The Underuse of Interventions in Veterans With Symptomatic Carotid Stenosis

Salomeh Keyhani, MD; Eric M. Cheng, MD, MS; Susan Ofner, MS; Linda S. Williams, MD; Ethan A. Halm, MD; and Dawn M. Bravata, MD

ABSTRACT

Objectives

To examine the receipt of carotid intervention among eligible patients post stroke in the Veterans Health Administration (VA).

Methods

We examined whether veterans admitted to a VA medical center in 2007 with a diagnosis of stroke and who were eligible for intervention, received carotid intervention in a period up to 6 months after their index hospitalization. We also examined whether demographics, comorbid conditions, stroke severity and availability of vascular intervention services were independently associated with receipt of intervention.

Results

Among the 5721 patients admitted, 253 ischemic stroke patients had evidence of some carotid stenosis and had data on side of stroke available. Among the 200 patients who had at least 50% to 99% stenosis of the carotid artery, 34 (17%) received intervention (95% confidence interval [CI], 11.79%-22.21%). In a multivariable model, black race and past history of diabetes were significantly associated with carotid intervention: An eligible black patient was 6 times more likely to NOT receive intervention compared to patients of other races (adjusted odds ratio [OR] = 6.54; 95% CI, 1.34-31.9), and a patient with diabetes was 3 times more likely to NOT receive intervention (adjusted OR = 3.38; 95% CI, 1.24-9.24) compared to nondiabetics. Stroke severity and availability of vascular surgery services was not associated with receipt of intervention.

Conclusions

Few patients with symptomatic carotid stenosis who were admitted with stroke to the VA received carotid intervention. Future research should be directed at improving access to this procedure among eligible patients in the VA.

Am J Manag Care. 2014;20(7):e250-e256

Stroke is the fourth leading cause of death and a leading cause of disability among adults in the US.[1] Approximately 10 to 15% of ischemic strokes are attributable to atherosclerosis of the internal carotid arteries.[2] Carotid stenosis is categorized as either symptomatic or asymptomatic. Patients with recent (less than 6 months) ischemic stroke or transient ischemic attack (TIA) in the vascular distribution of a partially blocked carotid artery are defined as having symptomatic carotid stenosis, and patients who have not had either a TIA or stroke in the distribution of the stenotic artery are defined as having asymptomatic carotid stenosis.[3]

Carotid endarterectomy (CEA) is the only surgical intervention proven in randomized controlled trials (RCTs) to reduce the risk of stroke.[4-9] Carotid artery stenting (CAS) is a newer, less invasive, percutaneous procedure that involves angioplasty of the carotid stenosis and placement of a stent to open the stenotic area.[10, 11] For persons with symptomatic severe (>70%) carotid stenosis, the absolute risk reduction for CEA is 17% over 2 years (8.5% per year).[12] This translates to an annualized number-needed-to-treat (NNT) of about 12, among the lowest annualized NNT reported for any secondary stroke intervention. In other words, CEA is highly effective at reducing the risk of subsequent stroke and is recommended in the management of patients with symptomatic severe carotid stenosis. Carotid stenting has never been compared to medical therapy. However, a large RCT that compared carotid stenting to CEA showed that patients undergoing either procedure had similar rates of a primary outcome consisting of stroke, myocardial infarction, or death during the periprocedural period, or ipsilateral stroke within 4 years of randomization.[13] A recent meta-analysis concluded that these procedures should be considered "complementary rather than competing modes of therapy" and patient selection may play a role in who would benefit from either modality of intervention.[14]

Although a number of studies have examined the appropriate use of CEA among patients who have received inter-

vention in the Medicare program,[3,15-17] very few studies have examined the underuse of this procedure in patients with stroke—those who stand to benefit the most from revascularization. To our knowledge only 1 study, published more than 15 years ago, examined the use of carotid intervention in a cohort of veterans which demonstrated underuse of CEA in both symptomatic and asymptomatic populations.[18] Given the large and well-accepted clinical benefit in stroke reduction, the appropriate receipt of revascularization in this high-risk population is particularly of interest.

Take-Away Points

Most national focus on performance measurement and quality reporting turn to simple measures such as receipt of an aspirin, a beta-blocker, or a simple lab test. Although more difficult to accurately measure, there is likely significant room for improvement around decisions about more complex measures that are just as important to a patient's health.

- Symptomatic carotid stenosis is uncommon among Veterans admitted to a VA hospital for acute ischemic stroke.
- Among those with symptomatic carotid stenosis, a minority of patients received carotid revascularization within 6 months after stroke.
- Availability of local vascular intervention services was not associated with receiving carotid revascularization.

In this study, we examined the use of carotid intervention among patients with an acute ischemic stroke in the Veterans Health Administration (VA) and determined factors associated with receipt of intervention. We specifically hypothesized that access to vascular surgery services at the VA medical center (VAMC) where patients were admitted for the management of their stroke may be associated with receipt of intervention.

METHODS

Data Sources

As part of the VA Stroke Special Study conducted in 2007, a multidisciplinary team with members drawn from the VA Office of Quality and Performance, the VA Stroke Quality Enhancement Research Initiative (QUERI), the VA Office of Patient Care Services, and the VA Office of Nursing Services was assembled to develop stroke quality measure specifications and to develop the data collection methodology.[19-21] Data from the VA Stroke Special Study pertaining to carotid imaging use was used in this study. Data on availability of carotid intervention services (CEA or CAS) was obtained from the National VA SAS databases. Data on receipt of carotid intervention in the Medicare program was obtained from the Medpar and physician supplier files. We examined whether any eligible veteran received CEA using *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) code 38.12 from the Medpar file and CPT code 35301 from outpatient data. Similarly, we identified patients who received CAS using *ICD-9-CM* codes 00.61 and 00.63 and CPT codes 37215 and 37216 6 months post stroke in the Medicare program.[3,22]

Data Collection

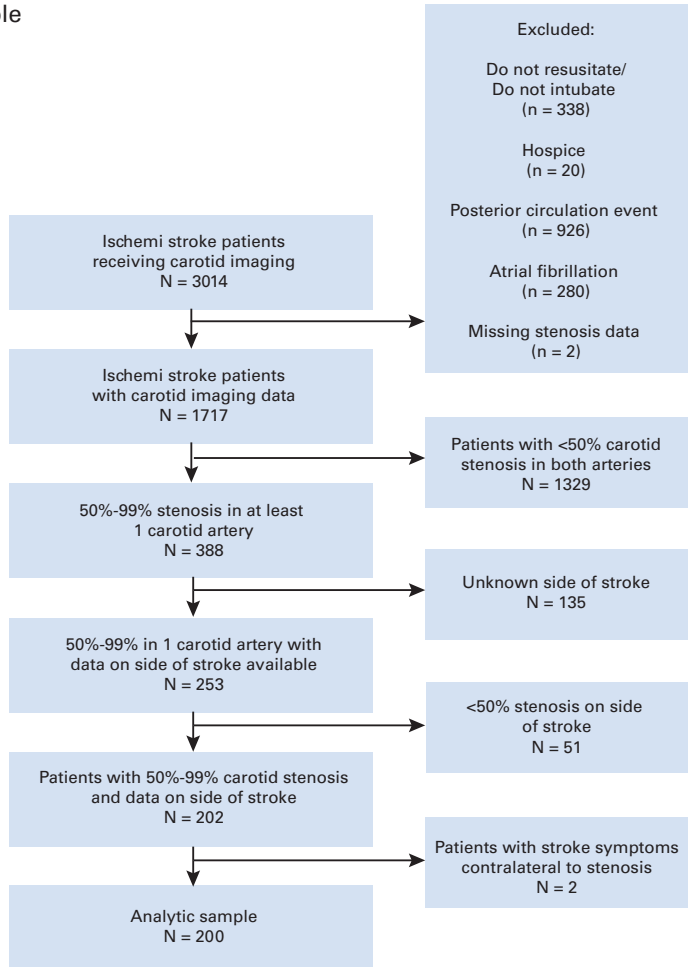
A national cohort of all veterans (N = 5721) admitted to a VAMC between October 1, 2006, and September 30, 2007, with a primary discharge diagnosis of ischemic stroke were identified from VA administrative data using a modified high specificity algorithm of *ICD-9-CM*.[23] A sample of 5000 medical records was obtained by including all veterans at small-volume centers (≤55 patients in fiscal year 2007) and an 80% random sample of veterans at high-volume centers (>55 patients in fiscal year 2007). Trained nurse abstractors confirmed a diagnosis of ischemic stroke in 3987 patients and then proceeded with a chart review of 307 data elements among the confirmed patients. Data elements especially relevant to this study from chart review include results of carotid studies, receipt of carotid intervention, comorbid conditions, code status, and stroke characteristics. Inter-rater reliability was greater than 70% for over 90% of data elements.

Study Population

Among the 3987 patients, 3014 received at least 1 carotid imaging test (**Figure**). We excluded the following patients: those with a code status of do not resuscitate/do not intubate (N = 338) or who were discharged to hospice (N = 20), because these patients would likely be too ill to receive CEA or CAS; patients with posterior circulation stroke (N = 926) because the carotid stenosis would be classified as asymptomatic (see assessing side of stroke, below); patients who had atrial fibrillation (N = 280) because the original randomized controlled trials excluded such patients; and patients with missing data on carotid stenosis (N = 2). That left 1717 patients for the analyses.

The American Academy of Neurology recommends CEA for severe (70%-99%) symptomatic stenosis and considers CEA as only moderately useful for symptomatic patients with 50%-69% stenosis.[12] Current guidelines do not recommend surgery for patients with less than 50% stenosis.[12] Similarly, the American Heart Association and the American Stroke Association guideline recommends carotid intervention for patients at average or low surgical risk who experience nondisabling ischemic stroke or transient cerebral ischemic symptoms, within 6 months of the event,

Figure. Analytic Sample



if the stenosis of the lumen of the ipsilateral internal carotid artery is more than 70% as documented by noninvasive imaging or more than 50% as documented by catheter angiography, and the anticipated rate of perioperative stroke or mortality is less than 6%.[10] We considered patients appropriate for intervention if they had documented carotid stenosis between 50% and 99% and had had a stroke in the distribution of the carotid artery. Among the 1717 patients with data on carotid imaging, 388 had stenosis of 50%-99% in at least 1 artery. However, we only had data on side of stroke for 253 (65%) of these patients and could not conclusively evaluate underuse of carotid intervention in patients without data on the side of stroke. Therefore, the main sample for the analyses included 253 patients with documented severe carotid stenosis and a stroke in the distribution of the carotid artery (Figure).

Variables

The key outcome measure was **not** receiving guideline-recommended carotid intervention within 6 months of hospital discharge for acute ischemic stroke for patients with severe symptomatic carotid stenosis. The main independent variables included age, race, stroke severity based on the retrospective National Institutes of Health (NIH) Stroke Scale, comorbid conditions, and availability of vascular surgery at the VAMC where the patient was admitted for stroke. Among the 130 hospitals in the VA, 84 hospitals have vascular surgery services.

Analyses

Because the vast majority of patients (>76%) in the VA receive CEA as the method for carotid revascularization, and because a recent meta-analysis suggested CEA and CAS are comparable[14], we examined the combined receipt of carotid intervention rather than these procedures separately. First, we determined the proportion of eligible patients who received carotid intervention in the VA. We also examined receipt of carotid intervention up to 6 months post stroke in the Medicare program for patients aged ≥65 years.

We then examined factors associated with guideline-recommended receipt of carotid intervention, defined as a patient with significant stenosis on the same side as his

or her stroke. Because the guidelines more strongly recommend receipt of intervention for those with severe stenosis (70%-99%),[11] we limited the multivariable analyses to these patients. We ran bivariate tests between not having a CEA or stent and various explanatory factors. For continuous measures, we used 2 sample *t*-tests or Wilcoxon's non-parametric 2-sample test. For binary factors, we used Fisher's exact or χ^2 square tests. Factors which were statistically significant at the 0.05 level were entered into a multivariable logistic regression model. We also included factors deemed clinically important such as age >75 years, severity on the NIH stroke scale[24], Charlson comorbidity score, and whether or not the hospital of the patient's stroke admission had access to a vascular surgeon. The logistic model was fit using generalized estimating equations techniques[25] to accommodate the clustering of patients within hospitals.

In a sensitivity analysis, we included patients for whom side of stroke data were missing, to examine whether factors associated with underuse of imaging were consistent across this larger sample. Analyses were conducted using SAS for Windows version 9.1 (SAS Institute, Cary, North Carolina).

RESULTS

Receipt of Carotid Intervention among Eligible Patients

Among the 253 ischemic stroke patients who had carotid stenosis and had data on side of stroke available (Figure), 202 patients had 50%-99% stenosis of the carotid artery and were eligible to receive carotid intervention. Two patients who received CEA had symptoms to the stenosis (i.e. a symptomatic stenosis) and were excluded from the analyses. Among the remaining 200 patients with carotid stenosis, 34 (17%) received intervention (95% CI, 11.79%-22.21%). In other words, 83% of eligible patients with 50%-99% stenosis did not receive appropriate intervention.

Among the 200 eligible patients, 84 had stenosis of 70% or greater and 26 (30.95%) of these patients received intervention appropriately. Among the 116 with 50%-69% carotid stenosis, 8 (6.9%; 95% CI, 2.29%-11.51%) received intervention appropriately. Of note, our review of Medicare data suggested that none of the eligible patients aged 65 and older received carotid intervention in the Medicare program in the 6-month period post discharge; therefore, all of the interventions for these veterans occurred within the VA system.

Characteristics of Eligible Patients as a Function of Intervention

In bivariate analyses, patients who did not receive intervention were on average older than patients who received intervention although this difference was not statistically significant (67.8 years vs 63.5 years; $P = .09$) (**Table 1**). A higher proportion of black patients were in the group of patients who did not receive intervention compared to those who did receive intervention (24.1% vs 4.0%; $P = .008$). A higher proportion of patients with diabetes were also in the group of patients who did not receive intervention (51.7% vs 23.1%; $P = .01$).

In a multivariable model, we examined lack of receipt of appropriate carotid intervention as a function of age greater than 75 years, black race, stroke severity (based on the retrospective NIH Stroke Scale), past history of diabetes, and presence of onsite vascular surgery service at the VAMC where the patient was treated for stroke. Although onsite vascular surgery was not significantly associated with receipt of carotid intervention in univariate analyses, we retained this variable in the final model because we had hypothesized that this variable is important to receipt of appropriate intervention. Black race and past history of diabetes were significantly associated with carotid intervention: An eligible black patient was 6 times more likely to NOT receive intervention compared to patients of other races (adjusted odds ratio [OR] = 6.54; 95% CI, 1.34-31.9), and a patient with diabetes was 3 times more likely to NOT receive intervention (adjusted OR = 3.38; 95% CI, 1.24-9.24) compared to nondiabetics. Availability of vascular surgery services was not associated with receipt of intervention (Table 1).

The sensitivity analyses which included patients with side of stroke missing (147 total patients) demonstrated findings similar to those of the main analysis, in which black patients and those with diabetes were less likely to receive intervention (**Table 2**).

DISCUSSION

In this national study of veterans with recent stroke, we found substantial underuse of proven effective revascularization. Fewer than 1 in 5 (17%) patients for whom national guidelines recommend CEA or CAS had a procedure within 6 months of their stroke. In the setting of considerable underuse, those patients with severe (>70%-99%) carotid stenosis were more likely to be revascularized, compared with those with more moderate stenosis (50%-69%). Those results should be expected because the RCTs show that there is a greater efficacy of carotid revascularization among patients with tighter carotid stenosis.

We did not find an association between access to vascular surgery services and receipt of intervention, but this may be a consequence of the very low rate at which stroke

Table 1. Characteristics of Eligible Patients Who Received Intervention Among Patients With 70% or Greater Symptomatic Carotid Stenosis

	Side of Stroke Known (n = 84)			Includes Patients With Missing Side of Stroke (n = 147)		
	Received CEA/CAS	Did Not Receive CEA/CAS	*P*	Received CEA/CAS	Did Not Receive CEA/CAS	*P*
Demographics						
Age :Mean (SD)	63.5 (10.9),	67.8 (10.1)	.09	64.8 (10.7)	68.7 (10.4)	0.04
Male	26 (100%)	58 (100%)		41 (100%)	105 (99.1%)	0.99
Race						
White (%)	20 (80.0%)	43 (74.1%)	**.008**	34 (85.0%)	83 (78.3%)	**0.04**
Black (%)	1 (4.0%)	14 (24.1%)		2 (5.0%)	19 (17.9%)	
Other (%)	4 (16.0%)	1 (1.7%)		4 (10.0%)	4 (3.8%)	
Clinical Characteristics						
NIHSS Mean (SD)	5.0 (3.3)	5.5 (3.2)	.39	3.6 (3.3)	3.7 (3.4)	0.85
Hypertension	23 (88.5%)	50 (86.2%)	.99	33 (80.5%)	90 (84.9%)	0.52
Hyperlipidemia	16 (61.5%)	32 (55.2%)	.59	22 (53.7%)	60 (56.6%)	0.75
Diabetes Mellitus	6 (23.1%)	30 (51.7%)	**.01**	10 (24.4%)	49 (46.2%)	0.02
Coronary Artery Disease	7(26.9%)	23 (39.7%)	.26	13 (31.7%)	43 (40.6%)	0.32
Depression	2 (7.7%)	9 (15.5%)	.49	6 (14.6%)	20 (18.9%)	0.55
COPD/asthma	2 (7.7%)	8 (13.8%)	.72	5 (12.2%)	15 (14.2%)	0.76
Congestive heart failure	0 (0.0%)	4 (6.9%)	.31	1 (2.4%)	13 (12.3%)	0.11
Peripheral vascular disease	2 (7.7%)	7 (12.1%)	.71	7 (17.1%)	14 (13.2%)	0.55
Cancer	0 (0.0%)	1 (1.7%)	.99	0 (0.0%)	2 (1.9%)	0.99
Dementia	2 (7.7%)	5 (8.6%)	.99	2 (4.9%)	9 (8.5%)	0.73
Charlson Comorbidity Index (median, range)	1 (0,6)	1 (0,7)	.08	1 (0,6)	1 (0,7)	0.08
Availability of Vascular Surgery at VA Medical Center	21 (80.8%)	47 (81.0%)	.99	35 (85.4%)	83 (78.3%)	0.33

Boldfaced numbers are statistically significant. CAS indicates carotid artery stenting; CEA, carotid endarterectomy; COPD, chronic obstructive pulmonary disease; NHSS, National Institutes of Health Stroke Scale.

patients received carotid intervention and the small sample. In addition, eligible black patients with symptomatic carotid stenosis were significantly less likely to receive intervention. Prior VA research has also demonstrated this disparity, but found that it was due to patient preferences and black patients being less likely to opt for intervention.[26] However, in this same dataset we previously reported that blacks were less likely to have a carotid imaging test post stroke, and that this difference was largely dependent on overall low rates of post stroke carotid imaging in both blacks and whites in just a few hospitals.[27] Taken together, these findings do suggest that further study of possible reasons for the observed disparities in imaging and intervention should be explored.

This paper demonstrates that underuse of CEA persists in the VA. Our results are particularly concerning in the context of both the efficacy of this procedure in symptomatic and asymptomatic populations and the use of this procedure nationally. For persons with symptomatic severe (>70%) carotid stenosis, CEA is highly effective at reducing the risk of subsequent stroke (annualized number needed to treat of about 12).[12] However, the benefit of CEA for persons with asymptomatic carotid stenosis is much more modest. A meta-analysis of the 2 largest RCTs showed that CEA for asymptomatic carotid stenosis reduces the risk of stroke or death from about 2% to 1% per year, translating to an annualized NNT of about 100.[12]

Although the clinical benefit for the treatment of carotid stenosis is strongest among patients with symptomatic disease, the majority of CEAs performed in the United States are performed on patients with asymptomatic carotid artery stenosis.[3,15,17] Data from the New York Carotid Artery Study, a cohort study of Medicare patients who received CEA, suggests that about 72.5% of surgeries are performed on asymptomatic patients.[3] The use of CAS has demonstrated a fourfold increase between 1997 and 2008, growing from 0.1 to 0.6 procedures per 1000 Medicare ben-

Table 2. Adjusted Odds Ratio of NOT Receiving Carotid Intervention Among Eligible Patients with Severe Symptomatic Carotid Stenosis

	Side of Stroke Known (n = 84)			Includes Patients With Missing Side of Stroke (n = 147)		
	Adjusted Odds Ratio	95% CI	*P*	Adjusted Odds Ratio	95% CI	*P*
Age >75	2.24	(0.72, 6.90)	.16	2.23	(0.90, 5.50)	.08
Black	6.54	(1.34, 31.99)	**.02**	4.67	(1.13, 19.27)	**.03**
NIHSS	0.99	(0.86, 1.14)	.92	0.97	(0.87, 1.08)	.59
Diabetes	3.38	(1.24, 9.24)	**.02**	2.64	(1.06, 6.60)	**.04**
Vascular Surgeon at VAMC	0.75	(0.19, 2.96)	.68	0.54	(0.20, 1.51)	.24

Boldfaced numbers are statistically significant. NHSS indicates National Institutes of Health Stroke Scale.

eficiaries[22], with over two-thirds of procedures performed on patients who are asymptomatic.[28,29] Similarly, in the VA, 60% of procedures are performed on patients who are asymptomatic. Why so few patients with symptomatic disease and especially stroke receive intervention despite its superior efficacy in this population is of particular concern.

Our results may also be of interest to settings beyond the VA. In this era of quality improvement, most national focus on performance measurement and quality reporting turns to simple measures such as receipt of an aspirin, a beta-blocker, or a simple lab test (eg, glycolated hemoglobin and lipids). Collecting data on procedures is more complex and requires multiple variables. The VA has been a leader in evaluating the appropriate use (both underuse and overuse) of interventions partly because its incentive structure is different and has a primary mission of improving the quality of care delivered to veterans. The national VA commitment to improving quality is evidenced by the development of the Health Services Research and Development Quality Enhancement Research Initiative, which focuses on improving the quality of care delivered in multiple areas, including diabetes, mental health, substance abuse, stroke, ischemic heart disease, and heart failure. Other health systems have much less incentive to focus on improving care in areas that are not the focus of national performance metrics. There needs to be a collective investment in developing measures around the underuse and overuse of procedures and services that cost the health system significant resources and have a higher impact on morbidity and mortality. Without a national investment in developing measures and public reporting, it is doubtful that quality improvement, as often seen in the VA, will move into these more complex and costly areas.

Limitations

This study has a number of limitations that deserve comment. We did not have side of stroke on 35% of the sample. To address this limitation, in our multivariable analyses we conducted a sensitivity analysis which included patients with missing side of stroke but who were eligible for intervention based on presence of symptomatic severe stenosis. Inclusion of this larger sample confirmed our main findings. In addition, this study was a medical record abstraction and therefore we do not have data on patient preferences for intervention. However, we did collect some data on documented reasons for not performing the procedure. Physicians documented that 3 patients who were eligible refused intervention and that another 28 had specific reasons for not wanting the procedure performed (data on type of reason were not available). If these patients had been excluded from the set of eligible patients, the rate of underuse would still approach 80%, which confirms the underuse of this procedure in the population. However, it is still possible that many reasons were not documented and our estimates represent an overestimate of underuse in the VA. In addition, some veterans under age 65 could have received intervention in a non-VA hospital and we were unable to capture information on non-VA sources for this procedure. Finally, we hypothesized that lack of availability of vascular surgery services are associated with underuse of intervention. The 84 eligible patients with severe stenosis in our sample were seen in 53 hospitals. The number of eligible patients within each hospital ranged from 1 to 5 with 35 (66.04%) hospitals having only 1 patient. A larger sample consisting of more patients within hospitals would be required to more fully investigate patient-level vs institution-level factors. More research is necessary before fully dismissing access to vascular surgery services as a potential explanatory factor for the underuse of this procedure.

In conclusion, few stroke patients with symptomatic carotid stenosis in the VA received carotid intervention. Future research should be directed at improving access to this procedure among eligible patients.

Author affiliations: San Francisco VA Medical Center HSR&D REAP, San Francisco, CA, and Division of General Internal Medicine, UCSF, San Francisco, CA (SK); Department of Neurology, VA Greater Los Angeles Healthcare System, Los Angeles, CA, and Department of Neurology, University of California at Los Angeles, Los Angeles, CA (EMC); VHA HSR&D Center of Excellence on Implementing Evidence-Based Practice; Richard L. Roudebush VA Medical Center, Indianapolis, IN, Indiana University Center for Aging Research, Indiana University School of Medicine, Indianapolis, IN, Regenstrief Institute, Indianapolis, IN (LSW); Department of Biostatistics, Indiana University School of Medicine (SO); VHA HSR&D Stroke Quality Enhancement Research Initiative Program; Indianapolis, IN (SK, EMC, SO, LSW, DMB); Department of Neurology, Indiana University School of Medicine (LSW, DMB); Department of Internal Medicine, Indiana University School of Medicine (DMB); Departments of Internal Medicine and Clinical Sciences, University of Texas Southwestern Medical Center, Dallas, TX (EAH).

Funding source: The project reported here was supported by the Department of Veterans Affairs, Veterans Health Administration (VHA), Office of Quality and Performance and Health Services Research and Development Service Quality Enhancement Research Initiative (RRP 09-184). SK is also supported by a VA HSR&D Career Development Award. EMC is supported by a Career Development Award from NIH/NINDS (K23NS058571).

Author disclosures: The authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article. The views expressed in this article are those of the authors and do not necessarily represent the views of the Department of Veterans Affairs.

Authorship information: Concept and design (SK, EMC, LSW); acquisition of data (SK, DMB); analysis and interpretation of data (SK, EMC, SO, LSW, DMB); drafting of the manuscript (SK, SO); critical revision of the manuscript for important intellectual content (SK, EMC, LSW, EAH, DMB); statistical analysis (SK, SO); provision of study materials or patients (SK); obtaining funding (SK); administrative, technical, or logistic support (SK, LSW, DMB); supervision (SK).

Address correspondence to: Salomeh Keyhani, MD, MPH, San Francisco VA Medical Center, 4150 Clement St (111A1), San Francisco, CA 94121. E-mail: salomeh.keyhani@ucsf.edu.

REFERENCES

1. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics--2011 update: a report from the American Heart Association. *Circulation*. 2011;123(4):e18-e209.

2. White H, Boden-Albala B, Wang C, et al. Ischemic stroke subtype incidence among whites, blacks, and Hispanics: the Northern Manhattan Study. *Circulation*. 2005;111(10):1327-1331.

3. Halm EA, Tuhrim S, Wang JJ, Rojas M, Hannan EL, Chassin MR. Has evidence changed practice?: appropriateness of carotid endarterectomy after the clinical trials. *Neurology*. 2007;68(3):187-194.

4. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med*. 1991;325(7):445-453.

5. North American Symptomatic Carotid Endarterectomy Trial. Methods, patient characteristics, and progress. *Stroke*. 1991;22(6):711-720.

6. MRC European Carotid Surgery Trial: interim results for symptomatic patients with severe (70-99%) or with mild (0-29%) carotid stenosis. European Carotid Surgery Trialists' Collaborative Group. *Lancet*. 1991;337(8752):1235-1243.

7. Endarterectomy for asymptomatic carotid artery stenosis. Executive Committee for the Asymptomatic Carotid Atherosclerosis Study. *JAMA*. 1995;273(18):1421-1428.

8. Halliday A, Harrison M, Hayter E, et al. 10-year stroke prevention after successful carotid endarterectomy for asymptomatic stenosis (ACST-1): a multicentre randomised trial. *Lancet*. 2010;376(9746):1074-1084.

9. Halliday A, Mansfield A, Marro J, et al. Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. *Lancet*. 2004;363(9420):1491-1502.

10. Brott TG, Halperin JL, Abbara S, et al. 2011 ASA/ACCF/AHA/AANN/AANS/ACR/ASNR/CNS/SAIP/SCAI/SIR/SNIS/SVM/SVS guideline on the management of patients with extracranial carotid and vertebral artery disease: executive summary: a report of the American College of Cardiology Foundation/American Heart Association Task Force on practice guidelines, and the American Stroke Association, American Association of Neuroscience Nurses, American Association of Neurological Surgeons, American College of Radiology, American Society of Neuroradiology, Congress of Neurological Surgeons, Society of Atherosclerosis Imaging and Prevention, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of NeuroInterventional Surgery, Society for Vascular Medicine, and Society for Vascular Surgery. *Stroke*. 2011;42(8):e420-463.

11. Goldstein LB, Bushnell CD, Adams RJ, et al. Guidelines for the primary prevention of stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2011;42(2):517-584.

12. Chaturvedi S, Bruno A, Feasby T, et al. Carotid endarterectomy--an evidence-based review: report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. *Neurology*. 2005;65(6):794-801.

13. Brott TG, Hobson RW 2nd, Howard G, et al. Stenting versus endarterectomy for treatment of carotid-artery stenosis. *N Engl J Med*. 2010;363(1):11-23.

14. Liu ZJ, Fu WG, Guo ZY, Shen LG, Shi ZY, Li JH. Updated systematic review and meta-analysis of randomized clinical trials comparing carotid artery stenting and carotid endarterectomy in the treatment of carotid stenosis. *Ann Vasc Surg*. 2012;26(4):576-590.

15. Halm EA, Chassin MR, Tuhrim S, et al. Revisiting the appropriateness of carotid endarterectomy. *Stroke*. 2003;34(6):1464-1471.

16. Halm EA, Press MJ, Tuhrim S, Wang J, Rojas M, Chassin MR. Does managed care affect quality? appropriateness, referral patterns, and outcomes of carotid endarterectomy. *Am J Med Qual*. 2008;23(6):448-456.

17. Karp HR, Flanders WD, Shipp CC, Taylor B, Martin D. Carotid endarterectomy among Medicare beneficiaries: a statewide evaluation of appropriateness and outcome. *Stroke*. 1998;29(1):46-52.

18. Horner RD, Oddone EZ, Stechuchak KM, Johnston DC, Grambow SC. Who doesn't receive carotid endarterectomy when appropriate? *J Vasc Surg*. 2004;39(1):162-168.

19. Arling G, Reeves M, Ross J, et al. Estimating and reporting on the quality of inpatient stroke care by Veterans Health Administration Medical Centers. *Circ Cardiovasc Qual Outcomes*. 2012;5(1):44-51.

20. Keyhani S, Arling G, Williams LS, et al. The use and misuse of thrombolytic therapy within the Veterans Health Administration. *Medical Care*. 2012;50(1):66-73.

21. Ross JS, Arling G, Ofner S, et al. Correlation of inpatient and outpatient measures of stroke care quality within Veterans Health Administration hospitals. *Stroke*. 2011;42(8):2269-2275.

22. Goodney PP, Travis LL, Malenka D, et al. Regional variation in carotid artery stenting and endarterectomy in the Medicare population. *Circ Cardiovasc Qual Outcomes*. 2010;3(1):15-24.

23. Reker DM, Reid K, Duncan PW, et al. Development of an integrated stroke outcomes database within Veterans Health Administration. *J Rehabil Res Dev*. 2005;42(1):77-91.

24. Williams LS, Yilmaz EY, Lopez-Yunez AM. Retrospective assessment of initial stroke severity with the NIH Stroke Scale. *Stroke*. 2000;31(4):858-862.

25. Diggle PJ, Heagerty PJ, Liang KY, Zeger SL. *Analysis of Longitudinal Data*. Oxford, UK: Clarendon Press; 1996.

26. Oddone EZ, Horner RD, Johnston DC, et al. Carotid endarterectomy and race: do clinical indications and patient preferences account for differences? *Stroke*. 2002;33(12):2936-2943.

27. Cheng EM, Keyhani S, Ofner S, et al. Lower use of carotid artery imaging at minority-serving hospitals. *Neurology*. 2012;79(2):138-144.

28. Gray WA, Chaturvedi S, Verta P; Investigators and the Executive Committees. Thirty-day outcomes for carotid artery stenting in 6320 patients from 2 prospective, multicenter, high-surgical-risk registries. *Circ Cardiovasc Interv*. 2009;2(3):159-166.

29. Nallamothu BK, Lu M, Rogers MA, Gurm HS, Birkmeyer JD. Physician specialty and carotid stenting among elderly Medicare beneficiaries in the United States. *Arch Intern Med*. 2011;171(20):1804-1810. ■