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Risk factors for perioperative death and stroke after carotid endarterectomy: Results of the New York Carotid Artery Surgery Study

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Abstract

Background—The benefit of carotid endarterectomy(CEA) is heavily influenced by the risk of perioperative death or stroke. This study developed a multivariable model predicting the risk of death or stroke within 30 days of CEA.

Methods—The New York Carotid Artery Surgery (NYCAS) Study is a population-based cohort of 9308 CEAs performed on Medicare patients from January 1998 through June 1999 in New York State. Detailed clinical data were abstracted from medical charts to assess sociodemographic, neurological, and comorbidity risk factors. Deaths and strokes within 30 days of surgery were confirmed by physician over-reading. Multivariable logistic regression was used to identify independent patient risk factors.

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Results—The 30-day rate of death or stroke was 2.71% among asymptomatic patients with no history of stroke/TIA, 4.06% among asymptomatic ones with a distant history of stroke/TIA, 5.62% among those operated on for carotid TIA, 7.89% of those with stroke, and 13.33% in those with crescendo TIA/stroke-in-evolution. Significant multivariable predictors of death or stroke included: age ≥80 years(OR=1.30; 95% CI, 1.03-1.64), non-white(OR=1.83; 1.23-2.72), admission from the ED(OR=1.95; 1.50-2.54), asymptomatic but distant history of stroke/TIA (OR=1.40; 1.02-1.94), TIA as indication for surgery(OR=1.81; 1.39-2.36), stroke as the indication(OR=2.40; 1.74-3.31), crescendo TIA/stroke-in-evolution(OR=3.61; 1.15-11.28), contralateral carotid stenosis ≥50% (OR=1.44; 1.15-1.79), severe disability(OR=2.94; 1.91-4.50), coronary artery disease(OR=1.51; 1.20-1.91), and diabetes on insulin(OR=1.55; 1.10-2.18). Presence of a deep carotid ulcer was of borderline significance (OR=2.08; 0.93-4.68).

Conclusions—Several sociodemographic, neurological, and comorbidity risk factors predicted perioperative death or stroke after CEA. This information may help inform decisions about appropriate patient selection and facilitate comparisons of risk-adjusted outcomes among providers or about the impact of different surgical processes of care.

Keywords

carotid endarterectomy; risk factors; prognosis; complications; outcomes

Introduction

Carotid endarterectomy (CEA) is one of the most common types of vascular surgery performed in the U.S. with over 117,000 cases done annually.[1] Several large, multinational randomized controlled trials (RCTs) have shown that for among carefully selected patients by experienced surgeons, CEA plus medical therapy reduced the risk of stroke and death compared to existing medical therapy alone.[2-5] The RCTs, and the national CEA subspecialty guidelines based on them, stress that the expected benefit of surgery for an individual patient is critically dependent on his or her risk of perioperative death or stroke.[3, 6,7]

New endovascular procedures for treating internal carotid artery stenosis with angioplasty and stenting techniques are growing in popularity and have generated much controversy. Although the results of RCTs comparing stenting to carotid surgery are mixed,[8] and the appropriate role for stenting is uncertain, stenting is promoted as an option for patients who are deemed “high risk” or “too old” or “too sick” to safely undergo CEA.

Taken together, this underscores the need for empirically-validated data on risk factors for perioperative death or stroke after CEA. The validity and usefulness of most prior studies of predictors of adverse events after CEA has been limited by their focus on: single risk factors, single institutions,[9-14], lack of multivariate analyses,[14-18] in-hospital complications,[15, 16, 19-21] uncertainty about the clinical indications for surgery in many patients,[22] or the highly selected patients and surgeons who participated in RCTs[23-27] or were treated in veterans hospitals.[28, 29] The generalizability of the risk factors identified in the North American RCTs is limited by their exclusion of patients ≥80 years old or those with major comorbid conditions.[3, 30] These ‘older and sicker’ patients comprise a significant proportion of the CEAs done in the US.[5, 22, 31, 32] Multicenter studies of CEA in community practice that did use multivariable techniques to identify predictors of perioperative complications point to a mixed and inconsistent set of sociodemographic, neurological, and comorbidity risk factors.[5, 22, 28, 33-39] No prior population-based studies have had the very large numbers of symptomatic and asymptomatic patients and detailed clinical data on neurological indications for CEA and severity of carotid disease to have the granularity and statistical power to permit in-depth investigation of a large number of clinically important prognostic factors.

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This study sought to use clinically detailed data from the New York Carotid Artery Surgery Study (NYCAS), a large, population-based cohort study of CEA outcomes, to develop a multivariable model predicting the risk of death and stroke within 30 days of CEA based on a combination of sociodemographic, neurological acuity, carotid disease severity, and comorbid illness burden patient characteristics. We were particularly interested in examining how the presence, timing and acuity of neurological symptoms, severity of carotid disease, and neurological disability, influenced perioperative outcomes.

Methods

Study Population

The New York Carotid Artery Surgery (NYCAS) study examined all Medicare beneficiaries who underwent CEA between January 1, 1998 and June 30, 1999 in New York (NY) State. Details of the cohort assembly have been published previously.[32] Briefly, eligible cases (ICD-9 code 38.12) with Medicare fee-for-service insurance were identified using Medicare Part A hospital claims. Medicare managed care cases that had CEA were identified with an algorithm that used the NY state hospital discharge database, age (≥65 years), and the Medicare eligibility files. Copies of the inpatient medical records were requested by Island Peer Review Organization (IPRO--the Medicare quality improvement organization in NY). The study was approved by the Mount Sinai Institutional Review Board.

We reviewed the medical charts of 10,817 of 11,406 potentially eligible cases (94.8%). Of these, we excluded: cases with no CEA performed (110), same side operations for restenosis (308), CEA combined with other major procedures (490), and cases without complete clinical risk factor data (601). The results reported are based on 9308 cases.

Data Collection and Measurement

Detailed clinical information was abstracted from hospital charts by trained nurse abstractors including: sociodemographics, admission source, neurological, medical and surgical history, admission neurologic exam, functional status, laboratory values, medications, and diagnostic imaging test results. We collected data on numerous individual comorbid conditions, as well as calculate the Revised Cardiac Risk Index[40] and Charlson comorbidity scores.[41] Severe disability was defined as bedridden or unable to walk/attend bodily needs without assistance (modified Rankin score of 4 or 5). The indication for surgery was based on the acuity of the presenting neurologic symptoms in the 12 months prior to surgery, according to the following hierarchy (stroke-in-evolution, crescendo TIA, stroke, carotid TIA, and asymptomatic). Patients without neurologic symptoms referable to a carotid artery distribution in the 12 months prior to surgery were defined as asymptomatic. Crescendo TIAs were defined as ≥ 3 TIAs within 3 days of surgery and stroke-in-evolution was defined as a stroke with progressing or fluctuating neurologic deficits over 1 or 2 days. Patients with crescendo TIAS and stroke-in-evolution had similarly high risks of complications and were combined into a group called “acute syndromes.”

Data on the percent stenosis of the operated and non-operated internal carotid artery and presence of a deep carotid lesion ulcer was abstracted by research nurses from all available diagnostic imaging tests. Carotid angiography was considered to be the most accurate test followed by Doppler ultrasound, and then magnetic resonance angiography. For the small number of cases where no imaging test was available, we used stenosis information from preoperative notes. Abstractors passed quality assurance tests and inter-rater reliability was very high (Kappas from 0.60 to 1.0).

Outcomes

Information about perioperative deaths, strokes and TIAs (as potentially misclassified strokes) was abstracted from the medical record of the index admission and all readmissions within 30 days of surgery including review of admission and progress notes, discharge summaries, and brain imaging reports. Cases identified by the research nurses as having a death, stroke, or TIA were independently reviewed and confirmed by two study physicians (including a neurologist). Initial agreement was 95%, and disagreements resolved by consensus.

Analysis Plan

There were two primary adverse outcomes: 1) Death or non-fatal stroke within 30 days of surgery, and 2) all strokes within 30 days of surgery (fatal and non-fatal). The relationship between outcomes and each risk factor (indications for surgery, recency of symptoms, disease severity, sociodemographics, admission source, and comorbidity) was examined with chi square tests and Cochrane-Mantel-Haenzel tests for trend for categorical variables and t-tests and Wilcoxon rank sum tests for continuous data, as appropriate. We examined the impact of the severity and acuity of cerebrovascular disease in several ways. Among symptomatic patients, we examined the impact of the recency of carotid symptoms based cut-points from the literature and on our national expert panel.[3132, 42] We also assessed the influence of the severity of the neurologic event triggering surgery (TIA, stroke, or acute syndromes). Among patients who the trials and guidelines consider asymptomatic (those with no stroke or TIA in the year prior to surgery), we assessed whether complications were higher among those with a distant past history of stroke or TIA (events more than 1 year prior to CEA) compared to asymptomatic patients with no history of cerebrovascular disease.

Age was examined as a continuous variable and by age intervals. For the multivariate analyses, age was dichotomized as ≥80 v. <80 years since there appeared to be a threshold effect and the main CEA RCTs excluded patients ≥80 years old. Non-whites refers to Blacks and Hispanics. Patients with “unknown” or “other” race/ethnicity had similar complication rates with Whites and were combined with them. Secondary analyses that excluded patients with “unknown or other” race produced similar results. For multilevel variables, we combined those with similar complication rates in the multivariable analysis. All risk factors significant at the $p < 0.2$ level were entered in a multivariable, logistic regression model. The primary outcome was combined 30-day risk of death and non-fatal stroke. Rates of all perioperative strokes (fatal or non-fatal) were the secondary outcome. We used generalized estimating equations to account for clustering of cases among surgeons and hospitals. All analyses consider two-sided p values of .05 as statistically significant and were performed using SAS statistical software version 9.1 (SAS Institute, Cary, North Carolina).

Results

Patient Characteristics

Characteristics of the 9308 CEAs performed in NY State during the study period are shown in Tables 1 and 2. The mean age was 74.6 ± 6.8 years (range 40-98), and 44.3% were women. Most patients had hypertension, coronary artery disease, and multiple comorbid conditions (median 2 comorbidities). With respect to the neurological indications for surgery, 71.5% of patients were asymptomatic, 18.9% had a carotid TIA, 9.3% strokes, and 0.3% an acute syndrome. Nearly all patients (95.4%) were operated on for high grade carotid stenosis (70% to 99%)—a finding consistent among symptomatic and asymptomatic cases. The CEAs were performed by 482 surgeons in 167 hospitals.

Univariate Associations Between Neurological Indication for CEA and Outcomes

Within the 30 days of surgery, there were 106 deaths (1.14%) and 305 (3.28%) strokes. The combined rate of perioperative death or non-fatal stroke was 3.99%. Table 2 shows the associations between the neurological indication for surgery and adverse outcomes. The 30-day rate of death or stroke among asymptomatic patients was 3.01% compared to 6.44% for symptomatic ones (p<.0001; Odds Ratio for symptomatic {OR}=2.22; 95% CI 1.80-2.74).

Among asymptomatic patients, those with distant history of stroke/TIA (>1 year before surgery) had higher risks of combined death or stroke (and any stroke) compared to those with no history of cerebrovascular disease (4.06% v. 2.71%, p<.007; Table 2). Defining asymptomatic patients with no history of cerebrovascular disease as the lowest risk reference group, asymptomatic patients with a distant history of stroke/TIA had 50% higher odds of death or stroke (OR=1.52; CI, 1.11-2.07), those operated on for carotid TIAs had double the risk (OR=2.14; CI, 1.64-2.78), those operated on for stroke triple the risk (OR=3.07; CI, 2.28-4.14), and those with acute syndromes five-fold greater risk (OR=5.52; CI, 1.90-16.03). Neurological acuity had a similar, statistically significant impact on the risk of stroke alone (data not shown).

Among symptomatic patients, those with stroke as the indication for surgery had a higher risk of complication compared to those with TIA (7.89% v. 5.62%; p<.02; OR=1.44, CI, 1.04-1.98). Among patients operated on for stroke, those with major strokes had over double the odds of death or stroke compared to those with minor stroke (14.58% v. 6.54%; OR=2.44; CI: 1.41-4.22, P<.001).

Among patients with TIA or minor stroke, death and stroke (but not any stroke) was more common among those with more recent carotid symptoms (p<.05 for trend, Table 2). There appeared to a threshold effect whereby operating within 2 weeks of TIA or minor stroke increased risk of death or stroke compared to > 2 weeks (7.14% v. 5.13%, p=.04). Rates of any stroke for patients operated on within 2 weeks of TIA/minor stroke were not statistically greater (5.53% v. 4.40%, p=.2). For those with major stroke, there was no significant impact of timing of surgery (< 2 or < 6 weeks) on major complications.

Univariate Associations Between Other Patient Factors and Outcomes

Patients 80 years or older had significantly higher rates of death or stroke (4.82% v. 3.73%, p<.02). There was no simple linear association between age (or deciles of age) and outcomes. Women had marginally higher rates of death and stroke (4.29% v. 3.74%) though these differences were not statistically significant (p=.18). The degree of stenosis of the operated carotid artery was not related to the risk of complications, however, the presence of a deep carotid ulcer did increase the risk of death or stroke (8.05% v. 3.91%, p<.01). Those with ≥ 50% stenosis of the contralateral carotid artery had higher rates of death or stroke (5.0% v. 3.37%, p<.0001). Other factors associated with significantly higher risk of complications included: Non-White race, being admitted from the Emergency Department (ED), transfer from another facility, severe neurologic disability, Revised Cardiac Risk Index, Charlson comorbidity score, coronary artery disease, valvular heart disease, atrial fibrillation, congestive heart failure, cerebrovascular disease, renal insufficiency, and diabetes.

Multivariable Predictors of Perioperative Outcomes

Table 3 displays the risk factors found by multivariable regression to be independent predictors of complications. The risk of death or stroke rose with increasing neurological severity: distant cerebrovascular disease (OR=1.38), TIA as the indication for CEA (OR=1.78), stroke as the indication (OR=2.34) and acute syndromes as reasons for surgery (OR=3.51). Several of other indicators of severity of carotid and neurological disease (contralateral stenosis ≥ 50%, admitted from the ED, and severe disability) also increased the risk of adverse outcomes. The presence of a deep carotid ulcer was marginally associated with greater odds of adverse events (OR=2.08; CI, 0.93-4.68, p<.07). The wide confidence intervals here may be related to the rarity of deep ulcers as a risk factor (<1% of cases). Two sociodemographic factors (age ≥ 80 years and Non-White) and two comorbid illness factors also independently increased the odds of death and stroke (coronary artery disease and diabetes requiring insulin). In alternate multivariable models, the presence of diabetes (independent of type of drug therapy) was also a significant predictor of adverse events (OR=1.28, CI: 1.03-1.60), though it was not as strong a prognostic factor as having diabetes treated with insulin. Risk factors for perioperative stroke alone were similar and included: Non-White, admitted from the ED, neurological acuity, contralateral stenosis ≥ 50%, severe disability, and coronary artery disease. Checking analyses that controlled for surgeon volume did not alter the patient risk factor model presented in Table 3.

Discussion

We used data from the statewide NYCAS cohort study of 9,308 CEAs performed by 482 surgeons in 167 hospitals to identify independent patient risk factors for death and stroke within 30 days of surgery. NYCAS is the largest, clinically detailed, population-based study of CEA outcomes and risk factors in community practice. Among the 25 potential patient factors that were examined, we identified four domains of variables that were independently associated with higher risk of perioperative death and stroke, several of which represent prognostic factors that have not previously been assessed or reported.

We were able to use the large NYCAS dataset to stratify patients into several distinct neurological acuity subgroups which represent new findings. Most prior work focused on differences in complications between patients operated for symptomatic v. asymptomatic carotid disease. Our results confirm the well-documented finding that symptomatic patients have twice the risk of perioperative death or stroke compared to asymptomatic ones.[6, 7, 18, 35] While prior studies and the national guidelines largely consider asymptomatic patients as a homogenous low risk group, this study shows that asymptomatic patients with a history of distant cerebrovascular disease (stroke or TIA or stroke >1 year prior to surgery) have one-third higher risk adjusted complication rates compared to patients with no history of stroke or TIA. This is important because three-quarters of CEAs in the US are done in asymptomatic patients, and these patients have less to gain from surgery.[32,43, 44]

Among symptomatic patients, stroke as the indication for surgery (compared to TIA) has also been identified in some,[33, 35, 36, 39] but not all[22, 24, 18] prior investigations. Some of the heterogeneity in the literature appears influenced by whether ocular TIAs (low risk) are lumped together with cerebral TIAs or not.[18, 27] Unfortunately, we were not able to distinguish ocular from hemispheric TIAs in our dataset. The current study expands this work by identifying three distinct prognostic subgroups among symptomatic patients who have a stepwise increase in the risk of complications—those operated on for TIA, stroke, and the acute syndromes (crescendo TIA or stroke-in-evolution). This also confirms the finding of a systematic review which combined data from 10 studies and concluded that patients with crescendo TIA and stroke-in-evolution constitute a very high risk group.[18] The NYCAS study had nearly as many of these unusual cases as were present in all of these 10 studies combined.

Our multivariable model also highlighted two other poor prognostic factors (admission from the ED and severe disability) that are additional measures of neurological acuity. Admission from the ED was a poor prognostic factor even after stratifying for recent carotid symptoms so this factor may capture ways in which patients admitted from the ED may differ in other ways regarding subtle differences in neurologic severity, trajectory of symptoms, or comorbid illness burden, among other possible factors. Severe disability probably represents substantial loss of brain function due to a large territory major stroke. Patients who had severe disability had triple the complication risk (13.08% rate of death or stroke) confirming the recommendations of our national expert panel who felt that such patients were inappropriate candidates for CEA because the harms of surgery outweighed the benefits.[31]

We also identified two anatomic risk factors. Patients with 50% to 99% stenosis of the contralateral internal carotid artery (significant, but non-occluded disease on the non-operated side) had 44% greater risk-adjusted complication rates probably due to diminished collateral blood flow capacity. Most prior work focuses on the impact of total contralateral occlusion,[11, 13, 24, 45] though we have previously reported worse outcomes with 50-99% contralateral stenosis in other patient populations.[18, 20, 39] We are uncertain about what to conclude from the trend towards double the risk of adverse events among patients with deep carotid artery ulcers. The borderline finding (p=.07) is likely due to its rarity as a risk factor. Ulcerated plaques of any severity increased the risk of complications in NASCET,[24] was of borderline significance in ECST,[23] and was not a risk factor Academic Medical Center Consortium observational study.[38]

NYCAS provided a unique opportunity to evaluate the impact of advanced age on outcomes because the mean age was 75 years. In NYCAS, patients ≥80 years old had one-third higher risk-adjusted odds of death or stroke confirming the results a prior registry[20] and VA study.[29] While many studies examined age ≥80 years as a univariate risk factor, the literature is mixed on this topic[46] and interpretation limited by lack of formal multivariable analyses in most cases.[14, 46] Additionally, most of the RCTs excluded patients older than 80 years (as well as those with major comorbidities) because of concerns about higher risk and more limited life expectancy. The RCTs of CEA v. carotid stenting reported much higher risk of perioperative complications in patients ≥80 years old.[5, 47] Taken together, this suggests that octogenarians comprise a high risk group for whom the benefits of any carotid revascularization (CEA or stenting) may be greatly diminished compared to their younger counterparts.

Our finding that coronary artery disease and diabetes increases the risk of complications was expected and consistent with the prior literature on CEA, as well as the larger cardiac risk assessment literature.[48] That diabetes requiring insulin was a more robust prognostic variable (compared to any type of diabetes) is a novel finding, though one that makes sense clinically as a marker of more severe diabetes and vascular disease burden.

The fact that Black and Hispanic patients had worse outcomes even after adjusting for age, neurologic and comorbidity factors was unexpected and the reasons for such potential disparities in surgical outcomes should be the subject of further investigations. The few previous studies that examined racial and ethnic disparities in CEA outcomes found conflicting results.[12,19, 21, 28]

It is worth noting that we did not find differences in results by gender, degree of ipsilateral stenosis, history of heart failure or atrial fibrillation, among other characteristics that have sometimes found to be risk factors in other studies.[45, 46] These differences may be due to variations in the type of study samples or use of multivariable techniques.

Several strengths and limitations are worth noting. NYCAS is the largest, most clinically detailed, population-based study of CEA outcomes in unselected, community practice. The very large number of cases enabled us to examine the independent impact of over 25 potential sociodemographic, neurological, and comorbidity risk factors among both symptomatic and asymptomatic patients. All data were based on detailed independent chart review, and we ascertained deaths and strokes within 30 days of surgery (not just those that occurred during the index hospitalization).

However, like all observational cohort studies, we relied on information on risk factors and complications documented in the medical records during usual practice. There was no standard approach to pre- or post-surgical assessment as could have done in a prospective trial. That said, we had access to the full complement of inpatient notes, diagnostic imaging results, and operative reports, and all deaths and strokes were confirmed by physician over-reading. While the data reflects practice in 1998-1999, operative techniques and perioperative management for CEA have been consistent over the intervening period, and there is no reason to believe that association between risk factors and outcomes would change considerably over time. Finally, just because certain subgroups had higher risks of adverse events after CEA does not mean that such patients should not have surgery. Whether patients with risk factors we identified as increasing the short term risk of death or stroke due to surgery would also be at higher long term risk of death or stroke if they were managed with medical therapy alone is unknown. The decision to have surgery must balance benefits and harms.

These results have several practical implications. From a clinical standpoint, information about risk factors should help referring physicians, neurologists, surgeons, and anesthesiologists better weigh the risks and benefits of CEA for an individual patient. This prognostic information may also help identify those who might be considered potential candidates for carotid stenting because they are too high risk from CEA. From a research and quality improvement perspective, there is a need for CEA-specific risk-adjustment models so that outcomes among different patients and providers can be fairly compared. Similarly, since RCTs of various surgical and anesthesia techniques are rarely undertaken, observational data are often used to highlight processes of care associated with better outcomes—something that requires appropriate risk-adjustment. CEA-specific risk models appear to be superior to the standard generic cardiac risk assessment tools.[48] Finally, most of the prognostic factors we identified (indication for surgery, contralateral stenosis, neurologic disability, and diabetes on insulin) are only knowable from the medical record. This has implications for risk adjustment models and surgical audit studies based solely on hospital discharge databases.

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Table 1

Patient Characteristics and Associations with Perioperative Outcomes of CEA (N=9308)

Patient Risk Factor	Prevalence (%)	Death/Stroke* Rate (%)	P value	Any Stroke Rate† (%)	P value
Sex					
Male	55.7 (5181)	3.74 (194)	.18	3.07 (159)	.21
Female	44.3 (4125)	4.29 (177)		3.54 (146)	
Age					
<70	23.1 (2152)	3.72 (80)		3.39 (73)	
70-79	53.3 (4958)	3.73 (185)	.07	3.05 (151)	.35
80+	23.6 (2198)	4.82 (106)		3.69 (81)	
Race/Ethnicity					
White	93.6 (8662)	3.80 (329)		3.14 (272)	
Black	2.5 (231)	6.93 (16)	<.0001	5.63 (13)	<.0001
Hispanic	2.2 (200)	9.50 (19)		7.00 (14)	
Other/unknown	2.3 (215)	3.26 (7)		2.31 (6)	
Admitted from ED					
Yes	10.1 (938)	9.38 (88)	<.0001	7.04 (66)	<.0001
No	89.9 (8317)	3.37 (280)		2.85 (237)	
Admit Source					
Home	96.5 (8937)	3.84 (343)	<.0001	3.12 (279)	<.0001
Transfer	3.5 (321)	8.41 (27)		7.79 (25)	
Stenosis of Operated Artery					
Occluded	0.2 (15)	6.67 (1)		6.67 (1)	
70-99%	95.4 (8877)	4.04 (359)		3.31 (294)	
60-69%	2.9 (268)	3.36 (9)	.44	3.36 (268)	.52
50-59%	1.0 (88)	0.00 (0)		0.00 (0)	
30-49%	0.5 (47)	4.26 (47)		2.13 (47)	
0-29%	0.1 (13)	0.00 (0)		0.00 (0)	

Patient Risk Factor	Prevalence (%)	Death/Stroke* Rate (%)	P value	Any Stroke Rate† (%)	P value
Stenosis of Non-operated					
Occluded	5.8 (542)	6.09 (33)		5.35 (29)	
70-99%	21.7 (2023)	5.14 (104)		4.00 (81)	
60-69%	5.4 (500)	4.60 (23)	.0013	4.20 (21)	.0037
50-59%	5.15 (479)	3.55 (17)		2.92 (24)	
30-49%	11.3 (1051)	3.24 (34)		2.38 (25)	
0-29%	50.6 (4713)	3.39 (160)		2.86 (135)	
Ulcerated plaque					
None	94.4 (8788)	3.86 (339)		3.00 (279)	
Shallow	4.7 (433)	5.77 (25)	.02	4.85 (21)	.07
Deep	0.9 (87)	8.05 (7)		5.75 (5)	
Operated artery					
Left	50.9 (4741)	4.03 (191)	.83	3.31 (157)	.85
Right	49.1 (4567)	3.94 (180)		3.24 (148)	
Severe neurologic disability					
Yes	2.6 (237)	13.08 (31)	<.0001	9.28 (22)	<.0001
No	97.4 (9071)	3.75 (340)		3.12 (283)	
Revised Cardiac Risk Index					
0	19.2 (1789)	2.12 (38)		1.84 (33)	
1	44.5 (4143)	3.21 (133)	<.0001	2.80 (116)	<.0001
2	28.1 (2617)	5.27 (138)		4.39 (115)	
≥3	8.2 (759)	8.17 (62)		5.40 (41)	
Charlson comorbidity score					
0	17.4 (1619)	1.98 (32)		1.79 (29)	
1	32.2 (2994)	3.07 (92)	<.0001	2.71 (81)	<.0001
2	26.4 (2459)	4.76 (117)		3.94 (2459)	
≥ 3	24.0 (2236)	5.81 (2236)		4.38 (2236)	

Patient Risk Factor	Prevalence (%)	Death/Stroke* Rate (%)	P value	Any Stroke Rate† (%)	P value
Coronary artery disease					
Yes	60.8 (5660)	4.38 (248)	.02	3.52 (199)	.11
No	39.2 (3648)	3.37 (123)		2.91 (106)	
Active coronary disease					
Yes	4.0 (375)	4.27 (16)	.78	3.47 (13)	.83
No	96.0 (8933)	3.97 (355)		3.27 (292)	
Valvular heart disease					
Yes	14.2 (1317)	5.62 (74)	.001	4.40 (58)	.01
No	85.9 (7989)	3.72 (297)		3.09 (247)	
Atrial Fibrillation					
Yes	9.2 (856)	5.63 (48)	.01	3.76 (32)	.41
No	90.8 (8452)	3.82 (323)		3.23 (273)	
Hypertension					
Yes	78.2 (7278)	4.12 (300)	.20	3.45 (251)	.08
No	21.8 (2029)	3.50 (71)		2.66 (54)	
Congestive heart failure					
Yes	9.4 (875)	6.40 (56)	.0001	4.23 (37)	.10
No	90.6 (8433)	3.74 (315)		3.18 (268)	
Peripheral vascular disease					
Yes	30.1 (2802)	4.25 (119)	.40	3.32 (93)	.88
No	69.9 (6506)	3.87 (252)		3.26 (212)	
Renal insufficiency					
Yes	4.8 (447)	6.26 (28)	.01	4.03 (18)	.36
No	95.2 (8861)	3.87 (343)		3.24 (287)	

Patient Risk Factor	Prevalence (%)	Death/Stroke* Rate (%)	P value	Any Stroke Rate† (%)	P value
Cerebrovascular disease*					
Yes	44.1 (4108)	5.60 (230)	<.0001	4.67 (192)	<.0001
No	55.9 (5200)	2.71 (141)		2.17 (113)	
Diabetes mellitus					
Yes	29.7 (2766)	5.06 (140)	.0006	3.98 (110)	.01
No	70.3 (6541)	3.53 (231)		2.98 (195)	
Diabetes on insulin					
Yes	7.4 (689)	6.39 (44)	.0008	4.50 (31)	.06
No	92.6 (8619)	3.79 (327)		3.18 (274)	
Pulmonary disease					
Yes	19.1 (1782)	4.71 (84)	.08	3.42 (244)	.70
No	80.9 (7526)	3.81 (287)		3.24 (61)	
Current smoking					
Yes	14.9 (1392)	4.45 (62)	.33	3.74 (52)	.30
No	85.1 (7916)	3.90 (309)		3.20 (253)	
Alcohol use					
Yes	9.1 (850)	3.41 (29)	.37	2.82 (24)	.43
No	90.9 (8458)	4.04 (342)		3.32 (281)	

*Death/stroke=combined rate of death or non-fatal stroke

†Any stroke=fatal or non-fatal stroke

*History of stroke or TIA at any time point

Table 2

Rates of Perioperative Death and Stroke Following CEA by Neurological Indication, Acuity and Timing of Surgery (N=9308)

Specific Neurological Indication for CEA	Number	Prevalence (%)	Death/Stroke Rate % (#)	Any Stroke Rate % (#)
Asymptomatic	6553	71.5	3.01 (200)	2.48 (165)
Carotid TIA	1763	18.9	5.62 (99)	4.54 (80)
Minor Stroke	718	7.7	6.54 (47)	5.57 (40)
Major Stroke	144	1.5	14.58 (21)	11.80 (17)
Acute Syndromes	30	.32	13.33 (4)	10.0 (3)
Crescendo TIA	15	0.16	13.33 (2)	6.67 (1)
Stroke-in-evolution	15	0.16	13.33 (2)	13.33 (2)
Global Categories of Neurological Acuity				
Asymptomatic	6653	71.5	3.01 (200)	2.48 (165)
No stroke or TIA ever	5200	55.9	2.71 (141)	2.17 (113)
Distant stroke or TIA*	1453	15.6	4.06 (59)	3.58 (52)
Symptomatic	2655	28.5	6.44 (171)	5.27 (140)
Carotid TIA	1763	18.9	5.62 (99)	4.54 (80)
Stroke	862	9.3	7.89 (68)	6.61 (57)
Acute syndromes	30	0.32	13.33 (4)	10.0 (3)
Timing of CEA in Relation to Recency of Carotid Symptoms in Symptomatic Patients				
TIA/Minor Stroke	2496	100.0	5.93 (148)	4.85 (121)
<2 days	198	7.9	7.58 (15)	6.06 (12)
2-6 days	418	16.8	7.18 (30)	5.98 (25)
7-14 days	379	15.2	6.86 (26)	4.75 (18)
>14 days	1501	60.1	5.13 (77)	4.40 (66)
Major Stroke	144	1.5	14.58 (21)	11.80 (17)
< 6 weeks	93	1.0	15.05 (14)	12.90 (12)
6 weeks to 1 year	51	0.5	13.72 (7)	9.80 (5)

[*] Distant stroke or TIA means > 1 year prior to CEA

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Table 3
Multivariate Predictors of Perioperative Death and Stroke after CEA

Outcome/Risk Factor	Odds Ratio	95% CI	P-value
Combined Death and Non-fatal Stroke			
Age ≥ 80 years	1.30	1.03-1.64	.03
Non-White	1.83	1.23-2.72	.002
Admitted from ER	1.95	1.50-2.54	<.0001
Distant history of stroke/TIA	1.40	1.02-1.94	.03
TIA as indication for CEA	1.81	1.39-2.36	<.0001
CVA as indication for CEA	2.40	1.74-3.31	<.0001
Acute Syndrome as indication	3.61	1.15-11.28	.02
Contralateral stenosis ≥50%	1.44	1.15-1.79	.0008
Deep carotid plaque ulcer	2.08	0.93-4.68	.07
Severe disability	2.94	1.91-4.50	<.0001
Coronary artery disease	1.51	1.20-1.91	.0006
Diabetes on insulin	1.55	1.10-2.18	.01
Any Stroke			
Non-White	1.74	1.10-2.72	.008
Admitted from ER	1.73	1.27-2.35	<.0001
Distant history of stroke/TIA	1.60	1.14-2.24	.006
TIA as indication for CEA	1.88	1.42-2.50	<.0001
CVA as indication for CEA	2.54	1.79-3.59	<.0001
Acute Syndrome as indication	3.45	1.00-12.0	.05
Contralateral stenosis ≥50%	1.42	1.11-1.80	.003
Severe disability	2.17	1.33-3.53	.003
Coronary artery disease	1.38	1.08-1.75	.02

CI=confidence interval; Non-white=Black or Hispanic