Elective and Isolated Carotid Endarterectomy: Health Disparities in Utilization and Outcomes, but Not Readmission

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Financial support: Dr. Kennedy was supported by Public Health Service National Research Service Award T32 HL007034 from the National Heart, Lung, and Blood Institute.

Background: Carotid endarterectomy (CEA) has been shown to decrease future ischemic stroke risk in selected patients. However, clinical trials did not examine the risk-benefit ratio for nonwhites, who have a greater ischemic stroke risk than whites. In general, few studies have examined the effects of race on CEA use and complications, and data on race and CEA readmission are lacking.

Methods: This study used administrative data for patients discharged from California hospitals between January 1 and December 31, 2000. Selection criteria of cases included: ICD-9 principal procedure code 38.12, principal diagnostic code 433 and diagnosis-related group 5. There were 8,080 white and 1,196 nonwhite patients (228 blacks, 643 Hispanics, 325 Asians/Pacific Islanders) identified that underwent an elective and isolated CEA. For both groups, CEA rates were compared. Logistic regression was used to examine the independent effects of race on in-hospital death and stroke, as well as CEA readmission.

Results: Rates of CEA use were more than three times greater for whites than nonwhites, although nonwhites were more likely to have symptomatic disease. For all patients, the complication rate was 1.9%. However, the odds of in-hospital death and stroke were greater for nonwhites than whites, but after adjustment for patient and hospital factors, these differences were only significant for stroke (OR=1.7, P=0.013). For both outcomes, the final models had good predictive accuracy. Overall, CEA readmission risk was 7%, and no significant racial differences were observed (P=0.110).

Conclusions: The data suggest that CEA is performed safely in California. However, nonwhites had lower rates of initial CEA use but higher rates of in-hospital death and stroke than whites. Racial differences in stroke risk persisted after adjustment for patient and hospital factors. Finally, this study found that despite significant racial disparities in initial CEA use, whites and nonwhites were similar in their CEA readmission rates. These findings may suggest that screening initiatives are lacking for nonwhites, which may increase their risk for poorer outcomes.

Key words: carotid endarterectomy ■ utilization ■ mortality ■ stroke ■ prevention ■ health differences ■ race/ethnicity

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BACKGROUND

Carotid endarterectomy (CEA) has been shown to be better than medical management alone at reducing the risk of ischemic stroke in both symptomatic and asymptomatic patients with significant carotid artery disease.[1,2] Despite its proven efficacy, prior work has demonstrated that CEA is less likely to be utilized by nonwhites than whites, even when it is appropriately indicated.[3,4] This observation is further underscored when one considers that nonwhites have a greater ischemic stroke risk than whites.[5-9] On the other hand, several studies have also suggested that perioperative complications, including death and stroke, are more common among nonwhites, although the results have been conflicting.[10-14] Major clinical trials did not address these areas because the enrolled participants were mainly white, male and younger than patients typically encountered in practice. Therefore, observational studies have provided important subgroup data not otherwise available.

In general, few studies have examined the effects of race on CEA utilization patterns or perioperative outcomes. Prior work done in California has documented racial/ethnic disparities in the use of cardiovascular procedures, including cardiac catheterization, percutaneous transluminal coronary angioplasty (PTCA), and coronary artery bypass graft (CABG) surgery, which is consistent with other reports.[15] A better understanding of CEA use and outcomes with respect to race could inform the planning of public health strategies aimed at the elimination of existing racial disparities in stroke morbidity and mortality. Accordingly, this study sought to address these issues by using an inpatient statewide database. Specifically, one goal was to examine the effects of race on both CEA use and complications (i.e., in-hospital death and stroke). Another goal was to examine the effects of race on CEA readmission. To date, published data in this area are lacking, and such an analysis could provide further insights into CEA utilization patterns in general.

METHODS

Study Subjects

To investigate the possible effects of race on CEA utilization and outcomes, hospitalization data for the state of California were obtained from the Agency for Health-

Table 1. Patient characteristics on index CEA admission

	All Patients Total=9,276		Whites Total=8,080		Nonwhites Total=1,196		χ^2 Test P Value
Variable	**n**	**%**	**n**	**%**	**n**	**%**	
Age (Years)							**<0.001**
15–64	1,698	18.3	1,428	**17.7**	270	**22.6**	
65–74	3,359	36.2	2,857	**35.3**	502	**42.0**	
≥75	4,219	45.5	3,795	**47.0**	424	**35.4**	
Female	3,977	42.9	3,506	**43.4**	471	**39.4**	**0.009**
Payment Source Medicare/Medicaid	7,214	77.8	6,267	77.6	947	79.2	0.209
Hypertension	5,988	64.6	5,113	**63.3**	875	**73.2**	**<0.001**
Diabetes Mellitus	2,223	24.0	1,780	**22.0**	443	**37.0**	**<0.001**
Heart Failure	410	4.4	352	4.4	58	4.8	0.439
Atrial Fibrillation	630	6.8	575	**7.1**	55	**4.6**	**0.001**
Ischemic Heart Disease	3,165	34.1	2,737	33.9	428	35.8	0.193
Hyperlipidemia	2,302	24.8	1,981	24.5	321	26.8	0.083
Malignant Disease	129	1.4	120	**1.5**	9	**0.8**	**0.044**
Chronic Obstructive Pulmonary Disease	1,313	14.2	1,202	**14.9**	111	**9.3**	**<0.001**
Former/Current Smoker	2,410	26.0	2,174	**26.9**	236	**19.7**	**<0.001**
Pneumonia	51	0.6	40	0.5	11	0.9	0.064
Acute Renal Failure	39	0.4	25	**0.3**	14	**1.2**	**<0.001**
Accident in Residential Institution	171	1.8	149	1.8	22	1.8	0.991
Admission Day on a Weekend	320	3.5	245	**3.0**	75	**6.3**	**<0.001**
Emergency Department Admission	683	7.4	534	**8.6**	149	**12.5**	**<0.001**
Do-Not-Resuscitate Status in Chart	106	1.1	95	1.2	11	0.9	0.437
Electrocardiographic (ECG) Monitoring	180	1.9	152	1.9	28	2.3	0.282
Patch Procedure Used	145	1.6	129	1.6	16	1.3	0.501
Shunt Procedure Used	9,276	100.0	8,080	100.0	1,196	100.0	
Head/Neck Ultrasound	336	3.6	297	3.7	39	3.3	0.474
Cerebral Angiography	1,439	15.5	1,231	15.2	208	17.4	0.055
Head CT/MRI Scan	274	3.0	215	**2.7**	59	**4.9**	**<0.001**
Endotracheal Intubation	99	1.1	81	1.0	18	1.5	0.114
Length of Hospital Stay ≥3 Days	2,646	28.5	2,139	**26.5**	507	**42.4**	**<0.001**
Total Charges ≥$23,900	2,654	28.6	2,212	**27.4**	442	**37.0**	**<0.001**
Discharge During Oct.–Dec. 2000	2,135	23.0	1,849	22.9	286	23.9	0.430
Hospital: Government (Nonfederal) Operated	850	9.2	728	9.0	122	10.2	0.183
Hospital: ≥400 Beds	5,368	57.9	4,679	57.9	689	57.6	0.845
Hospital: ≥100 CEAs Done per Year	2,966	32.0	2,717	**33.6**	249	**20.8**	**<0.001**
Hospital: <7% CEAs Done on Nonwhites	3,035	32.7	2,943	**36.4**	92	**7.7**	**<0.001**
Indications for CEA							**0.002**
Asymptomatic	7,820	84.3	6,849	**84.8**	971	**81.2**	
Symptomatic	1,456	15.7	1,231	**15.2**	225	**18.8**	
Prior stroke	778	8.4	632	7.8	146	12.2	
Transient ischemic attack	373	4.0	317	3.9	56	4.7	
Amaurosis fugax	364	3.9	332	4.1	32	2.7	
Denominator							
California resident population ≥15 years old	26,236,666		13,610,705		12,715,961		

CEA: carotid endarterectomy; CT: computed tomography; MRI: magnetic resonance imaging; Nonwhites include 228 blacks, 643 Hispanics and 325 Asians/Pacific Islanders; P values in bold suggest that the corresponding variable significantly differs between whites and nonwhites.

care and Research Quality.[16] For any given year, these files contain between 3.6–3.8 million discharges from >400 nonfederal hospitals.[17] Specifically excluded from this data set were all federally operated institutions such as military base hospitals (serving mainly active-duty military personnel) and Veterans Affairs (VA) hospitals (serving mainly former military personnel). With this statewide data set, population-based estimates of CEA rates could be determined. Patients were considered for the present analysis if they were discharged between January 1 and December 31, 2000. To be included, cases had to have: 1) an *International Classification of Diseases, Ninth Revision* (ICD-9) principal procedure code 38.12 (CEA), 2) principal diagnostic code 433 (precerebral carotid artery stenosis or occlusion), and 3) diagnosis-related group 5 (extracranial vascular procedure).[18,19] This validated algorithm results in a more homogeneous CEA patient population by excluding those that underwent a combined/staged CABG surgery or an urgent/emergent CEA. In selecting only those that underwent an elective and isolated CEA, measures of perioperative risk due to this procedure alone are more valid. Patients that underwent CEA in the previous year were also excluded to partially identify first-time CEA patients. The analysis was restricted to patients ≥15 years of age since CEA is mainly performed on adults, and this cut-off is consistent with government data reports.

Comparison of whites and nonwhites was the main focus of this study. Race was determined from the discharge abstract with a single variable that identified mutually exclusive racial/ethnic categories. Specifically, each patient was categorized as white, black, Hispanic or Asian/Pacific Islander. Therefore, nonwhites were defined to be blacks, Hispanics and Asians/Pacific Islanders. Of the nearly 34 million residents in California, Census 2000 records indicate that 47% are white, 7% are black, 32% are Hispanic and 11% are Asian/Pacific Islander.[20] Admittedly, heterogeneity likely exists within these groups. For example, among Hispanics, 77% are Mexican, 2% are Salvadoran and 1% each is Puerto Rican and Guatemalan. Among Asians/Pacific Islanders, 25% are Chinese, 25% are Filipino, 12% are Vietnamese, 9% each are Korean and Asian Indian, and 8% are Japanese. Health practices, experiences and other factors are likely to be different for these subgroups. Race/ethnicity is ideally determined from self-reports rather than discharge abstracts. However, there is reasonable concordance between the two, especially for whites and blacks,[21] as well as for Hispanics with stroke.[7] In addition, for detecting the effects of racism and discrimination, discharge abstracts may be preferable since they capture the observer's perception.[22]

Table 2. CEA rates by sex, age and race

	CEA Rate per 100,000		CEA Rate Ratio
Subgroup	**W**	**NW**	**W vs. NW**
Females			
Age (Years)			
15–64	10.4	1.9	5.6
65–74	180.4	63.2	2.9
≥75	213.7	69.4	3.1
Males			
Age (Years)			
15–64	15.4	2.7	5.6
65–74	283.8	95.2	3.0
≥75	411.9	142.7	2.9

CEA: carotid endarterectomy; W: whites; NW: nonwhites; Nonwhites include blacks, Hispanics and Asians/Pacific Islanders; rates are standardized to the year 2000 U.S. resident population.

Study Measures

For the CEA utilization analysis, the main outcome was the total number of patients undergoing a CEA, as defined above. In the perioperative events analysis, the main outcomes were: 1) whether or not a patient had an in-hospital death during the index CEA admission, and 2) whether or not a patient had an in-hospital stroke during the index CEA admission. In-hospital death status was obtained directly from the discharge abstract, while in-hospital stroke was defined using ICD-9 diagnostic code 997.0 (surgical complications of the nervous system: iatrogenic cerebrovascular infarction or hemorrhage) listed in any coding position.[18,19] With the CEA readmission analysis, the main outcome was whether or not a patient had ≥2 CEA admissions during the year 2000.

As stated earlier, the main predictor for this study was race/ethnicity. Surgical indication for CEA was considered a potential covariate. Specifically, patients having a prior history of stroke (ICD-9 diagnostic codes 342 or 438), transient ischemic attack (435, 437.1 or 781.4) or amaurosis fugax (362.34 or 368.12) on the index CEA admission were classified as symptomatic.[18,19] Patients not coded for any of these conditions were classified as asymptomatic. Other potential covariates included patient age; sex; payment source; comorbid conditions; smoking status; other patient-level clinical factors; do-not-resuscitate (DNR) order status; process-of-care variables (e.g., operative patching/shunting); and hospital-level factors such as government (nonfederal) ownership, bed capacity, volume of CEAs performed and fraction of CEAs performed on nonwhites.

Statistical Analysis

To examine the effects of race upon CEA utilization, race-specific rates were calculated with the total number of CEA patients as the numerator and the corresponding California resident population as the denominator.[23] Final rates, with 95% confidence intervals (CIs), were age- and sex-adjusted, as well as directly standardized to the U.S. resident population for the year 2000.[24] To examine the independent effects of race on perioperative complications and CEA readmission risk, logistic regression models were used for each outcome (i.e., in-hospital death: 1=yes, 0=no; in-hospital stroke: 1=yes, 0=no; CEA readmission: 1=yes, 0=no). Predictive covariates were chosen using stepwise selection with an alpha level of 0.05, and race was forced into all final models. The Hosmer-Lemeshow goodness-of-fit test was used to assess the adequacy of the models to the data, while Harrell's C-statistic, which is equivalent to the area under the curve for the receiver operating characteristic, was used to assess the discrimination power (i.e., predictive accuracy) of the models.[25,26] For all analyses, SAS® version 9 (SAS Institute, Inc., Cary, NC 2003) was used.

RESULTS

Summary Characteristics

A total of 8,080 white and 1,196 nonwhite patients (228 blacks, 643 Hispanics, 325 Asians/Pacific Islanders) underwent ≥1 elective and isolated CEA during the year 2000 in California (Table 1). Nonwhites were somewhat younger than whites (means ages of 70.8 vs. 72.7 years old, *P*<0.001) and had a lower fraction of females admitted (39.4% vs. 43.4%, P=0.009). As expected, nonwhites had higher rates of hypertension (73.2% vs. 63.3%, P<0.001) and diabetes mellitus (37.0% vs. 22.0%, P<0.001), but lower rates of atrial fibrillation (4.6% vs. 7.1%, P<0.001). In addition, nonwhites had higher rates of acute renal failure (1.2% vs. 0.3%, P<0.001), but lower rates of chronic obstructive pulmonary disease (9.3% vs. 14.9%, P<0.001), smoking (19.7% vs. 26.9%, *P*<0.001) and malignant disease (0.8% vs. 1.5%, P<0.001). Several potential markers of poor outcome were also greater among nonwhites, including length of hospital stay and total charges, as well as rates of an emergency department admission and head computed tomography (CT)/magnetic resonance imaging (MRI) imaging. Interestingly, nonwhites were more likely to be admitted on the weekend. Consistent with prior reports, nonwhites were less likely to go to high-volume hospitals for their CEA procedure. Nonwhites were also less likely to go to hospitals that performed relatively few CEAs on nonwhite patients. Regarding CEA indication, nonwhites had higher rates of symptomatic disease than whites (18.8% vs. 15.2%, P=0.002).

CEA Utilization Patterns

Not surprisingly, this study found that rates of CEA use increased with increasing age (Table 2). Males had higher age-specific rates than females. In all instances, whites had higher age- and sex-specific rates than nonwhites. The age- and sex-adjusted rates of CEA use per 100,000 were 51.2 (95% CI: 50.1–52.4) for whites and 15.6 (14.7–16.6) for nonwhites (Table 3). Therefore, whites underwent CEA at rates about three-fold greater than nonwhites. These results were similar when stratified by CEA indication (data not shown).

Post-CEA Outcomes

During the one-year study period, there were a total of 46 in-hospital deaths (0.5%), 154 in-hospital strokes (1.7%) and 180 combined in-hospital deaths/strokes (1.9%) (Table 4). Among the 46 patients who died, 12 (26.1%) had a stroke, nine (19.6%) had a cardiac complication, and eight (17.4%) had both a stroke and cardiac complication. Importantly, this study found that nonwhites had higher rates of in-hospital death (1.0% vs. 0.4%, P=0.007), stroke (2.5% vs. 1.5%, P=0.014) and combined death/stroke (2.8% vs. 1.8%, P=0.015) than whites. As expected, the combined in-hospital morbidity and mortality rates were higher for symptomatic than asymptomatic patients (5.8% vs. 1.2%, P<0.001) (Table 5). In the logistic regression analysis, nonwhites had greater odds for an in-hospital death and stroke than whites, but after adjustment for patient and hospital factors, the results were only significant for stroke (OR=1.7, P=0.013) (Table 6). Consistent with prior reports, CEA indication and comorbid conditions were independently associated with increased complications. In addition, adverse in-hospital events were also associated with operative patching, DNR order status, emergency department admission and admission to a hospital that did few CEAs on nonwhites (Table 6). Although the predictors of in-hospital death changed somewhat for in-hospital stroke, both final models adequately fit the data and showed good predictive accuracy.

This study also found that most patients underwent CEA only once during the one-year observation period. Specifically, 8,631 patients had a single CEA admission, 640 patients had two CEA admissions, four patients had three CEA admissions, and one patient had four CEA

Table 3. Sex- and age-adjusted CEA rates and odds ratios by race

Subgroup	CEA Rate (95% CI) per 100,000	OR (95% CI)
Whites	**51.2** (50.1–52.4)	
Nonwhites	**15.6** (14.7–16.6)	**3.4** (3.2–3.6)
Blacks	16.7 (14.6–19.1)	3.1 (2.7–3.5)
Hispanics	18.2 (16.7–19.8)	3.1 (2.9–3.4)
Asians/Pacific Islanders	12.6 (11.1–14.2)	4.3 (3.9–4.8)

CEA: carotid endarterectomy; CI: confidence interval; OR: odds ratio of undergoing a CEA; ORs are expressed as whites versus other racial groups; Rates are standardized to the year 2000 U.S. resident population.

admissions. Overall, the CEA readmission rate was about 7%, and no significant racial differences were observed (P=0.109) (Table 4). These results were supported by the logistic regression models (Table 6). The independent predictors of CEA readmission included sex, age, discharge months, emergency department admission, electrocardiographic monitoring, and admission to high-volume and government-operated hospitals (Table 6). The final model showed an adequate fit to the data, but its predictive accuracy was less than optimal.

DISCUSSION

Giacomini previously showed that whites were more likely to undergo a CEA than nonwhites (i.e., blacks, Hispanics and Asians) using California data for the year 1990.[3] For their analysis, patients who were urgently or emergently admitted with similar diagnoses were identified through ICD-9 codes 433.1 (occlusion/stenosis of the carotid artery) and 433.3 (occlusion/stenosis of multiple/bilateral precerebral arteries), and then their risk-adjusted odds of undergoing a CEA were determined rather than their CEA rates. Examining Medicare patients ≥65 years of age, Gillum showed that CEA rates (using all procedures for the numerator) were highest for whites, intermediate for Hispanics and lowest for blacks.[4] These results are consistent with the findings reported here. Lower CEA rates in blacks may be due to a number of factors, including a patient's aversion to surgery, bias of the referring physician or operating surgeon, as well as clinical factors. Importantly, Gillum did not consider Asians/Pacific Islanders and, for the present study, this subgroup actually had the lowest CEA rate after adjustment for age and sex. Their low rate may reflect specific barriers to care encountered by this group such as lack of insurance, language difficulties, immigration status, use of alternative therapies and other acculturation issues.[27] Among VA patients hospitalized for either ischemic stroke or transient ischemic attack, Oddone *et al.* showed that whites had significantly higher CEA rates than blacks for patients pooled across all appropriateness ratings [white vs. black RR=7.4 (95% CI: 3.3–17.0)].[28] Whites also had significantly higher CEA rates for patients rated with inappropriate/uncertain indications [RR=16.8 (2.2–124.4), potential overuse by whites] but not for patients rated with appropriate indications [RR=1.3 (0.7–2.6), potential underuse by blacks]. In the latter group, however, only five blacks received CEA, which raises concern about the sample size given the negative results.

The fact that whites had higher CEA rates than nonwhites in this study has several implications. First, these results may represent appropriate use of CEA by each racial group. For example, higher CEA rates for whites might be explained by a greater risk of symptomatic disease and high-grade extracranial carotid artery stenosis or a lower risk of intracranial atherosclerotic disease (a relative contraindication for CEA).[3,4,29,30] However, given that symptomatic disease was more common among nonwhites, these findings could represent potential CEA overuse by whites and/or underuse by nonwhites. It is worth noting that the benefits of CEA are greater and occur sooner for symptomatic than for asymptomatic patients.[1,2] Consequently, it is more likely that overuse of CEA would tend to occur in the latter group, given their narrower therapeutic benefit. The proportion of CEA patients who were asymptomatic in this study (>80%) may suggest that surgeons in California are more aggressive in their treatment of such patients. On the other hand, surgeons may not be aware of existing disparities in healthcare and may benefit from education.[31] Indeed, there is evidence that fewer nonwhites have undergone cardiovascular surgery due to their perceived higher risk shortly after the introduction of physician report cards.[32] As noted earlier, referral bias and patient preferences may be contributing factors, although recent data suggest that the latter is unlikely to play a major role.[33]

The combined in-hospital stroke and death rate in this study was 1.9%, which is less than the 3% set by the American Heart Association guidelines for operative risk regarding CEA.[34] Therefore, this procedure is performed relatively safely in the state of California. However, this study also found that in-hospital death and stroke were more common among nonwhites than whites. These results were supported by several other findings. For ex-

Table 4. Post-CEA outcome events

	All Patients Total=9,276		Whites Total=8,080		Nonwhites Total=1,196		χ^2 Test P Value
Post-CEA Outcome	**n**	**%**	**n**	**%**	**n**	**%**	
In-hospital death	46	0.5	34	**0.4**	12	**1.0**	**0.007**
In-hospital stroke	154	1.7	124	**1.5**	30	**2.5**	**0.014**
In-hospital death or stroke	180	1.9	146	**1.8**	34	**2.8**	**0.015**
CEA readmission	645	7.0	575	7.1	70	5.9	0.109

CEA: carotid endarterectomy; Nonwhites=228 blacks (deaths=2, strokes=5, deaths/strokes=6, CEA readmissions=10) + 643 Hispanics (deaths=8, strokes=17, deaths/strokes=20, CEA readmissions=42) + 325 Asians/Pacific Islanders (deaths=2, strokes=8, deaths/strokes=8, CEA readmissions=18); P values in bold suggest that the corresponding outcome event rates significantly differ between whites and nonwhites.

ample, nonwhites had greater lengths of hospital stay and incurred greater total charges than whites. As discussed by Huber et al., increased length of hospital stay may be a marker for poor outcome, although other factors may influence the timing of a patient's discharge such as pre-existing medical conditions, the home social environment and financial considerations.[11] Further, it is not surprising that patients with increased complications and/or length of hospital stay would also have greater total charges incurred, given the added cost due to care and days spent in the hospital. Nonwhites had a higher frequency of head imaging performed, which also supports a greater complication risk for this group. Indeed, one would expect that a head CT/MRI would be considered for any postoperative patient showing significant neurological deficits. Interestingly, Mitchell et al. suggested that physician claims for postoperative head imaging and exploratory neck surgery may be good indicators of postprocedural complications following CEA.[35]

Relatively few studies have examined the effects of race on CEA complications, and the results have been conflicting. Differences in the source populations, case definitions and other methodological issues are likely explanations. For example, in the study by Dardik et al.,[13] which showed blacks had a higher risk for stroke but not death, only elective and isolated CEAs were considered like the present study. However, complication rates were calculated using the number of CEAs rather than the number of CEA patients, which could lead to an underestimation of risk. Further, only five deaths occurred among blacks, making power issues a concern regarding the negative findings reported in that study. Consequently, the use of both multiyear and multistate (or national) databases may be the most practical approach for examining perioperative outcomes between races. Alternatively, pooling data from published studies may be the next best option. Indeed, one prior meta-analysis found that blacks had a greater risk of perioperative death by >40% following CEA.[14] Identifying subgroups of patients at risk for complications is important for planning the care of patients potentially undergoing elective and isolated CEA. However, there is no consensus as to what independent factors best predict post-CEA outcomes. Having objective criteria to assess the adequacy of a model and its predictive accuracy, such as those used here, may allow for better study comparisons.

Consistent with previous results, this study found the complication odds increased for those with symptomatic disease and heart failure.[19,36-38] The likelihood of adverse perioperative events was also greater for those with other conditions such as acute renal failure and pneumonia. If these conditions were pre-existing, then delaying surgery may have been appropriate; if they developed after surgery, then closer monitoring and more aggressive treatment may have been warranted. In contrast to prior studies,[37,39] patching was found to increase the likelihood of a poor outcome. One might expect this result if patients undergoing patching (versus primary closure) represent more complex and technically challenging cases. The odds of perioperative death were higher for patients with an emergency department admission, which could be a marker for severity of disease and overall poorer health, and with DNR status in their medical chart, which could represent patient/family preferences for certain care and/or omissions of other care.[40] Interestingly, DNR status raises issues about what the appropriate indications are for prophylactic surgery in such patients and whether or not potential "overuse" of CEA is a concern. A stroke was also more likely to occur at hospitals with low fractions of nonwhites undergoing CEA. This finding is unclear but may suggest that such hospitals have proportionately more high-risk patients rather than less-effective or lower-quality care.

Importantly, this study did not find CEA volume to be independently associated with perioperative outcomes. This is in agreement with results from national data reported by Elixhauser et al.[41] However, baseline data in the present study showed that nonwhites were less likely to go to high-volume hospitals and hospitals that performed relatively few CEAs on nonwhites. This may suggest that although certain hospitals may not perform an overall high volume of CEAs, they may have proportionately greater experience with nonwhite patients. These differences were not explained by other hospital characteristics such as bed size or ownership. Whether these observations are also true for individual surgeons should be examined in future studies. This could have implications for the doctor–patient relation-

Table 5. Post-CEA outcome: in-hospital death/stroke rates by race and CEA indication

CEA Indication	All Patients		Whites		Nonwhites		Outcome Rate Ratio	χ^2 Test
	%	(n/denom)	%	(n/denom)	%	(n/denom)	NW vs. W	P Value
Symptomatic	5.8	(85/1,456)	5.5	(68/1,231)	7.6	(17/225)	1.4	0.232
Asymptomatic	1.2	(95/7,820)	1.1	(78/6,849)	1.8	(17/971)	1.5	0.103
All patients	1.9	(180/9,276)	**1.8**	(146/8,080)	**2.8**	(34/1,196)	**1.6**	**0.015**

CEA: carotid endarterectomy; n: number of in-hospital death/stroke events; denom: denominator; NW: nonwhites; W: whites; Nonwhites include blacks, Hispanics and Asians/Pacific Islanders; Symptomatic patients include those with prior stroke, transient ischemic attack or amaurosis fugax; P values in bold suggest that the corresponding outcome event rates significantly differ between whites and nonwhites.

ship, such as patient preferences for certain hospitals/surgeons and opportunities for potential screening with subsequent diagnostic and therapeutic plans. Interestingly, nonwhites were more likely to be admitted on the weekend. Given that this study focused on patients undergoing elective and isolated CEA, it is reasonable to expect that the procedures were scheduled taking into account both the patient's and operating surgeon's availability. Therefore, this observation may reflect the patient's work schedule or other personal factors, as well as the surgeon's preferences.

To the authors' knowledge, this is the first study to directly examine the relationship between race and CEA readmission risk, and the data showed no significant association over a one-year period. These findings have several implications. First, whatever the barriers are that result in differential first-ever CEA use between whites and nonwhites, they seem to be minimized or even eliminated for those undergoing a subsequent CEA. These results may suggest that screening initiatives are lacking for nonwhites, increasing their risk for a poorer outcome later. Second, CEA readmission may represent either contralateral or recurrent ipsilateral stenosis of the carotid arteries. Consequently, carotid artery disease may progress similarly for whites and nonwhites after initial treatment. Regarding the mechanism, some investigators have observed that early restenosis is often due to smooth myointimal hyperplasia rather than atherosclerotic plaque formation.[42-44] In addition, comparing studies with respect to the incidence of recurrent carotid artery stenosis after CEA may be difficult due to varying definitions of restenosis, as well as the methods and length of follow-up.[45] In one meta-analysis, Frericks et al. reported that the risk of >50% restenosis was about 10% at one year (similar to the 7% readmission risk found in the current study), 3% at two years, 2% at three years and 1% per year thereafter.[46] It is also possible that some patients with recurrent stenosis may have been treated with carotid angioplasty and stenting, which may become a more widely used alternative to CEA in the future, especially for higher-risk patients.

For the multivariate analysis, the likelihood of having a CEA readmission was increased with younger age, which may indicate a ceiling effect for the oldest patients, and with males, who may have had greater atherosclerotic disease. Readmission odds were also higher for patients having an emergency department admission and electrocardiographic monitoring on the index CEA, which may be markers for clinical instability and/or disease severity. Having the index CEA performed at a high-volume or government hospital increased the likelihood of a subsequent CEA admission and may represent the regionalization of resources that draw certain patient populations as opposed to differences in care. Being discharged between October and December decreased the chances of readmission within the same year, which would be expected if such patients had their readmissions the following year rather than a true sea-

Table 6. Logistic regression analysis of post-CEA outcome events

In-Hospital Death			In-Hospital Stroke			CEA Readmission		
Variable	**OR**	**(95% CI)**	**Variable**	**OR**	**(95% CI)**	**Variable**	**OR**	**(95% CI)**
Model 1			**Model 1**			**Model 1**		
NW vs. W	**2.4**	(1.2–4.6)	NW vs. W	**1.7**	(1.1–2.5)	NW vs. W	0.8	(0.6–1.1)
Model 2			**Model 2**			**Model 2**		
NW vs. W	1.7	(0.8–3.5)	NW vs. W	**1.7**	(1.1–2.7)	NW vs. W	0.8	(0.6–1.0)
Prior stroke	**4.2**	(2.1–8.1)	Prior stroke	**7.1**	(5.0–10.0)	Age, Years		
CHF	**5.8**	(3.8–11.9)	TIA	**3.9**	(2.4–6.5)	15–64	1.0	
ARF	**16.2**	(5.9–44.7)	CHF	**2.4**	(1.4–4.1)	65–74	0.8	(0.7–1.0)
Pneumonia	**4.7**	(1.5–14.2)	Afib	**1.7**	(1.1–2.9)	≥75	**0.7**	(0.6–0.9)
ED admission	**3.1**	(1.5–6.2)	COPD	1.5	(1.0–2.3)	Female	**0.8**	(0.7–0.9)
DNR order	**4.9**	(1.4–16.8)	Patching used	**2.8**	(1.2–6.2)	ED admission	**1.5**	(1.1–2.0)
Patching used	**6.2**	(2.1–18.9)	<7% CEAs on NWs	**1.7**	(1.2–2.4)	ECG monitoring	**2.1**	(1.3–3.2)
						Oct.-Dec. discharge	**0.3**	(0.2–0.4)
						Government hospital	**1.8**	(1.5–2.3)
						≥100 CEAs per year	1.2	(1.0–1.5)
C-statistic	0.82		C-statistic	0.76		C-statistic	0.63	
HL P value	0.72		HL P value	0.43		HL P value	0.78	

CEA: carotid endarterectomy; OR: odds ratio; CI: confidence interval; NW: nonwhite; W: white; CHF: congestive heart failure; ARF: acute renal failure; TIA: transient ischemic attack; ED: emergency department; Afib: atrial fibrillation; COPD: chronic obstructive pulmonary disease; DNR: do not resuscitate; ECG: electrocardiographic; Oct-Dec: October–December; HL: Hosmer-Lemeshow goodness-of-fit test; Nonwhites include blacks, Hispanics and Asians/Pacific Islanders; OR values in bold suggest that the corresponding variable is significantly associated with the outcome.

sonal pattern. Finally, although the multivariate model provided a good fit to the data, the less-than-optimal predictive accuracy suggests that further research is needed to identify the determinants of CEA readmission.

When interpreting the findings reported here, the potential limitations of using administrative databases should be kept in mind. First, this study only considered hospital CEAs during a one-year period. Therefore, factors contributing to the selection of CEA candidates prior to hospitalization could not be taken into account, including possible biases of the referring physician and/or operating surgeon, as well as a patient's aversion to surgery or lack of access to care. Second, the results from important diagnostic studies such as carotid ultrasound or angiography, which influence CEA appropriateness and outcomes, were not available (e.g., degree of stenosis, presence of intracranial carotid atherosclerosis, unilateral versus bilateral disease, post-CEA patency of the carotid artery). Third, administrative databases lack detailed information on the clinical presentation that guides subsequent evaluation and treatment. Similarly, coding errors, relative undercoding and general imprecision of ICD-9 codes may underestimate the prevalence of chronic conditions. Fourth, these data did not allow for a direct assessment of all relevant processes of care (e.g., use of preoperative aspirin/ticlopidine, general versus local/regional anesthesia, operative technique and length of stay in the intensive care unit). Fifth, postprocedural complications and other adverse events may be underreported (e.g., when a patient's postoperative neurological exam is not performed by a neurologist). Sixth, although this study used a fairly large database, the number of adverse in-hospital events was limited, especially for nonwhites. This likely contributed to some wider-than-expected confidence intervals. It was already stated that future studies of post-CEA outcomes should consider multiyear-multistate databases, or pooled data from prior studies, to have sufficient power to detect racial differences. Finally, as discussed earlier, the definition of race/ethnicity was subject to misclassification, and heterogeneity is likely to exist within each group.

The authors attempted to minimize the effects of all of these limitations by considering a number of covariates relevant to the care and outcome of CEA patients. The California data allowed up to 30 diagnostic and 15 procedural codes (more than any other state), thereby decreasing the chances of saturation effects for the coding of important diseases and procedures. Regarding ICD-9 codes, prior work has shown that surgical complications are more accurately coded than medical complications and that stroke is more accurately coded than other conditions.[47-50] Research has also found that multivariate models derived from administrative data are comparable to models derived from medical chart review.[51] In addition, for the predictors included in the final models here, the percentages of CEA patients are consistent with prior reports of similarly selected CEA patients.[13,52,53] Regarding access to CEA, in California, whites and nonwhites are similar in their rates of uninsurance and usual source of care.[54] Further, the fraction of CEA patients using Medicare/Medicaid as the primary source of payment was not significantly different between whites and nonwhites. Consequently, although socioeconomic measures were less than optimal in this study, differential access to care is probably less of a concern than would otherwise be expected, especially in comparison to other parts of the United States. Therefore, although potential confounding and information bias cannot be ruled out, the findings of this study may still be helpful with respect to identifying high-risk subgroups of CEA patients.

In summary, the present study found that elective and isolated CEA is performed relatively safely in the state of California based upon the low complication rates observed, although the latter partially reflects the high proportion of asymptomatic patients who underwent the procedure. Notably, nonwhites had lower rates of CEA use despite a higher prevalence of symptomatic disease than whites. These findings may imply that greater uniformity is warranted in the selection of CEA patients. Nonwhites also had higher rates of in-hospital death and stroke. Patient and hospital factors largely accounted for racial differences in mortality but not stroke. Further, while the predictors changed for in-hospital death and stroke, the final multivariate models of both had good predictive accuracy. Therefore, these results may help to identify potentially high-risk CEA patients, whose risk-benefit ratio should be carefully weighed in the preoperative planning phase. Interestingly, despite differences in first-ever CEA use, whites and nonwhites had comparable rates of CEA readmission. These findings may suggest that the progression of carotid artery disease is similar for both groups after having an initial CEA and that screening initiatives are lacking among nonwhites.

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