Contemporary Outcomes of Coronary Artery Bypass Grafting Among Patients With Insulin-Treated and Non–Insulin-Treated Diabetes

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Background. More than 40% of patients undergoing coronary artery bypass grafting (CABG) have diabetes. However, it is unknown how insulin treatment status influences cardiac surgical outcomes among patients with diabetes.

Methods. All isolated CABG, CABG plus aortic valve replacement or plus mitral valve repair/replacement procedures performed in 2012 were extracted from the California CABG Outcomes Reporting Program database. Patients were grouped into three categories: (1) no diabetes, (2) non–insulin-treated diabetes (NITDM), and (3) insulin-treated diabetes (ITDM). Demographic and clinical baseline characteristics and observed postoperative major adverse events, including 30-day mortality, stroke, deep sternal wound infection, prolonged ventilation, new dialysis requirement, renal failure, and 30-day readmission were compared. Multivariable logistic regression models were developed for predicting the impact of NITDM and ITDM on postoperative major adverse events.

Results. A total of 14,051 patients underwent isolated CABG or CABG plus aortic/mitral valve procedures in California during 2012; 6700 (47.7%) had no diabetes, 5165 (36.8%) had NITDM, and 2183 (15.6%) had ITDM. Compared with the nondiabetic and NITDM groups, the ITDM group was younger, more frequently women and nonwhite, and had a higher prevalence of preoperative comorbidities (all $p < 0.05$). After adjusting for baseline risk factors and surgery type compared with patients without diabetes, both NITDM and ITDM were associated with significantly increased risk of major adverse events [NITDM: adjusted odds ratio (AOR), 1.15, 95 % confidence interval (CI), 1.04 to 1.26, $p = 0.005$; ITDM: AOR, 1.49, 95% CI, 1.32 to 1.68, $p < 0.0001$]. A subgroup comparison indicated a similar gradient of risk for each category of cardiac surgery.

Conclusions. Patients with diabetes undergoing CABG have substantially increased risk of major adverse events. Patients with ITDM represent an especially high-risk group.

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The overall prevalence of diabetes continues to grow, with an estimated 171 million patients worldwide and a projected doubling by 2030 [1]. Currently, more than 25% of patients undergoing coronary artery revascularization have diabetes, a proportion that is likely to also rise over time [2]. Recent studies have reported superiority of coronary artery bypass grafting (CABG) over percutaneous coronary intervention (PCI) for diabetic patients with multivessel disease, suggesting that CABG may remain the preferred method of revascularization for such patients with current technology [3, 4]. Understanding the relative outcomes of diabetic patients undergoing CABG is therefore paramount to improving patient outcomes.

Patients with insulin-treated diabetes (ITDM) may represent an especially high-risk subgroup for long-term outcomes after coronary artery revascularization [5, 6]. Compared with patients treated with other agents [non–insulin-treated diabetes (NITDM)], patients who require insulin typically have diabetes that is more difficult to control and may also have had a longer duration of disease [7, 8]. Among patients undergoing PCI, it was shown that patient with NITDM have outcomes similar to nondiabetic patients, whereas patients with ITDM have substantially higher rates of restenosis and target lesion failure [9, 10]. Whether a similar gradient of outcomes exists among contemporary patients undergoing surgical coronary artery revascularization is uncertain [11–14].

In this study, we investigated the association between insulin treatment status and major adverse outcomes after CABG among a contemporary cohort of patients. We hypothesized that patients with ITDM would have substantially increased rates of perioperative complications and overall mortality for both isolated CABG and combined CABG/valve replacement/repair surgeries.

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Material and Methods

Data Source

Data were obtained from the California CABG Outcomes Reporting Program (CCORP), which is managed by the California Office of Statewide Health Planning and Development. CCORP requires California hospitals to submit detailed clinical information on preoperative demographic characteristics and clinical conditions and on outcomes relevant to the CABG surgery. The CCORP data are used for annually public reporting of risk-adjusted CABG outcomes by hospital and surgeon. The data collection system, based on specifications from The Society of Thoracic Surgeons, includes a multiple step data-cleaning process and annual onsite audits to ensure data accuracy. The CCORP data collection procedures and analysis methods are described in detail elsewhere [15]. In addition, California Patient Discharge Data (PDD) were also obtained from the California Office of Statewide Health Planning and Development. The PDD include all discharges from licensed California hospitals. The study was approved by the Committee for the Protection of Human Subjects of the California Health and Human Services Agency on June 3, 2011 (project 04-08-58).

Data Analysis

During 2012, 124 hospitals submitted data, including patient demographic characteristics, clinical characteristics, postoperative complications, and observed in-hospital mortality. For identifying operative mortality, the clinical registry data were linked to death records from the California Department of Public Health to identify patients who died at home or at facilities other than the operating hospital within 30 days after CABG surgery. The clinical data were also linked to the PDD for 2012 and 2013 to identify hospital readmissions within 30 days after discharge among patients who remained alive but not transferred to other acute hospitals. A hospital readmission was counted only if the patient was readmitted to an acute care hospital with an *International Classification of Diseases, Ninth Revision, Clinical Modification* principal diagnosis code that indicated a heart-related condition, an infection, or a complication that was likely related to the CABG or CABG plus valve surgery. This algorithm is similar to other states that report readmission rates after CABG surgery [16]. Readmissions were identified both at the hospital performing the CABG and any other California hospital where the patient was admitted within 30 days of being discharged. For patients who were readmitted multiple times over 30 days, only the first readmission was counted.

Statistical Analyses

We classified all CABG patients into three clinical groups: (1) had no diabetes, (2) had NITDM, and (3) had ITDM. All CABG procedures were also classified into three surgical categories: (1) isolated CABG, (2) CABG plus aortic valve replacement (AVR), and (3) CABG plus mitral valve (MV) repair or replacement. We compared patient baseline demographic and clinical characteristics and postoperative major adverse events (MAEs) among the three clinical groups for each surgical category. MAEs included operative mortality (defined as patients who died in hospital regardless of length of stay or who died outside of the operating hospital within 30 days of operation), postoperative stroke (defined as patients who had a postoperative neurologic deficit of abrupt onset caused by a disturbance in blood supply to the brain that did not resolve within 24 hours), deep sternal wound infection (defined as within 30 days postoperatively, a deep sternal wound infection or mediastinitis that required operative intervention), prolonged ventilation (defined as patients who had prolonged postoperative pulmonary ventilator >24 hours), new dialysis requirement or renal failure (defined as patients who had a new requirement for dialysis or acute renal failure or worsening renal function that resulted in an increase of serum creatinine to $\geq$4.0 or 3 times the most recent preoperative creatinine concentration), and 30-day hospital readmissions. Categorical variables were compared by χ^2 analysis, and continuous variables were compared by Student's t test. Differences were considered statistically significant if p was less than 0.05.

To determine the impact of diabetes on MAEs, we developed multivariable logistic regression models in which both diabetes type and surgery type (isolated CABG, CABG plus AVR, or CABG plus MV repair/replacement) were added as a predicting factor, in addition to patient demographic characteristics and clinical risk factors. All model fit analyses were evaluated with Hosmer-Lemeshow goodness-of-fit statistics. The c statistic was reported as a measure of predictive power.

A further subgroup analysis was performed with a general linear model to compare risk-adjusted MAE rates among diabetic groups for each surgical type. Results are presented as percentages or odds ratios (ORs) and with 95% confidence intervals (CIs). All data analyses were conducted with SAS version 9.3 (SAS Institute, Cary, NC).

Results

As shown in Figure 1, a total of 14,051 non-salvage patients underwent isolated CABG or CABG plus aortic value/MV procedures in California during 2012; 6700 (47.7%) of these patients were nondiabetic, 5165 (36.8%) had NITDM, and 2183 (15.6%) had ITDM (Fig 1). Compared with the nondiabetic and NITDM groups, patients with ITDM were younger, more often women and nonwhite, and had a higher prevalence of preoperative dialysis, peripheral arterial disease, cerebrovascular disease, prior myocardial infarction, and congestive heart failure (all $p < 0.05$) (Table 1).

Observed MAEs

Among the three groups, there was a gradient of outcomes. Nondiabetic patients had the lowest overall event rates, whereas patients with NITDM were of intermediate higher risk, and patients with ITDM had the highest risk