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Evaluation of regional variations in length of stay after elective, uncomplicated carotid endarterectomy in North America

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Abstract

Objective: The objective of this study was to evaluate factors affecting regional variation in length of stay (LOS) after elective, uncomplicated carotid endarterectomy (CEA).

Methods: Data were obtained from the Vascular Quality Initiative database and included patients with complete data who received elective CEA without complications between 2012 and 2017 across 18 regions in North America and 294 centers. The main outcome measure was LOS >1 day after surgery (LOS >1 postoperative day [POD]). Using least absolute shrinkage and selection operator regression, multivariable modeling, and mixed-effects general linear modeling, we evaluated whether regional variations in LOS were independent of demographic, clinical, or center-related factors and to what extent these factors accounted for postoperative variation in LOS.

Results: A total of 36,004 patients were included. Mean postprocedure LOS was 1.6 ± 6.6 days. Overall, 24% of patients had an LOS >1 POD. After adjustment for important demographic, clinical, and center-related factors, the region in which a patient was treated independently and significantly affected LOS after elective, uncomplicated CEA. Region and center of treatment accounted for 18% of LOS variation. Demographic, clinical, and surgical factors accounted for another 32% of variation in LOS. Of these factors, postoperative discharge to a facility other than home (odds ratio [OR], 6.3; confidence interval [CI], 5.2–7.6), use of intravenous (IV) vasoactive agents (OR, 3.2; CI, 3–3.4), intraoperative drain placement (OR, 1.4; CI, 1.3–1.55), and female sex (OR, 1.4; CI, 1.3–1.5) were associated with longer LOS. Factors associated with LOS ≤1 POD

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included preoperative aspirin (OR, 0.88; CI, 0.8–0.96) and statin use (OR, 0.9; CI, 0.83–0.98), high surgeon volume (highest quartile: OR, 0.68; CI, 0.5–0.87), and completion evaluation after CEA (eg, Doppler, ultrasound; OR, 0.87; CI, 0.8–0.95). We also found that use of IV vasoactive medications varied significantly across regions, independent of demographic and clinical factors.

Conclusions: Significant regional variation in LOS exists after elective, uncomplicated CEA even after controlling for a wide range of important factors, indicating that there remain unmeasured causes of longer LOS in some regions. Even so, modification of certain clinical practices may reduce overall LOS. Regional differences in use of IV vasoactive medications not driven by clinical factors warrant further analysis, given the strong association with longer LOS.

Keywords

Carotid stenosis; Carotid endarterectomy; Length of stay; Regional variations; Clinical practice

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In the era of value-based medicine, managing the cost and quality of care provided for the vascular patient is ever more important. More than 150,000 carotid endarterectomies (CEAs) are performed annually in the United States, with large variations in length of stay (LOS) after surgery (1–20 days)[1–3] and hospitalization costs ($7000–$36,000).[2] In evaluating the cost of care after CEA and Medicare reimbursement rates, McDonald et al[2] found that Medicare reimbursement for CEA is often less than the cost of hospital care. Postoperative complications and LOS for more than an average of 1 day after surgery can result in substantial loss of revenue for health care systems. Revenue loss can range from $3000 per patient to as much as $23,000 for patients needing longer hospital stay for postoperative complications or comorbidity management.

Data from the Vascular Study Group of New England demonstrated significant variation in LOS across centers in their region.[1] Furthermore, as a participant in the Vascular Quality Initiative (VQI), we have observed national LOS variation after CEA across VQI regions. Reasons for this regional variation are not immediately clear and may represent differences in patient mix or region- or center-specific factors, such as case volume, complication rates, or surgeon care preferences. Whereas other studies have evaluated the effects of postoperative complications on LOS[1] or focused on a single institution,[3,4] we set out to gain a better understanding of factors contributing to LOS in patients who had elective, uncomplicated CEA using a large, nationally representative data set. Theoretically, these patients could be discharged by postoperative day (POD) 1. In studying this cohort, we can better elucidate whether differences in LOS relate to modifiable care decisions or significant regional differences that may not be accounted for by current data.

METHODS

Data were derived from the VQI, a North American registry containing perioperative and 1-year data collected by individual institutions on patients receiving 12 types of vascular procedures. Data on CEA patients included operations performed between 2003 and 2017 across 18 different VQI-defined regions in North America and 294 different medical centers (https://www.vqi.org/components-of-the-vqi/regional-quality-groups/). Data were deidentified. Regions were deidentified as well. The Stanford Institutional Review Board waived a consent process, given the deidentified nature of the data analysis.

For the purposes of this study, after removal of variables with >30% missing data, we included all patients with complete data who underwent elective, uncomplicated CEA. Thus, patients who underwent emergent CEA or had a recorded major postoperative complication, such as bleeding, stroke, or return to the operating room, or who experienced a postoperative in-hospital death were excluded. Of note, minor complications such as neck swelling, urinary retention, and new-onset arrhythmias are not captured in the VQI database. After evaluating the volume of data from different centers, we found that although the database included patients treated as far out as 2003, these were only at a few centers, which could bias our overall statistical models. To avoid this, we elected to analyze contemporary data from 2012 to 2017 to obtain better representation of national and region-specific trends. Our major outcome variable was the categorical variable LOS >1 POD. LOS was recorded by whole days in the VQI registry.

Statistical analysis

Using two-tailed t-tests for continuous variables and χ^2 testing for categorical variables, we compared demographic and clinical differences between patients who were discharged on POD 1 and those who were not.

Model building

Regional variation in LOS.—Our objective was to identify whether regional variation in LOS persisted after accounting for clinical, demographic, and surgical factors that could influence LOS. We employed a two-step process whereby the first step used a variable selection process to identify predictors most associated with LOS >1 POD. Given the hundreds of variables that we could have used, we elected to employ a machine-learning algorithm to agnostically identify variables most associated with LOS after CEA. Specifically, the least absolute shrinkage and selection operator (LASSO) is a statistical method, often employed in data mining, that can enhance a model's predictive accuracy and generalizability by selecting a subset of variables that most strongly correlate with the outcome of interest.[5] This method contrasts with other variable selection methods, such as hypothesis-driven variable selection, based on expert opinion as to which variables should be included; bivariate screening; and forward, backward, or stepwise variable selection techniques. Each of these techniques has problematic biases that are both theoretical and empirically founded.[6,7] For example, it can be difficult to rely on expert opinion alone in high-dimensional data.[7,8] In the case of forward or backward variable selection, these methods do not necessarily identify a statistical model with the best data fit, are not ideal in situations in which variables may be highly correlated, and are prone to include variables that are not actually correlated with the outcome at hand.[6] Important advantages of LASSO are that it provides a subset of variables with the goal of providing the best model fit, and the final model is less likely to suffer from data overfitting.[5,9]

LASSO regression was carried out using 10-fold crossvalidation. All variables with nonzero LASSO coefficients were then further evaluated for multicollinearity, corresponding to a variable inflation factor >2.5.[10] Any remaining correlated variables were removed, leaving a final set of variables for multivariable analysis. For evaluating regional variation, we used a fixed-effects multivariable logistic regression model in which region was treated as a categorical dependent variable.

Independent factors affecting LOS >1 day.—To evaluate the demographic, clinical, and surgical factors related to LOS, we accounted for the fact that each patient observation was not completely independent because patients treated within certain regions at different centers are more likely to be subject to similar practices compared with patients from other regions and centers. Thus, we controlled for region and center clustering by building a mixed-effects model in which patients were nested within centers and centers were nested within regions. We treated demographic, clinical, and surgical factors as fixed effects and center and region as random effects. To evaluate the variance in LOS due to regional and center clustering, we used the pseudo-R^2 method.[11] To evaluate the relative contribution of demographic, clinical, and surgical factors to LOS, we used chi-pie analysis.[1,12] Data analysis was performed in R version 3.2.1.[13]

RESULTS

Of the 77,638 patients included in the VQI CEA database, after exclusion criteria were applied, there remained 36,004 patients who underwent elective, uncomplicated CEA and were included in our final analysis. A total of 11,884 patients had surgery before 2012 and were excluded, 8461 patients were excluded for emergent surgery, 3010 were excluded for in-hospital death, and the remaining 18,279 patients were excluded because of missing data. Overall, 24% of patients had an LOS >1 POD. As illustrated in Fig 1, there were significant unadjusted differences in the proportion of patients with LOS >1 POD after elective, uncomplicated CEA by region (16%−33%; $P < .001$). However, in general, the proportion of patients with LOS >1 POD decreased year by year (Fig 2). Mean LOS for the entire cohort was 1.6 days (±6.6 days). Average LOS by region is also illustrated in Fig 1. Table I details the demographic and clinical factors that differed between patients discharged on POD 1 and those discharged thereafter across all regions. Overall, patients discharged by POD 1 were younger and more likely to be male, white, and discharged home vs another facility, and they had fewer comorbidities including fewer preoperative neurologic events. Of the total cohort, 38% had a prior neurologic event, defined as an ipsilateral or contralateral cortical or ocular stroke or transient ischemic attack that occurred at varying times before elective surgery. Of those with prior events, 11% were symptomatic (ie, occurring ≤2 weeks before surgery).

Regional variation in LOS.

Our final multivariable logistic regression model demonstrated significant regional variation in LOS (Fig 3; Supplementary Table I, online only). Based on a reference region with a median LOS, eight regions had significantly longer LOS despite adjustment for multiple demographic, clinical, and center-related factors. Only two regions had significantly lower LOS than the median of all regions.

Independent factors affecting LOS >1 day.

Our nested mixed-effects model aimed to understand the demographic, clinical, and surgical factors related to LOS, adjusting for patients clustered within centers that are clustered within regions. This model captured 50% of the variation in LOS after elective, uncomplicated CEA. Region and center of treatment accounted for 18% of variation in LOS, whereas demographic, clinical, and surgical factors accounted for the remaining 32% of LOS variation. The factors significantly associated with LOS >1 POD are detailed in Table II (Supplementary Table II, online only).

Chi-pie analysis allowed us to further quantify the relative contributions of different factors related to LOS variation, independent of region (Fig 4). This analysis demonstrated the primary drivers of longer LOS to be perioperative practices (52%), patient comorbidities (22%), and perioperative disposition (15%). Perioperative practices were defined as factors including use of intravenous (IV) vasoactive agents, total procedure time, anesthesia type, drain or shunt use, antibiotic use, intraoperative monitoring practices, completion imaging, and decision about administration of medications (such as heparin, protamine, and dextran). Within perioperative practices, use of vasoactive medications accounted for 38% of LOS variation, whereas anesthesia choice (general vs local vs regional) and choice of drain placement accounted for 2.5% of LOS variation each. Within the category of patient comorbidities, prior neurologic event accounted for 3% of variation and anemia accounted for another 3%. Preoperative disability (ie, modified Rankin score; 2.4%), diabetes (2.5%), and chronic obstructive pulmonary disease (2%) also contributed to longer LOS. Symptomatic status accounted for 1% of variation, although this represented only a small portion of the total patient population. The “other” category in our chi-pie analysis included center and surgeon volume, which accounted for 0.1% and 0.4% of LOS variation, respectively.

Given the large influence that the use of vasoactive medications had on LOS (both vasopressors and vasodilators), we evaluated factors associated with use of these medications by multivariable regression modeling after initial LASSO screening for important variables. In the VQI data set, use of IV vasoactive medication is defined as having a continuous infusion for ≥15 minutes or more than one dose required for >1 hour after surgery for hypertension or hypotension. Evaluating use of medication for both hypotension and hypertension, we find that there was significant regional variation in IV vasoactive medication use (Fig 5). Most interestingly, though, whereas center volume did not significantly affect LOS in our first multivariable analysis, center volume was significantly associated with use of IV vasoactive medications. This difference became significant at the second highest quartile, whereby patients treated at centers performing >35 operations were less likely to receive IV vasoactive medications (odds ratio [OR], 0.58; confidence interval [CI], 0.4–0.9; $P = .005$). Patient insurance was also associated with use of IV vasoactive agents such that patients with commercial insurance were less likely to receive IV vasoactive medications (OR, 0.9; CI, 0.88–1; P .04). Surgeon volume was not significantly associated with IV vasoactive medication use (highest quartile [>40 operations]: OR, 0.83; CI, 0.66–1.06; $P = .16$). Supplementary Table III (online only) details other factors significantly associated with use of IV vasoactive medications.

DISCUSSION

Significant regional variation in LOS exists after elective, uncomplicated CEA independent of measurable demographic, clinical, and surgical differences. In looking at specific factors that drive LOS independent of region, use of vasoactive medications, surgeon volume, and patient discharge disposition stand out as primary measurable factors. Further analysis showed that whereas surgeon volume was significantly associated with LOS, center volume was not. Specifically, surgeons performing at least more than four operations had lower odds of prolonged LOS (OR, 0.75; CI, 0.59–0.96; $P = .02$) compared with surgeons who performed fewer operations. Conversely, center volume was a significant factor in use of vasoactive medications, whereas surgeon volume was not. Specifically, centers in which >35 operations were performed had a lower likelihood of use of IV vasoactive medications (OR, 0.58; CI, 0.4–0.9; $P = .005$). This analysis is important as it can assist health care organizations in better understanding drivers of LOS and help focus investigation on the underlying causes of factors prolonging LOS (eg, use of IV vasoactive medications) and finding ways to optimize other factors that are less modifiable (eg, patient comorbidities). Furthermore, although understanding the drivers of prolonged LOS after elective, uncomplicated CEA is important from a quality standpoint, the cost considerations to the health care system are also important. As described by Glaser et al[1] and others,[14] whereas reimbursement for elective, uncomplicated CEA varies regionally and across payers, in general, reimbursement for uncomplicated CEA exceeds hospitalization costs. However, LOS >1 POD can result in a net loss in revenue.[1] Given a mean LOS of 1.6 days in this study cohort, in conjunction with regional variations in LOS, it is possible that certain regions experience a net loss in revenue for CEA based on longer LOS alone.

This analysis represents the first evaluation of variations in LOS across North America after elective, uncomplicated CEA. Compared with previous analyses that looked at single-center experience with complicated and uncomplicated CEA, we similarly found that female sex[3,15] and patient comorbidities such as renal insufficiency,[4,15] heart failure,[3,4] and chronic obstructive pulmonary disease[3] were associated with longer LOS. We also found that patients with insulin-dependent diabetes, coronary artery disease, hypertension, and increasing American Society of Anesthesiologists class (a measure of patient comorbidity status) were also at higher risk of LOS >1 POD. Whereas the magnitude of the difference for some clinical factors is small (eg, age [OR, 1.01], coronary artery disease [OR, 1.1], creatinine concentration [OR, 1.1], or hemoglobin level [OR, 0.9]), vascular patients tend to have multiple comorbidities, and thus small individual risks begin to add up to clinically relevant risk of longer LOS when they are present in the same patient (eg, an older patient with anemia, severe coronary artery disease, and renal insufficiency).

We did find that patients taking aspirin and statins preoperatively were less likely to have an LOS >1 POD, which could indicate that the quality of preoperative medical management affects overall postoperative LOS, although it is unclear from our analysis whether medical optimization beforehand would ameliorate the issue of longer LOS. It could also be the case that patients receiving more optimal preoperative medical regimens are treated at institutions with better coordination of care and more standard postoperative care pathways leading to reduced LOS.

Whereas patient comorbidities may be more difficult to optimize in clinically meaningful ways, there are potentially modifiable factors found in our analysis and in previous studies that, if addressed, could lead to shorter LOS. For instance, previous authors have found that use of general anesthesia,[15] longer operative times,[3,4] electroencephalography (EEG) use,[3] drain placement,[4] and shunting for certain indications[4] and even performing surgery later in the week[1] prolonged LOS. Although some practices may be an indicator of patients with technically difficult operations, routine occurrence of such clinical practice patterns should prompt re-evaluation if they are also associated with longer patient LOS. For example, use of regional or local anesthesia may prevent the side effects associated with general anesthesia, such as need for vasoactive medications[16] and urinary retention, which may shorten patient recovery time and lead to shorter LOS. Also, choosing to perform CEA earlier in the week when resources for disposition planning are more readily available may also lead to shorter LOS.

Another important finding is that surgeons and their operative experience affect LOS. In our analysis, we find that higher volume surgeons (more than four operations) were more likely to discharge patients by POD 1. Center volume was not a significant factor. This is somewhat surprising because surgeon volume may theoretically drive center volume. However, this finding remained even in controlling for interactions between surgeon volume and center volume. This may indicate that higher volume surgeons have learned practices that help reduce LOS, even when working at centers with lower volume. Higher volume surgeons may also practice at multiple types of centers. Given that surgeon volume independently affects LOS, surgeons can play an instrumental role in decreasing LOS after elective CEA within their health care organizations and regions by identifying practices and care algorithms that can reduce postoperative hospital days.

Patient disposition also substantially contributes to longer LOS. This is unsurprising at many institutions where obtaining beds at skilled nursing facilities can be difficult because of patient insurance, bed availability, and family preferences. One potential way to combat this is to identify patients before surgery who may have high postoperative care needs and obtain preauthorization for skilled nursing. Another potential way to address this issue is to partner with nursing and rehabilitation facilities to reduce friction in the transfer process.

Our analysis also illuminates a need to better understand the use of IV vasoactive medications around the time of surgery for CEA. In their analysis of LOS after CEA within a single region, Glaser et al[1] similarly found that use of IV vasoactive medications significantly increased risk of LOS >1 POD. What is interesting from our analysis is that use of these medications varied from region to region. This is not an expected finding, as we initially believed that use of IV vasoactive medications would be driven by clinical indications. However, even after controlling for clinical factors such as preoperative hypertension and antihypertensive use, regional differences remain. Because our analysis does not provide causal reasons for this finding, we can only speculate that regional variations could be driven by differences in anesthesia choice and practices across the country. This could be the reason that surgeon volume was not associated with use of IV vasoactive agents but center volume was. There may also be issues related to cost of these medications or the cost related to higher acuity care as those with commercial insurance were less likely to be prescribed IV vasoactive medications. Further analysis into the cause of regional differences in IV vasoactive medications could potentially help reduce LOS after CEA, given how much use of these medications is associated with longer LOS in our analysis of national data. Furthermore, given that prior work has shown an association with use of these medications and higher long-term mortality,[16] reducing use of IV vasoactive medications may have a mortality benefit as well.

Aside from regional variations in use of IV vasoactive medications, we found many clinical variables associated with their use (Supplementary Table III, online only). Whereas certain factors, such as age, race, and sex, are associated with IV vasoactive medication use and cannot be modified, we do find that routine shunting, dextran, and longer procedure times increase the likelihood of medication use and are potentially modifiable. In addition, preoperative medical management can affect need for IV vasoactive agents and warrants further consideration.[16] Again, our findings are indicative of associations, and further research into the causative nature of clinical and surgical practices associated with IV vasoactive medication use is warranted.

Whereas our results represent a national sample of almost 40,000 patients, there are limitations to our analysis. Given the retrospective nature of this analysis, it is difficult to tease out what is causal and what is simply associated with longer LOS. For instance, although EEG monitoring is associated with LOS >1 POD, it is likely not the EEG monitoring itself that causes longer LOS, but it could be that surgeons who prefer to use EEG monitoring are less likely to discharge patients on POD 1. Another possibility is that a surgeon may choose to use EEG in particular cases of patients at high risk of stroke, and these patients are likely to be observed longer. These nuances are difficult to delineate when using registry data, which are not as granular as other methods, such as chart review. Another illustration of this is our finding that lack of antibiotic administration due to medical reasons was associated with longer LOS. The reasons for this are unclear and warrant further investigation.

Another limitation of this study is that we could not measure all factors related to LOS. Indeed, our nested mixed-effects model captured 50% of the variation in LOS as measured by pseudo-R^2. Other factors that were not captured in the VQI database, for instance, include factors such as routine use of the intensive care unit postoperatively and Foley catheterization. Both of these factors have been found in other analyses to be associated with longer postoperative LOS.[3] Furthermore, the association of IV vasoactive medications and need for ICU care could also drive why using these medications is associated with longer LOS. Differences in ICU utilization, especially, could account for large LOS variations because ICUs are not usually well suited to handle patient discharge home after surgery. We also are not able to measure minor complications that may not require reoperation but may delay discharge because they are not captured in the VQI.

We also found that there were substantial amounts of missing data in the VQI registry, requiring exclusion of an additional 18,279 patients. Thus, there is a possibility that inclusion of these patients could change the association of certain, perhaps weaker findings. However, we elected against imputation as even with this exclusion, we were left with

>30,000 patients; our multivariable model captured up to 50% of the variance in LOS, with findings similar to previous studies for certain drivers of LOS. Furthermore, given our stringent use of LASSO for variable selection and mixed-effects modeling, we do believe that we are capturing true associations with the relatively large subset of data we ultimately analyzed.

Another potential limitation worth mentioning is our lack of ability to tease apart the interaction between center participation in the VQI and quality improvement efforts. That is, participation in the VQI often includes a quality improvement effort in addition to the data registry component. Indeed, we see that from 2012 to 2017, the proportion of patients in the VQI centers with a LOS >1 day decreased. Although we controlled for length of center participation in the VQI, we did not find an association between length of center participation and LOS (Supplementary Table II, online only). Because all regions included in the analysis had participated in the VQI for an average of at least 5 years, we did not find length of region participation to be significant either, and this variable was found to be insignificant in our LASSO variable selection process and did not make it to the final model. One way to better tease apart the effect of VQI participation would be to use a separate data set including non-VQI-participating centers and to compare LOS trends. Despite these limitations, the major strengths of this work are that we analyzed data from a large sample of patients across North America and used agnostic analytical methods to identify variables for inclusion in our final models, thus reducing bias from choosing variables a priori.

CONCLUSIONS

In North America, there are significant regional variations in LOS after elective, uncomplicated CEA that are apart from measured demographic or clinical factors. Furthermore, choices in perioperative care, such as use of IV vasoactive medications for elective CEA, also regionally vary. This is concerning because these practices do not appear to be solely driven by patient-related factors. Even so, there are certain practices (eg, preoperative medical optimization and disposition planning) that can be modified to potentially reduce LOS after CEA and increase value within the health care system.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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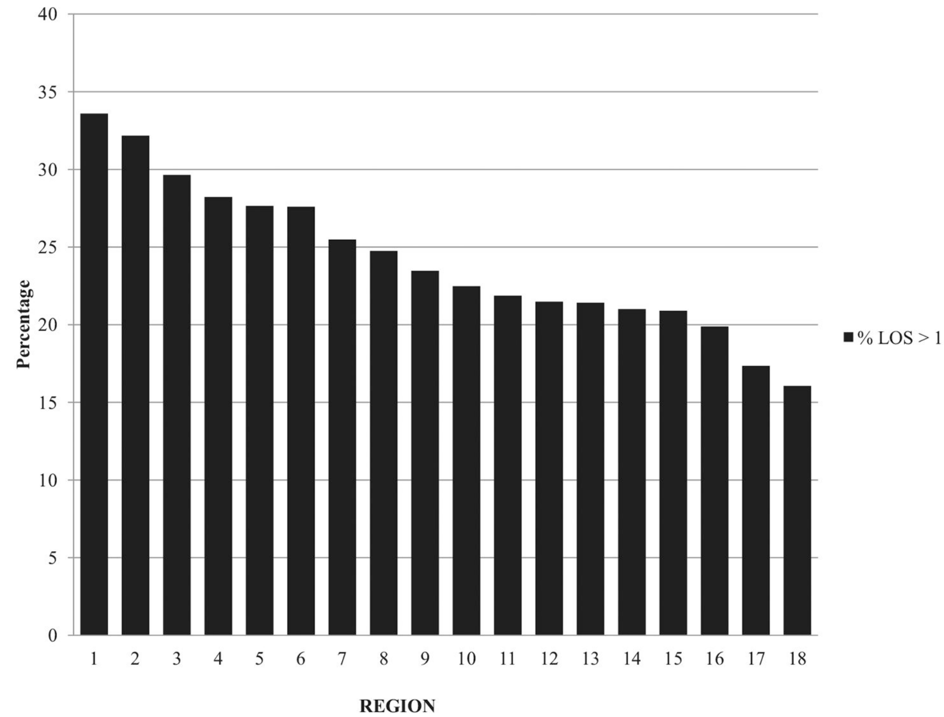
ARTICLE HIGHLIGHTS

- **Type of Research:** Retrospective study using prospectively collected data of the Vascular Quality Initiative
- **Key Findings:** Mean length of stay (LOS) of 36,004 patients after elective, uncomplicated carotid endarterectomy was 1.6 ± 6.6 days. Region and center predicted LOS; discharge to a facility, use of intravenous vasoactive agents, drain placement, and female sex predicted longer LOS. Preoperative aspirin and statin, high surgeon volume, and completion ultrasound evaluation predicted shorter LOS.
- **Take Home Message:** Limiting intravenous vasoactive drugs and drains with liberal use of antiplatelet agents and completion duplex ultrasound may decrease LOS after carotid endarterectomy.



Mean LOS* (± SD)	1.6 ± 2	1.5 ± 1.2	1.5 ± 1.2	1.5 ± 1.3	1.6 ± 3	1.5 ± 1.2	1.7 ± 10	1.4 ± 1.2	1.4 ± 2	1.5 ± 2.4	1.8 ± 11	1.5 ± 7.4	2.1 ± 16	1.4 ± 1.8	1.3 ± 1.3	1.4 ± 1.5	1.3 ± 1.2	1.8 ± 14

Fig 1.

Proportion of patients with length of stay (*LOS*) >1 postoperative day *(POD)* and average LOS by region. SD, Standard deviation. *Mean LOS in days.

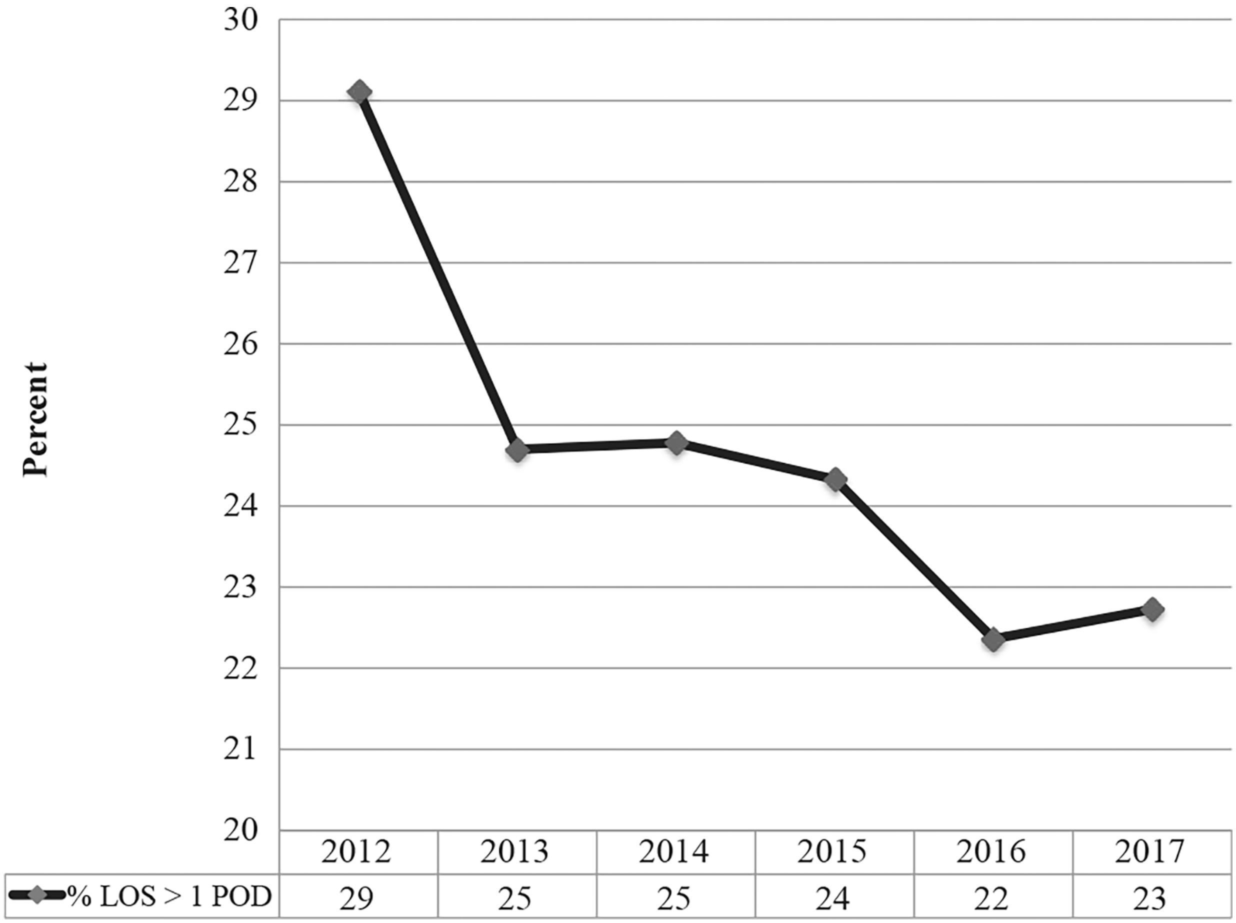


Fig 2.

Proportion of patients with length of stay (*LOS*) >1 postoperative day (*POD*) after elective carotid endarterectomy (CEA) by year.

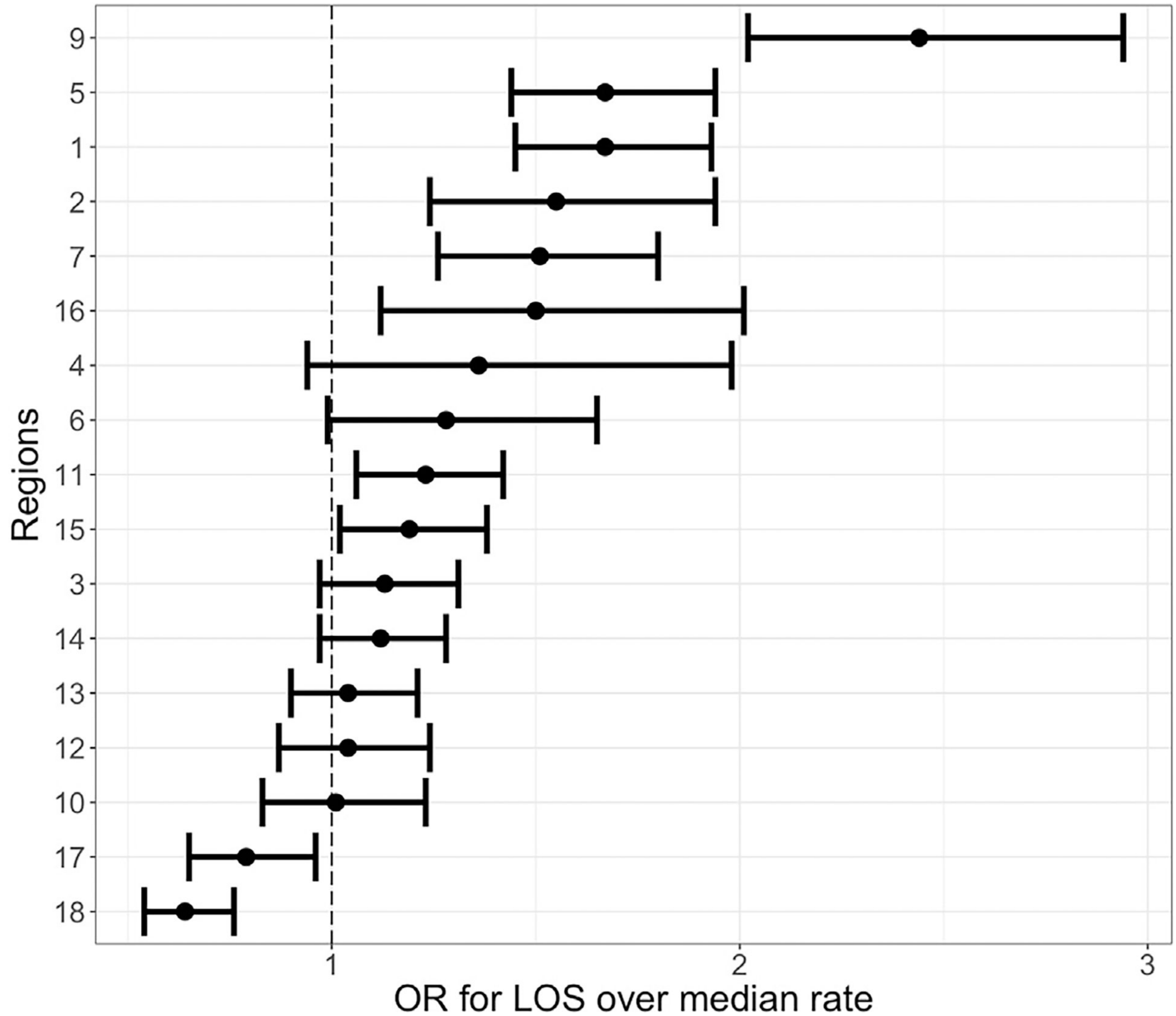


Fig 3.
Regional variation in length of stay (*LOS*) after multivariable adjustment. Controlled for multiple demographic, clinical, surgical, and volume-related factors. Full model detailed in Supplementary Table I (online only). Region 8 is the reference region. *OR*, Odds ratio.

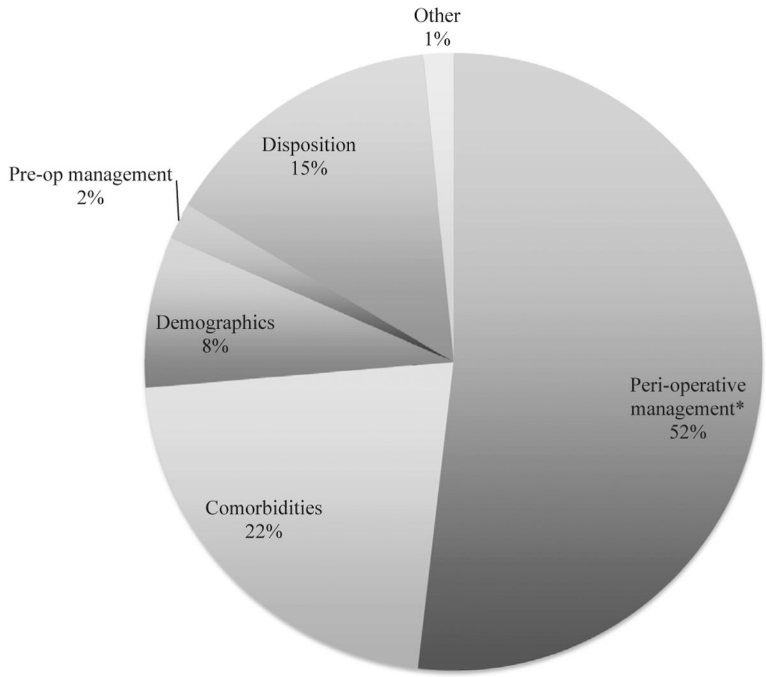


Fig 4.

Percentage of variance explained by variables in multivariate model for length of stay (LOS) >1 postoperative day (POD). *Defined as use of intravenous (IV) vasoactive agents, total procedure time, anesthesia type, drain or shunt use, antibiotic use, intraoperative monitoring practices, completion imaging, and decision about administration of medications (such as heparin, protamine, and dextran).

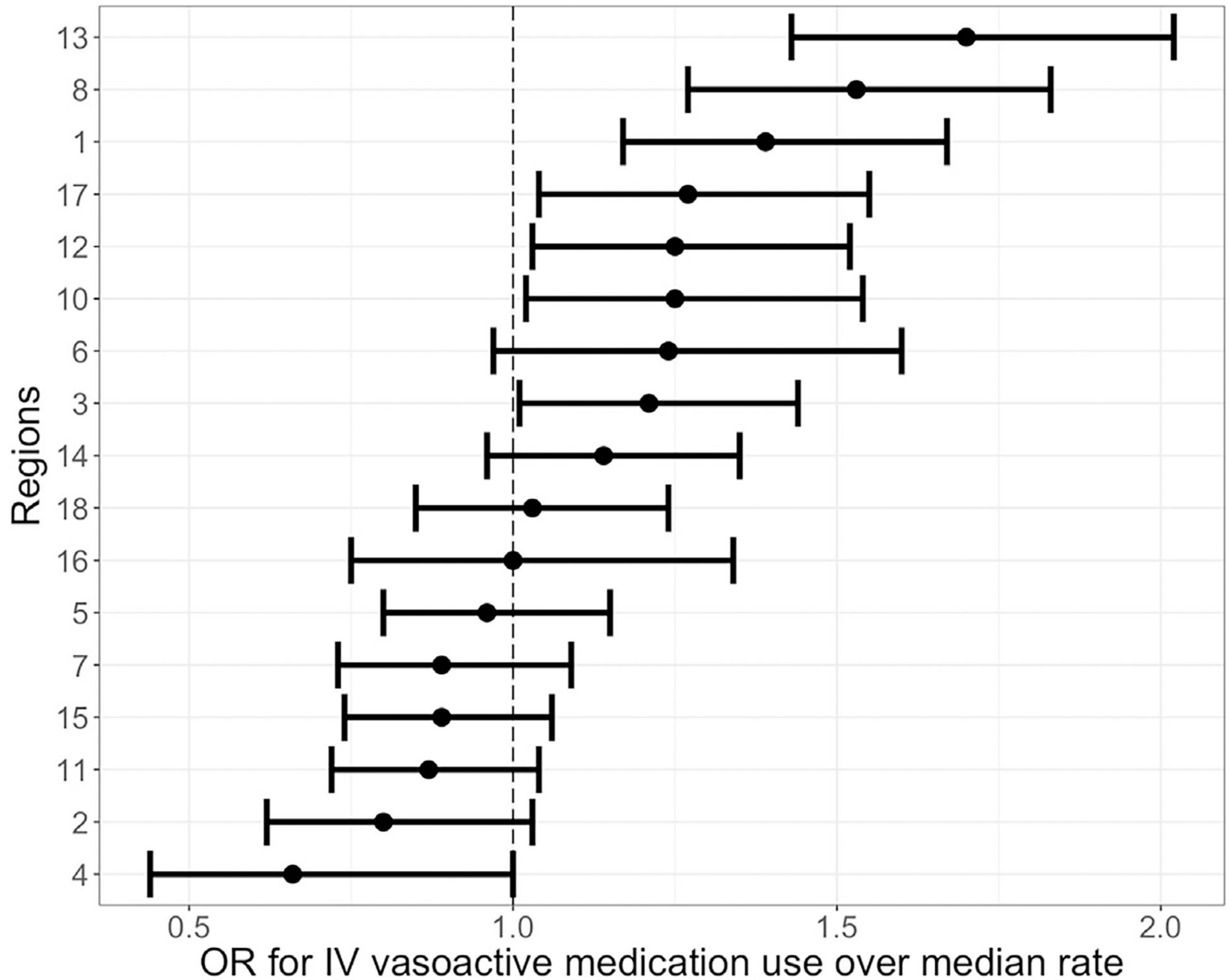


Fig 5.

Regional variation in use of intravenous *(IV)* vasoactive medications. Region 9 is the reference region. *OR*, Odds ratio.

Table I.

Demographic and clinical differences for patients discharged on postoperative day (*POD*) 1 vs those discharged later

Variable	Discharge by POD 1 (n = 27,410)	Discharge after POD 1 (n = 8594)	*P* value
Age, years	70 ± 9	71 ± 9	<.001
Male sex	63	55	<.001
Race			
White	93	90	<.001
Black	3	6	<.001
Asian	1	0.9	NS
Other	3	3.1	NS
Discharge destination: home	99	93	<.001
Insulin-dependent diabetes	10	14	<.001
Current smoker	26	25	NS
CAD	25	28	<.001
COPD	20	24	<.001
CHF	8	12	<.001
End-stage renal disease	0.2	0.2	NS
Prior neurologic event	37	54	<.001
Symptomatic neurologic event (≤2 weeks before surgery)	4	5	<.001

CAD, Coronary artery disease; *CHF*, congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *NS*, not significant.

Categorical variables are presented as percentage. Continuous variables are presented as mean ± standard deviation.

Table II.

Significant factors affecting likelihood of length of stay (LOS) >1 postoperative day (POD) after elective, uncomplicated carotid endarterectomy (CEA) based on nested multivariate mixed-effects model[a]

Variable	OR	95% CI	*P* value
Age	1.01	1.01–1.02	<.001
Female sex	1.4	1.3–1.5	<.001
Race (vs white)			
African American	1.4	1.2–1.5	<.001
Native American	1.8	1.02–3.3	.045
Primary insurer (vs Medicare)			
Medicaid	1.2	1.0–1.4	.002
Non-U.S. insurance	3.6	1.6–8	.003
Self-pay	1.5	1.2–1.9	.001
Discharge other than home (eg, SNF)	6.3	5–7.6	<.001
Hypertension	1.2	1.05–1.3	.005
Insulin-dependent diabetes	1.3	1.2–1.4	<.001
CAD	1.1	1.05–1.2	<.001
CHF	1.1	1.01–1.2	.03
COPD	1.3	1.2–1.4	<.001
Creatinine (numeric)	1.1	1.02–1.1	.003
Preoperative nursing home residence	0.5	0.4–0.7	<.001
Preoperative ambulation requiring assistance	1.3	1.01–1.3	.03
Preoperative modified Rankin score	1.2	1.2–1.3	<.001
ASA class	1.2	1.1–1.3	<.001
Hemoglobin (numeric)	0.9	0.9–0.94	<.001
Preoperative medications			
Aspirin	0.88	0.8–0.96	.003
Statin	0.9	0.8–0.98	.01
Anticoagulant	1.4	1.2–1.5	<.001
Noncompliant beta-blocker use	2.6	1.1–5.8	.03
History of prior neurologic event	1.2	1.1–1.3	<.001

Variable	OR	95% CI	*P* value
Symptomatic neurologic event (≤2 weeks before surgery)	1.5	1.3–1.7	<.001
Preoperative radiation exposure	1.4	1.01–1.7	.005
Preoperative MRA	1.1	1.02–1.2	.02
Preoperative CTA	1.1	1.02–1.2	.004
General anesthesia (vs local)	1.4	1.04–2	.03
Shunting (vs no shunting)			
For preoperative indication only	1.2	1.01–1.5	.04
For intraoperative indication only	1.2	1.05–1.4	.006
Drain placed	1.4	1.3–1.5	<.001
EEG use	1.3	1.2–1.4	<.001
Completion evaluation (eg, duplex ultrasound, arteriography, Doppler)	0.87	0.8–0.95	.002
Use of IV intravenous medication for hypotension or hypertension	3.2	3–3.45	<.001
Antibiotics not used for medical reason	3.3	2–5	<.001
Total procedure time (numeric)	1.01	1.0–1.01	<.001
Surgeon volume (highest quartile, >40 operations)	0.72	0.57–0.9	.005

ASA, American Society of Anesthesiologists; *CAD*, coronary artery disease; *CHF*, congestive heart failure; *CI*, confidence interval; *COPD*, chronic obstructive pulmonary disease; *CTA*, computed tomography angiography; *EEG*, electroencephalography; *IV*, intravenous; *MRA*, magnetic resonance angiography; *OR*, odds ratio; *SNF*, skilled nursing facility.

[a] Full model detailed in Supplementary Table II (online only).