Similar Outcomes in Diabetes Patients After Coronary Artery Bypass Grafting With Single Internal Thoracic Artery Plus Radial Artery Grafting and Bilateral Internal Thoracic Artery Grafting

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Background. The purpose of this study was to determine in patients with diabetes mellitus whether single internal thoracic artery (SITA) plus radial artery (RA) grafting yields outcomes similar to those of bilateral internal thoracic artery (BITA) grafting.

Methods. From January 1994 to January 2011, 1,325 diabetic patients underwent primary isolated coronary artery bypass graft surgery with either (1) SITA plus RA with or without saphenous vein (SV) grafts (n = 965) or (2) BITA with or without SV grafts (n = 360); an internal thoracic artery was used in all patients to graft the left anterior descending coronary artery. Endpoints were in-hospital outcomes and time-related mortality. Median follow-up was 7.4 years, with a total follow-up of 9,162 patient-years. Propensity score matching was performed to identify 282 well-matched pairs for adjusted comparisons.

Results. Unadjusted in-hospital mortality was 0.52% for SITA plus RA with or without SV grafts and 0.28% for BITA with or without SV grafts, and prevalence of deep sternal wound infection was 3.2% and 1.7%, respectively. Unadjusted survival at 1, 5, 10, and 14 years was 97%, 88%, 68%, and 51% for SITA plus RA with or without SV grafts, and 97%, 95%, 80%, and 66% for BITA with or without SV grafts, respectively. Among propensity-matched patients, in-hospital mortality (0.35% versus 0.35%) and prevalence of deep sternal wound infection (1.4% versus 1.4%) were similar ($p > 0.9$) in the two groups, as was 1-, 5-, 10-, and 14-year survival: 97%, 90%, 70%, and 58% for SITA plus RA with or without SV grafting versus 97%, 93%, 79%, and 64% for BITA with or without SV grafting, respectively (early $p = 0.8$, late $p = 0.2$).

Conclusions. For diabetic patients, SITA plus RA with or without SV grafting and BITA with or without SV grafting yield similar in-hospital outcomes and long-term survival after coronary artery bypass graft surgery. Therefore, both SITA plus RA and BITA plus SV grafting should be considered for these patients.

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Forty percent of patients undergoing coronary artery bypass grafting (CABG) today have diabetes mellitus [1]. Use of arterial grafts, compared with venous grafts, is associated with better outcomes after CABG for diabetic patients [2]. However, it remains unclear which arterial grafting strategy—single internal thoracic artery (SITA) plus radial artery (RA) grafting or bilateral internal thoracic artery (BITA) grafting—results in better short- and long-term outcomes for these patients. Therefore, we sought to determine for diabetic patients whether SITA plus RA grafting yields in-hospital outcomes and long-term survival similar to those of BITA grafting.

Patients and Methods

From January 1994 to January 2011, 1,325 diabetic patients with multisystem coronary artery disease underwent

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Abbreviations and Acronyms

BITA = bilateral internal thoracic artery
CABG = coronary artery bypass grafting
DSWI = deep sternal wound infection
EF = ejection fraction
ITA = internal thoracic artery
LITA = left internal thoracic artery
RA = radial artery
RITA = right internal thoracic artery
SITA = single internal thoracic artery

primary isolated CABG with either (1) SITA plus RA with or without saphenous vein grafts (hereafter referred to as SITA plus RA; n = 965) or (2) BITA with or without saphenous vein grafts (hereafter referred to as BITA; n = 360). An internal thoracic artery (ITA) was used in all patients to graft the left anterior descending coronary artery (LAD). Mean age was 59 ± 8.8 years, and 83% were men (Table 1).

Patients were identified and preoperative, operative, and postoperative variables (Appendix E1) retrieved from the prospective Cleveland Clinic Cardiovascular Information Registry. This database is populated concurrently with patient care and has been approved for use in research by the Institutional Review Board, with patient consent waived.

Variables and Definitions

A coronary artery system was considered importantly stenotic if it contained 50% or greater diameter obstruction. The majority (88%) of coronary arteries with 50% or greater stenosis that were grafted by either a radial artery or a second ITA were severely stenosed (70% or more); only 12% were moderately stenosed. Incomplete revascularization was defined as failure to graft any coronary system containing 50% or more stenosis, or both LAD and circumflex coronary artery systems for 50% or greater left main trunk stenosis. Left ventricular function was echocardiographically graded as normal (ejection fraction [EF] 60% or more), mild (EF 40% to 59%), moderate (EF 25% to 39%), or severe (EF less than 25%).

Endpoints

Endpoints were (1) in-hospital adverse outcomes defined as for The Society of Thoracic Surgeons National database (http://www.ctsnet.org/file/rptdataspecifications252_1_forvendorspgs.pdf); and (2) time-related mortality. Vital status after hospital discharge was obtained by routine anniversary follow-up questionnaires supplemented with data from the Social Security Death Master File [3, 4], accessed on October 27, 2011, with a closing date of April 27, 2011. A total of 9,162 patient-years of follow-up data were available for analyses. Median follow-up was 7.4 years, with 10% of survivors followed for at least 13 years.

Statistical Analysis

All analyses were performed using SAS version 9.4 statistical software (SAS Institute, Cary, NC).

LONG-TERM SURVIVAL. Survival was assessed nonparametrically using the Kaplan-Meier method [5] and parametrically using a multiphase hazard model [6]. The latter involved resolving the number of hazard phases for instantaneous risk of death (hazard function) and estimating shaping parameters (for details, see: www.lerner.ccf.org/qhs/software/hazard).

PROPENSITY SCORE MATCHING. Because patient characteristics differed between the two groups (SITA plus RA and BITA; Table 1), in the spirit of a "natural experiment" we attempted to fairly compare outcomes using propensity score–based matching [7–9]. That was accomplished in two steps. First, a parsimonious multivariable logistic regression was used to identify differences in preoperative characteristics of patients in the SITA plus RA group and BITA group to obtain insight into these differences (see Appendix E1 for list of variables analyzed). Bootstrap bagging for variable selection, with automated analysis of 500 resampled data sets, was used to accomplish this, followed by tabulating the frequency of both single factors and closely related clusters of factors [10]. We retained factors that occurred in 50% or more of the bootstrap models (Supplemental Table E1). The C-statistic for this parsimonious model was 0.83. Second, the parsimonious model was augmented into a saturated propensity model by including patient characteristics that were not statistically significantly different between groups, but represented demographic, cardiac, and noncardiac comorbidities not represented (see Appendix E1). The C-statistic for this model was 0.84. A propensity score representing the probability of BITA group membership given the variables included in the propensity model, regardless of whether the patient received BITA grafts, was then calculated for each patient. A greedy matching strategy [11] based on propensity scores alone was used to match patients receiving SITA plus RA and BITA, yielding 282 well-matched pairs (78% of possible matches; Supplemental Fig E1). BITA cases with propensity scores deviating more than 0.10 from those of SITA plus RA cases were considered unmatched. Standardized differences demonstrated that covariable balance was achieved across nearly all variables (Supplemental Fig E2), and the two groups were balanced with respect to the target vessel for RA and second internal thoracic artery graft (Table 2).

MISSING VALUES. A number of variables examined in multivariable analyses had missing values (see "Patients with data available" in Table 1). Of the 35 variables used for the propensity score, 18 had no missing data, 8 had more than 0% but less than 2% missing data, 6 had between 10% and 15%, and 3 had greater than 20% missing data. The pattern of missing data appeared arbitrarily, so "missing at random" was assumed. We used fivefold multiple imputation [12] with a Markov chain Monte Carlo technique to impute missing values (SAS PROC MI; SAS Institute, Cary, NC). In multivariable