of late cardiac tamponade, 1 of reexploration for bleeding, 1 of mediastinitis, 1 of acute cholecystitis, and 2 of long intubation (defined as intubation period > 48 hrs). None had neurologic disturbance immediately after surgery. However, 2 patients had postoperative cerebral infarction, presumably related to postoperative atrial fibrillation. Both patients were discharged with full neurological recovery. The OPCABG group contained 1 case of late tamponade and 1 of long intubation. No cerebral complications occurred immediately after surgery. One patient, however, had a minor cerebral infarction, possibly from postoperative atrial fibrillation, and recovered completely by the time of hospital discharge. There was no statistically significant difference in the incidence of major morbidity, and the duration of ICU stay was the same between the two groups.

Table 3. Operative data

	Overall	ONCABG	OPCABG	P value
No. of anastomoses	3.2 ± 0.9	3.4 ± 0.8	2.8 ± 0.8	<0.0001
No. of LITA anastomoses	1.4 ± 0.5	1.4 ± 0.5	1.2 ± 0.4	0.0027
No. of RITA anastomoses	1.8 ± 0.7	2.0 ± 0.8	1.6 ± 0.7	0.0005
ITA flow (ml/min)	84.9 ± 35.9	88.6 ± 37.8	77.0 ± 30.3	0.0401
ICU stay (days)	4.4 ± 6.6	4.3 ± 6.8	4.6 ± 6.3	0.7053

LITA, left internal thoracic artery; RITA, right internal thoracic artery; ITA, internal thoracic artery; ICU, intensive care unit; ONCABG, on-pump coronary artery bypass grafting; OPCABG, off-pump coronary artery bypass grafting.

Discussion

In 2000, we developed a new CABG program aimed at (1) avoiding the perioperative neurological complications associated with ascending aortic maneuvers and/or with the use of cardiopulmonary bypass; and (2) obtaining the best possible long-term patency and survival results. Therefore patients scheduled for CABG underwent screening chest CTs and neck and head MRAs to evaluate ascending aortic disease and occlusive neck and intracranial artery disease. If deemed necessary, a patient might also undergo preoperative brain-stress ^{133}Xe single-photon emission CT to evaluate intracranial perfusion status. All patients underwent AITACR procedure with either ONCABG or OPCABG after individual screening and allocation. The effect of OPCABG procedure on a patient's postoperative renal function and remote outcome has not been fully clarified. However, at the beginning of the present study we set the inclusion criteria for OPCABG as serum creatinine > 1.5 mg/dl, which still remains a matter of debate.

It is our belief that the surgical quality of coronary anastomosis in ONCABG is generally superior to that in beating-heart OPCABG anastomosis. The surgical quality in anastomosis is most likely to influence the long-term results. For these reasons, we believe that individualized allocation to the OPCABG technique should be performed instead of a compulsory OPCABG strategy for all revascularization candidates if the best possible long-term results may be expected.

Long-term patency of the graft is an important key factor determining the long-term success rate after CABG. In this sense there has been growing interest in completing CABG, using all arterial grafts.[4,7,8] The concept of complete arterial revascularization has been based on the assumption that all arterial grafts are associated with superior long-term patency rates. In the literature, grafts reported for use in complete arterial revascularization include the ITA, radial artery, gastroepiploic artery, and others.[9,10] However, recent results have suggested that all arterial grafts do not function postoperatively as favorably as the ITA graft.[11–13] Thus as an extreme approach to complete arterial revascularization, Tector and associates reported a CABG graft strategy that exclusively used ITAs with T- or I-shaped grafts in patients with triple-vessel disease.[4]

We have been interested in AITACR since 2000 and reported the success rate and most suitable graft design for AITACR from our experience in 2005.[14] In the present study, no patient experienced intraoperative cerebral complications. However, 3 patients (1 in the OPCABG group and 2 in the ONCABG group) experienced postoperative cerebral complications, possibly related to postoperative atrial fibrillation. This may illustrate the importance of prophylaxis against postoperative atrial fibrillation or transient anticoagulation.

There was a statistically significant difference in the patient profiles between the two groups. The OPCABG group had better LVEF than the ONCABG group. The reason for this difference could not be explained through this study. There were statistically more patients in the OPCABG group with a history of diabetes mellitus, old cerebral infarction, and disease in the ascending aorta than in the ONCABG group. This difference is related to our selection criteria for OPCABG.

One of the technical differences between the two groups was the total number of distal coronary anastomoses and the ITA stem flow. The total flow in the ONCABG group was greater than in the OPCABG group, and the OPCABG group had fewer distal anastomoses than the ONCABG group did. These differences could be a result of the difference in the number of diseased coronary vessels in the two groups (Table 3).

There were several limitations in this study. It was a

retrospective, nonrandomized study investigating perioperative cerebral complications in a small number of patients who underwent AITACR. The allocation to the type of revascularization procedures (on-pump or off-pump) was determined by our selection criteria. There may thus have been an unavoidable patient allocation bias.

In terms of overall mortality and morbidity in the present series, the incidence of neurological complications was comparable or better than those in other reports in the literature.[15] When patients were allocated by our criteria to either the on-pump or the off-pump group in the AITACR program, excellent results with acceptable morbidity were achieved. A large-scale randomized trial is indicated to investigate further the role of minimizing neurological complications in the individualized OPCABG AITACR approach and of obtaining better long-term results. In summary, we conclude that the individualized OPCABG approach in our AITACR program is reasonable and safe with excellent immediate neurological outcomes.

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