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Diabetes control decreases morbidity and mortality after carotid endarterectomy

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Background. Single-institution studies have demonstrated a negative effect of diabetes mellitus on outcomes after carotid endarterectomy (CEA). The aim of this study was to compare patients with explicitly controlled and uncontrolled diabetes at the population level.

Methods. Using the National Inpatient Sample 2006–2013, we selected patients undergoing CEA. Rates of stroke, myocardial infarction (MI), and hospital mortality, as well as duration of stay and cost were compared among patients with uncontrolled diabetes (UCDM), well-controlled diabetes (WCDM), and those without diabetes (NDM).

Results. We reviewed data from 614,190 patients undergoing CEA. Patients with UCDM, compared with those with WCDM and NDM, had higher rates of stroke (3.27%, 0.93%, and 0.94%, respectively; $P < .0001$), MI (3.35%, 1.10%, and 0.87%, respectively; $P < .0001$), and higher hospital mortality (1.43%, 0.25%, and 0.27%, respectively; $P < .0001$). On multivariate analysis, patients with UCDM compared with WCDM were more likely to develop stroke (odds ratio[OR], 1.45; 95% confidence interval [CI], 1.23–1.71), and MI (OR, 2.26; 95% CI, 1.96–2.60) and were more likely to die (OR, 2.74; 95% CI, 2.19–3.42). Patients with WCDM compared with patients without diabetes had similar likelihoods of stroke (OR, 0.96; 95% CI, 0.90–1.02) and MI (OR, 1.04; 95% CI, 0.98–1.10) but were actually less likely to die (OR, 0.85; 95% CI, 0.76–0.95).

Conclusion. Patients with uncontrolled diabetes had poorer outcomes after CEA than those with controlled diabetes, whose outcomes were comparable to if not better than individuals without diabetes.

In the 1990s, NASCET (North American Symptomatic Carotid Endarterectomy Trial) and ACAS (Asymptomatic Carotid Atherosclerosis Study) found carotid endarterectomy (CEA) to be an effective method for prophylaxis against strokes in patients with symptomatic and asymptomatic severe carotid artery stenosis.[1,2] The benefits of CEA outweigh the risks according to these studies, as long as the postoperative rate of morbidity and mortality are <3% in asymptomatic patients and 6% in symptomatic patients.[3,4] Therefore, investigation of risk factors for adverse perioperative events is imperative.

The leading causes of morbidity and mortality after CEA are cardiovascular complications, and thus, cardiovascular risk factors are among the most studied.[5-7] One such factor is diabetes mellitus (DM), which has been implicated in the risk for complications after other vascular procedures on the abdominal aorta or in cases of critical limb ischemia.[8,9] In single-institution studies, patients with DM have an increased risk for postoperative morbidity and mortality.[10-12] However, there remains a debate over DM as a risk factor when undergoing CEA, because other single-institution studies found no differences in the outcomes of patients with and without diabetes.[13-15]

People with diabetes are at increased risk for stroke as well as an increase in stroke severity compared with those without DM.[16-19] It has been demonstrated that the risk for stroke in the diabetic population is associated with the level of hyperglycemia, which indicates that glycemic control may mitigate some of the added risk for stroke.[20] However, the existing literature regarding the effect of DM on CEA outcomes has not compared explicitly the outcomes in patients with controlled and uncontrolled diabetes, likely due to power limitations on such a subgroup analysis in single-institution studies. In the current study, we conducted a retrospective analysis at the population level. With this sample size, we were able to separate patients into controlled and uncontrolled cohorts, allowing us to identify whether glycemic

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control mitigates the reported added risk for DM on CEA outcomes.

Materials and Methods

The National/Nationwide Inpatient Sample (NIS) from 2006 to 2013 was used as a data source for analysis. Developed as a part of the Agency for Healthcare Research and Quality (AHRQ) Healthcare Cost and Utilization Project (HCUP), the NIS is the largest, administrative, all-payer hospital discharge database in the United States and contains information about approximately 20% of all admissions to acute care community hospitals throughout the nation. The sample strategy of the NIS data allows for computing of national estimates. These data are available publicly and do not include identifiers that might be linked to personal patient information. Full description of the NIS and its elements is available at http://www.hcup-us.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp.

For the study population, we selected patients who were hospitalized electively with a principal diagnosis of carotid artery stenosis (International Classification of Diseases, Ninth Revision, Clinical Modification [ICD-9-CM] diagnosis codes 433.10 and 433.11) and underwent CEA (ICD-9-CM procedure code 38.12) on a single vessel (ICD-9-CM procedure code 00.40). In this group, patients <50 years old accounted only for 1.4% of all patients and were excluded from analysis. The remaining study population was categorized into 3 analyzed groups: patients with uncontrolled diabetes (UCDM; ICD-9-CM diagnosis codes 250.x2 and 250.x3), patients with diabetes not stated as uncontrolled, which we called well-controlled diabetes (WCDM; ICD-9-CM diagnosis codes 250.x0 and 250.x1), and patients with no history of diabetes (NHDM; all the others). In computing national estimates, we used new revised trend weights for data 2006–2011 (available at http://www.hcup-us.ahrq.gov/db/nation/nis/trendwghts.jsp).

Rates of postoperative complications (postoperative stroke and cerebral hemorrhage, acute myocardial infarction [MI], and cardiac arrest) and hospital mortality were compared between groups, as well as duration of hospital stay and cost. To identify procedure-related, postoperative complications, the following ICD-9-CM diagnosis codes for the secondary diagnoses were used: 997.02, 430–431, and 432.x for postoperative stroke and cerebral hemorrhage; 410.xx and 427.5 for MI and cardiac arrest. Patients with symptomatic status were selected with the following ICD-9-CM diagnosis codes: 362.31, 368.12, 433.11, 434.xx, 435.x, and 781.4.[21] Comorbidities were identified with 29 AHRQ comorbid measures that were the NIS data elements.

SAS 9.4 software (SAS Institute, Cary, NC) was used for data analysis and all statistics. Crude rates of postoperative complications or hospital mortality in each study group were computed and compared by χ^2 test. To exclude the confounding effects of different patient characteristics, multivariable logistic regression analysis was employed with stepwise selection with adjustment for patient age, sex, race, comorbidities, and symptomatic status. Odds ratios (OR) with 95% confidence intervals (95% CI) were computed for each study group and compared. To account for inflation during the multiyear study time, total charges for hospital stay were adjusted to the year 2013 with the Consumer Price Index Inflation Calculator (available at http://data.bls.gov/cgi-bin/cpicalc.pl). Using the HCUP Cost-to-Charge Ratio Files, charges were transformed into hospital costs that evaluated hospital expenses more accurately. Because hospital duration of stay and cost were not normally distributed and skewed to the right, they are presented as median values with interquartile ranges, and the nonparametric Wilcoxon rank sum test was used for their intergroup comparison. To minimize the effects of the potential confounders on hospital duration of stay and cost in the intergroup comparison, we also ran the generalized linear model (SAS GENMOD procedure with gamma model with log link) with adjustment for the same covariates as in the logistic regression model.

Results

We reviewed 614,190 patients who underwent CEA. Of these patients, 1.1% (6,925) were categorized as UCDM, 30.6% (187,628) as WCDM, and 68.3% (419,637) as having NHDM. Demographic information for each group, including age, sex, and race, as well as comorbid conditions and symptomatic status, are listed in Table I. With respect to these risk factors, the 3 groups were rather heterogeneous. Patients in the UCDM group tended to be younger, were more likely to be female, black, or Hispanic, and had more comorbid conditions and greater proportion of symptomatic patients than the other groups.

The crude rates of postoperative outcomes shown in Fig 1 indicate that this group was at greater risk than patients in the other groups. Patients in the UCDM group had higher rates of postoperative stroke (3.3%), MI (3.4%), and hospital mortality (1.4%) than those in the WCDM group (0.9%, $P < .0001$ for stroke; 1.1%, $P < .0001$ for MI; 0.3%, $P < .0001$ for hospital mortality) and those without the disease (0.9%, $P < .0001$ for stroke; 0.9%, $P < .0001$ for MI; 0.23%, $P < .0001$ for hospital mortality). The differences between the latter 2 groups with respect to the rates of postoperative stroke ($P = .862$) and hospital mortality ($P = .264$) were not significant, but the WCDM group was more likely to develop MI than the NHDM group (OR, 1.27; 95% CI, 1.20–1.34; $P < .0001$).

We compared crude rates of postoperative complications and mortality between symptomatic and asymptomatic patients within each group and between the groups. The results of this analysis are listed in Table II. For all outcomes and all diabetes groups, symptomatic patients had greater rates of complications and mortality than asymptomatic patients ($P < .0001$ for all analyses).

For symptomatic patients, the rate of postoperative stroke was similar among all groups with diabetes ($P = .379$). Rates of MI were greater in the UCDM group than in the WCDM patients and those without disease ($P < 001$ in both cases) but was similar among patients with UCDM and those without diabetes ($P = .54$). There was no difference observed in the crude rate of hospital mortality between any of the groups ($P = .14$ and $P = .15$ for WCDM and NHDM groups, respectively). Patients with WCDM, however, had lower rates of hospital mortality than those in the NHDM group ($P < .0001$).

Among asymptomatic patients, the rates of all outcomes were greater in the UCDM group than in with the WCDM patients or the NHDM group ($P < .0001$ for all analyses). Controlled patients had a greater rate of MI than patients without diabetes ($P < .0001$) but had similar rates of stroke and death compared with the NHDM group ($P = .14$ and $P = .26$, respectively).

Odds ratios with 95% CIs from the multivariable logistic regression analysis are shown in Fig 2, with the NHDM patients as the reference group. UCDM patients compared with the NHDM group were more likely to develop postoperative stroke (OR, 1.45; 95% CI, 1.23–1.71), and MI (OR, 2.26; 95% CI, 1.96–2.60) and to die after CEA (OR, 2.74; 95% CI, [2.19–3.42). WCDM patients relative to the NHDM group had a significantly lower likelihood of hospital mortality (OR, 0.9; 95% CI, 0.76–0.95) but similar likelihoods of postoperative stroke (OR, 1; 95% CI, 0.90–1.02) and MI (OR, 1; 95% CI, 0.98–1.10).

The distributions of the parameters of hospital resource utilization (total hospital duration of stay and cost) as well as the ORs with 95% CI in the intergroup comparisons are listed in Table III. For analysis of these outcomes, WCDM patients were the reference group. UCDM patients had longer and costlier ($P < .0001$ each) hospital stays than WCDM patients, who, in turn, had longer and costlier

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