Incomplete Revascularization After Coronary Artery Bypass Graft Operations Is Independently Associated With Worse Long-Term Survival

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Background. **Complete revascularization (CR) has been suggested to provide benefits to both early and long-term outcomes, but the magnitude of the benefit and frequency of incomplete revascularization (IR) after coronary artery bypass graft operations is rarely explored and is the subject of the present study.**

Methods. **All patients who underwent isolated bypass operations (March 1995 to September 2007) at the Queen Elizabeth II Health Sciences Center (Halifax, NS, Canada) were identified. Revascularization was considered complete if each significantly diseased territory received at least 1 graft. Clinical characteristics of the CR and IR groups were examined to determine barriers of CR. A nonparsimonious Cox proportion model and survival curves were constructed to examine the association of CR and death after adjusting for clinically relevant covariates.**

Results. **A total of 8,570 patients underwent isolated nonredo bypass operations. IR, based on our strict definition, occurred in 19% of the patients. The territories most commonly affected were the right coronary and circumflex coronary territories. After adjustment for relevant clinical differences, IR was a significant independent predictor of long-term mortality (hazard ratio, 1.2; 95% confidence interval, 1.1 to 1.3). IR was also a significant independent predictor of hospital readmission for cardiac reasons after discharge (hazard ratio, 1.2; 95% confidence interval, 1.0 to 1.3).**

Conclusions. **Despite advances in surgical revascularization, IR can occur in up to 19% of patients. IR significantly affects long-term death and readmission to hospital for cardiac reasons, and avoiding IR should therefore be a priority for surgeons during preoperative planning.**

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Responsible for nearly one-third of all deaths in those aged older than 35, coronary artery disease (CAD) is a leading cause of death in developing countries [1]. In the United States alone, more than 1 million coronary revascularization procedures are completed yearly to treat CAD [2]. To date, a well-established revascularization treatment for CAD patients is coronary artery bypass grafting (CABG) [3, 4]. A key advantage of CABG operations compared with other therapies is the ability to provide a higher proportion of complete revascularization (CR) of all diseased myocardial territories.

The advantages of CR have been suggested, but the magnitude of this benefit has not always been evident. In CABG operations, in which CR is achieved in a significant proportion of patients, patients have been shown to have improved early and long-term outcomes along with fewer repeat revascularization procedures [5–7]. Yet, despite the growing body of evidence surrounding CR, clinical practice, particularly with percutaneous revascularization, continues to revolve around targeted or incomplete revascularization (IR) [8, 9]. Several barriers limit CR, including the preference of the operator, patient-related factors, and the technical complexity of the procedure. Given these factors and a continuing lack of conclusive randomized controlled trials, a universal consensus has yet to be reached regarding optimal revascularization guidelines [10, 11].

With a significant subset of the population requiring intervention for the treatment of CAD, having a more comprehensive understanding of the effect of completeness of revascularization is important. To our knowledge, no large-scale study has yet addressed barriers to or the effect of CR on patient outcomes. The primary objective of this study was to clarify the effect of CR and IR in CABG operations with respect to long-term death. In doing so, we aimed to further understand the types of patients with IR to predict which patients stand the greatest benefit from surgical intervention.

Material and Methods

Patients and Data Sources

All patients who underwent isolated CABG operations from 1995 to 2007 at the Queen Elizabeth II Health Sciences Center (Halifax, NS, Canada) were identified using the Maritime Heart Center (MHC) Cardiac Surgery Registry. The MHC Cardiac Surgery Registry is a detailed

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prospectively collected clinical database containing preoperative, intraoperative, and postoperative data on all of cardiac surgical operations performed from March 1995 to present. MHC Cardiac Surgery Registry in-hospital mortality data are 100% complete, but the registry does not capture postdischarge follow-up data, which were obtained from administrative data. The MHC Cardiac Surgery Registry data were linked to the Nova Scotia Vital Statistics and Canadian Institute of Health Information databases housed by the Population Health Research Unit at Dalhousie University to examine death and hospital readmission data. Only patients from whom a link was possible were included in the study. All linked patients underwent complete follow-up regardless of emigration or readmission to another hospital. The study population was restricted to patients undergoing nonredo CABG.

Definitions

The study population was analyzed based on three characteristics: the territory of disease, the territory grafted, and the extent of revascularization. The diseased territories were divided into the left anterior descending (LAD) coronary artery territory (LAD and diagonal [D] branches), the left circumflex (Cx) coronary artery territory (Cx and obtuse marginal [OM] branches), and the right coronary artery (RCA) territory (acute marginal and inferior vessels). A cardiac radiologist, who was unaware of planned revascularization strategy, estimated the degree of angiographic stenosis was visually at the time of cardiac catheterization. For the LAD territory, a disease was characterized if left main stenosis exceeded 50% or LAD, D1, or D2 exceeded 70% stenosis. A disease in the Cx territory was defined as LM exceeding 50% or Cx, OM1, OM2, OM3, or Ramus exceeding 70% stenosis. In contrast, disease in the RCA territory was defined as RCA, posterior descending coronary artery, left ventricular branch, or acute marginal branch exceeding 70% stenosis.

Grafted territories were similarly divided into the LAD, Cx, and RCA territories. The LAD territory was grafted if graft(s) were completed to the LAD, D1, or D2. The Cx territory was grafted if graft(s) to the Cx, OM1, OM2, OM3, or Ramus were performed. Lastly, the RCA territory was grafted if graft(s) to the RCA, posterior descending coronary artery, left ventricular branch, or acute marginal branch were accomplished.

Requirements for CR involved having each diseased territory receive at least 1 graft. Revascularization would therefore be considered IR if one or more diseased territories remained ungrafted. The primary outcomes of interest were long-term death and freedom from hospital readmission for cardiac reasons. We defined cardiac reasons for readmission as any ischemic episode or acute coronary syndrome or repeat revascularization by percutaneous coronary intervention (PCI) or CABG.

Preoperative Variables

Preoperative variables of interest included age, gender, body mass index (BMI), chronic obstructive pulmonary disease (COPD), history of ischemic heart disease, renal failure (serum creatinine >176 μmol/L), peripheral and cerebral vascular disease, recent myocardial infarction (MI), defined as the occurrence of an MI in the 21 days before the operation, left ventricular ejection fraction (<0.40 vs >0.40), urgency of operation (emergency for immediate operation, urgent if needed to be performed within 24 hours, in-hospital urgent if the patient was hospitalized before surgery, and elective or outpatient), diabetes, congestive heart failure, intraaortic balloon pump (IABP), and number of diseased vessels (triple-vessel or left main disease vs. single-vessel or double-vessel disease). Intraoperative variables of interest included the number of distal anastomoses, sequential grafting, number, and type of arterial graft (bilateral internal mammary artery grafting), complete revascularization (defined as 1 or more grafts to each significantly diseased territory), off-pump operations, cross-clamp time, IABP, and total cardiopulmonary bypass (CPB) time.

Operative Technique

A median sternotomy was performed in all patients. CABG operations with CPB were performed in a standardized fashion using ascending aortic cannulation and two-stage venous cannulation of the right atrium. During CPB, the mean arterial pressure target was set at 60 mm Hg, and the body temperature was allowed to drift to a minimum of approximately 32°C. Intermittent cold blood cardioplegia (1:4 blood-to-crystalloid ratio with maximal K^+ concentration 22 mEq/L) was delivered antegrade through the aortic root unless otherwise indicated. Off-pump operations were performed in a limited number of patients based on surgeon preference through a standardized approach, as previously described [10].

All anastomoses were constructed with continuous suture technique using 7-0 or 8-0 monofilament sutures. In all cases, the choice of conduits or construction of grafts, or both, was based on surgeon preferences rather than fixed criteria. Arterial conduits were harvested with minimal trauma (nonskeletonized IMA), and all were treated with a papaverine solution or nitroglycerine/calcium channel blocker (verapamil) solution before use. Heparin was given at a dose of 300 to 400 IU/kg to achieve target activated clotting time exceeding 450 seconds in the CPB group compared with 200 IU/kg in the off-pump group. On completion of anastomoses both groups received protamine sulfate to reverse the effects of heparin and return the activated clotting time to preoperative levels.

No special blood conservation techniques were used other than nonhemic prime, retransfusion of all contents of the oxygenator at the end of CPB, and acceptance of normovolemic anemia. Postoperative use of nonhemic volume expanders was routine. Antifibrinolytics were used in 100% of patients and included tranexamic acid or aprotinin.

Postoperative Management

All patients received intravenous nitroglycerine infusions for the first 24 hours upon return from the operating room unless hypotensive (systolic blood pressure