Surgeon Case Volume and 30-Day Mortality After Carotid Endarterectomy Among Contemporary Medicare Beneficiaries Before and After National Coverage Determination for Carotid Artery Stenting

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Background and Purpose—After the 2005 National Coverage Determination to reimburse carotid artery stenting (CAS) for Medicare beneficiaries, the number of CAS procedures increased and carotid endarterectomy (CEA) decreased. We evaluated trends in surgeons’ past-year CEA case-volume and 30-day mortality after CEA, and their association before and after the National Coverage Determination.

Methods—In a retrospective cohort study of patients undergoing CEA (2001–2008) and CAS (2005–2008) using Medicare data, we described yearly trends of CEA and CAS rates, patient characteristics, and 30-day mortality after CEA. We used logistic regression adjusting for patient- and surgeon-level factors to assess the effect of surgeon case volume on 30-day mortality after CEA.

Results—We identified 454717 CEA and 27943 CAS patients. Patients undergoing CEA in recent years were older and had more comorbidities than earlier years. CEA rates per 10,000 beneficiaries declined from 18.1 in 2002 to 12.7 in 2008, whereas median surgeon past-year case-volume declined from 27 to 21. The CAS rates peaked at 2.3 per 10,000 beneficiaries in 2006 but declined to 1.8 in 2008, resulting in declining overall revascularization procedure rates during 2005 to 2008. Thirty day post-CEA mortality was 1.40% (95% confidence interval, 1.34–1.47) in 2001 to 2002 and 1.17% (1.10–1.24) in 2007 to 2008. Surgeon’s past-year case-volume of <10 was associated with higher 30-day mortality consistently during 2001 to 2008.

Conclusions—The rate of CEA procedures decreased substantially during 2001 to 2008, as did surgeon past-year case-volume. The postprocedural mortality in Medicare beneficiaries was high compared with trial patients but somewhat improved over time. Those operated by lower past-year case-volume surgeons had increased mortality.

Key Words: carotid endarterectomy ■ carotid stenosis ■ Medicare ■ outcomes research

Carotid artery stenosis is a major risk factor for ischemic stroke, and randomized trials conducted in the 1980s to 1990s demonstrated that carotid endarterectomy (CEA) reduced the overall stroke risk for symptomatic and asymptomatic patients with severe carotid stenosis. The relationship between surgeon case-volume and postprocedural outcomes has been examined extensively for CEA, and many have reported that low surgeon case-volume is associated with worse periprocedural outcomes. This is particularly concerning when considering that surgeons participating in trials had shown proficiency in the procedure (eg, average yearly case-volume of 20 for those participated in Asymptomatic Carotid Atherosclerosis Study), and that with improvement in the medical therapy over time, the relative benefit of CEA over medical treatment alone shown in the trials is not guaranteed in current routine clinical practice.

With the 2005 National Coverage Determination (NCD), the Center for Medicare and Medicaid Services began...
reimbursements for carotid artery stenting (CAS) as an alternative revascularization procedure for Medicare beneficiaries at high-surgical risk meeting the following criteria: (1) ≥70% symptomatic carotid stenosis, (2) 50% to 70% symptomatic carotid stenosis enrolled in an approved study, or (3) ≥20% symptomatic carotid stenosis and enrolled in an approved study.10 Over the following years, the number of CAS procedures performed among Medicare beneficiaries grew, whereas the rate of CEA procedures declined.11,12 We hypothesized that the reduction in the overall rate of CEA as in the Medicare beneficiaries may have caused case-volumes of the individual performing surgeons to decline, leading to worse periprocedural outcomes. The objective of this study is to examine the decline in past-year case-volumes of surgeons performing CEA before and after the NCD for CAS and to assess its effect on 30-day post-CEA mortality.

Methods

Data Sources

We used 2000 to 2008 Medicare claims data for all patients who underwent inpatient CEA (ICD-9-CM code: 38.12) or CAS (ICD-9-CM codes: 00.61, 00.63, 00.64). The data comprised administrative claims for fee-for-service beneficiaries accounting for >80% of the total Medicare population13 and provides information on inpatient and outpatient healthcare services covered under Medicare Parts A and B, as well as patient demographics, Medicare enrollment, and date of death.

Study Sample

The study sample consisted of patients undergoing inpatient CEA between 2001 and 2008 or inpatient CAS between 2005 and 2008. We required patients to be at least 66 years of age at the time of the procedure with 365 days of continuous Medicare fee-for-service enrollment. If they underwent multiple carotid revascularizations, we selected the first one. We used CPT-4 code 35301 for CEA and CPT-4 codes 37215 and 37216 (appearing after 2005) for CAS to identify the claims for the performing surgeons. We required these claims to have procedure dates during patients’ hospitalization period and excluded all those with modifier codes for procedure assistance. Patients with no identifiable performing surgeon were excluded (Figure I in the online-only Data Supplement).

Surgeon Case Volume and Subspecialty

We identified surgeons performing CEAs using Unique Physician Identifier Numbers or National Provider Identifiers. When multiple claims for a procedure were available (<0.3%), we randomly selected one of the surgeons. For each CEA procedure, the performing surgeon’s past-year case-volume was calculated as the number of CEAs performed during the prior 365 days. Subspecialty information was available from the claims.

Outcome

We assessed all-cause mortality in the 30 days after CEA. We collected data on patients’ date of death from Medicare vital status file.14

Patient Characteristics

Using inpatient and outpatient claims and validated algorithms whenever possible, the following comorbidities were identified in the year before the CEA/CAS hospitalization: atrial fibrillation, heart failure, myocardial infarction, diabetes mellitus, hypertension, gastrointestinal bleeding, chronic obstructive pulmonary disease, chronic kidney disease, cancer, depression, and anemia (algorithms in Table I in the online-only Data Supplement). We defined prior ischemic stroke as an ICD-9-CM code of 433.xx (occlusion and stenosis of preclinical arteries), 434.xx (occlusion of cerebral arteries), 436 (acute, but ill-defined, cerebrovascular disease), 437.x (other and ill-defined cerebrovascular disease), or 438.xx (late effects of cerebrovascular disease), and transient ischemic attack (TIA) as an ICD-9-CM code of 435 (transient cerebral ischemia) in the primary or secondary discharge diagnosis during the 180 days preceding the CEA/CAS hospitalization. These algorithms were selected as a result of their high sensitivity to capture strokes in administrative claims data.15 We also identified patients who underwent coronary artery bypass graft procedures during the hospitalization before or on the same day as CEA or CAS (ICD-9-CM codes 36.1x, 36.2, or V45.81 or CPT-4 codes 33510–33536). Patients were categorized as having undergone elective CEA unless hospital admission type was defined as urgent or emergent. As a measure of overall comorbidity burden, we calculated the Elixhauser comorbidity score, developed as a predictive score for in-hospital death, healthcare costs, and length of hospitalization using administrative data.16,17

Statistical Analysis

We assessed the rate of CEA and CAS procedures (number of procedures per 10000 Medicare beneficiaries) for each calendar year using the total number of enrollees as the denominator. The rates were standardized to the age, sex, and race distribution of beneficiaries in the most recent year (2008).

We then assessed the change in characteristics of patients undergoing CEA and performing surgeon specialty over time by aggregating patients into 4 two-year time blocks (2001–2002, 2003–2004, 2005–2006, and 2007–2008). We also assessed changes in characteristics of patients undergoing CAS in 2005 to 2006 and 2007 to 2008. We report proportions for categorical variables and means with standard deviations for continuous variables. To assess trends in changes of CEA patient characteristics over time, we used Cochran-Armitage test, and to assess differences in characteristics of patients undergoing CEA and CAS in 2005 to 2008, we used chi-squared test.

We evaluated changes in surgeon past-year case-volume distributions in the 4 time blocks and aggregated 2001 to 2002 and 2003 to 2004 blocks because the distributions were similar. Given that no clinically meaningful or established cut-offs for categorizing the surgeon CEA case-volumes have been reported, we first visually evaluated the relationship between 30-day mortality and continuous surgeon past-year case-volume by fitting a restricted logistic cubic spline regression model using the SAS macro by Spiegelman et al.,18 which allows modeling of smooth nonlinear relationships between a continuous exposure and an outcome while adjusting for other covariates.19

Using the visualization of the relationship between past-year case-volume and 30-day mortality, we categorized the past-year case-volume into 4 levels. We estimated the rate of 30-day post-CEA mortality overall and by case-volume category in the 4 time blocks. To assess the change in post-CEA 30-day mortality over time, we estimated the relative risk of 30-day mortality in the later time blocks relative to the 2001 to 2002 block, using logistic regression, adjusting for all patient- and surgeon-level measured covariates and surgeon case-volume category. We also estimated the relative risk of 30-day mortality for CEAs performed by surgeons in higher past-year case-volume categories compared with the lowest category in each time block.

All analyses were performed using SAS version 9.3 (SAS Institute, Cary, NC). The study was approved by Brigham and Women’s Hospital’s institutional review board.

Results

Trends in Rates of CEA and CAS and CEA Surgeon Case-Volume

We identified 454717 patients and 8648 performing surgeons for CEA during the period of 2001 to 2008 and 27943 patients
undergoing CAS during 2005 to 2008. The standardized rate of CEA procedures performed per 10,000 Medicare beneficiaries per year was 17.8 in 2001, peaked in 2002 at 18.1, and declined thereafter to the trough of 12.7 in 2008 (Figure 1). The yearly rate of CAS was 1.5 per 10,000 beneficiaries in 2005, peaked at 2.3 in 2006, a year after the NCD, and declined to 1.8 in 2008. During this time, the yearly number of distinct surgeons performing CEA procedures in our sample decreased from 6192 in 2001 to 5571 in 2008, and the median past-year volume decreased from its highest in 2002 at 27 (interquartile range, 14–47) to 21 (interquartile range, 11–35) in 2008. The distribution of surgeon past-year CEA case-volume was highly right-skewed, and the peaks moved leftwards over the 3 time periods (Figure 2). Over the study period, the proportion of CEA procedures performed by surgeons with past-year case-volume of 45 and above decreased, whereas more CEA procedures were increasingly being performed by surgeons with past-year case-volume <30. The decline in the median past-year case-volume over the years occurred across all subspecialties but was most drastic for vascular surgeons (Figure II in the online-only Data Supplement). Between 2005 and 2008, the number of CAS-performing physicians increased (1133 in 2005, 1614 in 2006, 1706 in 2007, and 1738 in 2008) and median past-year CAS case-volume was 10 in 2006, 9 in 2007, and 8 in 2008.

**Trends in CEA Patient Characteristics**

Over the study period, we observed that patients selected for CEA became older and tended to have a higher comorbidity burden over time, with increased proportions of patients with comorbidities including atrial fibrillation, chronic obstructive pulmonary disease, depression and chronic kidney disease, and higher mean Elixhauser comorbidity scores. On the other hand, the proportion of patients with prior stroke, TIA, myocardial infarction slightly decreased and concurrent coronary artery bypass graft and nonelective admissions became less prevalent (Table 1). Patients undergoing CAS between 2005 and 2008 were slightly older and much sicker than CEA patients over the same time period, as evidenced by higher mean Elixhauser scores and higher prevalence of all of the comorbidities.

![Figure 1. The standardized rates of carotid endarterectomy (CEA) and carotid artery stenting (CAS) procedures per 10,000 Medicare beneficiaries 2001 to 2008.](http://stroke.ahajournals.org/)

**Surgeon CEA Past-Year Case-Volume and 30-Day Mortality**

Figure 3 provides a visual inspection of the relationship between surgeon past-year case-volume and 30-day mortality in patients undergoing CEA. The curve shows the trend in the relative risk of 30-day mortality for the past-year case-volume of the performing surgeon ranging from 0 to 265 with the reference volume of 30. For instance, the 30-day mortality of patients undergoing CEA by surgeons with past-year case-volume of 0 is almost 1.5x higher than those undergoing CEA performed by surgeons with case-volume of 30. The relative risk of 30-day mortality was highest for surgeons with CEA case-volume of 0 (odds ratio, just below 1.5) and declined sharply as the case-volume increased to 10 (odds ratio, >1.2). The slope of the curve gradually leveled off between the case-volumes of 10 and 20 (odds ratio at 20, >1.1), but kept decreasing above the case-volume of 20, with wide confidence intervals in the higher range reflecting small number of procedures performed by surgeons with large case-volume. As such, we categorized past-year surgeon case-volume as 0 to 9, 10 to 19, 20 to 39 and ≥40.

We observed a total of 5758 deaths within 30 days of the CEA procedures (30-day mortality=1.27%; 95% confidence interval, 1.23–1.30). Over the study period, the unadjusted 30-day post-CEA mortality decreased from 1.40% in 2001 to 1.17% in 2007 to 2008 (Table 2). The observed 30-day mortality of CEA performed by surgeons with <10 past-year case-volume was consistently higher compared with those performed by higher case-volume surgeons (eg, 1.79% in <10 case-volume versus 1.19% in ≥40 case-volume category in 2001–2002, and 1.42% versus 1.04% in 2007–2008). The logistic regression analysis showed that the increased relative risk of 30-day mortality for low (<10) case-volume surgeons remained significantly higher compared with higher past-year case-volume surgeons, after controlling for patients’ demographics, comorbidities and admission type, presence of concurrent coronary artery bypass graft, and the subspecialty of the surgeons. This was true across all time blocks, although results were not all significant. The relative risk of 30-day post-CEA mortality comparing higher versus lowest past-year case-volume surgeons remained fairly constant across the time blocks, despite large reduction in the overall mortality risk (Table 3).
We observed a significant decrease in the rate of CEA procedures over time coupled with a decrease in the past-year case volumes of performing surgeons in our elderly Medicare fee-for-service beneficiaries from 2001 to 2008. The overall 30-day post-CEA mortality was 1.27% in our patients, which was higher than those reported in the recent randomized trials of CEA versus CAS; 0.9% in Stent-Supported Percutaneous Angioplasty of the Carotid Artery Versus Endarterectomy (SPACE) trial, 1.2% in Endarterectomy Versus Angioplasty in Patients With Symptomatic Severe Carotid Stenosis (EVA-3S), and 0.3% in Carotid Revascularization Endarterectomy vs Stenting Trial (CREST).20–22 The 30-day post-CEA mortality improved slightly overtime, but CEAs performed by lower past-year case-volume surgeons were associated with higher 30-day mortality after adjusting for patients’ demographics, comorbidities, hospital admission type, presence of concurrent coronary artery bypass graft and surgeon subspecialty, before and after the 2005 NCD to reimburse CAS.

Table 1. Baseline Characteristics of the Medicare Patients Undergoing CEA 2001 to 2008 and CAS 2005 to 2008

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<td>N</td>
<td>125077</td>
<td>122262</td>
<td>108755</td>
<td>98623</td>
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<td>13944</td>
<td>13999</td>
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<tr>
<td>Age Mean (SD)</td>
<td>75.7 (5.9)</td>
<td>75.8 (6.0)</td>
<td>75.9 (6.1)</td>
<td>76.0 (6.2)</td>
<td>&lt;0.001</td>
<td>76.4 (6.3)</td>
<td>76.3 (6.3)</td>
<td>&lt;0.001</td>
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<td>≥80 26.4% 27.8% 28.6% 29.7%</td>
<td>&lt;0.001</td>
<td>32.2% 31.2%</td>
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<td>Gender Female</td>
<td>43.8% 43.3% 43.1% 42.6%</td>
<td>&lt;0.001</td>
<td>39.9% 40.5%</td>
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<td>Race White</td>
<td>94.9% 94.4% 94.1% 93.9%</td>
<td>&lt;0.001</td>
<td>93.5% 92.8%</td>
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<td>Admission type Nonelective</td>
<td>24.1% 22.0% 21.3% 20.7%</td>
<td>&lt;0.001</td>
<td>29.4% 29.1%</td>
<td>&lt;0.001</td>
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<td>Elix. &gt;3</td>
<td>14.5% 15.8% 16.6% 16.6%</td>
<td>&lt;0.001</td>
<td>30.4% 29.6%</td>
<td>&lt;0.001</td>
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<td>Stroke 16.4% 16.5% 15.9% 15.7%</td>
<td>&lt;0.001</td>
<td>25.1% 22.8%</td>
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<td>TIA 2.6% 2.4% 2.2% 1.8%</td>
<td>&lt;0.001</td>
<td>3.3% 2.5%</td>
<td>&lt;0.001</td>
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<td>CABG‡ 20.8% 20.4% 19.5% 17.5%</td>
<td>&lt;0.001</td>
<td>12.8% 10.9%</td>
<td>&lt;0.001</td>
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<td>Comorbidities Atrial fibrillation 15.0% 15.4% 15.6% 16.4%</td>
<td>&lt;0.001</td>
<td>20.8% 21.0%</td>
<td>&lt;0.001</td>
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<td>Heart failure 9.5% 9.6% 9.3% 9.0%</td>
<td>&lt;0.001</td>
<td>16.7% 16.3%</td>
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<td>Myocardial infarction 2.6% 2.5% 2.1% 2.2%</td>
<td>&lt;0.001</td>
<td>2.4% 2.3%</td>
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<td>GI bleed 8.8% 8.6% 8.1% 7.6%</td>
<td>&lt;0.001</td>
<td>9.2% 9.1%</td>
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<td>COPD 30.4% 31.6% 32.3% 32.4%</td>
<td>&lt;0.001</td>
<td>36.9% 37.8%</td>
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<td>CKD 18.5% 21.8% 24.4% 26.9%</td>
<td>&lt;0.001</td>
<td>32.7% 35.1%</td>
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<td>Cancer 14.5% 14.3% 14.6% 15.4%</td>
<td>&lt;0.001</td>
<td>17.1% 18.3%</td>
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<td>Anemia 23.9% 25.5% 26.6% 28.7%</td>
<td>&lt;0.001</td>
<td>32.4% 33.9%</td>
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<td>Hypertension 83.2% 86.5% 88.8% 90.4%</td>
<td>&lt;0.001</td>
<td>91.6% 91.9%</td>
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<td>Diabetes 46.2% 47.3% 49.8% 51.9%</td>
<td>&lt;0.001</td>
<td>52.8% 54.7%</td>
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<td>Depression 7.9% 8.6% 9.1% 9.5%</td>
<td>&lt;0.001</td>
<td>10.3% 10.7%</td>
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<td>Surgeon specialty Vascular 33.0% 36.0% 37.5% 39.7%</td>
<td>&lt;0.001</td>
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<td>Cardiothoracic 23.2% 25.1% 26.4% 28.8%</td>
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<td>General 33.5% 32.8% 31.1% 28.8%</td>
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<td>Other 10.3% 6.1% 5.0% 4.7%</td>
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CABG indicates coronary artery bypass graft surgery; CAS, carotid artery stenting; CEA, carotid endarterectomy; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; Elix. score, Elixhauser score; GI bleed, gastrointestinal bleeding; and TIA, transient ischemic attack.

*P values from Cochran-Armitage test for trend over the 4 y blocks.
†P values from chi-squared test for proportions between CEA vs CAS patients in 2005–2008.
‡CABG procedure performed before or on the same day as the CEA or CAS during the same hospitalization.

Discussion

We observed a significant decrease in the rate of CEA procedures over time coupled with a decrease in the past-year case volumes of performing surgeons in our elderly Medicare fee-for-service beneficiaries from 2001 to 2008. The overall 30-day post-CEA mortality was 1.27% in our patients, which was higher than those reported in the recent randomized trials of CEA versus CAS; 0.9% in Stent-Supported Percutaneous Angioplasty of the Carotid Artery Versus Endarterectomy (SPACE) trial, 1.2% in Endarterectomy Versus Angioplasty in Patients With Symptomatic Severe Carotid Stenosis (EVA-3S), and 0.3% in Carotid Revascularization Endarterectomy vs Stenting Trial (CREST).20–22 The 30-day post-CEA mortality improved slightly overtime, but CEAs performed by lower past-year case-volume surgeons were associated with higher 30-day mortality after adjusting for patients’ demographics, comorbidities, hospital admission type, presence of concurrent coronary artery bypass graft and surgeon subspecialty, before and after the 2005 NCD to reimburse CAS.

Standardized rates of CEA declined between 2002 and 2008, but it does not seem that all of these patients were selected for CAS instead of CEA as the increased CAS rate
was less than the decline in the CEA rate. This is consistent with recent studies among Medicare beneficiaries, which found a reduction in the overall rate of carotid revascularization over 2001 to 2007. This may be explained by improved medical management of atherosclerosis in general or carotid stenosis, leading to a reduction in the incidence of asymptomatic or symptomatic carotid stenosis, a perception of reduced relative benefit from carotid revascularization especially in asymptomatic patients, improved use of diagnostic procedures allowing for better patient selection, or dissemination of evidence on the increased peri-procedural risks in certain subpopulations.

Our results suggest that the association between 30-day post-CEA mortality and surgeon past-year case volume remained fairly constant before and after the NCD. Overall, 30-day mortality after CEA decreased, despite the fact that patients were older and had a heavier comorbidity burden in the later years of this study, a trend which persisted after controlling for patient characteristics and surgeon case volumes. This may be attributed, in part, to the widespread use of aspirin and statins, which have been shown to improve CEA outcomes and to general improvement of perioperative hospital care. Among CEA patients with part D coverage in 2007 to 2008, the proportion of patients using statins increased only slightly (Table II in the online-only Data Supplement). We did not have data on drug prescriptions for patients in earlier periods, nor could we reliably capture the use of aspirin throughout the study period as over-the-counter prescriptions are not reimbursed by Part D.

This is the first study in the full contemporary fee-for-service elderly Medicare beneficiaries investigating the CEA volume–outcome relationship and the effect of the CAS NCD on surgeon past-year case-volume and 30-day mortality after CEA. One of the major strengths of our study is the size of the study sample and its representativeness. We had access to all inpatient and outpatient claims for fee-for-service Medicare patients undergoing inpatient CAS and CEA.

On the other hand, our study should be interpreted in the context of certain limitations. Most importantly, clinical data on some important potential confounders were limited or unavailable. We were unable to assess what proportion of CEA patients met the indication for CAS as per the NCD. We defined symptomatic status as having any hospital ICD9-CM code for strokes and TIAs in the prior 6 months before the procedure. The proportion of symptomatic patients is likely misestimated as the algorithm does not capture stroke/TIAs not resulting in hospitalizations, transient monocular blindness, or stroke/TIAs that lead to hospitalizations during which CEA was performed, and at the same time, as we were unable to distinguish a contralateral event to an ipsilateral event in our data. We also could neither identify patients who were at high surgical risk, not assess their degree of carotid stenosis. The decline in mortality over time that we observed could therefore be attributed, in part, to the channeling of higher risk patients to CAS, resulting in a lower risk CEA patient pool. If high-volume surgeons are more likely to treat lower risk patients who are not symptomatic as previously suggested, our results would be biased in favor of higher volume surgeons.

We assessed mortality, a hard end point, but did not assess the volume–outcome association for perioperative strokes because postprocedural events were not distinguishable from preprocedural events that lead to hospitalizations in our data. Our study sample consisted of patients covered under the fee-for-service Medicare plan. Although Medicare is the payer for >70% of the CEA procedures nationwide, we could not capture CEA patients covered by other Medicare plans or by non-Medicare plans. Finally, not all

Table 2. Overall Crude 30-Day Mortality and Adjusted Relative Odds of 30-Day Death

<table>
<thead>
<tr>
<th>Crude 30-Day Mortality (95% CI) by Year, Number of Patients</th>
<th>Adjusted† Relative Risk (95% CI) of Death Within 30 Days Compared With 2001–2002</th>
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</thead>
<tbody>
<tr>
<td>1.40% (1.34–1.47)</td>
<td>1.30% (1.23–1.36)</td>
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<tr>
<td>N=125 777</td>
<td>N=122 262</td>
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</tbody>
</table>

CABG indicates coronary artery bypass graft surgery; CI, confidence interval; N, number of patients; and TIA, transient ischemic attack.

*P value for trend.
†Adjusted for age, sex, race, admission type, Elixhauser comorbidity score, presence of concurrent CABG procedure, presence of stroke/TIA within 180 days, surgeon case–volume category, surgeon specialty, and all comorbidities presented in Table 1.

<table>
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<tr>
<td>&lt;10</td>
<td>1.79</td>
<td>1.74</td>
<td>1.41</td>
<td>1.42</td>
<td>&lt;0.001</td>
<td>Reference</td>
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<td></td>
<td>(1.61–1.99)</td>
<td>(1.56–1.94)</td>
<td>(1.25–1.60)</td>
<td>(1.27–1.59)</td>
<td></td>
<td>0.87 (0.75–1.01)</td>
<td>0.78 (0.67–0.91)</td>
<td>0.95 (0.81–1.13)</td>
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<tr>
<td>10–19</td>
<td>1.51</td>
<td>1.33</td>
<td>1.32</td>
<td>1.19</td>
<td>0.001</td>
<td>0.79 (0.69–0.91)</td>
<td>0.71 (0.61–0.82)</td>
<td>0.80 (0.50–0.73)</td>
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<td></td>
<td>(1.36–1.66)</td>
<td>(1.20–1.48)</td>
<td>(1.18–1.47)</td>
<td>(1.06–1.33)</td>
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<td>(0.97–1.19)</td>
<td>(0.97–1.19)</td>
<td>(0.97–1.19)</td>
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<tr>
<td>20–39</td>
<td>1.35</td>
<td>1.19</td>
<td>1.09</td>
<td>1.08</td>
<td>&lt;0.001</td>
<td>0.71 (0.62–0.82)</td>
<td>0.72 (0.62–0.82)</td>
<td>0.72 (0.61–0.86)</td>
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<td></td>
<td>(1.24–1.47)</td>
<td>(1.09–1.31)</td>
<td>(0.98–1.20)</td>
<td>(1.07–1.20)</td>
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<td>(0.91–1.19)</td>
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<td>(0.91–1.19)</td>
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<tr>
<td>40</td>
<td>1.19</td>
<td>1.16</td>
<td>0.96</td>
<td>1.04</td>
<td>&lt;0.001</td>
<td>0.71 (0.62–0.82)</td>
<td>0.72 (0.62–0.82)</td>
<td>0.72 (0.61–0.86)</td>
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<td></td>
<td>(1.08–1.30)</td>
<td>(1.06–1.27)</td>
<td>(0.86–1.08)</td>
<td>(0.91–1.20)</td>
<td></td>
<td>(0.91–1.19)</td>
<td>(0.91–1.19)</td>
<td>(0.91–1.19)</td>
</tr>
</tbody>
</table>

CABG indicates coronary artery bypass graft surgery; CEA, carotid endarterectomy; CI, confidence interval; and TIA, transient ischemic attack.

*P value for trend.
†Adjusted for age, sex, race, admission type, Elixhauser comorbidity score, presence of concurrent CABG procedure, presence of stroke/TIA within 180 days, surgeon case–volume category, surgeon specialty, and all comorbidities presented in Table 1.

### Procedures

The rate of CEA procedures in the elderly Medicare fee-for-service beneficiaries decreased by >20% as did performing surgeon past-year case-volume by >20% in the median volume, between 2001 and 2008. The overall 30-day mortality after CEA was 1.3% in our elderly Medicare patients, which was higher than that in the recent randomized clinical trials of CEA versus CAS. Although the mortality improved slightly over time, lower surgeon case-volume was consistently associated with higher 30-day post-CEA mortality before and after the NCD for CAS. The 30-day death, stroke, and MI after CAS and CEA can be used to monitor the quality of these procedures and outcomes in routine clinical practice. Therefore, these data should be widely collected together with relevant clinical risk factors and made available to clinical providers and decision makers in the field to optimize patient selection and applying evidence-based standards on the training and proficiency requirements for the proceduralists.

### Conclusions

The funding agency had no role in the design and conduct of the study, or in the collection, management, analysis, and interpretation of the data, or in the preparation, review, or approval of the article, or in the decision to submit the article for publication.

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### Disclosures

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Surgeon Case Volume and 30-Day Mortality After Carotid Endarterectomy Among Contemporary Medicare Beneficiaries: Before and After National Coverage Determination for Carotid Artery Stenting

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Supplemental Table I: Algorithms used to define comorbidities and reference to their validation studies where available

Supplemental Figure I: Patient Enrollment and Eligibility Flow Chart

Supplemental Table II: Trends in the proportion of patients with pre-procedural use of statins among Medicare Patients undergoing CEA in 2007-2008 with full 12 months prior part D coverage

Supplemental Figure II: Reduction in the Median Case-Volume over time by Surgeon Specialty
**Table I:**

Algorithms used to define comorbidities and reference to their validation studies where available

<table>
<thead>
<tr>
<th>Comorbidity/Procedures</th>
<th>Algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atrial Fibrillation&lt;sup&gt;1&lt;/sup&gt;</td>
<td>In-patient or out-patient diagnosis of 427.31</td>
</tr>
<tr>
<td>Heart Failure&lt;sup&gt;2&lt;/sup&gt;</td>
<td>In-patient diagnosis of 428.xx, 398.91, 402.01, 402.11, 402.91, 404.01, 404.11, 404.91, 404.03, 404.13, or 404.93</td>
</tr>
<tr>
<td>Myocardial Infarction&lt;sup&gt;3&lt;/sup&gt;</td>
<td>In-patient diagnosis of 410.x1 in the primary or secondary position</td>
</tr>
<tr>
<td>Gastrointestinal Bleeding&lt;sup&gt;4&lt;/sup&gt;</td>
<td>Inpatient or outpatient diagnosis of: 456.0, 530.7, 531.xx-534.xx, 535.x1 except 535.71, 537.83, 578.x</td>
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<tr>
<td>COPD</td>
<td>Inpatient or outpatient diagnosis of 490, 491.xx-496</td>
</tr>
<tr>
<td>CKD</td>
<td>In-patient or outpatient diagnosis of: 582.xx, 583.xx, 585.x, 586, 587, 250.4x, 403.xx, 404.xx, 572.4, 580.xx, 584.x, 580.0x, 580.4, 580.89, 580.9, 582.4, 791.2, 791.3, 274.10, 440.1, 442.1, 453.3, 581.xx, 593.xx, 753.0x, 753.3, 866.00, 866.01, 866.1x</td>
</tr>
<tr>
<td>Diabetes&lt;sup&gt;5&lt;/sup&gt;</td>
<td>In-patient or out-patient diagnosis of 250.xx, 357.2, 362.xx, or 366.41</td>
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<tr>
<td>Hypertension&lt;sup&gt;6&lt;/sup&gt;</td>
<td>In-patient or outpatient diagnosis of: 401.x-405.x</td>
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<tr>
<td>Cancer</td>
<td>In-patient or outpatient diagnosis of: 140-208, excluding non-melanoma skin cancer (173.xx)</td>
</tr>
<tr>
<td>Depression</td>
<td>In-patient or outpatient diagnosis of: 293.83, 296.2x, 296.3x, 296.90, 298.0, 300.4, 309.0, 309.1, 309.28, 311</td>
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<tr>
<td>Anemia</td>
<td>In-patient or outpatient diagnosis of 280.x-285.xx</td>
</tr>
</tbody>
</table>

Supplemental Figure I:

Patient Enrollment and Eligibility Flow Chart

560,279 first inpatient CEA claims identified in institutional files 2001-2008

Excluded:
Patients < 66 years old at procedure (N=54,268)

506,011 eligible patients

Excluded:
Patients with no identifiable claim for operating surgeon (N=51,294)

454,717 patients
Supplemental Table II

Trends in the proportion of patients with pre-procedural use of statins among Medicare Patients undergoing CEA in 2007-2008 with full prior 12 months part D coverage

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
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<th>2008</th>
<th></th>
<th></th>
<th>p-value*</th>
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<tr>
<td></td>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>Q1</td>
<td>Q2</td>
</tr>
<tr>
<td>statins†</td>
<td>66.5%</td>
<td>64.4%</td>
<td>64.0%</td>
<td>64.4%</td>
<td>64.0%</td>
<td>66.3%</td>
</tr>
<tr>
<td>N</td>
<td>3,496</td>
<td>4,964</td>
<td>5,304</td>
<td>5,163</td>
<td>5,339</td>
<td>5,544</td>
</tr>
</tbody>
</table>

* p-values for the trend tested by Cochran Armitage test

† The percentages represent the proportion of patients who had at least one prescription filled during the 12 month prior to undergoing CEA.
Supplemental Figure II:
Reduction in the Median Case-Volume over time by Surgeon Specialty