Physician Specialty and Carotid Stenting Among Elderly Medicare Beneficiaries in the United States

Brahmajee K. Nallamothu, MD, MPH; Mingrui Lu, MPH; Mary A. M. Rogers, PhD; Hitinder S. Gurm, MD; John D. Birkmeyer, MD

Background: The use of carotid stenting is rising across the United States. How physician specialty relates to its utilization rates or outcomes is uncertain.

Methods: We performed an observational analysis of fee-for-service Medicare beneficiaries 65 years or older undergoing carotid stenting between 2005 and 2007 in 306 hospital referral regions (HRRs). We first determined how frequently carotid stenting was performed by different specialists within each HRR and then used multivariable regression models to compare population-based utilization rates and 30-day outcomes for this procedure across HRRs based on the proportion performed by cardiologists, surgeons, radiologists, or a mix of specialists.

Results: In 272 HRRs where at least 15 procedures were performed during the study period, we identified 28 700 carotid stenting procedures performed by 2588 operators. While cardiologists made up approximately one-third of these operators, they were responsible for 14 919 (52.0%) procedures. Significant differences were noted in the characteristics of patients treated by cardiologists compared with other specialties, including higher rates of invasive cardiac procedures and lower rates of acute stroke or transient ischemic attacks in the 180 days prior to carotid stenting. Population-based utilization rates were significantly higher in HRRs where cardiologists performed most procedures relative to HRRs where most were done by other specialists or a mix of specialists ($P < .001$). In contrast, risk-standardized outcomes did not differ across HRRs based on physician specialty.

Conclusions: Carotid stenting is being performed by operators from diverse specialties. Hospital referral regions where cardiologists perform most procedures have higher population-based utilization rates with similar outcomes.


NARLY 100 000 AMERICANS undergo carotid endarterectomy each year with the goal of reducing their risk of stroke.¹ This operative procedure is performed by surgeons, traditionally following diagnostic carotid and cerebral angiography by radiologists. A promising and innovative alternative to carotid endarterectomy is carotid stenting, which is a minimally invasive, endovascular procedure that may be of particular benefit in high-risk patients.² Since its initial approval in late 2004, use of carotid stenting has grown rapidly across the United States.³⁴ with enthusiastic adoption by operators from several diverse physician specialties including surgery, radiology, and cardiology.³ While its performance by surgeons and radiologists is not unexpected, the large numbers of cardiologists involved with carotid stenting has been somewhat more surprising, especially given their limited prior experiences with carotid disease or stroke care in general. Yet for many reasons a cardiologist performing carotid stenting makes perfect sense.⁶⁷ Cardiologists care for many elderly patients with atherosclerotic heart disease, so their involvement could lead to greater recognition and earlier treatment of carotid disease. Extensive experience with catheter-based techniques in the coronary arteries also makes it potentially straightforward for them to learn the skills required for it. Yet the involvement of cardiologists in carotid stenting is not without concern. The overall benefits of carotid stenting remain controversial,⁸ and a growing role of cardiologists in other noncardiac vascular interventions has led to increases in their overall use with no differences in patient outcomes.⁹¹⁰ Accordingly, we examined national data on elderly Medicare beneficiaries to de-
For the aforementioned reasons, we focused on comparing carotid stenting performed by cardiologists with those done by other specialists. Understanding how physician specialty may affect the utilization rate of a novel procedure like carotid stenting has important implications for optimizing its dissemination.

### METHODS

#### DATA SOURCES AND STUDY COHORT

From the Centers for Medicare & Medicaid Services (CMS), we obtained Physician Carrier (Part B), Medicare Provider Analysis and Review (MEDPAR), and Denominator files from January 1, 2005, to December 31, 2007. Physician Carrier files include data on claims for procedures from noninstitutional health care providers, such as physicians, while MEDPAR files include data on acute care hospitalizations and Denominator files contain information on eligibility and enrollment. Data on all Medicare beneficiaries 65 years or older enrolled in fee-for-service programs within the United States were included. The institutional review board of the University of Michigan and the CMS approved this protocol prior to its initiation. The requirement for informed consent was waived and approved.

From the Physician Carrier files, we identified all procedures of carotid stenting using Healthcare Common Procedure Coding Systems (HCPCS) codes 37215 and 37216. We determined the specialty of the operator performing carotid stenting using the Medicare specialty code associated with the procedure and then organized them into the following 3 categories: (1) those performed by cardiologists, (2) those performed by surgeons, and (3) those performed by radiologists. Surgeons included vascular and general surgeons as well as other surgical specialties (eg, cardiovascular surgeons, neurosurgeons). In cases when a specialty code was unreported or reflected broader fields of practice (ie, general practice or internal medicine), we searched the 2007 Medicare Unique Physician Identification Number (UPIN) Directory to determine if a more narrow specialty (eg, cardiology) was associated with that operator. Although uncommon, procedures performed by operators from specialties other than the 3 previously listed (n=679) or those performed by 2 or more operators from different specialties (n=150) were included in a separate category.

Information on age, sex, and race were also obtained for each procedure from the Physician Carrier files. For the subset of patients continuously enrolled in fee-for-service programs at least 1 year prior to their procedure (n=28,889), we reviewed all claims in the Physician Carrier and MEDPAR files to collect data on the presence of comorbidities. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnostic codes associated with these claims were used to calculate an Elixhauser comorbidity score.16 We also used these claims to determine if in the 180 days prior to carotid stenting a patient (1) had undergone a cardiac catheterization (with or without concomitant carotid x-ray angiography) or coronary intervention or (2) received a recent diagnosis of acute stroke or transient ischemic attack (TIA) based on a hospitalization or physician claim. A 180-day period was chosen, given that this length of time was also used by the Carotid Revascularization Endarterectomy vs Stenting Trial (CREST) investigators to define symptomatic disease.

### HOSPITAL REFERRAL REGIONS AND RATES OF POPULATION-BASED UTILIZATION AND OUTCOMES

Each procedure of carotid stenting was mapped to a hospital referral region (HRR) based on the patient’s residence zip code using the Dartmouth Atlas of Cardiovascular Health Care.10 Hospital referral regions are large geographic units representing distinct health care markets for tertiary care that were constructed by examining empirical patterns of care related to major cardiovascular and neurosurgical procedures in elderly Medicare beneficiaries. After assigning each procedure to 1 of 306 HRRs and determining the specialty of the operator that performed it, we further categorized HRRs into the following 3 groups: (1) those where cardiologists performed most (>50%) carotid stenting; (2) those where surgeons performed most carotid stenting; and (3) those where radiologists performed most carotid stenting. “Mixed” HRRs where no specialty performed most carotid stenting were included as a separate group. Only data from HRRs where 15 or more procedures were performed during the study period were included.

We calculated population-based utilization rates for carotid stenting in each HRR over the 3-year study period. Numerators for these rates were the total number of procedures performed on patients within the HRR, while denominators were the total number of beneficiaries within the HRR at the midpoint of each year within the study period. Utilization rates were then adjusted for differences in age (65-69, 70-74, and ≥75 years), sex, and race (black or nonblack) across HRRs using direct standardization techniques and subsequently averaged over the 3-year period. For each HRR, we also calculated (1) 30-day risk-standardized mortality and (2) 30-day risk-standardized mortality or stroke admission. We determined death at 30 days using Denominator files and stroke admission using the MEDPAR files. Risk-standardization was performed using 2-level models that accounted for clustering at the HRR level and adjusted for age, sex, race, recent diagnosis of acute stroke or TIA, Elixhauser comorbidity score, embolic protection device use, and total volume of the operator performing the procedure over the study period. From these models, we then calculated predicted and expected 30-day rates for each HRR for both outcomes to generate a standardized ratio. We multiplied this ratio by the overall 30-day mortality rate and the 30-day mortality or stroke admission rate in the study population to generate risk-standardized rates.

### STATISTICAL ANALYSIS

Analyses were performed at both the procedural and HRR level. Descriptive statistics were used to evaluate for differences in the characteristics of patients undergoing carotid stenting across specialties. We then examined how adjusted utilization rates and 30-day risk-standardized outcomes for carotid stenting varied across HRRs where cardiologists performed less than 23%, 25% to 50%, and more than 50% of the procedures. Multivariable linear regression models were then used to assess if rates of utilization and risk-standardized 30-day mortality differed between HRRs where most procedures were performed by cardiologists, relative to HRRs where most procedures were performed by surgeons or radiologists or mixed HRRs. At the HRR level, these models accounted for (1) the number of operators performing carotid stenting per 100,000 enrollees; (2) the geographic region (Northeast, South, Midwest, West); and (3) the age-, sex-, and race-adjusted rate of carotid endarterectomy in 2004. Although imperfect, we attempted to account for the overall prevalence of carotid disease in the HRR as well as overall “enthusiasm” for referral for carotid revascularization in that...
REFERENCES IN THE PREVIOUS TEXT

region by using adjusted utilization rates of carotid endarterectomy in the HRR during 2004, the year prior to the widespread introduction of carotid stenting.

All analyses were performed using SAS version 9.2 (SAS Institute, North Carolina) and Stata version 11.0 (StataCorp, College Station, Texas). P < .05 was considered significant and all tests were 2-sided.

RESULTS

In 272 HRRs where at least 15 cases were performed, we identified 28,700 carotid stenting procedures performed in 26,938 patients between January 1, 2005, and December 31, 2007. Of these, 14,919 procedures (52.0%) were performed by cardiologists, 7,840 (27.3%) by surgeons, and 5,112 (17.8%) by radiologists, with the remaining 829 (3.2%) performed by other specialties that were largely represented by neurology and internal medicine. Of the operators performing carotid stenting, 904 (34.9%) were cardiologists, 864 (33.4%) were surgeons, 719 (27.8%) were radiologists, and 101 (3.9%) were other specialists. Among surgeons, vascular surgeons made up the largest group (n = 539 [62.4%]), followed by general surgeons (n = 180 [20.8%]), neurosurgeons (n = 68 [7.9%]), and cardiothoracic surgeons (n = 68 [7.9%]). The number of procedures performed during the study period grew across all specialties but was most prominent for cardiologists and surgeons (Figure 1).

Table 1 displays the characteristics of patients undergoing carotid stenting across specialties. No significant differences were seen by sex or race across procedures performed by cardiologists relative to other specialists, although modest differences in age were noted across groups. The overall mean number of Elixhauser comorbidity conditions were slightly higher in procedures performed by cardiologists, but there were key differences in the presence of specific conditions. For example, cardiologists were more likely to perform procedures in patients with Elixhauser comorbidities related to cardiovascular conditions but less likely to do so in those with neurological conditions. Finally, rates of cardiac catheterization (including with concomitant carotid x-ray angiography) and coronary intervention in the 180 days prior to carotid stenting were significantly higher in patients undergoing carotid stenting by cardiologists. However, rates of recent diagnosis of acute stroke or TIA in the 180 days prior to carotid stenting were much less in this group.

The proportion of carotid stenting performed by cardiologists within each HRR varied substantially across markets, with a mean of 45.5% that ranged from 0% in 2 HRRs to 100% in 1 HRR. Cardiologists performed most procedures in 115 of the 272 HRRs (42.3%) included in this analysis (Figure 2). By comparison, surgeons performed most procedures in 41 HRRs (15.1%) and radiologists in 37 HRRs (13.6%). The remaining 79 mixed HRRs had no single specialty performing most procedures. Characteristics of the HRRs are displayed in Table 2, stratified by the specialty that performed most carotid stenting in that market. Overall, HRRs where cardiologists performed most procedures were more frequently located in the Midwest and South and had a higher number of operators performing carotid stenting per 100,000 enrollees.

The overall mean (SD) age-, sex-, and race-adjusted rate of carotid stenting was 3.3 (2.4) per 10,000 enrollees during the study period. Substantial variation existed in its use across HRRs with adjusted utilization rates varying from 0.3 to 20.2 per 10,000 enrollees. Hospital referral regions where cardiologists performed most carotid stenting had significantly higher adjusted utilization rates than those where cardiologists performed 25% or fewer (4.3 per 10,000 enrollees vs 2.5 per 10,000 enrollees; P < .001) (Figure 3), but no difference in 30-day risk-standardized mortality (1.9% vs 1.9%; P = .26) or 30-day risk-standardized mortality or stroke admission (4.6% vs 4.8%; P = .12). After accounting for the number of operators, geographic region, and baseline rates of carotid endarterectomy in 2004, HRRs where cardiologists performed most carotid stenting had significantly higher adjusted utilization rates relative to HRRs where most were done by other specialists or a mix of specialists but no differences in risk-standardized outcomes (Table 3).

COMMENT

Our study has 3 noteworthy findings. First, we found that cardiologists in the United States currently play an important role in carotid stenting. Approximately one-third of the operators performing this procedure in Medicare beneficiaries are cardiologists and they are responsible for more than half the total procedures. Surgeons and radiologists, in contrast, were responsible for 28% and 18% of procedures, respectively. Second, we found that cardiologists treat patients substantially different from other specialists. Not surprisingly, procedures by cardiologists more frequently involved patients with cardiac conditions or recent invasive cardiac procedures. Yet these patients also had fewer neurologic conditions, including less evidence of recent acute stroke or TIA. While it is not possible to
paralysis and other neurological conditions.

Involvement in the early evaluation of patients with stroke using diagnostic angiography influenced patient selection (i.e., case finding of severe carotid stenosis by cardiologists during diagnostic angiography) was performed by cardiologists more often than surgeons (24%), radiologists (18%), or others (34%), which suggests the possibility that routine angiography might be performed by cardiologists more often than other specialties for carotid stenting. This proportion was much lower among those treated by surgeons (24%), radiologists (18%), or others (34%), which suggests the possibility that routine angiography might be performed by cardiologists more often than other specialties for carotid stenting. This proportion was much lower among those treated by surgeons (24%), radiologists (18%), or others (34%), which suggests the possibility that routine angiography might be performed by cardiologists more often than other specialties for carotid stenting. This proportion was much lower among those treated by surgeons (24%), radiologists (18%), or others (34%), which suggests the possibility that routine angiography might be performed by cardiologists more often than other specialties for carotid stenting.

Unlike many medical procedures, carotid stenting is a “cross-disciplinary” technology that is performed by operators from several, diverse physician specialties. These groups have widely different clinical opportunities and incentives for performing it, which could lead to important differences in how patients are selected for carotid stenting. For example, cardiologists care for a large number of patients with atherosclerotic heart disease. These individuals may also have coexisting carotid disease that may or may not be symptomatic. Involvement of cardiologists in the care of these patients could lead to greater recognition of carotid stenosis in the general population and subsequent referral for carotid stenting, particularly among less symptomatic patients. For example, we found that more than 50% of patients who were treated by cardiologists and also underwent cardiac catheterization prior to carotid stenting had carotid and cerebral angiography performed simultaneously. This proportion was much lower among those treated by surgeons (24%), radiologists (18%), or others (34%), which suggests the possibility that routine angiography might be performed by cardiologists more often than other specialties for carotid stenting.

Radiologists, in contrast, typically have little direct involvement in the early evaluation of patients with stroke and carotid stenosis, relying primarily on referrals from other physicians. Surgeons are the only operators involved in carotid stenting who also perform carotid endarterectomy, the open-surgical procedure that is the current standard for carotid revascularization. This may make them less likely to view carotid stenting as a first-line therapy and restrict their use to select cases. Differences in educational training may also contribute to their overall decision to perform carotid stenting. For example, cardiologists routinely use standard 0.014-in (0.0356-cm) wire-based equipment and embolic protection devices for their coronary interventions, both of which are requirements for most carotid stenting. It is possible that these differences in educational training may also contribute to their overall decision to perform carotid stenting. For example, cardiologists routinely use standard 0.014-in (0.0356-cm) wire-based equipment and embolic protection devices for their coronary interventions, both of which are requirements for most carotid stenting. It is possible that these differences in educational training may also contribute to their overall decision to perform carotid stenting.

Understanding the role of physician specialty in carotid stenting is not just of theoretical interest, but importantly, has practical implications. In 2006, CMS raised considerable controversy when it proposed modifying its current national coverage decision for carotid stenting to allow only physicians who perform carotid endarterectomy to determine which patients would be suitable for carotid stenting. Although the goal was to improve overall decision making for carotid stenting, cardiologists and radiologists were concerned that this would have essentially left surgeons as the sole gatekeepers for its use. Although CMS subsequently retreated from this proposed modification, our findings suggest that decisions about using this procedure may indeed be linked to physician specialty. If this is true, promoting multidisci-
plenary decision making around carotid stenting could reduce unwanted variation in its adoption. The inclusion of specialists not directly involved in carotid stenting, like neurologists, may also aid in these decisions, particularly since they are more experienced in identifying stroke-related complications and caring for these patients in the long term.15

These issues all take on even greater relevance, given current controversies surrounding the clinical effectiveness of carotid stenting relative to carotid endarterec-

Table 2. Characteristics of HRRs Categorized by the Physician Specialty That Performed Most Carotid Stenting in That Market

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Where Cardiologists Performed Most Carotid Stenting (n=115)</th>
<th>Where Surgeons Performed Most Carotid Stenting (n=41)</th>
<th>Where Radiologists Performed Most Carotid Stenting (n=37)</th>
<th>Mixed (n=79)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fee-for-service population per HRR, mean (SD)</td>
<td>127 169 (133 537)</td>
<td>103 367 (71 931)</td>
<td>102 133 (92 916)</td>
<td>103 929</td>
<td>.38</td>
</tr>
<tr>
<td>Geographic distribution of HRRs, No. (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.02</td>
</tr>
<tr>
<td>Northeast</td>
<td>13 (11.3)</td>
<td>12 (29.3)</td>
<td>2 (5.4)</td>
<td>15 (19.0)</td>
<td></td>
</tr>
<tr>
<td>Midwest</td>
<td>33 (28.7)</td>
<td>6 (14.6)</td>
<td>9 (24.3)</td>
<td>24 (30.4)</td>
<td></td>
</tr>
<tr>
<td>South</td>
<td>45 (39.1)</td>
<td>19 (46.3)</td>
<td>14 (37.8)</td>
<td>30 (38.0)</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>24 (20.9)</td>
<td>4 (9.8)</td>
<td>12 (32.4)</td>
<td>10 (12.7)</td>
<td></td>
</tr>
<tr>
<td>Age-, sex-, and race-adjusted rate of carotid endarterectomy per 10,000 enrollees in 2004, mean (SD)</td>
<td>30.4 (12.4)</td>
<td>29.6 (11.5)</td>
<td>22.5 (10.7)</td>
<td>27.7 (9.4)</td>
<td>.003</td>
</tr>
<tr>
<td>Operators performing carotid stenting per 100,000 enrollees, mean No. (SD)</td>
<td>25.2 (11.5)</td>
<td>21.0 (6.9)</td>
<td>18.9 (7.8)</td>
<td>21.8 (9.5)</td>
<td>.003</td>
</tr>
</tbody>
</table>

Abbreviation: HRRs, hospital referral regions.
tomy. For example, the CREST investigators recently reported that both procedures led to similar rates of stroke, myocardial infarction, or death in 2502 patients over a mean follow-up period of 2.5 years. 12 Although this appears to suggest overall equivalence between the 2 strategies, the large International Carotid Stenting Study (ICSS)—also published in 2010—found higher rates of this combined end point with carotid stenting. 16 In addition, both trials found a significant interaction between age and outcomes that favored carotid endarterectomy in older patients, which is of direct relevance for the elderly Medicare population we studied. With this degree of uncertainty about the role of carotid stenting, it is likely that substantial variation in its use will continue and could intensify in regions with greater enthusiasm for its adoption. 17

Our study should be interpreted with the following limitations in mind. We relied on Medicare claims data, which are inherently limited in their ability to understand the clinical context in which a procedure may be used. For example, we could not directly determine whether patients were “symptomatic” or “asymptomatic” and had to rely on the presence of claims data suggesting a recent diagnosis of acute stroke or TIA. As a result, we are unable to comment on the overall appropriateness of its use across specialties despite wide variation in its adoption. It may be that markets where cardiologists are performing most procedures are “overutilizing” carotid stenting or that markets where surgeons or radiologists predominately perform the procedure have important barriers that limit access and are “underutilizing” it. Importantly, either concern may be overcome by promoting multidisciplinary decision making to optimize its use. Along similar lines, it could be argued that differences in adoption of carotid stenting across markets may be due to variation in the prevalence of carotid disease or the overall enthusiasm of physicians for carotid revascularization within a region. Although admittedly an imperfect measure, we attempted to account for these factors in our analysis by using adjusted utilization rates for carotid endarterectomy in 2004. An additional counterargument to this concern are recent data reporting large differences in rates of carotid stenting across markets—a degree of variation that is unlikely to be explained by differences in these factors alone. 3,4

Another consideration is that findings in Medicare claims data may not be generalizable to younger patients or managed care populations. Although some of these concerns could be overcome using data from clinical registries, those sources have their own limitations. They are typically limited to select high-volume centers and have no information on “at-risk” denominator populations to determine how its use by different specialties might have an impact on utilization rates. An additional complicating factor is that different professional organizations (eg, the American College of Cardiology and the Society for Vascular Surgery) are promoting unique registries, often to their own physician constituents. 18,19 This may prevent these registries from providing a comprehensive picture of carotid stenting in the United States and limits their ability to address policy-based questions across different specialties and broad patient populations. In contrast, this is a particular advantage of using Medicare claims data. Finally, the most reliable outcome we were able to evaluate was mortality, which is generally low following carotid stenting. Our ability to assess other important outcomes, like the development of stroke, is more limited within claims data.

![Figure 3. Mean rate of carotid stenting per 10,000 enrollees in hospital referral regions where cardiologists performed most carotid stenting had higher adjusted utilization rates than others (P < .001).](image)

Table 3. Characteristics of HRRs Categorized by the Physician Specialty That Performed Most Carotid Stenting in That Market

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HRRs</th>
<th>Where Cardiologists Performed Most Carotid Stenting (n=115)</th>
<th>Where Surgeons Performed Most Carotid Stenting (n=41)</th>
<th>Where Radiologists Performed Most Carotid Stenting (n=37)</th>
<th>Mixed (n=79)</th>
<th>P Valuea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age-, sex-, and race-adjusted rate of carotid stenting per 10,000 enrollees, mean</td>
<td></td>
<td>4.3</td>
<td>2.9</td>
<td>2.2</td>
<td>2.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>30-d Risk-standardized mortality</td>
<td></td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>.24</td>
</tr>
<tr>
<td>30-d Risk-standardized mortality or stroke admission</td>
<td></td>
<td>4.6</td>
<td>4.7</td>
<td>4.8</td>
<td>4.6</td>
<td>.66</td>
</tr>
</tbody>
</table>

Abbreviation: HRRs, hospital referral regions.

aP value represents comparison between HRRs where cardiologists performed most carotid stenting and mixed HRRs where no specialty performed most procedures after adjustment for the number of operators, geographic region, and rates of carotid endarterectomy in 2004. Comparisons were also significant for adjusted rates between HRRs where cardiologists performed most carotid stenting and HRRs where surgeons performed most procedures (P=.008) and HRRs where radiologists performed most procedures (P=.001), all other comparisons were nonsignificant (P>.05) for adjusted rates and risk-standardized mortality between groups of HRRs.
In conclusion, cardiologists perform the majority of carotid stenting in the United States. Procedures performed by cardiologists involve patients who appear to differ in important ways from those treated by other specialists like surgeons and radiologists. Hospital referral regions where cardiologists perform most procedures have significantly higher population-based utilization rates, suggesting an important role for physician specialty in the choice to use carotid stenting. Further studies are needed to better understand the specific nature of this relationship and whether multidisciplinary decision making by teams of specialists could optimize the use of this innovative technology.

Accepted for Publication: April 21, 2011.
Published Online: August 8, 2011. doi:10.1001 /archinternmed.2011.354

Correspondence: Brahmajee K. Nallamothu, MD, MPH, Department of Internal Medicine, Health Services Research and Development Center of Excellence, 1500 E Medical Center Dr, B1 226 Taubman, Ann Arbor, MI 48109-0022 (bnallamo@med.umich.edu).

Author Contributions: Dr Nallamothu had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Nallamothu, Rogers, and Birkmeyer. Acquisition of data: Nallamothu. Analysis and interpretation of data: Nallamothu, Lu, Rogers, Gurum, and Birkmeyer. Drafting of the manuscript: Nallamothu and Lu. Critical revision of the manuscript for important intellectual content: Nallamothu, Lu, Rogers, Gurum, and Birkmeyer. Administrative, technical, and material support: Nallamothu and Birkmeyer. Study supervision: Nallamothu and Birkmeyer.

Financial Disclosure: None reported.

Funding/Support: This project was supported by grant 5R21AG032155-02 from the National Institutes of Health.

Role of the Sponsor: The funding agency was not involved in the design and conduct of the study; in data management or analysis; or in manuscript preparation.

Disclaimer: The views expressed in this article are those of the authors and do not necessarily represent the views of this agency or the Department of Veterans Affairs and the Department of Health and Human Services.

Additional Contributions: We are grateful to Onur Baser, PhD, and Li Wang, MSc, for their roles in preparing data.