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Surgical specialty and outcomes for carotid endarterectomy: evidence from the National Surgical Quality Improvement Program

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ABSTRACT

Background: Carotid endarterectomy (CEA) has been performed since the 1950s and remains one of the most common surgical procedures in the United States. The procedure is performed by cardiothoracic, general, neurologic, and vascular surgeons. This study uses data from the National Surgical Quality Improvement Program (NSQIP) to examine the outcomes after CEA when performed by general or vascular surgeons.

Materials and methods: Data included 34,493 CEAs from years 2005 to 2010 recorded in the NSQIP database. Primary outcomes measured were length of stay, 30-d mortality, surgical site infection, cerebrovascular accident, myocardial infarction, and blood transfusion requirement. Secondary outcomes measured were the remaining intraoperative outcomes from the NSQIP database.

Results: After controlling for patient and surgical characteristics, patients treated by general surgeons did not have a significantly different LOS or 30-d mortality than those treated by vascular surgeons. Patients of general surgeons had nearly twice the risk of acquiring a surgical site infection (odds ratio [OR] = 1.94; $P = 0.012$), >1.5 times the risk of cerebrovascular accident (OR = 1.56; $P = 0.008$), and >1.8 times the risk of blood transfusion (OR = 1.85; $P = 0.017$) than those of vascular surgeons. Patients of general surgeons had less than half the risk of having a myocardial infarction (OR = 0.34; $P = 0.031$) than those of vascular surgeons.

Conclusions: Surgical specialty is associated with a wide range of postoperative outcomes after CEA. Additional research is needed to explore practice and cultural differences across surgical specialty that may lead to outcome differences.

Subject Category: Vascular.

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1. Introduction

In the United States, cerebrovascular disease accounts for nearly 130,000 deaths annually and is the fourth leading cause of death [1]. The large majority of strokes are ischemic in origin and as many of 20% of those are due to atherosclerotic disease of the carotid artery [2]. Although there are various methods of treating carotid artery stenosis, carotid endarterectomy (CEA) is considered the standard of care and remains the most frequently performed surgical procedure to prevent stroke [3,4]. CEA has been performed since the 1950s; however, since the publication of the North American Symptomatic Carotid Endarterectomy Trial [5], the European Carotid Surgery Trial [6], and the Asymptomatic Carotid Atherosclerosis Study [7] in the early 1990s, the number of procedures performed in the United States has markedly increased [4].

Numerous reports on outcomes emphasizing perioperative mortality and stroke after CEA have been published. Studies have been conducted analyzing the effects of race, surgeon volume, hospital volume, shunting, intraoperative imaging, cerebral monitoring, as well as many other factors on CEA outcomes [8–11]. Investigations of the effect of surgical specialty on CEA outcomes have produced conflicting results. Some have reported no significant difference in effect of surgical specialty on outcomes [5,10,12,13] and others have demonstrated a significant effect of surgical specialty on outcomes for CEA [9,14–16]. Although Transient ischemic attack and stroke outcomes are included in some reports, there are many other outcomes associated with CEA that have not been as well studied. The purpose of this study was to examine the relationship between surgical specialty and outcomes from CEA using data from the American College of Surgeons private sector National Surgical Quality Improvement Program (NSQIP). This data set offers an opportunity to examine the effect of surgical specialty on a wide array of surgical outcomes, including hospital length of stay (LOS) and 30-d mortality, as well as surgical site infection (SSI), myocardial infarction (MI), cerebrovascular accident (CVA), blood transfusion requirement, and 11 other perioperative outcomes.

2. Methods

2.1. Data

CEA was identified as a primary procedure using current procedure terminology code of 35301. Patients with additional procedures performed at the time of CEA were not excluded *a priori*, but by considering CEA only as a principal procedure, cases where CEA was performed secondarily to a major procedure, such as coronary artery bypass graft surgery, were excluded. This process identified 34,493 CEAs performed between the years 2005 and 2010 from all participating institutions. These cases represent only a fraction of the total CEAs performed during these years since NSQIP only samples cases at participating hospitals and is not all inclusive. [17,18]. Most of these procedures were performed by vascular surgeons ($N = 32{,}848$) and general surgeons ($N = 1{,}645$). Analyses were stratified by these two surgical specialties.

All patient characteristic and outcome data were taken from the NSQIP database collected using standard NSQIP methodology [17,18]. Data were collected by a trained staff of surgical clinical nurse reviewers who worked in conjunction with the surgeon champion for accurate data collection. Uniformity was maintained through the use of an operation manual, which outlined data collection procedures and variable definitions, as well as routine conference calls, site visits, and annual meetings [19]. Surgeon specialty was assigned by the surgical clinical nurse reviewer using either the surgical service line most closely associated with the principal operative procedure or the surgeon's self-declared specialty [20]. For CEA, if a surgeon was board certified in both vascular and general surgery, the surgeon was considered a vascular surgeon [20].

Of the 60 patient characteristics collected for the NSQIP database, variables that had the greatest relevance to the CEA procedure were selected. Preoperative characteristics included age, sex, race/ethnicity, anesthesia type, American Society of Anesthesiologists (ASA) class, operation time, and comorbidities (Table 1). Age was divided into quartiles including 20–64, 65–74, 75–79, and 80+ years. Similarly, operation time, recorded in minutes, was divided into quartiles including <84, 85–109, 110–139, and 140+. Race/ethnicity was stratified by white (non-Hispanic), black (non-Hispanic), Hispanic (including all Hispanic ethnicities), and other (including all other races recorded in the database: American Indian, Alaska Native, Asian, Pacific Islander, Native Hawaiian, or unknown race not of Hispanic origin). Anesthesia type was divided into four categories, the most common anesthesia type being general ($N = 29{,}077$), followed by regional ($N = 3{,}709$), then monitored ($N = 1{,}372$), then all the other types ($N = 335$), including spinal, epidural, other, and no anesthesia. Most patients were rated at an ASA class 3 ($N = 26{,}801$) or class 4 ($N = 4{,}582$), with very few rated at class 1 ($N = 54$) or class 5 ($N = 12$). For statistical analyses, ASA class was divided into two categories, "1, 2, and 3" and "4 and 5." Comorbidities selected include diabetes, smoking, previous Percutaneous coronary intervention (PCI), previous previous cardiac surgery (PCS), hypertension requiring medication, and history of congestive heart failure (CHF), MI, angina, peripheral vascular disease (PVD), or CVA.

In addition to LOS, 30-d postoperative mortality, and any outcome variables, we selected four of NSQIP's 17 perioperative outcomes that were relevant to CEA: SSI, MI, CVA, and blood transfusion requirement. We also created two composite outcome variables. The first measured the incidence of any of the 17 intra- or postoperative outcomes of interest. These 17 outcomes included cardiac arrest, CVA, blood transfusion requirement, intubation lasting >48 h, failure of graft/prosthesis, wound dehiscence, three types of SSI, MI, venous thromboembolism, urinary tract infection, renal insufficiency, sepsis, pneumonia, septic shock, and acute renal failure. The second composite outcome variable measured the incidence of 30-d mortality, MI, or CVA. The SSI outcome included superficial SSI, deep incision SSI, and organ space SSI that occurred within 30 d of the procedure. Superficial SSI included infections that involved only the skin or subcutaneous tissue of the incision. Deep incision SSI included infection of the deep soft tissue (muscle and fascia) of the incision, whereas organ space SSI included infections of any of the organs or spaces

Table 1 – Summary statistics of patients undergoing carotid endarterectomy stratified by surgeon specialty.

Variable	General (*N* = 1,645)	Vascular (*N* = 32,848)	P value
Age (y)	71.3	71.1	0.440
20–64	22.7%	24.3%	
65–74	36.6%	36.4%	
75–79	19.9%	18.4%	
80+	20.7%	20.8%	
Sex			0.016
Male	56.3%	59.3%	
Female	43.7%	40.7%	
Race/ethnicity			<0.001
White, non-Hispanic	80.5%	84.2%	
Black, non-Hispanic	4.9%	3.8%	
Hispanic	5.3%	3.0%	
Other	3.2%	1.3%	
Anesthesia			<0.001
General	86.4%	36.5%	
Regional	5.5%	31.3%	
Monitored	6.3%	19.3%	
Other	1.8%	9.6%	
ASA class			0.031
1	0.2%	0.2%	
2	7.2%	8.9%	
3	77.6%	77.7%	
4	15.0%	13.2%	
5	0.0%	0.0%	
Operation time	118.5	116.5	0.106
<84	21.8%	24.5%	
85–109	26.7%	25.9%	
110–139	28.1%	24.5%	
140+	23.3%	25.0%	
Comorbidities			
Diabetes	28.0%	27.9%	0.911
Smoker	28.8%	27.8%	0.388
Hx of CHF	0.7%	1.0%	0.217
Hx of MI	1.5%	1.5%	0.876
Hx of Angina	1.8%	2.7%	0.040
Hx of PVD	8.5%	9.7%	0.102
Previous PCI	17.8%	18.8%	0.327
Previous PCS	22.9%	22.8%	0.933
HT medication	84.8%	85.5%	0.448
CVA	14.7%	15.5%	0.398

Hx = History; HT = Hypertension.

unconnected to the incision but which were manipulated during the procedure. Patients with any one of these types of SSI were regarded as having an SSI in our analyses. The outcome of MI was recorded in the incidence of any new acute MI that occurred during the procedure or within 30 d postoperatively. The CVA outcome was recorded in the incidence of the patient's development of symptoms lasting for >24 h within 30 d postoperatively. Mortality was recorded as any death occurring during the procedure or within 30 d postoperatively. This was an institutional review board exempt study.

2.2. *Statistical analysis*

Statistical analysis was performed primarily to determine whether surgical specialty was significantly associated with outcomes after controlling for patient and surgical characteristics. The first statistical analysis performed was univariate analysis to determine whether there were differences in patient characteristics across surgeon specialty. This was done using *t*-tests for continuous variables and chi-square tests for binary and categorical variables. Patient outcomes were also compared across surgical specialty using *t*-tests and chi-square tests, without controlling for any patient characteristics.

Logistic regression was then used to model the effect of surgical specialty on binary outcomes after controlling for patient and surgical characteristics. Areas under the receiver operating characteristic curves were calculated to assess model performance. Multivariate analysis of LOS was performed using a generalized linear regression model. This was done because LOS was highly skewed and clearly violated the normality assumption of classical linear regression. For the generalized linear model, we assumed a gamma family of distributions and a log link function. We report the marginal effects from the generalized linear models, which show the effect of a 1 unit change in the independent variable on the outcome. A deviance test was calculated to assess goodness-of-fit.

If a significant imbalance in patient covariates existed between general and vascular surgeons, then a regression model may not adequately control for covariates. Therefore, a propensity score matching analysis that dealt with potential covariate imbalance was performed. The propensity score model was fit using a logistic regression model with general surgical specialty as the dependent variable and controlled for covariates as previously described. Predicted probability of treatment by a general surgeon (i.e., the propensity score) was then computed from the fitted regression model. Patients of general surgeons were matched 1:5 to patients of vascular surgeons. Patients were matched based on a *k*-nearest neighbor match with a max-min common support restriction.

The primary metric for the propensity score analysis was the average effect of treatment on the treated (ATT). This is the difference between the outcome for a patient treated by a general surgeon and the outcome for a patient treated by a vascular surgeon. To deal with the uncertainty induced by both the selection process and the data, a standard bootstrapping algorithm was used to compute 95% confidence intervals. Reported inferences for the ATT are based on 50 bootstrap replicates. All statistical analyses were performed using STATA (version 12.1; StataCorp LLP, College Station, TX) and the psmatch2 routines [21]. Statistical significance for all analyses was defined as a P value < 0.05.

3. Results

3.1. *Patient characteristics*

There were 34,493 CEAs recorded in the NSQIP database between 2005 and 2010. Data from all participating institutions in the database were included. The Figure shows the number of CEAs recorded in the NSQIP database each year from 2005 to 2010, stratified according to surgical specialty. Most of the procedures were performed by vascular surgeons with an

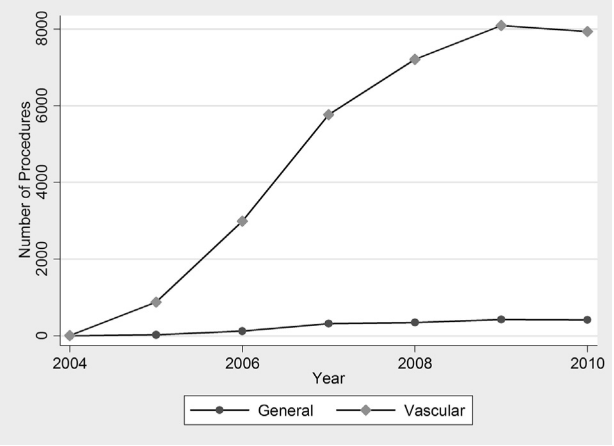

Fig. – Number of carotid endarterectomies performed in the NSQIP stratified by surgical specialty, 2005–2010.

increasing number of procedures recorded up to 2009. Procedures performed by general surgeons also increased up to 2009.

Across the two surgical specialty strata, patient characteristics were similar in regard to age and most of the comorbidities, including diabetes, smoking, and previous PCI (Table 1). There were, however, some significant differences in patient characteristics across surgeon specialties. For example, general surgeons used significantly less general anesthesia and more regional, monitored, and other anesthesia as compared with vascular surgeons ($P < 0.001$). Other differences across specialty included gender, race/ethnicity, ASA classification, and history of angina.

3.2. *Patient outcomes*

Without controlling for patient characteristics, most of the postoperative outcomes were not significantly different across surgeon specialty (Table 2). Mortality, LOS, and patients with any postoperative outcome were all similar across surgical specialty. General surgeons had a higher rate of postoperative CVA than vascular surgeons ($P = 0.011$) as well as higher blood transfusion requirements ($P = 0.018$). There was also a significant difference in SSI between specialties ($P = 0.017$). Vascular surgeons had a higher rate of postoperative MI than general surgeons ($P = 0.024$).

3.3. *Length of stay*

After controlling for patient characteristics, there was still no significant difference in LOS between the surgeon specialties (Table 3). As would be expected, older age (75 years and older), higher ASA class (4 and 5), and all the statistically significant comorbidities resulted in a significant increase in LOS. The use of regional anesthesia was associated with a significantly shorter LOS ($P < 0.001$).

Table 2 – Summary of all NSQIP outcomes stratified by surgeon specialty.

Variable	General (N = 1,645)	Vascular (N = 32,848)	P value
Mortality	1.1%	0.7%	0.113
LOS (d)	2.8	2.7	0.186
Cardiac arrest requiring CPR	0.4%	0.3%	0.718
Cerebrovascular accident	2.4%	1.6%	0.011
Transfusion requirement	1.0%	0.6%	0.018
Intubated >48 h	0.8%	0.8%	0.859
Graft/prosthesis failure	0.1%	0.1%	0.626
Wound dehiscence	0.0%	0.1%	0.254
SSI	1.0%	0.5%	0.017
MI	0.2%	0.7%	0.024
Venous thromboembolism	0.1%	0.2%	0.452
Urinary tract infection	0.9%	0.8%	0.552
Renal insufficiency	0.1%	0.1%	0.845
Sepsis	0.2%	0.5%	0.177
Pneumonia	0.9%	0.9%	0.974
Septic shock	0.1%	0.2%	0.331
Acute renal failure with hemodialysis	0.2%	0.2%	0.383
Any outcome	6.3%	5.4%	0.114
Death, MI, or CVA	3.4%	2.8%	<0.001

CPR = Cardiopulmonary resuscitation.

3.4. *Surgical site infection*

Patients treated by general surgeons were 1.94 times more likely to have a postoperative SSI relative to patients treated by vascular surgeons ($P = 0.012$, Table 4). Patient older than 64 years (65–74, 75–79, 80+ years), all had reduced incidence of SSI ($P < 0.001$, $P = 0.040$, $P < 0.001$, respectively). Neither history of MI, CVA, nor PVD had a significant effect on postoperative SSI.

3.5. *MI and CVA*

General surgery differed from vascular surgery in both the occurrence of postoperative MI and postoperative CVA. Compared with CEAs performed by vascular surgeons, those performed by general surgeons had a 66% reduced odds of resulting in a postoperative MI ($P = 0.031$, Table 5), but they had a 56% greater odds of resulting in a postoperative CVA ($P = 0.008$, Table 6). Patients older than 64 years had an increased incidence of postoperative MI, and patients aged 80 years or older had four times the incidence than those aged 20–64 years ($P < 0.001$). Patients who received regional anesthesia had less than half of the risk of postoperative MI than patients who received general anesthesia ($P = 0.007$). Age and anesthesia type had no significant effect on postoperative CVA; however, higher ASA class was associated with an increased risk of CVA ($P = 0.007$). Diabetes, smoking, history of MI, angina, PCI, and CVA all were associated with an increased likelihood of postoperative MI, whereas only history of angina and CVA were associated with an increased risk of postoperative CVA.

Table 3 – Results of generalized linear model of effect of surgeon specialty on LOS, controlling for other covariates (deviance χ^2 = 24,518, P < 0.001).

Variable	Marginal effect	95% confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	0.09	−0.08	0.27	0.302
Age (y)				
20–64	Reference			
65–74	−0.03	−0.13	0.06	0.490
75–79	0.26	0.14	0.39	<0.001
80+	0.72	0.58	0.86	<0.001
Sex				
Female	Reference			
Male	−0.15	−0.23	−0.07	<0.001
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	1.19	0.91	1.46	<0.001
Hispanic	0.91	0.62	1.20	<0.001
Other	0.27	−0.08	0.62	0.134
Anesthesia				
General	Reference			
Regional	−0.28	−0.39	−0.17	<0.001
Monitored	−0.10	−0.28	0.09	0.303
Other	−0.20	−0.54	0.15	0.265
ASA class				
1, 2, and 3	Reference			
4 and 5	1.47	1.31	1.63	<0.001
Operation time				
<84	Reference			
85–109	0.12	0.01	0.22	0.030
110–139	0.18	0.07	0.29	0.001
140+	0.72	0.60	0.84	<0.001
Comorbidities				
Diabetes	0.23	0.14	0.32	<0.001
Smoker	0.07	−0.02	0.16	0.151
Hx of CHF	4.12	3.15	5.10	<0.001
Hx of MI	1.68	1.16	2.19	<0.001
Hx of Angina	1.86	1.46	2.27	<0.001
Hx of PVD	0.29	0.15	0.43	<0.001
Previous PCI	−0.09	−0.18	0.00	0.061
Previous PCS	−0.08	−0.17	0.01	0.067
HT medication	−0.09	−0.20	0.02	0.117
CVA	1.47	1.32	1.62	<0.001

Hx = History; HT = Hypertension.

Table 4 – Results of logistic regression model of effect of surgeon specialty on SSI, controlling for other covariates (area under ROC curve = 0.65).

Variable	Odds ratio	95% Confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	1.94	1.16	3.26	0.012
Age (y)				
20–64	Reference			
65–74	0.50	0.35	0.72	<0.001
75–79	0.52	0.34	0.81	0.004
80+	0.36	0.22	0.59	<0.001
Sex				
Female	Reference			
Male	1.24	0.91	1.69	0.168
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	0.83	0.39	1.79	0.639
Hispanic	1.42	0.72	2.80	0.312
Other	0.70	0.17	2.85	0.620
Anesthesia				
General	Reference			
Regional	1.00	0.62	1.62	0.990
Monitored	0.56	0.21	1.53	0.258
Other	0.50	0.07	3.61	0.493
ASA class				
1, 2, and 3	Reference			
4 and 5	0.92	0.60	1.42	0.720
Operation time				
<84	Reference			
85–109	1.18	0.77	1.82	0.444
110–139	0.94	0.59	1.48	0.780
140+	1.54	1.02	2.32	0.041
Comorbidities				
Diabetes	1.17	0.85	1.60	0.333
Smoker	0.98	0.71	1.37	0.928
Hx of CHF	1.51	0.46	4.95	0.493
Hx of MI	1.18	0.42	3.30	0.757
Hx of angina	1.07	0.46	2.49	0.870
Hx of PVD	1.28	0.83	1.99	0.263
Previous PCI	0.90	0.62	1.31	0.571
Previous PCS	1.38	0.99	1.92	0.055
HT medication	1.04	0.68	1.57	0.869
CVA	1.05	0.72	1.55	0.794

bgfbbsb

3.6. *Blood transfusion requirement*

Patients treated by general surgeons were almost twice as likely to receive a blood transfusion than those patients treated by vascular surgeons ($P = 0.017$, Table 7). Patient age categories aged older than 64 years (65–74, 75–79, 80+ years), all had an increased risk of blood transfusion requirement, with patients older than 75 years at greater than twice the risk ($P = 0.048$, $P = 0.001$, $P = 0.001$, respectively). Diabetes and history of MI were associated with an increased risk of blood transfusion ($P = 0.001$ and $P < 0.001$, respectively), and a history of CHF was associated with over four times the risk of requiring a blood transfusion ($P < 0.001$).

3.7. *Mortality*

Of the 34,493 operations recorded in the database, 263 patients died within 30 d of their CEA. There were no significant differences found between surgical specialty and 30-d mortality, but several patient characteristics were associated with 30-d mortality. Patients who were aged >80 years had nearly three times greater odds of mortality than that of those from the age 20 to 64 years ($P < 0.001$). Patients rated as ASA class 4 or 5 had 2.4 times the odds of mortality compared with those patients rated 1, 2, or 3 ($P < 0.001$). History of CHF, MI, angina, PVD, and CVA all were significantly related to greater mortality. Anesthesia type had no significant association with mortality.

Table 5 – Results of logistic regression model of effect of surgeon specialty on postoperative MI, controlling for other covariates (area under ROC curve = 0.71).

Variable	Odds ratio	95% Confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	0.34	0.12	0.90	0.031
Age (y)				
20–64	Reference			
65–74	1.88	1.25	2.82	0.003
75–79	1.77	1.09	2.88	0.022
80+	4.05	2.62	6.26	<0.001
Sex				
Female	Reference			
Male	1.00	0.76	1.30	0.972
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	1.08	0.58	2.01	0.805
Hispanic	0.92	0.43	1.97	0.826
Other	2.30	1.07	4.96	0.033
Anesthesia				
General	Reference			
Regional	0.44	0.25	0.80	0.007
Monitored	0.50	0.21	1.23	0.132
Other	0.40	0.05	2.84	0.356
ASA class				
1, 2, and 3	Reference			
4 and 5	1.42	1.03	1.94	0.032
Operation time				
<84	Reference			
85–109	0.88	0.60	1.30	0.527
110–139	0.89	0.60	1.32	0.560
140+	1.44	1.01	2.05	0.042
Comorbidities				
Diabetes	1.40	1.07	1.85	0.015
Smoker	1.46	1.07	2.00	0.017
Hx of CHF	0.67	0.24	1.89	0.446
Hx of MI	2.16	1.15	4.07	0.017
Hx of angina	2.88	1.79	4.63	<0.001
Hx of PVD	1.43	0.98	2.07	0.061
Previous PCI	1.46	1.09	1.95	0.012
Previous PCS	1.26	0.94	1.68	0.122
HT medication	1.10	0.73	1.65	0.661
CVA	1.39	1.01	1.91	0.042

Hx = History; HT = Hypertension.

Table 6 – Results of logistic regression model of effect of surgeon specialty on postoperative CVA, controlling for other covariates (area under ROC curve = 0.63).

Variable	Odds ratio	95% Confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	1.56	1.13	2.17	0.008
Age (y)				
20–64	Reference			
65–74	0.86	0.69	1.08	0.189
75–79	0.89	0.68	1.17	0.407
80+	1.09	0.84	1.41	0.506
Sex				
Female	Reference			
Male	0.86	0.73	1.02	0.091
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	1.20	0.83	1.74	0.342
Hispanic	1.07	0.68	1.69	0.761
Other	0.71	0.32	1.61	0.414
Anesthesia				
General	Reference			
Regional	1.00	0.76	1.32	0.981
Monitored	0.90	0.57	1.42	0.661
Other	0.18	0.02	1.26	0.084
ASA class				
1, 2, and 3	Reference			
4 and 5	1.35	1.08	1.68	0.007
Operation time				
<84	Reference			
85–109	1.01	0.80	1.28	0.929
110–139	0.80	0.62	1.03	0.087
140+	1.16	0.92	1.46	0.218
Comorbidities				
Diabetes	1.10	0.91	1.32	0.325
Smoker	1.07	0.87	1.30	0.528
Hx of CHF	0.80	0.37	1.75	0.581
Hx of MI	1.55	0.91	2.64	0.105
Hx of angina	1.75	1.17	2.63	0.006
Hx of PVD	1.21	0.93	1.57	0.165
Previous PCI	0.88	0.71	1.11	0.282
Previous PCS	1.00	0.82	1.23	0.972
HT medication	1.01	0.79	1.29	0.934
CVA	2.12	1.75	2.55	<0.001

Hx = History; HT = Hypertension.

3.8. *Any outcome/complication*

After controlling for patient characteristics, the effect of surgical specialty on the composite outcome was not statistically significant. Smoking history, previous PCI or PCS, and use of hypertensive medications also did not have a significant effect on the aggregate outcome. The 80+ age category, black non-Hispanic race, and several comorbidities including diabetes, history of MI, angina, PVD, and CVA were all associated with an increased risk of a negative postoperative outcome compared with their respective reference groups. Patients with a history of CHF were more than three times more likely to have any negative postoperative outcome ($P < 0.001$). Regional and other anesthesia as well as male gender were associated with decreased odds of a negative postoperative outcome.

3.9. *Mortality, MI, and CVA*

Although there was a higher incidence of 30-d mortality, MI, and CVA in patients of general surgeons compared with vascular surgeons using univariate analysis, after controlling for patient characteristics, the effect of surgical specialty on the composite outcome was not statistically significant ($P = 0.110$, Table 8). Similar to the total composite outcome, the 80+ years age category, black non-Hispanic race, and several

Table 7 – Results of logistic regression model of effect of surgeon specialty on transfusion requirement, controlling for other covariates (area under ROC curve = 0.77).

Variable	Odds ratio	95% Confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	1.85	1.12	3.07	0.017
Age (y)				
20–64	Reference			
65–74	1.53	1.00	2.34	0.048
75–79	2.18	1.36	3.47	0.001
80+	2.29	1.43	3.68	0.001
Sex				
Female	Reference			
Male	0.87	0.66	1.16	0.350
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	1.17	0.64	2.13	0.601
Hispanic	0.60	0.25	1.49	0.274
Other	1.29	0.47	3.53	0.618
Anesthesia				
General	Reference			
Regional	0.54	0.29	1.00	0.051
Monitored	0.68	0.28	1.68	0.403
Other	0.49	0.07	3.52	0.477
ASA class				
1, 2, and 3	Reference			
4 and 5	3.33	2.47	4.51	<0.001
Operation time				
<84	Reference			
85–109	1.27	0.81	1.99	0.296
110–139	1.14	0.72	1.80	0.585
140+	2.15	1.43	3.24	<0.001
Comorbidities				
Diabetes	1.65	1.23	2.20	0.001
Smoker	1.31	0.94	1.82	0.115
Hx of CHF	4.20	2.46	7.19	<0.001
Hx of MI	3.06	1.76	5.31	<0.001
Hx of angina	1.42	0.80	2.51	0.226
Hx of PVD	1.37	0.91	2.05	0.127
Previous PCI	0.88	0.62	1.24	0.455
Previous PCS	0.83	0.59	1.15	0.260
HT medication	1.45	0.88	2.37	0.142
CVA	1.04	0.72	1.48	0.850

Hx = History; HT = Hypertension.

Table 8 – Results of logistic regression model of effect of surgeon specialty on composite outcome including 30-d mortality, postoperative MI, and postoperative CVA, controlling for other covariates (area under ROC curve = 0.65).

Variable	Odds ratio	95% Confidence interval		P value
		Lower	Upper	
Surgical specialty				
Vascular	Reference			
General	1.25	0.95	1.65	0.110
Age (y)				
20–64	Reference			
65–74	1.07	0.89	1.28	0.496
75–79	1.18	0.95	1.46	0.135
80+	1.80	1.47	2.20	<0.0001
Sex				
Female	Reference			
Male	0.86	0.75	0.98	0.024
Race/ethnicity				
White, non-Hispanic	Reference			
Black, non-Hispanic	1.35	1.02	1.78	0.037
White, non-Hispanic	1.04	0.73	1.49	0.820
Other	0.88	0.49	1.57	0.657
Anesthesia				
General	Reference			
Regional	0.84	0.67	1.06	0.136
Monitored	0.88	0.61	1.25	0.468
Other	0.51	0.21	1.23	0.133
ASA class				
1, 2, and 3	Reference			
4 and 5	1.59	1.36	1.87	<0.0001
Operation time				
<84	Reference			
85–109	0.98	0.81	1.18	0.804
110–139	0.84	0.69	1.03	0.088
140+	1.35	1.13	1.62	0.001
Comorbidities				
Diabetes	1.10	0.96	1.27	0.178
Smoker	1.15	0.98	1.34	0.083
Hx of CHF	1.65	1.08	2.51	0.020
Hx of MI	1.92	1.34	2.74	<0.0001
Hx of angina	1.91	1.43	2.55	<0.0001
Hx of PVD	1.41	1.16	1.71	<0.0001
Previous PCI	1.05	0.89	1.23	0.579
Previous PCS	1.06	0.91	1.24	0.441
HT medication	1.07	0.88	1.30	0.494
CVA	1.88	1.62	2.18	<0.0001

Hx = History; HT = Hypertension.

comorbidities including history of CHF, MI, angina, PVD, and CVA were all associated with an increased risk of a negative postoperative outcome compared with their respective reference groups. Not surprisingly, higher ASA class and longer operation times were also associated with increased odds of 30-d mortality, MI, and CVA.

3.10. *Propensity score matching*

Among propensity score matched groups, patients treated by general surgeons had a 6.3% risk of a negative postoperative outcome, as compared with a 4.6% risk incurred by patients treated by vascular surgeons (Table 9). This is a significant difference (ATT) of 1.8% ($P = 0.021$). In other propensity score matched groups, patients treated by general surgeons had a higher risk of longer LOS, SSI, CVA, blood transfusion requirement, mortality, and composite incidence of mortality, MI, and CVA than patients of vascular surgeons, but these differences were not significant. Patients treated by general surgeons had a lower risk of postoperative MI, but this was not significantly different than patients of vascular surgeons.

Table 9 – Results of the propensity score analysis.

Variable	General	Vascular	ATT	P value
LOS (d)	2.8	2.7	0.2	0.209
SSI	1.0%	0.4%	0.6%	0.056
MI	0.2%	0.4%	−0.2%	0.331
CVA	2.4%	1.6%	0.8%	0.083
Transfusion requirement	1.0%	0.4%	0.6%	0.075
Mortality	1.1%	0.7%	0.4%	0.219
Any outcome	6.3%	4.6%	1.8%	0.021
Mortality, MI, and CVA	3.4%	2.6%	0.9%	0.182

4. Discussion

CEA is one of the most commonly performed major surgical operations in the United States, and its postoperative outcomes have been well studied. Multiple patient and procedural variables have been shown to affect outcomes, as well as other factors such as hospital volume, surgeon volume, and surgical specialty [9,16,22–38]. Significant differences in outcomes across surgical specialty have, however, been limited primarily to death, stroke, and combined death and stroke. Of those that showed significant differences, Feasby *et al.* [9] reported that general surgeons had poorer mortality and stroke outcomes than neurosurgeons, vascular surgeons, and cardiothoracic surgeons. AbuRahma *et al.* [39] found that perioperative stroke rates were significantly higher for nonvascular surgeons, whereas O'Neill *et al.* [16] showed that neurosurgeons had lower mortality rates than non-neurosurgeons. A study by Hannan *et al.* [14] analyzing processes of care found that vascular surgeons had greater numbers of processes of care and, therefore, lower odds of adverse outcome after CEA compared with other specialties. In contrast, Cowan *et al.* [32] demonstrated that surgeon specialty and hospital volume had no statistically significant effect on mortality or postoperative stroke but that high surgeon volume significantly decreased mortality and stroke rates. An early study by Kempczinski *et al.* [12] also demonstrated no significant difference in postoperative death or stroke when surgeons were classified by specialty.

A relatively smaller number of studies have evaluated outcomes for CEA other than mortality and stroke. Length and cost of hospital stay, Transient ischemic attack, and carotid re-occlusion were evaluated by Hollenbeak *et al.* They found that patients of general surgeons had the lowest costs compared with patients treated by surgeons of other specialties, and patients treated by vascular surgeons had lower re-occlusion rates and shorter hospital stays than patients treated by general surgeons [15]. Teso *et al.* [40] demonstrated that patients of vascular surgeons had a decreased risk of cardiac complications compared with patients of general surgeons.

The results of this study suggest that surgical specialty has a significant effect on outcomes after CEA. Patients of general surgeons had nearly twice the risk of acquiring an SSI and >1.5 times the risk of CVA than patients of vascular surgeons. However, patients of general surgeons had less than half the risk of having an MI than patients of vascular surgeons. Of the remaining NSQIP outcomes measured, which were less specific to CEA, perioperative blood transfusion was the only other statistically significant outcome difference across specialty. Compared with patients of vascular surgeons, patients of general surgeons had nearly twice the risk of receiving a transfusion.

Our study also demonstrated that age 80 years and older was associated with nearly three times the mortality risk, four times the MI risk, and interestingly, a significantly decreased SSI risk than that of patients aged younger than 65 years. Female gender was associated with increased LOS and higher risk for any adverse outcome. Not surprisingly, ASA classes 4 and 5 were associated with increased risk of mortality, MI, and CVA, and a significant increase in LOS as compared with the other ASA classes. Regional anesthesia was found to be associated with better outcomes. Risk of MI, risk of any negative outcome, and hospital LOS were all decreased in patients who received regional anesthesia compared with patients who received general anesthesia.

Our finding of relatively low numbers of CEAs performed by general surgeons compared with the higher volumes of CEAs performed by vascular surgeons has been previously shown. Valentine *et al.* [41] demonstrated that the majority of general surgeons do not perform any major vascular procedures such as CEA, and younger general surgeons are performing fewer such procedures than their older counterparts. They attributed this to the rapid incorporation of endovascular technology into vascular practice. Solomon *et al.* [42] demonstrated that between 2000 and 2005, endovascular CEAs increased by 28.8% compared with open CEA. This increase in endovascular technique has driven vascular surgery to become an independent specialty with unique training requirements, and vascular surgery training has thus decreased among general surgery residencies [43]. This progressive loss of operative vascular experience among general surgeons likely contributes to the lower volume of CEAs performed by practicing general surgeons.

There are several limitations to this study. First, the degree of carotid stenosis, which has been shown to be important in determining CEA outcomes, is not included in our data set and we could not control for it [5,6]. Similarly, whether patients were symptomatic or asymptomatic from their disease was not included in our data set. The study was also limited by the assignment of surgical specialty by the surgical clinical nurse reviewer. Each institution develops its own internal process for determining the best surgical specialty designation for each procedure and can be based on the surgeon's board certification, self-declared specialty, or surgical service line most closely associated with the principal operative procedure [20]. Outcomes are only measured for 30 d postoperatively; therefore, long-term outcomes cannot be determined from NSQIP data. The limited number of procedures performed by other specialties must also be taken into consideration. Due to small sample size, inferences could not be made in regard to outcome differences of patients treated by neurosurgeons or cardiothoracic surgeons as in previous studies [9,16], and these data were excluded from our study. A larger sample size is needed to determine more accurate outcome differences associated with additional surgical specialties. Another limitation is the large number of procedures performed with spinal, epidural, or no anesthesia ($N = 335$). It seems unlikely that these types of anesthesia would be used, in particular no anesthesia, and that they represent coding errors.

The data used in this study also have many advantages over prior studies. This NSQIP data set provided CEA data through the year 2010 from institutions across the United States. This gives a more accurate reflection of CEA outcomes than previous studies that necessarily required participating surgeons to meet benchmarks and, therefore, excluded surgeons with lower success rates [5,7]. The greatest advantage is the vast number of variables recorded in the database, including 49 preoperative variables, 17 intraoperative variables, and 33 outcome variables.

Our analyses suggest that there are differences in outcomes after CEA across surgical specialty. Patients of general surgeons had nearly twice the risk of acquiring an SSI, >1.5 times the risk of CVA, and >1.8 times the risk of blood transfusion than patients of vascular surgeons but had less than half the risk of having an MI. Additional research is needed to explore cultural and practice pattern differences across surgical specialties that may be causative of these CEA outcome differences. More data from CEAs performed by other surgical specialties are also needed to better determine significant differences in outcomes compared with vascular and general surgery.

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ACS-NSQIP Disclaimer: The ACS-NSQIP and the hospitals participating in the ACS-NSQIP are the source of the data used herein; they have not verified and are not responsible for the statistical validity of the data analysis or the conclusions derived by the authors. This study does not represent the views or plans of the ACS or the ACS-NSQIP.

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