

The impact of incomplete revascularization and angiographic patency on midterm results after off-pump coronary artery bypass grafting

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Objectives: Higher rates of incomplete revascularization (IR) and reduced patency are possible drawbacks of off-pump coronary artery bypass grafting (OPCAB); both may adversely affect outcome after surgery. This study was conducted to shed light on the relationships among IR, angiographic patency, and midterm results after OPCAB surgery.

Methods: A total of 1604 consecutive patients underwent OPCAB during a 6-year period; 1581 patients (95%) underwent systematic postoperative angiography. Complete follow-up was achieved in 99.5% (median, 3.2 years; up to 6.5 years). A total of 216 patients had IR (13%), and 225 had at least 1 graft failure (FitzGibbon B or O).

Results: All the event-free survival rates for all-cause mortality ($P < .001$), cardiac death ($P = .020$), and major adverse cardiac and cerebrovascular events ($P < .001$) were lower in the IR group. By using the Cox proportional hazards model, IR was an independent risk factor for all-cause mortality (hazard ratio [HR], 1.80; 95% confidence interval [CI], 1.15-2.81). Of those who underwent postoperative angiography, the patients with graft failure experienced reintervention more frequently than those with all grafts patent (HR, 5.49; 95% CI, 3.43-8.77). Even with excluding patients who had undergone reintervention immediately after angiography, graft failure was still an independent risk factor for reintervention afterwards (HR, 2.41; 95% CI, 1.30-4.47).

Conclusions: Incomplete revascularization was relevant to higher midterm mortality after OPCAB, whereas the risk of reintervention was higher for patients with occluded grafts. Complete revascularization, coupled with achievement of a higher patency rate, could be expected to improve follow-up outcomes after OPCAB surgery. (J Thorac Cardiovasc Surg 2014;147:1225-32)

Since the introduction of off-pump coronary artery bypass (OPCAB), many studies have been published comparing OPCAB with conventional coronary artery bypass (CCAB). However, for major outcomes, such as mortality, OPCAB has not been demonstrated to be superior to CCAB.¹ In many randomized controlled trials,² the number of anastomoses was fewer and the rate of complete revascularization (CR) was lower in the OPCAB arm than in the CCAB arm, except for in a few studies³; similar observations were reported in retrospective studies.⁴ CR has been well recognized as a main goal of CCAB.^{5,6} Indeed, investigations

have demonstrated that incomplete revascularization (IR) is one of the predictors of long-term mortality, even in OPCAB patients.^{7,8}

Patency rate is another issue with OPCAB. A recently published, large-scale, randomized study² reported a lower patency rate in the OPCAB arm than in the on-pump arm on 12-month angiograms. This is partly because OPCAB is a more technically demanding procedure than CCAB. In fact, bypass grafting without extracorporeal circulation carries the risk of graft failure.

Lopes et al⁹ have recently demonstrated that vein graft failure 1 year after coronary artery bypass surgery is associated with an increased risk of death, myocardial infarction (MI), or revascularization at 4 years after the angiogram. This association is driven mostly by revascularization. Retrospective studies have also reported that patients undergoing OPCAB experienced reintervention more frequently at follow-up than those undergoing CCAB,^{10,11} and this may be owing to both IR and reduced patency in OPCAB. However, the relative contribution of the 2 possible causes has not yet been determined.^{10,12,13} Therefore, this study was conducted to shed light on the associations among IR, systematic angiographic evaluation, and midterm results after OPCAB surgery.

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Abbreviations and Acronyms

BITA	= bilateral internal thoracic artery
BSA	= body surface area
CCAB	= conventional coronary artery bypass
COPD	= chronic obstructive pulmonary disease
CI	= confidence interval
CR	= complete revascularization
CRF	= chronic renal failure
CT	= computed tomography
EuroSCORE	= European System for Cardiac Operative Risk Evaluation
HR	= hazard ratio
IR	= incomplete revascularization
LAD	= left anterior descending
LCx	= left anterior circumflex
MACCE	= major adverse cardiac and cerebrovascular event
MDCT	= multidetector computed tomography
MI	= myocardial infarction
OPCAB	= off-pump coronary artery bypass
PCI	= percutaneous coronary intervention
RCA	= right coronary artery

METHODS**Study Design**

This was a database study using Kokura Memorial Hospital (Fukuoka, Japan) patient medical records. The primary objective of this study was to compare the midterm results between the CR and the IR groups. The secondary objective was to investigate the effect of angiographic patency on midterm events. The study was approved by the Kokura Memorial Hospital Institutional Review Board.

Patients

From January 2000 to December 2005 inclusive, 1681 patients underwent isolated coronary artery bypass grafting by a single surgeon (H.O.) at Kokura Memorial Hospital. Seventy-seven patients who received CCAB were excluded, and the remaining 1604 (95%) consecutive OPCAB patients composed the study cohort. Almost half of the CCAB patients were in a hemodynamically unstable condition, even with an intra-aortic balloon pump; the remaining patients had previous cardiac surgery and required cardiopulmonary bypass for re sternotomy and exposure. Six OPCAB procedures were converted to CCAB because of hemodynamic deterioration, and they were included in the cohort of this study. All data were collected prospectively and entered into the institutional database. The definitions of preoperative data in this study were based on those reported in the European System for Cardiac Operative Risk Evaluation (EuroSCORE).¹⁴ Extracardiac arteriopathy includes any one or more of the following: claudication, carotid occlusion or greater than 50% stenosis, or previous or planned intervention on the abdominal aorta, limb arteries, or carotids.¹⁴

CR was defined according to the "traditional" classification described in the Coronary Artery Surgery Study⁵: revascularization is incomplete, with failure to graft into any system with significant stenosis (>50%) or

lack of grafting into both the left anterior descending (LAD) and circumflex (LCx) systems for 50% or greater left main trunk disease.

Surgical Technique

All OPCAB procedures were performed under general anesthesia. The heart was approached via median sternotomy. Heparin (100 KIU/kg and an additional dose) was administered to achieve and maintain the activated clotting time at more than 250 seconds. The strategies of graft selection and distribution have been described elsewhere.^{15,16} In specific cases, when distal vessels in the LCx or right coronary artery (RCA) systems were poorly visualized on preoperative angiography, and the territories of the vessels were deemed to have less myocardial viability based on the results of echocardiography and/or left ventriculography, we did not plan to place any grafts. These 98 cases were also included in the IR group throughout the study. Endarterectomy was performed if a coronary artery had a long, calcified plaque. Heparin was reversed with a half-reversal dose of protamine sulfate. Oral aspirin (100 mg) was administered from postoperative day 1 and through to and including the follow-up period.

Angiographic Evaluation

Bypass conduits and native coronary arteries were systematically evaluated in 95% of patients (1422 patients) by catheter-based angiography¹⁶ or multidetector computed tomography (MDCT; SOMATOM Sensation 16; Siemens AG, Munich, Germany) before discharge with the patients' written informed consent. The postoperative angiography was performed as a routine evaluation, and is standard of care in Japan. Patients with cerebrovascular disease, renal dysfunction, or respiratory failure were excluded for clinical reasons. Although all the patients underwent angiography within the same hospitalization period as the index OPCAB, the dates of the angiography were not available from our database. The experienced interventional cardiologists or the radiologists reviewed the results of graftography. On catheter-based angiography, the conduit was reviewed in at least 2 orthogonal views and scored on the worst appearance of the proximal anastomosis, body of the conduit, and distal anastomosis, according to the FitzGibbon classification.¹⁷ On MDCT, volume-rendering images and curved multiplanar reconstruction of the anastomotic sites and conduits were constructed to evaluate and score the patency, according to the same classification. Based on the results of angiography, the cardiologists and/or radiologists judged the suitability and the need for postoperative reintervention.

Of 1521 patients who underwent angiographic evaluation, 225 (14.8%) were identified as having at least 1 suboptimal graft (FitzGibbon B or O) and were included in the occlusion group. The remaining 1296 patients were identified as having all patent grafts (FitzGibbon A) and were included in the patent group.

Follow-up

Complete follow-up was achieved in 99.5% of cases (median, 3.2 years; range, 1 month to 6.5 years). The patients were followed up in our outpatient clinic at 1, 6, and 12 months after discharge and at yearly intervals thereafter. The latest information was obtained by telephone call or by the attending surgeons consulting the referring cardiologists. Eight patients were lost to follow-up, and their data were censored at the time of the last contact, at which point they were alive and had not had any cardiac events. Prospectively gathered data on follow-up included death from any cause (including in-hospital mortality), MI, reintervention (surgical or percutaneous coronary intervention [PCI]), and stroke, which was defined as a neurological deficit diagnosed by a neurologist and confirmed by computed tomography (CT). Major adverse cardiac and cerebrovascular events (MACCEs) were defined as all-cause mortality, nonfatal MI, repeated revascularization (including in-hospital reintervention), or stroke. If more than one event arose in one patient, only the time to the first event was analyzed.

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