From the Society for Vascular Surgery

Comparison of 30-day readmission rates and risk factors between carotid artery stenting and endarterectomy

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ABSTRACT

Objective: The aim of this study was to analyze the rates, reasons, and risk factors of 30-day readmission, both planned and unplanned, after carotid revascularization as well as to evaluate major outcomes associated with those readmissions.

Methods: Using the Premier Healthcare database, we retrospectively identified patients undergoing carotid endarterectomy (CEA) and carotid artery stenting (CAS) between 2009 and 2015. The primary outcome was 30-day all-cause readmission. Secondary outcomes included mortality and overall cost associated with readmissions. Univariate and multivariate analyses were used and further validated using coarsened exact matching on baseline differences between CEA and CAS patients.

Results: A total of 95,687 patients underwent carotid revascularization, 13.5% of whom underwent CAS. Crude 30-day readmission rates were 6.5% after CEA vs 6.1% after CAS ($P = .10$). Stroke, bleeding, pneumonia, and respiratory failure were the most common reasons for readmission after both CEA and CAS (6.7% vs 8.3%, 6.9% vs 5.3%, 3.4% vs 2.4%, and 4.4% vs 3.9%; all $P > .05$). Myocardial infarction and wound complications were more likely to be an indication for readmission after CEA (4.1% vs 2.5% and 4.1% vs 1.5%, respectively; $P < .05$). On the other hand, readmissions due to vascular or stent-related complications were more likely after CAS compared with CEA (5.8% vs 3.8%; $P = .003$). On multivariate analysis, CEA was found to be associated with 41% higher odds of readmission than CAS (adjusted odds ratio, 1.41; 95% confidence interval, 1.29-1.54; $P < .001$). Age, female gender, emergency/urgent procedures, concomitant cardiac procedures, rural hospitals, and Midwest region were significantly associated with 30-day readmission. Other risk factors included major preoperative comorbidities (diabetes, congestive heart failure, renal disease, chronic obstructive pulmonary disease, peripheral vascular disease, and history of cancer) as well as the occurrence of postoperative stroke and renal complications during the index admission and nonhome discharge. Coarsened exact matching between CEA and CAS patients also yielded higher adjusted rates of readmission after CEA (6.2% vs 4.9%; $P < .001$). On the other hand, patients readmitted after CAS had a longer length of hospital stay (5 days vs 4 days; $P = .001$), increased readmission mortality (6.2% vs 2.8%; $P < .001$), and higher rehospitalization costs ($8903 vs $7629; $P = .01$) compared with those readmitted after CEA.

Conclusions: Our results show that CAS is associated with lower 30-day readmission rates compared with CEA. However, CAS readmissions are more complex and are associated with higher mortality and costs. We have also identified patients who are at high risk of readmissions, which can help focus attention on interventions that can improve the management of these patients and reduce readmission rates. (J Vasc Surg 2017;■:1-13.)

Carotid revascularization has been shown to effectively reduce the risk of ischemic stroke in selected patients with severe carotid artery stenosis.[1] Prior studies have focused on the safety and efficacy of carotid endarterectomy (CEA) and carotid artery stenting (CAS).[2-8] However, reducing readmission has become an important measurable quality outcome and an area of active research because of the increased pressure placed on hospitals and the planned monetary penalties to be imposed on centers with higher than expected readmission rates. This has been established through the Hospital Readmissions Reduction Program and the Patient Protection and Affordable Care Act.[1,9-15] Between 2009 and 2011, nearly 10% of Medicare patients who underwent carotid revascularization returned to the hospital within 30 days of discharge.[1] CEA has been considered the surgical procedure with the third highest readmission rate.[16] However, a study published in the *Journal of the American College of Cardiology* found that CAS was associated with higher 30-day readmission rates compared with CEA.

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With the continuous improvement of revascularization techniques, we sought to evaluate 30-day readmission, including causes and risk factors, after CEA and CAS using a large nationwide database. This can offer insight into clinical decision-making and can guide effective strategies that can reduce readmission and improve the quality of care of patients undergoing carotid revascularization.

METHODS

Data source. A retrospective study using the Premier Healthcare database (PHD) between 2009 and 2015 was performed and approved by the Institutional Review Board. The PHD is a large, U.S. hospital-based, service-level, all-payer database that contains information on inpatient discharges, primarily from geographically diverse nonprofit, nongovernmental, community and teaching hospitals and health systems from rural and urban areas. The PHD is a dynamic database that is updated weekly. To date, the PHD maintains cumulative information from >700 hospitals with >80 million inpatient admissions since 2011 (approximately 20% of annual inpatient discharges in the United States).[17]

The PHD offers deidentified, Health Insurance Portability and Accountability Act-compliant data from standard hospital discharge billing files. These data include demographics and disease states; admission and discharge diagnoses; information on billed services, including costs and charges at the departmental level; and patient disposition and discharge health status. For most data elements, <1% of patient records have missing information; and for key elements, such as demographics and diagnostic information, <0.01% have missing data. Data are subject to an extensive validation process occurring during implementation and with each monthly data submission by the hospital to ensure accurate and complete reporting.

Subjects. Patients who underwent carotid revascularization (CAS or CEA) were identified using admission and primary procedure-specific codes from the *International Classification of Diseases, Ninth Revision, Clinical Modification* for CAS (00.63) and CEA (38.12). Patients with concomitant contralateral or ipsilateral carotid revascularization (0.12%), length of stay >30 days (0.35%), and death during the index hospital stay (0.6%) were excluded from the analysis. The need for informed consent of the patients was waived because the data are deidentified data and not considered human subjects research under federal guidelines.

Outcomes. The primary outcome of interest was 30-day readmission. Using a unique masked identifier, patients were tracked across the inpatient settings to assess consecutive admissions to the index hospital in a chronologic order as well as the cumulative number of days since the previous admission. Secondary outcomes included medical and surgical complications during both the initial hospitalization and the readmission stay. These were identified using secondary diagnosis and procedure codes provided in Supplementary Table I (online only). Device-related complications included stent occlusion, CEA patch infection, and occlusion of the carotid artery. Furthermore, in-hospital outcomes in readmitted patients including mortality, complications, and total hospitalization costs were analyzed. Costs are those reported by the hospital. They are not the charge to a payer or the amount reimbursed to the hospital. Currency data were presented as medians, adjusted for inflation for 2015 U.S. dollars using the Consumer Price Index Inflation Calculator from the U.S. Department of Labor. Symptomatic status was defined as presenting with transient cerebral ischemia, carotid artery stenosis with cerebral infarction, stroke, or transient limb paralysis as well as retinal vascular occlusion or retinal ischemia.

ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective analysis of the prospectively collected Premier Healthcare database
- **Take Home Message:** Of 95,687 patients who underwent carotid revascularizations, carotid artery stenting patients had lower 30-day readmission rates but more complex readmissions with higher mortality and costs than carotid endarterectomy patients.
- **Recommendation:** This study suggests that readmissions after carotid artery stenting, although less frequent, are more complex and have higher mortality rates and costs than readmissions after carotid endarterectomy.

Statistical analyses. Student independent *t*-tests and Wilcoxon rank sum tests were used to analyze continuous variables, and χ^2 tests were used to compare categorical variables. Multiple logistic regression models were used to study the association between 30-day readmission and patients' demographics, comorbidities, symptomatic status, and discharge destination as well as hospital teaching status and provider regions. Variables included in the final models were chosen on the basis of clinical relevance or a P value $\leq .20$ on initial bivariate analysis. C statistics and the Hosmer-Lemeshow test evaluated the models' predictive ability and goodness of fit, respectively. Regression models were also checked for multicollinearity using variance inflation factors for each covariate (mean variance inflation factor, 1.13; maximum, 1.56). The analysis was validated using coarsened exact matching (CEM) described by Iacus et al[18] to ensure valid evaluation of patients within each procedure and to avoid selection bias. Matching was performed on baseline characteristics that were significantly different