LESS IS MORE

Geographic Variation in Carotid Revascularization Among Medicare Beneficiaries, 2003-2006

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Background: Little is known about patterns in the use of carotid revascularization since a 2004 Medicare national coverage decision supporting carotid artery stenting. We examined geographic variation in and predictors of carotid endarterectomy and carotid stenting.

Methods: Analysis of claims from the Centers for Medicare & Medicaid Services from January 1, 2003, through December 31, 2006. Patients were 65 years or older and had undergone carotid endarterectomy or carotid stenting. The main outcome measures were annual age-adjusted rates of carotid endarterectomy and carotid stenting, factors associated with the use of carotid revascularization, and mortality rate at 30 days and 1 year.

Results: The rate of endarterectomy decreased from 3.2 per 1000 person-years in 2003 to 2.6 per 1000 person-years in 2006. After adjustment for demographic and clinical characteristics, there was significant geographic variation in the odds of carotid revascularization, with the East North Central region having the greatest odds of endarterectomy (odds ratio, 1.60; 95% confidence interval, 1.55-1.65) and stenting (1.61; 1.46-1.78) compared with New England. Prior endarterectomy (odds ratio, 3.06; 95% confidence interval, 2.65-3.53) and coronary artery disease (2.12; 2.03-2.21) were strong predictors of carotid stenting. In 2005, mortality was 1.2% at 30 days and 6.8% at 1 year for endarterectomy and 2.3% at 30 days and 10.3% at 1 year for stenting.

Conclusions: Significant geographic variation exists for carotid endarterectomy and carotid stenting. Prior endarterectomy and coronary disease were associated with greater odds of carotid stenting.

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CAROTID ENDARTERECTOMY has been the recommended treatment for patients with extracranial carotid artery disease since the publication of several randomized studies[1-5] in the 1990s comparing carotid endarterectomy with medical therapy. Trials in symptomatic and asymptomatic patients were stopped early because of the observed benefit of carotid endarterectomy.[4,5] Interim results of 1 trial prompted a National Institutes of Health alert to physicians in 1991 that highlighted the benefit of carotid endarterectomy for some patients with recent transient ischemic attack or stroke when performed at centers with low rates of perioperative complications.[6]

In the years that followed, the use of carotid endarterectomy increased in the United States[7] but varied considerably by geographic region.[8-10] Among common surgical procedures, including procedures without a robust evidence base, carotid endarterectomy had some of the greatest geographic variation.[8] Moreover, previous studies[11,12] have found that 30-day mortality rates associated with carotid endarterectomy in the Medicare population are higher than rates reported in clinical trials, although the risk of mortality is lower at high-volume centers than at low-volume centers.

See Invited Commentary at end of article

With the recent development of embolic protection devices, several randomized trials have compared carotid endarterectomy with percutaneous carotid artery stenting in patients with carotid artery disease and have had mixed results regarding myocardial infarction, stroke, and death.[13,14] Carotid stenting has been proposed as a therapeutic option for patients at high risk for surgical revascularization.[15] On October 12, 2004, the US Centers for Medicare & Medicaid Services (CMS) issued a national coverage decision supporting the use of Food and Drug Administration–approved carotid artery stents with embolic protection devices for symptomatic patients at high surgical risk

or in the context of a clinical trial. In light of that decision and its potential influence on the use of carotid revascularization, we examined geographic variation in and predictors of carotid endarterectomy and carotid stenting among Medicare beneficiaries in the United States aged 65 and older (hereafter referred to as elderly beneficiaries).

METHODS

DATA SOURCES

We obtained all inpatient, outpatient, and carrier claim files from CMS for all Medicare beneficiaries who underwent carotid endarterectomy or carotid stenting from January 1, 2003, through December 31, 2006. We also obtained all claims for all beneficiaries who underwent carotid magnetic resonance angiography (MRA) or x-ray angiography (invasive or noninvasive) during the same period. The inpatient files contain institutional claims for facility costs covered under Medicare Part A. The outpatient files contain claims for outpatient facility costs covered under Medicare Part B. The carrier files contain noninstitutional claims for physician services covered under Medicare Part B. In addition, we obtained denominator files for 100% of Medicare beneficiaries from 2003 through 2006. The denominator files contain beneficiary demographic characteristics, dates of death, and program eligibility and enrollment information. We limited the analysis to beneficiaries aged 65 years or older living in the United States. We included only claims filed during periods of fee-for-service coverage. The institutional review board of the Duke University Health System approved the study.

CAROTID REVASCULARIZATION AND DIAGNOSTIC IMAGING

We identified patients who underwent carotid endarterectomy by searching carrier claims from January 1, 2003, through December 31, 2006, for evidence of carotid endarterectomy (Healthcare Common Procedure Coding System [HCPCS] code 35301). The HCPCS codes specific to carotid stenting were assigned in 2004 and first appeared in the Medicare claims data in 2005. Therefore, we searched carrier claims from January 1, 2005, through December 31, 2006, for evidence of carotid stenting (HCPCS codes 37215 and 37216). We retained the claim-through date from each carrier claim as the carotid revascularization date. We searched all carrier claims from the 365 days before the revascularization date for carotid ultrasonography (HCPCS codes 93875, 93880, and 93882), carotid MRA (codes 70547, 70548, and 70549), and carotid x-ray angiography (codes 70498, 75660, 75662, 75665, 75671, 75676, and 75680).

PATIENT CHARACTERISTICS

Patient demographic characteristics included age, sex, race, and state of residence. In this analysis, we used the self-reported race category of black and combined all other categories as other.[16] We used state of residence to group beneficiaries into 9 US Census regions. We also assigned each beneficiary to 1 of 306 hospital referral regions (HRRs) according to zip code of residence.[17]

We identified comorbid conditions among patients undergoing carotid revascularization who had 12 prior months of Medicare eligibility using coding algorithms developed by Quan et al[18] and Birman-Deych et al.[19] Specifically, we searched all claims from the 365 days preceding the intervention date for evidence of cancer (*International Classification of Diseases, Ninth Revision, Clinical Modification* [*ICD-9.CM*][20] codes 140-172, 174-195, 200-208, and 238.6), chronic obstructive pulmonary disease (codes 416.8, 416.9, 490-505, 506.4, 508.1, and 508.8), congestive heart failure (codes 398.91, 402.x1, 404.x1, 404.x3, 428.x, and 425.4-425.9), coronary artery disease (codes 410.x-414.x, 429.2, and V45.81), dementia (codes 290.x, 294.1, and 331.2), diabetes mellitus (code 250), hypertension (codes 401-405 and 437.2), and renal disease (codes 403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 582.x, 583.0-583.7, 585.x, 586.x, 588.0, V42.0, V45.1, and V56.x). We also searched for evidence of peripheral vascular disease (*ICD-9-CM* codes 443.9, 441.x, 785.4, and V43.4) and cerebrovascular disease (codes 434.x-438.x). For patients who underwent carotid revascularization in 2005 or 2006, we searched for evidence of carotid endarterectomy (HCPCS code 35301) in the previous year.

MORTALITY

We summarized all-cause mortality at 30 days and 1 year for beneficiaries who underwent carotid endarterectomy or carotid stenting in 2004 and 2005, the first full year in which carotid stenting was covered by Medicare.[21] Beneficiaries who underwent carotid endarterectomy and carotid stenting during the year were included in both groups. Beneficiaries who had undergone multiple carotid endarterectomies or carotid stenting procedures during the year were followed up from the first observed procedure.

STATISTICAL ANALYSIS

We present categorical variables as frequencies with percentages. We used Kaplan-Meier methods to calculate the unadjusted 30-day and 1-year mortality rates. Using the direct standardization method, we calculated the annual age-adjusted rates of carotid endarterectomy and carotid stenting overall and by HRR. We calculated the annual rates of carotid endarterectomy and the rates for January 1, 2003, through December 31, 2004, and the rates for January 1, 2005, through December 31, 2006. We calculated the annual rates of carotid stenting for 2005 and 2006 only, because the HCPCS codes specific to carotid stenting were assigned late in 2004 after the CMS national coverage decision.[21] We calculated the ratio of the intervention rates in each HRR to the national rates and mapped these ratios. We suppressed the results for HRRs with 10 or fewer revascularization procedures to minimize the effect of unreliable estimates.

In addition to calculating the rates of carotid revascularization, we calculated the rates of carotid imaging performed before carotid revascularization. For interventions performed in 2005, we identified the carotid imaging procedures performed during the 365 days before the carotid revascularization. For example, for patients who underwent 2 carotid ultrasonography examinations and a carotid x-ray angiography before a carotid stenting procedure, we describe the pattern as "ultrasonography and x-ray angiography."

For each patient, we defined the first MRA or x-ray angiography performed from January 1, 2004, through December 31, 2006, as the index event and followed up the patient for 1 year to identify the use of carotid revascularization. Because detailed data with regard to clinical indications for carotid revascularization are not available in claims data, we used prior angiography (invasive or noninvasive) as a proxy for potential eligibility for revascularization. We limited the cohort to patients with 12 months of Medicare eligibility before the index date. We used logistic regression models to assess the independent effects of age, sex, race, US Census region, comorbid conditions, and index year on the use of carotid endarterectomy or carotid stenting. We used SAS statistical software, version 9.2 (SAS Institute Inc, Cary, North Carolina), for all analyses.

Table 1. Characteristics of the Study Population in 2005

Characteristic	No. (%) of Patients[a]		
	All Medicare Beneficiaries (n=29 623 989)[b]	Carotid Endarterectomy Cohort (n=66 698)	Carotid Stenting Cohort (n=7357)
Age group, y[c]			
65-69	9 151 407 (30.9)	11 865 (17.8)	1277 (17.4)
70-74	6 511 785 (22.0)	17 412 (26.1)	1808 (24.6)
75-79	5 776 292 (19.5)	18 521 (27.8)	1910 (26.0)
≥80	8 184 505 (27.6)	18 900 (28.3)	2362 (32.1)
Male sex	12 366 198 (41.7)	37 571 (56.3)	4437 (60.3)
Race			
Black	2 376 628 (8.0)	2252 (3.4)	299 (4.1)
Other	27 247 361 (92.0)	64 446 (96.6)	7058 (95.9)
US geographic region[d]			
New England	1 567 386 (5.3)	3036 (4.6)	298 (4.1)
Middle Atlantic	4 076 998 (13.8)	7991 (12.0)	1104 (15.0)
South Atlantic	6 253 429 (21.1)	14 922 (22.4)	1579 (21.5)
East North Central	5 275 212 (17.8)	12 998 (19.5)	1597 (21.7)
East South Central	2 053 815 (6.9)	5075 (7.6)	591 (8.0)
West North Central	2 317 122 (7.8)	5824 (8.7)	499 (6.8)
West South Central	3 216 044 (10.9)	8716 (13.1)	746 (10.1)
Mountain	1 665 820 (5.6)	2854 (4.3)	284 (3.9)
Pacific	3 198 163 (10.8)	5282 (7.9)	659 (9.0)
Comorbid conditions and risks			
Cancer	NA	9808 (14.7)	1280 (17.4)
Cerebrovascular disease	NA	31 822 (47.7)	4462 (60.6)
Chronic obstructive pulmonary disease	NA	24 197 (36.3)	2960 (40.2)
Coronary artery disease	NA	46 931 (70.4)	6048 (82.2)
Dementia	NA	2092 (3.1)	293 (4.0)
Diabetes mellitus	NA	25 395 (38.1)	3017 (41.0)
Hypertension	NA	60 418 (90.6)	6820 (92.7)
Peripheral vascular disease	NA	24 625 (36.9)	3386 (46.0)
Renal disease	NA	7004 (10.5)	1081 (14.7)
Previous imaging and interventions			
Ultrasonography only	NA	17 858 (26.8)	818 (11.1)
MRA only	NA	1541 (2.3)	59 (0.8)
X-ray angiography only	NA	1448 (2.2)	314 (4.3)
Ultrasonography and MRA	NA	17 970 (26.9)	650 (8.8)
Ultrasonography and x-ray angiography	NA	21 608 (32.4)	3848 (52.3)
MRA and x-ray angiography	NA	535 (0.8)	170 (2.3)
Ultrasonography, MRA, and x-ray angiography	NA	4460 (6.7)	1407 (19.1)
No previous imaging	NA	1278 (1.9)	91 (1.2)
Carotid endarterectomy	NA	1493 (2.2)	424 (5.8)

Abbreviation: MRA, magnetic resonance angiography, NA, not available.
[a] Percentages may not total 100 because of rounding.
[b] Data with regard to comorbid conditions and imaging were only available for the 297 579 Medicare beneficiaries eligible for inclusion in 2005.
[c] Indicates age at the time of first eligibility for all Medicare beneficiaries and age at the time of intervention for patients in the intervention cohorts.
[d] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Middle Atlantic includes New Jersey, New York, and Pennsylvania. South Atlantic includes Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. East South Central includes Alabama, Kentucky, Mississippi, and Tennessee. West South Central includes Arkansas, Louisiana, Oklahoma, and Texas. East North Central includes Illinois, Indiana, Michigan, Ohio, and Wisconsin. West North Central includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. Mountain includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Pacific includes Alaska, California, Hawaii, Oregon, and Washington.

RESULTS

There were almost 30 million Medicare beneficiaries 65 years or older in each year from 2003 through 2006. **Table 1** gives the demographic characteristics and regional distribution of all Medicare beneficiaries in 2005 and the demographic characteristics, clinical characteristics, and previous diagnostic imaging test results of beneficiaries who underwent carotid endarterectomy or carotid stenting from January 1, 2005, through December 31, 2005. The distribution of study variables was similar in each year of the study period (data not shown).

A total of 66 698 eligible beneficiaries underwent carotid endarterectomy and 7357 underwent carotid stenting in 2005. Among beneficiaries who underwent carotid endarterectomy, 56.1% were 75 years or older, 56.3% were men, and 3.4% were black. More than two-thirds of the beneficiaries had a prior diagnosis of coronary artery disease, 36.9% had a prior diagnosis of peripheral vascular disease, and 47.7% had a prior diagnosis of cerebrovascular disease. Carotid endarterectomy was most

Table 2. Carotid Revascularization by Year[a]

Procedure	No. of Procedures (Rate per 1000 Beneficiaries)			
	2003	2004	2005	2006
Carotid endarterectomy	88 698 (3.2)	85 349 (3.1)	76 387 (2.8)	69 920 (2.6)
Carotid stenting	NA	NA	8485 (0.3)	10 959 (0.4)
Total	**88 698 (3.2)**	**85 349 (3.1)**	**84 872 (3.1)**	**80 879 (3.0)**

Abbreviation: NA, not available.
[a]Rates are age adjusted by year.

frequently preceded by carotid ultrasonography and x-ray angiography (32.4%), ultrasonography and MRA (26.9%), or ultrasonography only (26.8%).

Of the 7357 beneficiaries who underwent carotid stenting in 2005, 58.1% were 75 years or older, 60.3% were men, and 4.1% were black. More than two-thirds had a prior diagnosis of coronary artery disease, 46.0% had a prior diagnosis of peripheral vascular disease, and 60.6% had a prior diagnosis of cerebrovascular disease. Carotid stenting was most frequently preceded by ultrasonography and x-ray angiography (52.3%).

From January 1, 2003, through December 31, 2006, a total of 320 354 carotid endarterectomies were performed in elderly Medicare beneficiaries (**Table 2**). The rate of carotid endarterectomy decreased slightly during this period from 3.2 to 2.6 per 1000 person-years. From January 1, 2005, through December 31, 2006, 19 444 carotid stenting procedures were performed in Medicare beneficiaries 65 years or older. The rate of carotid stenting and the absolute number increased from 2005 to 2006. The overall rate of carotid revascularization did not increase during the study period.

GEOGRAPHIC VARIATION

Substantial geographic variation was seen in the age-adjusted rates of carotid endarterectomy in the 2003-2004 period, with a nearly 9-fold difference between the highest rate (7.17 per 1000 person-years in Beaumont, Texas) and the lowest rate (0.82 per 1000 person-years in Honolulu, Hawaii). There was slightly less geographic variation in carotid endarterectomy rates in the 2005-2006 period (**Figure**, A; from 5.5 per 1000 person-years in Beaumont, Texas, to 0.79 per 1000 person-years in Honolulu, Hawaii).

The use of carotid stenting differed by HRR, but the variations were less pronounced than for carotid endarterectomy. In the 2005-2006 period, the highest rate of carotid stenting was 2.73 per 1000 person-years in St Joseph, Michigan, nearly 8 times higher than the national average (Figure, B). Fifty HRRs had rates that were at least 50% higher than the national average. Fewer than 11 carotid stenting procedures were performed in 46 HRRs, so we excluded these HRRs from the analysis.

Five HRRs had rates of carotid endarterectomy and carotid stenting at least 50% higher than the US average (Hattiesburg, Mississippi; Joplin, Missouri; Lawton, Oklahoma; Houma, Louisiana; and Kalamazoo, Michigan). In contrast, 2 HRRs had rates of carotid endarterectomy and carotid stenting at least 50% lower than the US average (Salt Lake City, Utah, and Albuquerque, New Mexico). In general, however, there was no clear relationship between the use of carotid stenting and that of carotid endarterectomy by HRR (data not shown).

PREDICTORS OF CAROTID REVASCULARIZATION

Table 3 gives the results of the models predicting the use of carotid endarterectomy and carotid stenting from 2004 through 2006 within 1 year of the first MRA or x-ray angiography. Carotid endarterectomy was performed more often in men (odds ratio [OR], 1.63; 95% confidence interval [CI], 1.61-1.65) and patients with peripheral vascular disease (1.37; 1.35-1.39). The procedure was more likely to be used in the East North Central region (1.60; 1.55-1.65) and the West North Central region (1.73; 1.67-1.80) compared with New England.

Carotid stenting was performed more often in men (OR, 1.62; 95% CI, 1.56-1.68), patients with peripheral vascular disease (1.58; 1.52-1.64), patients with coronary artery disease (2.12; 2.03-2.21), and patients who had undergone a previous carotid endarterectomy (3.06; 2.65-3.53). Carotid stenting was also more likely to occur in the Pacific region (1.65; 1.48-1.84) and the East North Central region (1.61; 1.46-1.78) compared with New England.

MORTALITY

Among patients who underwent carotid endarterectomy in 2004, 1029 (1.3%) died within 30 days of the index procedure and 5492 (7.0%) died within 1 year. In 2005, 845 (1.2%) died within 30 days of the index procedure and 4766 (6.8%) died within 1 year. Among patients who underwent carotid stenting, 178 (2.3%) died within 30 days of the index procedure and 803 (10.3%) died within 1 year.

COMMENT

In this retrospective cohort study of elderly Medicare beneficiaries, we found substantial geographic variation in the use of carotid endarterectomy and carotid stenting. The New England, Mountain, and Pacific regions tended to have the lowest rates of these procedures, whereas the East South Central, West South Central, East North Central, and West North Central regions tended to have higher rates of revascularization. There was a nearly 9-fold difference between the highest rate and lowest rate of carotid endarterectomy across HRRs in 2003 and 2004 and a 7-fold difference in 2005 and 2006. Across HRRs, the

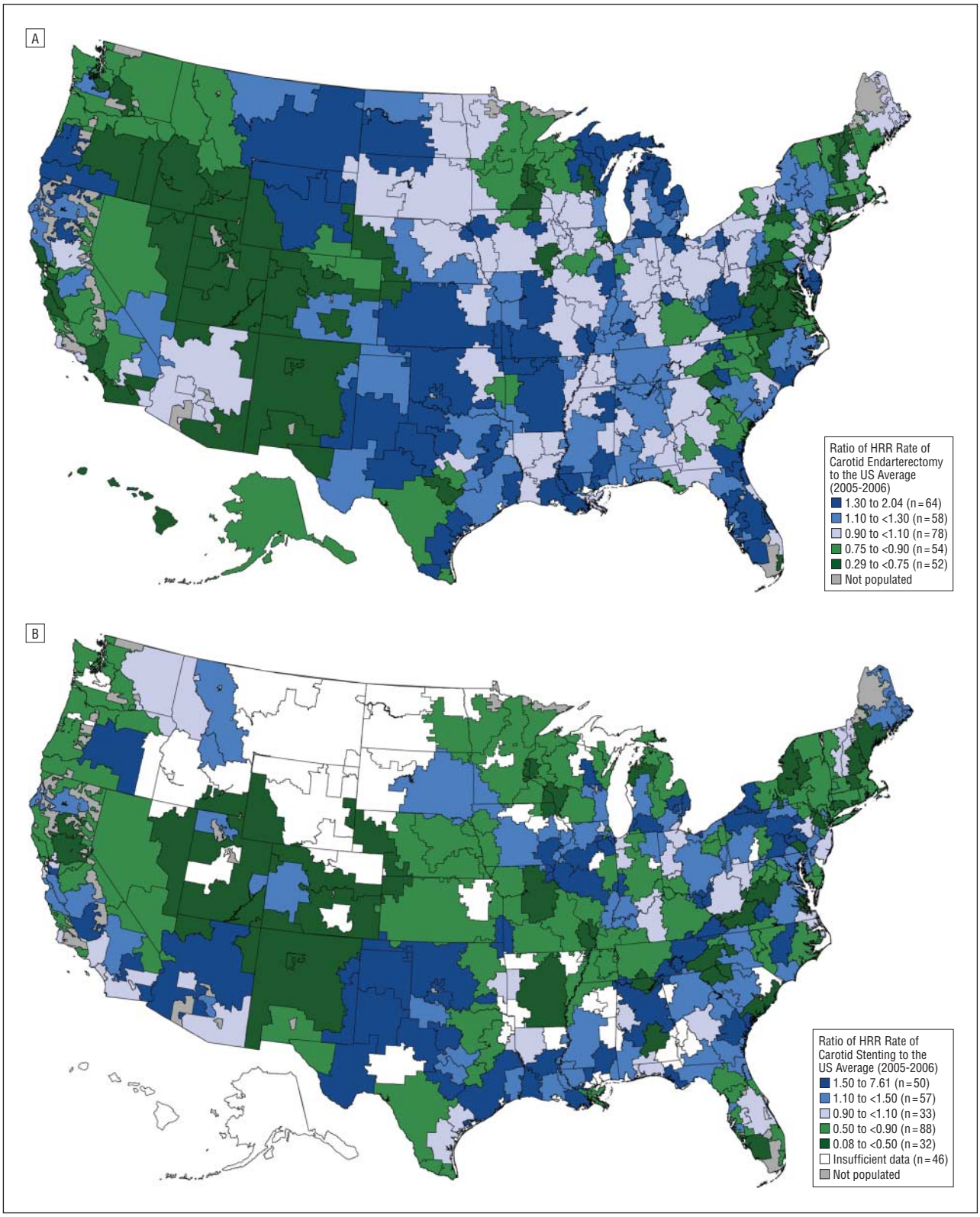

Figure. Hospital referral region (HRR) rates of carotid endarterectomy and carotid stenting. A, Ratio of rate of carotid endarterectomy by HRR to US national average, 2005-2006. B, Ratio of rate of carotid stenting by HRR to US national average, 2005-2006.

rates of carotid stenting ranged from 0.07 to 2.73 per 1000 person-years. In general, there was no clear relationship between rates of carotid endarterectomy and rates of carotid stenting by HRR, and overall rates of carotid revascularization did not increase during the study period. Previous studies[8,22-24] have found geographic variation in carotid endarterectomy, and a recent analysis[25] reported regional variation in carotid stenting.

We also found considerable variation in the use of diagnostic imaging before carotid revascularization. Most patients who underwent carotid stenting had previously undergone ultrasonography and x-ray angiography; almost one-fifth underwent ultrasonography, MRA, and x-ray angiography; and more than 10% underwent ultrasonography alone. Ultrasonography and MRA preceded carotid endarterectomy in more than one-quarter of the patients, and ultrasonography and x-ray angiography preceded carotid endarterectomy in approximately one-third of the patients. In 26.8% of patients who underwent carotid endarterectomy, only ultrasonography had been performed.

Reliance on ultrasonography alone before carotid endarterectomy is controversial. In a comparison of neurovascular imaging modalities before carotid endarterectomy, ultrasonography alone misclassified 28% of patients.[26] Yet, some have suggested that ultrasonography is sufficient for preprocedural imaging.[27] In a survey of surgeons in Canada, 4 of 37 neurosurgeons (10%) and 42 of 91 vascular surgeons (46%) identified duplex ultrasonography alone as the imaging modality of choice before carotid endarterectomy.[28] Our findings highlight the need for consensus regarding diagnostic imaging criteria for the identification and management of carotid artery disease.

We also found that the rate of carotid endarterectomy decreased slightly during the study period from 3.2 per 1000 person-years in 2003 to 2.6 per 1000 person-years in 2006. In the year immediately after the CMS national coverage decision supporting the use of carotid stenting,[21] the rate of carotid stenting was 0.4 per 1000 person-years. These findings are generally consistent with a recent study[25] that reported an endarterectomy rate of 2.7 per 1000 Medicare beneficiaries and a carotid artery stenting rate of 0.6 per 1000 beneficiaries. Whereas we relied on only those procedure codes specific to carotid artery stenting, Goodney and colleagues[25] used a slightly expanded algorithm to identify carotid artery stenting. The coding algorithm likely explains the slight difference in observed rates.

The low observed rate of carotid stenting is likely related to the fact that the CMS national coverage decision for carotid stenting was limited to patients at high surgical risk. The overall rate of revascularization did not increase, even with the introduction of a new therapeutic option for patients with carotid artery disease, because the rate of carotid endarterectomy decreased. This pattern of carotid revascularization will require additional study as physicians become more familiar with carotid stenting.

To explore variations in carotid revascularization, we used regression models to identify factors associated with the use of carotid endarterectomy and carotid stenting. Male sex and prior diagnosis of peripheral vascular disease were associated with greater odds of carotid endarterectomy and carotid stenting. However, patients undergoing carotid stenting were more likely to have a prior diagnosis of coronary artery disease and a prior carotid endarterectomy. This finding is consistent with the available evidence regarding the use of carotid stenting in clinical trials and registries to treat patients who are at similar or higher risk for carotid endarterectomy.[15] After adjustment for patient characteristics, significant geographic variations persisted in carotid revascularization.

Table 3. Predictors of Carotid Endarterectomy and Carotid Stenting, 2004-2006

Variable	Adjusted OR (95% CI)[a]	
	Carotid Endarterectomy (n=133 203)	Carotid Stenting (n=13 148)
Age per 5 years	0.93 (0.92-0.93)[b]	0.97 (0.95-0.98)[b]
Male sex	1.63 (1.61-1.65)[b]	1.62 (1.56-1.68)[b]
Race		
Black	0.49 (0.48-0.51)[b]	0.66 (0.60-0.72)[b]
Other	1 [Reference]	1 [Reference]
Comorbid conditions and risks		
Cancer	0.82 (0.80-0.83)[b]	0.94 (0.90-0.98)[c]
Cerebrovascular disease	0.49 (0.48-0.49)[b]	0.68 (0.65-0.70)[b]
Chronic obstructive pulmonary disease	0.99 (0.98-1.01)	1.12 (1.08-1.16)[b]
Coronary artery disease	1.27 (1.25-1.28)[b]	2.12 (2.03-2.21)[b]
Dementia	0.53 (0.52-0.55)[b]	0.56 (0.50-0.62)[b]
Diabetes mellitus	1.07 (1.05-1.08)[b]	1.07 (1.04-1.11)[c]
Hypertension	1.28 (1.25-1.30)[b]	1.23 (1.16-1.30)[b]
Peripheral vascular disease	1.37 (1.35-1.39)[b]	1.58 (1.52-1.64)[b]
Previous carotid endarterectomy	1.12 (1.05-1.20)[c]	3.06 (2.65-3.53)[b]
Renal disease	0.88 (0.86-0.90)[b]	1.08 (1.02-1.13)[c]
US geographic region[d]		
New England	1 [Reference]	1 [Reference]
Middle Atlantic	1.20 (1.16-1.24)[b]	1.31 (1.19-1.46)[b]
South Atlantic	1.38 (1.34-1.43)[b]	1.22 (1.10-1.34)[b]
East North Central	1.60 (1.55-1.65)[b]	1.61 (1.46-1.78)[b]
East South Central	1.39 (1.34-1.44)[b]	1.44 (1.29-1.60)[b]
West North Central	1.73 (1.67-1.80)[b]	1.46 (1.31-1.64)[b]
West South Central	1.51 (1.46-1.56)[b]	1.21 (1.09-1.34)[c]
Mountain	1.21 (1.16-1.26)[b]	1.15 (1.01-1.30)[e]
Pacific	1.24 (1.19-1.28)[b]	1.65 (1.48-1.84)[b]
Index year		
2004	1 [Reference]	1 [Reference]
2005	0.83 (0.82-0.84)[b]	6.92 (6.46-7.41)[b]
2006	0.63 (0.62-0.64)[b]	6.83 (6.38-7.31)[b]

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Multivariable model includes all variables listed.
[b] $P<.001$.
[c] $P<.01$.
[d] New England includes Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Middle Atlantic includes New Jersey, New York, and Pennsylvania. South Atlantic includes Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. East South Central includes Alabama, Kentucky, Mississippi, and Tennessee. West South Central includes Arkansas, Louisiana, Oklahoma, and Texas. East North Central includes Illinois, Indiana, Michigan, Ohio, and Wisconsin. West North Central includes Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, and South Dakota. Mountain includes Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming. Pacific includes Alaska, California, Hawaii, Oregon, and Washington.
[e] $P<.05$.

Finally, the 30-day mortality rate for carotid endarterectomy (1.2%) in 2005 was lower than the rates of 1.7% to 2.5% reported in a study from the mid-1990s[11] but remains higher than the rates of 0.5% to 0.8% published in the studies[4,5] that led to regulatory approval of the procedure. Likewise, the 30-day mortality rate for carotid stenting (2.3%) was higher than the rates reported in the initial randomized trial of carotid stenting with embolic protection devices (1.2%).[14] Because this analysis was limited to elderly Medicare beneficiaries, the differences between the mortality rates we observed and those re-

ported in clinical trials are not unexpected. The differences likely reflect the differential selection of high-risk patients into the carotid stenting cohort, consistent with the CMS national coverage decision.

Our study has some limitations. First, Medicare claims data do not include information about symptom status, the presence of high surgical risk features such as contralateral carotid occlusion, the presence of significant coronary artery disease and heart failure, and patient preferences. These variables are unlikely to explain the substantial geographic variation we observed but may lessen some of the observed differences. Unmeasured clinical variables may also confound the relationship between observed covariates and the receipt of carotid revascularization in the multivariable model. Second, the absence of detailed clinical data prevented us from calculating risk-adjusted mortality rates. To adjust the comparisons on the basis of the available data—and therefore imply risk adjustment—would be misleading. Third, because we restricted the multivariable analyses to patients who underwent MRA or angiography (invasive or noninvasive), the results may not be generalizable to patients for whom revascularization was preceded by carotid ultrasonography only. Fourth, the analysis included only patients enrolled in fee-for-service Medicare, so the generalizability of the results to all Medicare beneficiaries is unclear. Finally, we observed patients from the time they became eligible for Medicare, so carotid revascularization in patients younger than 65 years is not reflected in the analysis.

Significant geographic variation was seen in the use of carotid endarterectomy and carotid stenting among Medicare beneficiaries and variation in the carotid imaging modalities used before revascularization. Moreover, men and patients with a prior diagnosis of peripheral vascular disease were more likely to undergo carotid revascularization, and patients with a prior diagnosis of coronary artery disease or a prior carotid endarterectomy were more likely to undergo carotid stenting. These findings suggest that the development of consensus regarding clinical criteria for carotid imaging, such as a national standard for appropriate use criteria, is required. Moreover, these data highlight important differences between patients who undergo carotid revascularization with carotid endarterectomy and those who undergo stenting with embolic protection. Ongoing clinical trials will provide critical guidance for the treatment of patients who are eligible for either method of revascularization.

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INVITED COMMENTARY

The Good, the Bad, and the About-to-Get Ugly

National Trends in Carotid Revascularization

The history of carotid endarterectomy (CEA) is a fascinating good news, bad news story. Wide geographic variations in the use of CEA have been noted for 3 decades, though its popularity has been cyclical. The use of CEA doubled in the early 1980s, but then dropped in half following reports of frequent complications[1] and a national Medicare study reporting that one-third of CEAs were inappropriate.[2] Subsequently, multinational randomized controlled trials (RCTs) found that, among carefully selected patients and surgeons, CEA reduced the risk of stroke and death compared with medical therapy. Symptomatic patients (with recent carotid stroke or transient ischemic attack), showed great benefit (absolute risk reduction in stroke of 8% per year) over 2 to 3 years.[3] Asymptomatic patients had more modest benefit (absolute risk reduction of 1% per year) over 5 years.[4,5]

Good news followed these rare RCTs of surgery. Practice followed evidence and CEA use doubled.[1] A population-based Medicare study also found dramatic declines in CEA for "inappropriate" and "uncertain" indications (32% to 9% and 32% to 4%, respectively), and non-RCT indications (70%-6%).[6]

The bad news was that despite the dramatic drop in overuse, nearly 1 in 11 CEAs were still deemed inappropriate, mostly in asymptomatic patients with high comorbidity.[6] Paradoxically, there is also evidence that it is both *underused* and *overused* in minorities.[7,8] There has also been "mission creep." Carotid endarterectomy started out as revascularization for symptomatic patients, though now 70% to 80% of cases are for asymptomatic disease.[6]

Carotid angioplasty and stenting (CAS), the less-invasive but less well-proven endovascular alternative,