CME

Surgeon characteristics associated with mortality and morbidity following carotid endarterectomy

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Article abstract—*Purpose:* To identify surgeon characteristics associated with mortality or morbidity, following carotid endarterectomy (CEA). *Methods:* Data on all inpatient discharges from the 284 nonfederal Pennsylvania hospitals were obtained from the Pennsylvania Health Care Cost Containment Council for the period from 1994 to 1995. Physician data were obtained from the Physicians List of the American Medical Association, including name, gender, specialty, year of birth, board certified, and year of licensure. Cases were selected if any of six procedures codes were ICD-9-CM rubric 38.12, indicating CEA. *Results:* Among the 12,725 cases studied, in-hospital mortality was 0.7%, nonfatal morbidity was 3.0%, and the total bad outcome rate was 3.7%. Surgeons who performed 1 to 2 CEAs over 2 years had the highest mortality (2.0%) and total bad outcome (9.2%) rates. For surgeons performing three or more cases in 2 years, increased volume was not associated with better outcomes. A greater number of years since the surgeon was licensed was associated with greater mortality ($p = 0.001$), but not with morbidity or bad outcome rates. In regression analyses that adjusted for patient risk, both years since licensure and specialty predicted surgical mortality rate, but only volume predicted surgical bad outcome rate. *Conclusions:* More years since licensure and very low patient volume are associated with worse patient outcomes following CEA.

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Since 1991, the number of carotid endarterectomies (CEA) performed annually in the United States has increased dramatically. This increase followed the publication of two major clinical trials demonstrating marked benefit in symptomatic patients with severe stenosis[1]: the North American Symptomatic Carotid Endarterectomy Trial (NASCET)[2,3] and the European Carotid Artery Surgery Trial (ECST).[4] Both trials reported that CEA is highly beneficial for patients with recent transient ischemic attacks or nondisabling strokes and high-grade stenosis in the symptomatic carotid artery. In 1995, the Asymptomatic Carotid Atherosclerosis Study (ACAS) reported a significant but small absolute benefit of CEA in patients with asymptomatic carotid stenosis (greater than 60% reduction in lumen diameter)[5-7]: the ACAS trial has been controversial, however, in part because of concern that the small observed benefit may not be generalizable to community medical practice due to the very careful and strict selection of patients and surgeons for the trial.[1] In the absence of excellent surgeons, the benefit of CEA for asymptomatic carotid stenosis may disappear.

Appropriate performance standards, privileging procedures, and adverse event monitoring and review are required to ensure that surgical skills are adequate for individual surgeons.[1] In 1989, an Ad Hoc Committee on Carotid Surgery Standards of the Stroke Council of the American Heart Association made an initial attempt at defining upper limits for morbidity and mortality associated with carotid endarterectomy[8]: the 30-day mortality rate from all causes for all carotid endarterectomies should not exceed 2%, and the combined morbidity and mortality due to stroke during or after carotid endarterectomy should be less than 3% for patients with asymptomatic carotid stenosis, less than 5% for patient with transient ischemic attacks, less than 7% for patients with ischemic stroke, and less than 10% for patients with recurrent carotid disease in the same artery after CEA. These recommendations were echoed by the American Academy of Neurology in 1990,[9] the Joint Council of the Society for Vascular Surgery and the North American Chapter of the International Society for Cardiovascular Surgery in 1992,[10] and the American Heart Association consen-

See also pages 746 and 769

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sus congress in 1995.[11] A 1998 update by the American Heart Association appeared to recommend a lower maximally acceptable complication rate than recommended in the 1989 report.[12] The American Heart Association has also recommended development of methods for auditing individual surgeon's practice of CEA, limitation of surgical privileges to those who can document that their results fall within an acceptable range, and establishment of performance standards to define acceptable surgical volume as well as upper limits of morbidity/mortality.[11] Methods for ensuring and improving quality control[8,13-15] have been advocated for widespread use among surgeons performing CEA.[1] Factors that should be considered in such methodology include documented surgical performance (as demonstrated by regular unbiased audit of surgical outcomes), adequacy of surgical training, continuing medical education in surgical techniques, and acceptable surgical volume. However, despite a number of official recommended limits for surgical complication rates,[8,12] and despite attempts at applying available volume-outcome data for CEA,[16] to date there is insufficient information to determine acceptable surgical volume thresholds for surgeon privileging.

Methods. Patient data were obtained from the Pennsylvania Health Care Cost Containment Council (PHC4), an independent state agency responsible for collecting and reporting information on the cost and quality of Pennsylvania hospitals. The information presented here was derived from a data base of all inpatient discharges from 284 hospitals during 1994 to 1995 and included all Pennsylvania hospitals except federal facilities, such as the Department of Veterans Affairs hospitals. In addition to patient severity and morbidity, the PHC4 data contains information on more than 40 variables, including patient demographic characteristics, total charges, diagnoses and procedures, admission and discharge status, length of stay, name of admitting physician, name of surgeon, and expected source of payment.

PHC4 data differs from other commonly used administrative databases in that it includes information from Medisgroups. The Medisgroups information used in the present study was the admission severity score and morbidity following surgery.[17,18] During the period under study, all nonfederal hospitals in Pennsylvania were required by state law to collect and report severity data on each inpatient admission using the Medisgroups risk-adjustment procedure. The admission severity score is determined by age, sex, and at least 133 key clinical findings that were based on laboratory, radiology, and pathology exams, diagnostic procedures, patient history, and physical exam. Key clinical findings are abstracted from the medical record by hospital personnel who are required to achieve an interrater reliability standard of 95%. In Medisgroups' experience working with clinicians in client hospitals, data quality problems have been minimal.[17] The Medisgroups score is based on the patient's condition at admission, before to any surgical procedure and before a major diagnostic category has been established. The severity classification is made within 48 hours of admission. These scores range from zero to four and indicate the probability of mortality risk as follows: 0, (probability 0.000 to 0.001); 1, (probability 0.002 to 0.011); 2, (probability 0.012 to 0.057); 3, (probability 0.058 to 0.499); 4, probability 0.500 to 1.000).[19]

The Medisgroups morbidity score is determined by a second review of the patient's condition on day 7 of hospitalization, based on key clinical findings from day 3 through day 6. Patients are classified as morbid if their estimated risk of mortality is 1.2% or higher. This is equivalent to an admission severity score of greater than one. Patients discharged before day seven are classified as *nonmorbid*.[18]

Physician data were obtained from the Physicians List of the American Medical Association, the most comprehensive source of information on United States physicians available. This data base contains information on the primary, secondary, and tertiary specialty of each physician, as well as date of birth, gender, board certification, and year of licensure. Physician data and patient data were matched using physician name as the unique identifier. Of the 532 surgeons in the data base, there were 99 surgeons whose names could not be found on the Physicians List or who were on the list but who were missing information on age or year of licensure. Surgeons were classified in a subspecialty if they listed any of the following as one of their three specialties: vascular, neuro, cardiovascular, or thoracic. Surgeons were classified as general surgeons if they listed this as their primary specialty, and they did not list any of the four subspecialties above as their secondary or tertiary specialty.

Cases were selected when one of the six potential procedure codes was rubric 38.12, carotid endarterectomy, according to the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM). There were 14,439 CEA procedures performed at 153 hospitals.

Several criteria were used to exclude patients that were determined beforehand based on the need to control for potential confounding factors. These include the following:

1) We excluded 904 patients from the analysis who had ICD-9-CM codes indicating other cardiac and peripheral vascular procedures that might have increased the likelihood of a bad outcome not due to a CEA. Codes uses to exclude patients, (ICD-9 rubrics are in parentheses), were operations on valves or vessels of the heart (35.00 to 36.99); incision of the vessel/embolectomy (38.04, 38.08); endarterectomy (selected procedures) (38.14 to 16, 18); resection of vessel with anastomosis (selected procedures) (38.34 to 36, 38); resection of vessel with replacement (selected procedures) (38.44 to 46, 48); systemic to pulmonary artery shunt (39.0); intraabdominal venous shunt (39.1); other shunt or vascular bypass (selected procedures) (39.21 to 26, 29); other repair of vessels (selected procedures) (39.50 to 55); and extracorporeal circulation and procedures auxiliary to open heart surgery (39.60 to 39.69).

2) Two percent of cases were excluded because neither the physician listed as the surgeon of record nor the admitting physician had listed any specialties indicating an ability to perform CEA surgery (i.e., they were not surgeons). These physicians were from many different nonsurgical specialties including internal medicine, family practice, vascular and internal radiology, anesthesiology, and neuroradiology.

3) Patients with a Medisgroups severity score of three or four (2.2% of all patients) were excluded, as these patients had a greater presurgical risk of in-hospital mortality (i.e., greater than approximately 6%).

4) Patients were excluded from one hospital that did not report any occurrences of morbidity for more than 5,000 general inpatients during the period under study. Because this hospital was not recording morbidity information, the 259 cases from this hospital were excluded.

We did not exclude cases if CEA was listed as a secondary rather than a primary procedure except as noted above. There were 117 patients with CEA as a secondary procedure after the exclusions above. These patients had a very high mortality, (9 deaths), and morbidity, (an additional 14 cases). Among the deaths, the primary procedures listed were tracheostomy (4), insertion of transvenous leads (2), excisional debridement of wound (1), implantation of a pulsation balloon (1), and ventriculostomy (1). We decided not to exclude these patients because the procedures listed as "primary" were probably performed to address complications of CEA. Financial considerations may also influence the order of coding. For example, as tracheostomy is reimbursed at a higher rate than CEA, hospitals have an incentive to code tracheostomy as the primary procedure for patients with severe complications of CEA.[20] The final sample consisted of 12,725 cases.

Statistical analysis. The statistical analyses evaluated whether characteristics of the surgeon were associated with patient outcome, either in-hospital mortality or in-hospital bad outcome (mortality or morbidity). For these analyses categories were created for each of the following surgical characteristics: age, gender, specialty, years of experience, board certified, and surgical volume over 2 years. For ordinal variables, the Wilcoxon rank sum test was used to evaluate whether patient outcome varied by category. For categorical variables, such as gender and specialty, the chi-squared test of contingency was used.

Because patient risk may vary among surgeons, we also tested the associations between the surgeons' characteristics and patient outcome after adjusting for patient risk in a weighted linear regression analysis. The outcome variable in the regression analysis was either mortality or bad outcome rate. The independent variables were the characteristics of the surgeons. Dummy variables were used to indicate appropriate surgical specialties, and to indicate whether the surgeon had performed one or two cases during the 2-year period under study. Also included in the regression equation was a patient risk variable, predicted mortality rate or bad outcome rate as appropriate (see below). Each point in the regression analysis was weighted by the number of patients treated by the surgeon.

Patient risk was determined using two logistic regression models; one model to determine patient risk for mortality and the other to determine patient risk for bad outcome. Candidate variables for the logistic regression models included age, sex, payer, Medisgroups severity score, and source of admission. Except for age, all patient variables were treated as categorical. Due to missing data among covariates, particularly source of admission, these models were each based on 12,466 cases, which represented 98% of the final sample. Variables were selected for the final logistic regression model using the SPSS stepwise procedure (SPSS for Windows, version 10.0; SPSS Inc., Chicago, IL), and using 0.05 for the significance level to enter and remain in the model. Once the parameters were estimated, logistic regression models were developed to estimate the probabilities of mortality and bad outcome for each patient following the surgery. We then summed these probabilities for all patients of each surgeon and divided by the number of patients to estimate the expected mortality and bad outcome rates for the surgeon. These expected rates of mortality and bad outcomes were the patient risk variables included in the weighted regression analyses based on surgeon characteristics. A secondary analysis was performed to test whether surgeons with different experience levels treat higher risk patients, as determined by recorded risk factors.

Statistical significance for all univariate and multivariate analyses was determined at the 0.05 level. All analyses were done using SPSS statistical software.

Results. There were 89 deaths among the 12,725 CEA procedures performed, representing an in-hospital case fatality rate of 0.7%. There were an additional 387 cases of nonfatal morbidity (3.0%), for a total of 476 bad outcomes (3.7%).

The univariate analyses of patient characteristics with outcomes is shown in table 1. Three factors predicted mortality: source of admission ($p < 0.001$), primary procedure ($p < 0.001$), and patient age ($p = 0.038$). Mortality rates were higher for transfer patients (3.3%) and emergency admissions (1.4%) than for routine admissions (0.5%). Mortality was 0.6% when CEA was listed as the primary procedure and 7.7% when it was listed as a secondary procedure. Four factors predicted bad outcome rate: patient age ($p < 0.001$), source of admission ($p < 0.001$), primary procedure ($p < 0.001$), and payer ($p < 0.001$). Bad outcome rates were higher for transfer patients (10.1%) and emergency admissions (11.3%) than for routine admissions (2.7%).

Two separate multivariate logistic regression models based on 12,466 cases were used to predict in-hospital mortality and bad outcome based on patient characteristics. Only source of admission ($p < 0.001$) and patient age ($p = 0.028$) were significant predictors of mortality, as shown in table 2. No other factors were found to be significantly predictive of mortality, including sex and payer. Similarly, patient age ($p < 0.001$) and source of admission ($p < 0.001$) were found to be predictive of bad outcomes. Medisgroups severity score was not a significant predictor of either mortality or bad outcome, although by study design the range of severity scores was limited to (presurgical) predicted in-hospital mortality of less than 6%.

The relationship between surgical volume and outcome is shown in figure 1 and table 3. Surgeons in the lowest volume category (one or two CEAs in 2 years) had both the highest mortality (1.96%) and bad outcome (9.16%) rates. The association between surgical volume and outcome was significant for bad outcome ($p = 0.034$), but not for mortality alone. When the lowest volume category (one or two CEAs in 2 years) was excluded, the association between bad outcome rate and surgical volume was no longer significant ($p = 0.10$).

As shown in figure 2 and table 3, mortality increased with years since licensure of the surgeon ($p = 0.0008$). The association between years since licensure and overall bad

Table 1 The association of patient characteristics with outcomes

Characteristic	Number of patients	Number of deaths	Mortality rate	Number of bad outcomes	Bad outcome rate
Age, y					
<65	2,817	16	0.57%*	61	2.17%†
65–74	5,675	35	0.62%	190	3.35%
75+	4,098	38	0.93%	225	5.49%
Sex					
Male	7,375	60	0.81%	283	3.84%
Female	5,296	29	0.55%	193	3.64%
Source of admission					
Routine	10,864	59	0.54%†	293	2.70%†
Transfer	367	12	3.27%	37	10.08%
Emergency	1,284	18	1.40%	145	11.29%
CEA procedure					
Primary	12,608	80	0.63%†	453	3.59%†
Secondary	117	9	7.69%	23	19.66%
Payer					
Commercial	2,663	14	0.53%	69	2.59%†
Government	9,297	67	0.72%	383	4.12%
Other	765	8	1.05%	24	3.14%
Severity (Medis-Groups)					
0	254	3	1.18%	5	1.97%
1	385	5	1.30%	12	3.12%
2	11,774	75	0.64%	453	3.85%

* $p = 0.038$.
† $p < 0.001$ for the statistical significance of the difference among the rates for the categories of the characteristic. All other p values are >0.10.

outcome rate was not significant because surgeons with fewer years since licensure had higher morbidity rates. There was no significant association between years since licensure and predicted mortality rates. Thus, there was no indication that patient severity was significantly different for surgeons with more years of experience. Mortality increased with increased surgeon age ($p = 0.04$) but the association between surgeon age and overall bad outcome rate was not significant (table 3).

Outcome rates by specialty of the surgeon are shown in table 3. Fifty-nine neurosurgeons performed a total of 1,080 procedures with only one in-hospital death. Based on the chi-squared statistic, neurosurgeons had lower mortality rates than nonneurosurgeons (0.1% versus 0.8 %, $p = 0.012$). Preprocedure risk as measured by predicted mortality did not vary significantly across surgical specialty. Observed mortality rates and bad outcome rates did not significantly differ according to surgeon gender or board certification status.

A weighted linear regression model, weighted by the number of patients treated, showed that the surgeon variables that were predictive of observed mortality rates were predicted mortality ($p = 0.018$), years since licensure ($p < 0.01$), and neurosurgeon ($p < 0.01$), as shown in table 4.

Table 2 Logistic regression equations for predicting outcomes based on patient characteristics

	Mortality				Bad outcomes		
Patient characteristics	Regression coefficient	Standard error	Relative odds	Patient characteristics	Regression coefficient	Standard error	Relative odds
Constant	−7.292	0.970		Constant	−6.812	0.449	
Age (divided by 10)	0.293	0.133	1.34*	Age (divided by 10)	0.452	0.061	1.57†
Transfer	1.802	0.322	6.06†	Transfer	1.370	0.184	3.94†
Emergency	0.923	0.272	2.52†	Emergency	1.477	0.107	4.38†

* $p = 0.028$.
† $p < 0.001$.

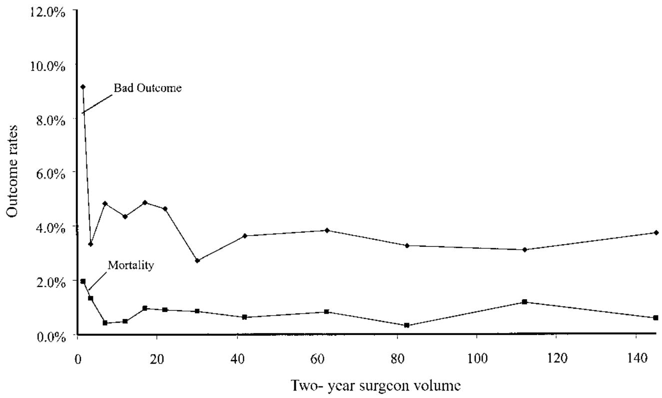

Figure 1. Relationship between outcome rates and 2-year surgeon volume.

After adjustment for years since licensure, predicted mortality, and surgical specialty, no other variables were found to be significantly predictive of observed mortality rates, including surgeon age, surgical volume, gender, and board certified.

In a similar weighted regression model for bad outcomes, the surgeon characteristics that were predictive of observed bad outcome rates were predicted bad outcome rate ($p < 0.001$) and "lowest volume category" (one or two CEAs in 2 years) ($p < 0.01$). When the lowest volume category was excluded, surgical volume was a marginally significant predictor of observed bad outcome rates ($p = 0.14$). After adjusting for the aforementioned variables, no other variables were found to be significantly predictive of observed bad outcome rates, including surgical specialty, surgeon age, years since licensure, gender, and board certified.

In order to test the sensitivity of these results to patient selection, we repeated the analysis after excluding those 117 patients for whom CEA was not listed as the primary procedure. The association between mortality and years since licensure did not change ($p = 0.002$). The association between neurosurgeon and lower mortality did not change ($p = 0.006$). Surgeons in the lowest volume category still had both the highest mortality (0.8%) and bad outcome (4.5%) rates, although neither result was significant overall. Thus the association between volume and outcome changed from significant to nonsignificant for bad outcomes when these patients were excluded.

Discussion. In this population-based study, we analyzed data for 12,725 CEAs performed in a recent 2-year period at nonfederal facilities in Pennsylvania to identify characteristics of surgeons associated with patient outcomes. The data incorporate prospectively-determined Medisgroups preprocedure severity scores, that allowed better risk adjustment than was possible with administrative data utilized in previous volume-outcome studies. Moreover, linkage of hospital discharge data with physician data from the AMA allowed assessment of the role of surgeon characteristics as predictors of outcome following CEA. We found that the characteristics of surgeons that predicted greater mortality were a surgical volume of only one or two cases over 2 years, 20 or more years since licensure, and specialty other than neurosurgery.

As in previous studies of CEA utilizing administrative data, we did not have complete clinical information available on surgical indications, degree of carotid stenosis, and specific comorbidities and complications. It is possible that differences in such factors across surgeons could have contributed to unadjusted confounding between surgeon characteristics and patient risk. To minimize potential confounding of surgeon characteristics and patient risk, we excluded cases with other major procedures that could themselves increase risk of adverse outcome (unless the procedure probably addressed a complication of the original CEA). In addition, we excluded cases with presurgical mortality risk of approximately 6% or greater, and then adjusted for presurgical risk among the remaining patients using proprietary Medisgroups severity index, which was not available in previous studies of CEA. Therefore, our results apply to this restricted subgroup of CEA procedures. Because of such exclusions, the mortality rate of 0.7% for patients in this study is lower than those reported in most previous population-based and multicenter studies, which have been as high as 2.8%[21-38] (DJL and RJ Kryscio, unpublished analyses of data from the National Hospital Discharge Survey, 1979 to 1993; DC Hsai, personal communication to DJL concerning results for Medicare patients, 1998). The mortality rate in the present study is similar, however, to recent results from academic medical centers[39] and to the average mortality rates reported in clinical trials of symptomatic[3,4,40] and asymptomatic[5,14,41-43] carotid stenosis utilizing very carefully selected patients and surgeons.

All those patients who were discharged alive before day 7 (79% of the sample), were classified as nonmorbid. Therefore, our outcome measure was not all complications, but only complications that prolonged hospital stay beyond 7 days. Minor self-limited complications were not completely ascertained.

Previous studies evaluating potential surgical volume-outcome relationships for CEA vary considerably in study design, statistical methods, data presentation, completeness of data reporting, and results.[22,23,44-53] Some of these studies had relatively small numbers of CEAs or surgeons to analyze,[22,23,46,47,50] and most of these studies did not adjust for confounding factors. Indeed, most of the previous studies that reported a surgeon volume-outcome relationship for CEA included CEAs combined with other procedures that could themselves increase risk,[22,46,47,53] while others had only limited exclusions based on other procedures of the carotid artery.[48] Therefore, some of the apparent risk in the lowest volume category in these studies may have been caused by surgeons likely to perform a high risk procedure in conjunction with a CEA. Alternatively, it is possible that some surgeons who performed one or two CEAs and had a higher percentage of bad

Table 3 The association of surgeon characteristics with outcomes

Characteristic	Surgeons	Number of procedures	Number of deaths	Mortality rate	Number of bad outcomes	Bad outcome rate
Gender						
Male	489	12,165	85	0.70%	458	3.76%
Female	18	302	1	0.33%	10	3.31%
Total	507	12,467	86	0.69%	468	3.75%
Age, y						
30 to 39	92	1,638	10	0.61%*	73	4.46%
40 to 49	203	5,800	34	0.59%	205	3.53%
50 to 59	101	2,931	20	0.68%	105	3.58%
60 to 64	28	818	10	1.22%	36	4.40%
65 or higher	16	237	6	2.53%	13	5.49%
Total	440	11,424				
Years since licensure						
1 to 5	39	824	1	0.12%§	37	4.49%
6 to 10	66	1,400	8	0.57%	66	4.71%
11 to 15	97	2,434	16	0.66%	71	2.92%
16 to 20	76	2,125	6	0.28%	76	3.58%
21 to 25	82	2,374	24	1.01%	91	3.83%
26 to 30	37	1,416	12	0.85%	51	3.60%
31 or more	36	862	13	1.51%	38	4.41%
Total	433	11,435				
Board certification confirmed						
Yes	409	10,647	78	0.73%	394	3.70%
No	123	2,078	11	0.53%	82	3.95%
Total	532	12,725				
Type of surgeon						
Cardiovascular	78	2,319	21	0.91%	93	4.01%
General	116	1,780	17	0.96%	85	4.78%
Neurosurgeon	59	1,080	1	0.09%	41	3.80%
Thoracic	59	1,139	10	0.88%	41	3.60%
Vascular	141	5,247	32	0.61%	175	3.34%
Other	79	1,160	8	0.69%	41	3.53%
Total	532	12,725	89		476	
Surgical volume (2-year)						
1 to 2	117	153	3	1.96%	14	9.16%‡
3 to 24	246	2,324	17	0.73%	106	4.56%
25 to 49	66	2,147	15	0.70%	71	3.31%
50 to 99	84	5,475	34	0.62%	196	3.58%
100 or more	19	2,573	20	0.78%	89	3.46%
Total	532	12,672				

* $p = 0.029$.
† $p < 0.001$.
‡ $p = 0.034$.

Significance was determined based on a global test of homogeneity for all categories.

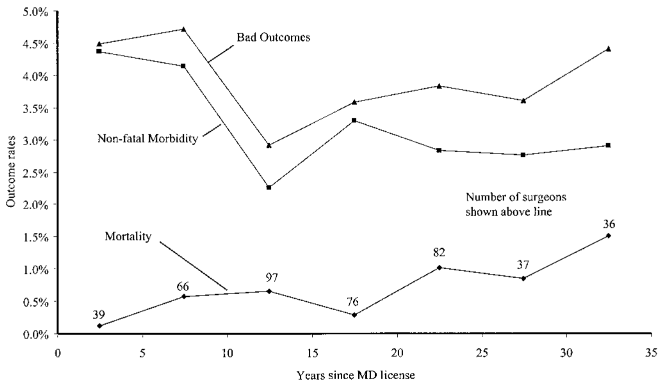

Figure 2. Relationship between outcome rates and surgeon experience.

outcomes simply stopped performing the procedure. In addition, many of the studies reported results of procedures performed in the 1980s,[22,23,44-49] and such results may not be generalizable to recent surgical experience, because the rates of mortality and nonfatal strokes have declined considerably since then. Several studies reported an inverse relationship between surgical volume and outcome following CEA,[22,46-50,53] but none of these explicitly documented a clear volume-outcome relationship for surgical volumes over a minimum threshold. In addition, some studies did not find a significant relationship,[23,44,45,51] and in others a relationship was present only in certain subgroups, such as patients with asymptomatic disease,[47] or CEAs performed by general surgeons.[49] In our study, the volume-outcome relationship was very weak (and not significant) among surgeons who performed on average more than one procedure every year (see figure 1 and table 3). Even if there is a volume outcome relationship for CEA surgery, it appears to be weaker than for CABG surgery.[54,56]

Because of concern that low surgical volumes could be associated with worse outcomes, surgical volume has been considered a potential factor in surgeon privileging. The volume threshold used for selecting surgeons for the ACAS trial was at least 12 CEAs per year.[13,15,57] Although 73% of surgeons fall below this threshold in Pennsylvania, there is no evidence that the majority of these surgeons have different outcomes from high-volume surgeons. Our results do suggest that surgeons with one or fewer cases per year had mortality rates that were 2.9 times higher than other surgeons (1.96% versus 0.68%). If these differences are due to surgical skill, these surgeons should not be privileged to do CEA. However, only 1.2% of the cases are performed by these "very low volume" surgeons. Therefore, eliminating these cases from our data set would not have a large impact on state-level rates, as this would decrease the overall mortality rate by only 0.02% (i.e., from 0.70% to 0.68%).

Time in surgical practice was more important than surgical volume as a predictor of patient outcome. Morbidity was highest in those recently licensed, whereas mortality increased with years since licensure, particularly after 20 or more years of practice (figure 2). No previous studies of CEA have assessed time in practice as a morbidity or mortality risk, but older physicians and a longer time in practice were found to be associated with higher mortality rates for CABG surgeons.[58] On the other hand, a study of laparoscopic cholecystectomy found that complications decrease with increasing years of surgical experience.[59] Practice outcomes may decline over time, because physicians in practice the longest may be less likely to adopt new procedural improvements, contributing to greater relative mortality. Other factors may also play a role in the relatively higher mortality rates for older surgeons, such as greater utilization of resident staff and a greater proportion of more difficult cases.

Previous studies that have examined surgeon specialty as a potential predictor of outcomes compared the combined stroke and death rate across surgical specialties and found no significant differences.[23,46,49] Similarly in our study, overall bad outcomes (morbidity or mortality) did not differ across surgical specialty. However, we found that neurosurgeons had significantly lower mortality rates than other surgeons. Likewise, Brott and Thalinger reported lower mortality among neurosurgeons (without performing statistical tests of mortality by surgeon type) in a

Table 4 *Weighted linear regression equations for predicting percentages with a given outcome based on surgeon characteristics*

	Mortality			Bad Outcomes	
Characteristic	Regression coefficient	Standard error	Characteristic	Regression coefficient	Standard error
n = 433			n = 530		
Constant	−0.894	0.485	Constant	−0.131	0.788
Predicted mortality	1.463*	0.615	Predicted bad outcome	1.019§	0.200
Neurosurgeon	−0.879‡	0.337	Lowest volume category (1 or 2)	4.758†	1.904
Years since licensure (divided by 10)	0.348‡	0.118			

* $p = 0.018$.
† $p = 0.013$.
‡ $p < 0.01$.
§ $p < 0.001$.

population-based clinical review in Cincinnati for 1980,[23] but a follow-up study in the same community for 1983 to 1984 found much higher mortality rates for neurosurgeons than reported for 1980 (2.6% versus 0.9%) and overall no significant difference in mortality across surgeon specialty.[46] Whether random variation with small sample sizes, unrecognized differences in patient selection, or differences in surgical technique are responsible for these differences by surgical specialty is not clear. Although it is possible that the lower mortality rate for neurosurgeons in our study could be due to patient selection, our results were adjusted for patient risk. In addition, previous studies suggest that patient risk is at least as high for neurosurgeons as for other surgeons who perform CEA,[23,46] because neurosurgeons had comparable or fewer patients who were asymptomatic[23,46] and more patients with focal deficits before surgery.[23] Based on these studies, it is unlikely that patient differences explain all of the difference in mortality experience by surgeon specialty.

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