EDUCATION CORNER

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Characterization of resident surgeon participation during carotid endarterectomy and impact on perioperative outcomes

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Introduction: **The impact of resident surgeon participation during vascular procedures on postoperative outcomes is incompletely understood. We characterized resident physician participation during carotid endarterectomy (CEA) procedures within the 2005-2009 American College of Surgeons National Surgical Quality Improvement Participant Use Datafile and evaluated associations with procedural characteristics and perioperative adverse events.**

Methods: **CEAs were identified using primary current procedural terminology codes; those performed simultaneously with other major procedures or unknown resident participation status were excluded. Group-wise comparisons based on resident participation status were performed using χ^2 or Fisher's exact test for categorical variables and *t* tests or nonparametric methods for continuous variables. Associations with perioperative adverse events (major = stroke, death, myocardial infarction, or cardiac arrest; minor = peripheral nerve injury, bleeding requiring transfusion, surgical site infection, or wound disruption) were assessed using multivariable logistic regression models adjusting for other known risk factors.**

Results: **A total of 25,280 CEA procedures were analyzed, of which residents participated in 13,705 (54.2%), while residents were absent in 11,575 (45.8%). Among CEAs with resident physician participation, resident level was categorized as junior (postgraduate year [PGY] 1-2) in 21.9%, senior (PGY 3-5) in 52.7%, and fellow (PGY ≥6) in 25.3%. Major adverse event rates with and without resident participation were 1.9% versus 2.1%, and minor adverse event rates with and without resident participation were 0.9% versus 1.0%, respectively. In multivariable models, resident physician participation was not associated with perioperative risk for major adverse events (odds ratio [OR], 0.90; 95% confidence interval [CI], 0.75-1.08) or minor adverse events (OR, 0.93; 95% CI, 0.72-1.21).**

Conclusions: **Resident surgeon participation during CEA is not associated with risk of adverse perioperative events. (J Vasc Surg 2012;55:268-73.)**

Traditional surgical education has been based on supervised participation in patient care with graduated levels of responsibility based on experience, with exposure and practice in the operating room as the predominant method for acquiring and developing procedural skills. Although operating room experience is regarded by many as an effective format for learning surgical technique,[1] expanding efforts directed at controlling healthcare costs and improving quality have been accompanied by increased interest in the impact of resident involvement in patient care, both inside and outside the operating room, on patient safety and outcomes. Resident physician work hours have been a major focus of initiatives introduced over the past decade intended to improve both education and safety; although influence of these measures on patient outcomes has been studied extensively, few analyses have included patients who did not receive resident care for comparison. Other limitations of published studies evaluating the influence of resident physician participation in patient care on surgical outcomes include the inability to characterize

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resident involvement within administrative datasets beyond hospital teaching status[2,3] and frequent combination of Vascular Surgery, General Surgery, and other specialty operations for analysis.[4-6]

Carotid endarterectomy (CEA) is an established treatment for patients with advanced symptomatic or asymptomatic carotid stenosis and is a procedure where technical factors potentially influence results. Although factors affecting CEA outcomes have been studied extensively, the impact of resident participation during CEA on perioperative outcomes has not been thoroughly characterized. We hypothesized that resident surgeon participation during CEA may be associated with longer procedure durations and higher perioperative adverse event rates. In order to evaluate the impact of resident physician participation on outcomes associated with CEA, we explored associations with procedural characteristics and perioperative adverse event rates using the American College of Surgeons National Surgical Quality Improvement (ACS-NSQIP) Participant Use Datafile. Residents scrubbed for surgical procedures are identified by postgraduate year within ACS-NSQIP, permitting detailed characterization of resident procedural involvement for analysis of associations with perioperative outcomes.

METHODS

Primary Current Procedural Terminology (CPT) code 35301 was used to identify CEA procedures from the 2005-2009 ACS-NSQIP Participant User Data File. The ACS-NSQIP is a national, prospective database that includes information from >200 participating community and academic medical centers throughout the United States.[7] The ACS-NSQIP records 135 variables, including preoperative risk factors, procedure-related variables, and 30-day postoperative mortality and morbidity outcomes for patients undergoing major inpatient and outpatient surgical procedures. Data are captured by formally trained surgical clinical reviewers at participating sites using standardized methods and entered into a Web-based collection system, and inter-rater reliability audits are conducted periodically for all sites to ensure data quality. The ACS-NSQIP Participant Use Datafile does not contain identifiable patient or hospital-level information and therefore is not considered human subjects research requiring Institutional Review Board review.

All available CPT codes (up to 21 per procedure) were queried, and CEAs performed with other major procedures during the same anesthetic were excluded from analysis, as were CEAs performed on patients with preoperative pneumonia, sepsis, wound infection, open wound, or no data indicating resident participation status. For descriptive purposes and subgroup comparisons, residents were categorized by level of training as junior for postgraduate years (PGY) 1 to 2, senior for PGY 3-5, and fellow for PGY ≥ 6.

Descriptive statistics are reported as mean ± standard deviation for continuous variables and number (percent) for categorical variables. Group-wise comparisons of preoperative and procedural factors based on resident participation status were performed using χ^2 testing for categorical variables and t tests or nonparametric methods for continuous variables based on data distributions, and adjustment for multiple testing was performed using the Bonferroni method. Associations between resident participation during CEA and perioperative major and minor adverse events were evaluated using logistic regression. Major adverse events were defined as occurrence of stroke, death, myocardial infarction (defined as new transmural myocardial infarction as manifested by new Q-waves on electrocardiogram), or cardiac arrest requiring cardiopulmonary resuscitation (CPR) within 30 days of CEA. Minor adverse events were defined as occurrence of at least one of the following within 30 days of CEA: peripheral nerve injury, bleeding requiring transfusion, surgical site infection (including superficial, deep, or organ space infection), or wound disruption.

For logistic models, resident surgeon participation was defined as any level trainee scrubbed during the CEA. Adjusted multivariable models were created by combining resident participation status with candidate covariates previously identified as risk factors for adverse events following CEA based on literature review, including: history of stroke,[8-11] history of transient ischemic attack (TIA),[8,12,13] diabetes,[8,11,14,15] hypertension,[16,17] coronary artery disease (defined as history of angina, myocardial infarction, or coronary revascularization),[9,11,16] smoking,[8] preoperative creatinine,[8,14] preoperative white blood cell (WBC) count,[18,19] general anesthesia (vs other),[8,9,20] age (evaluated as >80 years vs other),[10,12,21-23] female gender,[12] American Society of Anesthesiology (ASA) physical status classification (evaluated as ≥III vs other),[10,21,24] and emergent procedure status.[14,23] Candidate covariates were evaluated for inclusion in adjusted models using forward selection with $P < .05$ as the entry criterion. Procedure and anesthesia durations were intentionally omitted from multivariable models in order to avoid bias toward a type II error secondary to confounding associations between resident surgeon participation and these variables. Subgroup comparisons of adverse event rates based on resident training level were performed using χ^2 testing for categorical variables and analysis of variance for continuous variables. All statistical analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC).

RESULTS

Patient sample and resident participation. A total of 25,280 CEAs meeting the study inclusion criteria were identified; of these, 23,409 procedures (93%) had complete data for inclusion in multivariable models of major and minor adverse events. Forty-one percent of patients were female, and 17.6% of patients were >80 years old. Residents participated in 13,705 CEAs (54.2%), while residents were absent in 11,575 (45.8%). Group-wise comparisons based on resident participation status during CEA revealed generally comparable preoperative patient demographic and comorbidity data (Table I), including preoperative prevalence of prior stroke, TIA, and history of bleeding

Table I. Preoperative demographic and comorbidity factors in patients undergoing carotid endarterectomy categorized by resident physician participation status

Preoperative variable	*Resident present (n = 13,705)*	*Resident absent (n = 11,575)*	P[a]
Age >80 years	17.1%	18.2%	.0188
Female	40.4%	42.3%	.0021
Weight (kg)	80.7 ± 18.1	80.6 ± 18.6	.8918
White race	85.6%	83.5%	<.0001
History of stroke	24.3%	23.4%	.3876
History of transient ischemic attack	27.6%	28.4%	.1721
Hemiplegia	6.1%	5.0%	<.0001
Myocardial infarction within past 6 months	1.3%	1.4%	.5115
Hypertension requiring medication	85.4%	85.1%	.4926
Chronic obstructive pulmonary disease	9.4%	10.7%	.0011
Congestive heart failure within past 30 days	0.9%	0.8%	.1883
Diabetes requiring oral agent or insulin	27.4%	26.9%	.4324
History of bleeding disorder	20.4%	20.1%	.6206
Current dialysis	0.9%	1.0%	.4127
Current smoker (within 1 year)	27.6%	27.8%	.6692
Steroid use for chronic condition	2.1%	2.0%	.8781
Dependent functional status	5.2%	5.6%	.1694
American Society of Anesthesiology class ≥ III[b]	89.4%	91.4%	<.0001

Categorical variables are displayed as percentages, and continuous variables are displayed as mean ± standard deviation.
[a]$P < .002$ required for statistical significance at $\alpha = 0.05$ after adjustment for multiple testing using Bonferroni method.
[b]American Society of Anesthesiology physical status classification.

Table II. Carotid endarterectomy: Procedural characteristics categorized by resident participation status

Procedural characteristic	*Resident present (n = 13,705)*	*Resident absent (n = 11,575)*	P[a]
Emergency procedure	1.5%	1.7%	.4233
General anesthesia	82.9%	84.0%	.0135
Operative time (minutes)	127.6 ± 42.5	100.2 ± 37.8	<.0001
Anesthesia time (minutes)	194.3 ± 53.5	156.9 ± 50.5	<.0001
Intraoperative packed red blood cell transfusion	0.9%	0.6%	.0097

Categorical variables are displayed as percentages, and continuous variables are displayed as mean ± standard deviation.
[a]$P < .002$ required for statistical significance at $\alpha = 0.05$ after adjustment for multiple testing using Bonferroni method.

Table III. Thirty-day adverse event rates stratified by resident physician participation status

Perioperative adverse event	*Resident present (n = 13,705)*	*Resident absent (n = 11,575)*
Any major adverse event	259 (1.9%)	248 (2.1%)
Stroke	192 (1.4%)	199 (1.7%)
Myocardial infarction	69 (0.5%)	66 (0.2%)
Cardiac arrest requiring cardiopulmonary resuscitation	36 (0.3%)	28 (0.2%)
Death	85 (0.6%)	71 (0.6%)
Any minor adverse event	129 (0.9%)	117 (1.0%)
Surgical site infection	78 (0.6%)	66 (0.6%)
Peripheral nerve injury	33 (0.2%)	26 (0.2%)
Bleeding requiring transfusion	11 (0.1%)	18 (0.2%)
Wound disruption	8 (0.1%)	10 (0.1%)

Major adverse events defined as stroke, myocardial infarction, or death. Minor adverse events defined as peripheral nerve injury, bleeding requiring transfusion, surgical site infection, or wound disruption. Values displayed as N (%) with percentages rounded to nearest 0.1%.

Table IV. Multivariable model of major perioperative adverse events following carotid endarterectomy

Variable	*Odds ratio (95% confidence interval)*	P
Age >80 years	1.38 (1.11-1.71)	.004
History of stroke	1.96 (1.62-2.37)	<.001
History of transient ischemic attack	1.38 (1.14-1.67)	.001
Preoperative creatinine (mg/dL)[a]	1.08 (1.01-1.15)	.042
Preoperative white blood cell count ($1000/cm^3$)[a]	1.11 (1.04-1.19)	.003
American Society of Anesthesiology class ≥ III[b]	1.52 (1.02-2.27)	.041
Resident physician participation	0.90 (0.75-1.08)	.256

Major adverse events defined as occurrence of stroke, myocardial infarction, cardiac arrest requiring cardiopulmonary resuscitation, or death within 30 days after procedure.
[a]Odds ratios for continuous covariates expressed per standard deviation change.
[b]American Society of Anesthesiology physical status classification.

disorder. Compared with patients undergoing CEA without resident participation, those with resident participation had a greater prevalence of white race (85.6% vs 83.1%), a higher rate of preoperative hemiplegia (6.1% vs 5.0%), and a lower frequency of ASA physical status classification III or higher (89.4% vs 91.4%).

Procedural characteristics. Procedure-related factors based on resident physician participation status are summarized in Table II. Rates of emergency procedure status, use of general anesthesia, and intraoperative transfusion were similar between groups. CEAs performed with resident participation had a longer mean operative time (127.6 ± 42.5 vs 100.2 ± 37.8 minutes) and longer mean anesthesia time (194.3 ± 53.5 vs 156.9 ± 50.5 minutes; $P < .001$ for both comparisons).

Table V. Adjusted multivariable model of minor perioperative adverse events following carotid endarterectomy

Variable	*Odds ratio (95% confidence interval)*	P
American Society of Anesthesiology class ≥ III[a]	2.10 (1.17-3.76)	.012
Resident physician participation	0.94 (0.73-1.21)	.636

Minor adverse events defined as occurrence of any of the following: peripheral nerve injury, bleeding requiring transfusion, surgical site infection, or wound disruption.
[a]American Society of Anesthesiology physical status classification.

Perioperative outcomes. At least one major perioperative adverse event occurred within 30 days following CEA in 507 patients (2.0%). Stroke was the most common major adverse event overall (n = 391; 1.6%), followed by death (n = 156; 0.6%), myocardial infarction (n = 135; 0.5%), and cardiac arrest requiring CPR (n = 64; 0.3%). Rates of perioperative adverse events categorized by resident participation status are shown in Table III. Major adverse event rates were 1.9% among patients undergoing CEA with resident physician participation versus 2.1% of patients without resident physician participation. In adjusted multivariable modeling, resident surgeon participation during CEA was not associated with 30-day risk of major adverse events (odds ratio [OR], 0.90; 95% confidence interval [CI], 0.75-1.08; $P = .256$; Table IV). Factors that were associated with increased risk for major adverse events in multivariable models included age >80 years, history of stroke, history of TIA, preoperative serum creatinine, preoperative WBC count, and ASA class ≥III.

At least one minor adverse event occurred within 30 days following CEA in 246 patients (1.0%). Surgical site infection was the most common minor adverse event observed (n = 144; 0.6%), followed by peripheral nerve injury (n = 59; 0.2%), bleeding requiring transfusion (n = 29; 0.1%), and wound disruption (n = 18; <0.1%). Minor adverse event rates were 0.9% among patients undergoing CEA with resident physician participation versus 1.0% without resident physician participation (Table III). In adjusted multivariate modeling, we did not observe a significant association between resident participation and 30-day risk of minor complications (OR, 0.94; 95% CI, 0.73-1.21; $P = .636$). ASA class ≥III was the only variable with a significant association with risk of minor adverse events in multivariate modeling (Table V).

Subgroup comparisons based on resident training level. Among CEAs with resident participation, resident level was categorized as junior (PGY 1-2) in 21.9%, senior (PGY 3-5) in 52.7%, and fellow (PGY ≥6) in 25.3%. Among CEAs with resident physician participation, mean operative times stratified by resident level were 124.7 ± 40.7 minutes for junior, 126.9 ± 41.7 minutes for senior, and 131.7 ± 45.2 minutes for fellow ($P < .001$); anesthesia times were 187.9 ± 53.4 minutes for junior, 193.2 ± 51.8 minutes for senior, and 202.2 ± 55.9 minutes for fellow level residents ($P < .001$). Major perioperative event rates were 2.3% for junior, 1.7% for senior, and 1.9% for fellow level residents ($P = .120$). Minor perioperative adverse event rates were 1.0% for junior, 1.0% for senior, and 0.9% for fellow level residents ($P = .850$).

DISCUSSION

In our analysis of 25,280 procedures from the ACS-NSQIP Participant Use Datafile, we evaluated associations between resident participation during CEA, procedural factors, and perioperative adverse events. Thirty-day major and minor adverse event rates (2% and 1%, respectively) were generally comparable with published results from contemporary observational cohort studies and clinical trials,[10,23,25,26] and similar between CEAs with and without resident surgeon participation. Resident surgeon participation was not associated with increased risk for perioperative major or minor adverse events in adjusted multivariable models controlling for other known risk factors.

Prospective trials evaluating procedural interventions for carotid stenosis have commonly utilized an aggregate of stroke, death, or myocardial infarction as a primary end point[25,27]; we selected a similar combination of outcomes to define major adverse events for this analysis in order to facilitate comparisons with results of previously published studies reporting adverse event rates associated with CEA. Outcomes defining minor adverse events in our CEA-specific analysis (peripheral nerve injury, surgical site infection, wound separation, and bleeding requiring transfusion) were selected as end points due to plausible associations with operative management. A more inclusive approach to defining morbidity was undertaken by Raval et al in their evaluation of the influence on resident involvement on surgical outcomes[5]; they utilized a composite of all available ACS-NSQIP postoperative complication outcomes as the primary end point in their analysis of resident surgeon involvement in among a mix of General Surgery and Vascular Surgery procedures. In their study, resident intraoperative involvement was associated with a small but significant increase in risk of perioperative morbidity but also decreased risk of perioperative mortality, and the authors concluded that resident participation in patient care is safe and possibly associated with lower mortality risk. Although the observations from our relatively focused analysis of a single procedure lead to a generally similar conclusion, we chose to exclude systemic complications (such as renal failure or renal insufficiency, deep vein thrombosis, and postoperative pneumonia) from our composite minor complication end point due to the relatively infrequent occurrence of these adverse events following CEA.

We identified associations between resident physician participation during CEA and longer procedure and anesthesia durations. Among CEAs with resident involvement, mean operative and anesthesia times were longer with increasing resident levels, suggesting that greater degrees of trainee participation may occur when higher-level residents are scrubbed. Associations between resident physician participation and longer operative times have been reported by

others.[5] In their analysis of inguinal hernia repairs, Wilkiemeyer et al observed longer mean operative times when lower-level residents were scrubbed,[28] but did not observe any association between resident level and complication rates. Although resident participation may increase procedural duration due to slower technical performance by resident versus attending physicians, it is likely that additional factors also may have contributed to the observed differences in procedure and anesthetic durations. In their comparison of surgical outcomes between teaching and nonteaching Veterans Affairs hospitals, Khuri et al reported a greater frequency of technically complex procedures at teaching versus nonteaching hospitals.[29] Unfortunately, reoperative CEAs cannot be identified within ACS-NSQIP, and CPT code-based approaches also provide limited insight into anatomic factors or procedural complexity associated with CEA. Technical factors such as use of carotid shunts or performance of patch angioplasty also cannot be discerned using CPT codes, but would likely contribute to differences in outcomes if utilized with greater frequency when residents are present. Furthermore, it is likely that CEAs performed with resident physician participation also involved a greater frequency of care delivery by nonsurgeon trainees (including anesthesiologists, nurses, and/or surgical technicians); impact of nonphysician trainees cannot be accounted for within ACS-NSQIP and therefore may have exaggerated effects attributed to resident physicians in this analysis.

Several additional limitations of our analysis warrant specific discussion. First, without more detailed information regarding the specific procedural components performed by resident physicians, we are unable to speculate on interventions that might lead to improved operating room efficiency when residents are present. Second, because hospital-level data are not included within the ACS-NSQIP Participant Use Datafile, we must acknowledge that our observations may have been affected by institution- or region-specific factors that we could not account for. Third, although we were able to identify history of stroke and TIA among patients undergoing CEA, lack of details related to acuity of presentation and relative laterality of CEA and symptoms made reliable identification of symptomatic carotid stenosis impossible. Fourth, because outcomes occurring >30 days post-CEA are not captured within ACS-NSQIP, we are unable to determine whether resident physician participation is associated with later outcomes such as restenosis. Finally, we would like to emphasize that our multivariable models were created with the goal of adjusting risk associated with resident physician participation for other factors previously demonstrated to affect adverse event rates following CEA; as such, they should be considered adjusted models for use in evaluating resident participation effects rather than tools for patient selection or risk prediction. Despite these limitations, our findings suggest that resident physician participation during CEA does not adversely affect patient safety and that prolongation of procedure and anesthetic times associated with resident physician participation are not accompanied by increased risk for adverse events.

AUTHOR CONTRIBUTIONS

Conception and design: JGR, DM, MC
Analysis and interpretation: JGR, MC
Data collection: Not applicable
Writing the article: JGR, MC
Critical revision of the article: JGR, KK, RV, JJR, AS, TD, DM, MC
Final approval of the article: JGR, KK, RV, JJR, AS, TD, DM, MC
Statistical analysis: MC
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