Ten-year experience with off-pump coronary artery bypass grafting: Lessons learned from early postoperative angiography

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Objective: We performed early postoperative angiography to assess anastomosis accuracy and patency after off-pump coronary artery bypass grafting.

Methods: One thousand three hundred forty-five patients who underwent off-pump coronary artery bypass grafting between January 1998 and December 2007 were studied. Grafts for distal anastomoses were left internal thoracic artery (n = 1281), right internal thoracic artery (n = 679), right gastroepiploic artery (n = 836), radial artery (n = 14), and saphenous vein (n = 188). Groups underwent off-pump coronary artery bypass grafting without (group I, n = 234) or with (group II, n = 1111) intraoperative graft flowmetry. Early postoperative (≤7 days) angiography was performed in 1278 cases (95.0%) at 1.6 ± 1.2 postoperative days.

Results: Operative mortality was 1.6%. Average number of distal anastomoses was 3.0 ± 1.0. Postoperative angiography showed early patencies of 98.9% for arterial grafts and 88.2% for venous grafts ($P < .001$). In group II, intraoperative flowmetry-guided revision was performed in 2.2% of distal anastomoses. Patency of arterial grafts was significantly higher in group II than group I (97.2% vs 99.1%, $P < .001$); however, patency of venous grafts was not significantly different (86.0% vs 92.2%, $P = .099$). Early reoperation for graft revision according to angiographic findings was performed in 35 patients.

Conclusions: Early patency of venous grafts was significantly lower than that of arterial grafts. Intraoperative flowmetry and revision of abnormal grafts improved early graft patency, and reoperation according to early angiographic findings may further improve graft patency. (J Thorac Cardiovasc Surg 2010;139:256-62)

Because early graft patency can influence the outcome of coronary artery bypass grafting (CABG), there have been concerns about accuracy and patency of the grafts with the resurgent interest in off-pump CABG (OPCAB).[1,2] Of several methods to assess graft patency, ultrasonographic flowmetry has been used with increasing frequency because of its noninvasiveness, simplicity, and reproducibility; however, it underestimates or overestimates the anastomotic accuracy relative to angiography.[3-5] Although conventional angiography is the criterion standard technique, it has limitations as an intraoperative or early postoperative study.[6,7] Despite the limitations of current methods of assessing graft patency, however, early identification of graft compromise can facilitate timely graft revision, thereby ensuring a patent graft at discharge. The aims of this study included (1) assessment of the early angiographic results of a 10-year OPCAB experience, (2) evaluation of the efficacy of intraoperative graft flowmetry and early angiography, and (3) presentation of the results of early angiographically guided reinterventions.

MATERIALS AND METHODS

Patient Characteristics

Among the 1481 patients who underwent isolated CABG between January 1998 and December 2007, OPCAB was performed in 1345 cases (90.8%). During the study period there were 38 conversions (38/1383, 2.7%) to cardiopulmonary bypass during OPCAB, and those procedures were excluded from this study. Since the introduction of transit-time flow measurement (TTFM; Medi-Stim AS, Oslo, Norway) at our institution in 2000, we have derived criteria to predict abnormal grafts (occluded or competitive grafts) and revised the abnormal graft intraoperatively.[8] The study patients were divided into group I (n = 234), patients who underwent OPCAB before the introduction of TTFM, and group II (n = 1111), patients who underwent OPCAB after the introduction of TTFM in 2000. There were no differences in sex, preoperative risk factors such as dyslipidemia and history of stroke, acute coronary syndrome, and left ventricular dysfunction (left ventricular ejection fraction <35% measured by transthoracic echocardiography) between the groups. Other risk factors, however, such as hypertension ($P = .000$) and diabetes ($P = .011$), were more frequent in group II, and group II patients were also older than those in group I ($P = .001$). The average number of distal anastomoses per patient was 3.0 ± 1.0, with no significant intergroup difference (3.1 ± 1.1 in group I vs 3.0 ± 1.0 in group II, $P = .578$). The grafts used for distal anastomoses were left internal thoracic artery (ITA, n = 1281), right ITA (n = 679), right gastroepiploic artery (RGEA, n = 836), radial artery (n = 14), and saphenous vein (n = 188). Left and right ITAs were used at similar frequencies, whereas RGEAs were used predominately in group II, and saphenous veins and radial arteries were used predominately in group I (Table 1).

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Abbreviations and Acronyms

CABG = coronary artery bypass grafting
ITA = internal thoracic artery
LAD = left anterior descending coronary artery
OPCAB = off-pump coronary artery bypass grafting
RGEA = right gastroepiploic artery
TTFM = transit-time flow measurement

Early postoperative (≤7 days) angiography for evaluation of the anastomotic sites and patency of the grafts was performed in 1278 patients (95.0%) on postoperative 1.6 ± 1.2 days. Informed written consent, including the possible benefits and risks of postoperative angiography, was obtained from all patients. Patients who died, refused angiographic evaluation, or had postoperative development of acute renal failure were excluded from the angiographic follow-up. Patients with end-stage renal disease with long-term maintenance dialysis, however, were included in the angiographic follow-up.

Follow-up angiography included a selective graft angiogram with an additional native coronary angiogram taken when the graft angiogram revealed abnormal findings. All patients received continuous intravenous nitroglycerin until angiography was performed to avoid coronary spasm during the early postoperative period. If angiography demonstrated any abnormal finding, this was managed with medical follow-up, percutaneous intervention in the catheterization laboratory, or surgical intervention. Surgical intervention was indicated in cases with (1) abnormal findings including occlusion of the left anterior descending coronary artery (LAD) territory anastomosis, (2) occlusion of multiple distal anastomoses other than the LAD anastomosis, or (3) a graft trunk problem such as total or near total nonopacification of the proximal or middle graft trunk by graft angiography but well-visualized distal anastomoses and distal graft trunk by native coronary angiography.

The patients were continuously monitored with postoperative electrocardiography during stays in the intensive care unit and in the general ward until the chest tubes were removed. A standard 12-lead electrocardiogram was checked daily thereafter during the hospital stay. Occurrence of any short runs of atrial fibrillation during the hospital stay was considered to represent development of atrial fibrillation. Perioperative myocardial infarction was defined as positive results on at least 2 of 3 different tests: elevated peak serum creatine kinase isoenzyme level (>100 ng/mL), appearance of new Q waves on the electrocardiogram, or newly developed regional wall motion abnormalities on the postoperative echocardiogram. Postoperative acute renal failure was defined as an increase of more than 50% in serum creatinine level from the preoperative value or a need for renal replacement therapy irrespective of serum creatinine level. Stroke was defined as a new and sudden onset of neurologic deficits lasting longer than 24 hours with no apparent nonvascular causes.

A computer-based patient database system was used for this retrospective study. The study protocol was reviewed by the institutional review board and approved as a minimal risk retrospective study (approval no. H-0812-053-266) that did not require individual consent according to the institutional guidelines for waiving consent.

Surgical Techniques and Revascularization Strategies

The basic surgical procedures and principles of OPCAB have been previously described.[9] The operations were all performed by a single surgeon (K-B.K). The patients were heparinized with an initial 1.5 mg/kg dose of heparin and periodically received supplemental doses to maintain an activated clotting time longer than 300 seconds during OPCAB. During the study period, we changed revascularization strategies because of our early patency study after OPCAB.[10] Since the latter half of 1999, we have tried to perform total arterial revascularization and to avoid the use of venous grafts if possible, a skeletonized technique for harvesting the arterial graft has been used, and protamine has not been given at the end of the procedure. Since 2000, we have revised the abnormal graft intraoperatively under a collective interpretation of TTFM variables. The criteria for predicting abnormal grafts[8] were as follows: (1) systolic dominant or balanced pattern of the flow curve in the left coronary territories and systolic dominant pattern of the flow curve in the right coronary territories, (2) mean flow less than 15 mL/min, (3) pulsatility index greater than 3 in the left coronary territories and greater than 5 in the right coronary territories, and (4) insufficiency ratio greater than 2%. After performing each anastomosis, we examined the anastomosis status with TTFM and revised it if there was any abnormal finding in TTFM. All the anastomoses were rechecked with TTFM after completion of revascularization just before pericardial closure.

All patients stopped taking aspirin on the day of surgery and resumed aspirin beginning at 1 postoperative day. Ticlopidine hydrochloride (200 mg/day) was used simultaneously with aspirin for 2 postoperative months. If the patient had a high blood level of low-density lipoprotein cholesterol (>100 mg/dL) postoperatively, drug therapy was started.

Statistical Analysis

Statistical analyses were performed with the SPSS software package (version 12.0; SPSS, Inc, Chicago, Ill). The significance of differences between groups was assessed with the unpaired 2-tailed t test for continuous variables and with the χ^2 test and Fisher's Exact Test for categoric variables. Patient demographic and clinical characteristics associated with revision reoperation were assessed by univariate analysis (χ^2, t test) and multivariable analysis (multiple logistic analysis). The univariate variables with P values less than .3 were entered into the logistic regression to detect significant independent risk factors. All results were expressed as mean ± SD for continuous data and proportion for binary data.

RESULTS

Mortality and Morbidities

Operative mortality (any death within 30 days, including deaths after hospital discharge) among all patients was 1.6% (22/1345), and there was no difference between the groups (1.7% vs 1.6%, P not significant). Postoperative morbidities were atrial fibrillation (23.9%), perioperative myocardial infarction (5.7%), acute renal failure (2.8%), bleeding-related reoperation (3.9%), reoperation for graft revision (2.6%), stroke (1.6%), and mediastinitis (1.2%; Table 2). There were statistically significant differences between the groups in atrial fibrillation ($P < .001$), acute renal failure ($P = .049$), and graft revision–related reoperation ($P < .001$). The higher incidences of atrial fibrillation and acute renal failure in group II may be related to differences between the groups in risk factors such as hypertension, diabetes, and elderly age.

Among the postoperative morbidities, 5 of 21 cases of stroke (5/1278, 0.4%) and 11 of 38 cases of postoperative acute renal failure (11/1278, 0.9%) were suspected to be related to postoperative angiography. All 5 cases of catheterization-related stroke were of minor degree, and only 1 of the 11 patients with contrast medium–induced nephropathy required temporary renal replacement therapy.