Contemporary predictors of extended postoperative hospital length of stay after carotid endarterectomy

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Introduction: **Hospital length of stay (LOS) contributes to costs. Carotid endarterectomy (CEA) is performed frequently by vascular surgeons, making contemporary CEA LOS rates and predictors vital knowledge for quality evaluation and cost containment initiatives.**

Methods: **Using a prospective single-institution database, we retrospectively identified consecutive patients undergoing CEA from 2001 to 2011. Demographic and perioperative factors were prospectively collected. The primary end point was extended postoperative LOS (ELOS), defined as postoperative LOS ≥2 days. Factors associated with ELOS were analyzed in a multivariable logistic regression model. Rates of 1-year readmission and death were compared with the Kaplan-Meier method (log-rank test).**

Results: **Eight hundred forty patients underwent 897 CEAs with 39% of procedures among females and 35% for symptomatic disease. One hundred two (11.4%) patients were inpatients prior to the day of CEA ("preadmitted"); their preoperative days by definition are not included in ELOS. Median postoperative LOS was 1 day (interquartile range, 1-2). Four hundred fourteen patients (46.2%) had ELOS. Preadmission was associated with ELOS (72% vs 41%; $P < .01$) and ELOS patients were less likely to be discharged home (11.9% vs 1.5%; $P < .01$). There was no association between ELOS and unplanned 30-day postdischarge readmission (6.0% vs 7.0%; $P = .59$). On multivariable analysis, preoperative factors significantly associated with ELOS included preadmission (adjusted odds ratio [OR], 3.3; 95% confidence interval [CI], 1.9-5.7; $P < .001$), history of congestive heart failure (OR, 2.1; 95% CI, 1.1-4.2; $P = .03$), female gender (OR, 1.9; 95% CI, 1.4-2.6; $P < .001$), and history of chronic obstructive pulmonary disease (OR, 1.7; 95% CI, 1.0-2.9; $P = .04$). Operative factors included electroencephalography change (OR, 1.9; 95% CI, 1.2-3.2; $P = .01$), operating room start time after 12:00 pm (OR, 1.7; 95% CI, 1.2-2.4; $P < .01$), and total operating room time (OR, 1.5 per hour; 95% CI, 1.2-2.9; $P < .01$). Postoperative factors included transfer to intensive care unit (OR, 5.4; 95% CI, 3.1-9.4; $P < .01$), number of in-hospital postoperative complications (OR, 3.7; 95% CI, 2.2-6.5; $P < .01$), and Foley catheter placement (OR, 2.1; 95% CI, 1.3-3.4; $P < .01$). Over 1 year, ELOS was associated with increased hospital readmission (93.6% vs 84.7%; log-rank test, $P < .01$) and decreased survival (95.1% vs 98.3%; log-rank test, $P < .01$).**

Conclusions: **Nearly half of CEA patients were discharged on or after postoperative day 2. Interventions on modifiable risk factors, such as early Foley catheter placement to prevent urinary retention and morning CEA scheduling, may decrease LOS. ELOS may identify a subset of patients at increased risk for long-term readmission and mortality. (J Vasc Surg 2014;59:1282-90.)**

Health care costs in the United States continue to rise.[1] Average costs for inpatient hospital admissions, including surgical admissions, are likewise increasing,[2] and the first few days of hospital stays consume inordinate resources compared with subsequent days.[3] One strategy for surgeons to decrease utilization and help contain costs in this resource-limited setting may be through intervening on modifiable risk factors for postoperative hospital length of stay (LOS).

Vascular surgeons frequently perform carotid endarterectomies (CEAs).[4] Patients undergoing CEA can often be discharged home the day after surgery, but the predictors of extended postoperative length of stay (ELOS) remain undefined. We reviewed our CEA experience and identified predictors of ELOS to delineate points of potential prospective intervention. Additionally, we assessed the association between ELOS and rates of readmission and mortality over the following year.

METHODS

Data source. The Brigham and Women's Hospital maintains a secure, prospectively captured vascular surgery registry that includes demographics, comorbidities, intraoperative data, and outcomes as detailed below. With the approval of the Institutional Review Board, we retrospectively identified 896 consecutive CEAs performed by 10 board-certified vascular surgeons between November 29, 2001 and June 29, 2011. All combined procedures,

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including combined coronary artery bypass grafting-CEA procedures, were excluded.

Perioperative details. All CEAs were performed by staff vascular surgeons under general anesthesia with routine electroencephalographic (EEG) monitoring. Patients were given acetylsalicylic acid (81 mg or 325 mg) by mouth up to and including the morning of surgery. Endarterectomies were performed in a standard fashion with patch angioplasty closure. Shunting was performed selectively. Completion duplex ultrasound was routinely performed. Total operating room time was defined as the interval in minutes from patient entrance into the operating room until exit from operating room. Patients were observed in the recovery room prior to transfer to the ward. Select patients were transferred to the intensive care unit (ICU) for hypotension or hypertension requiring continuous intravenous drugs or other issues such as neurological changes, cardiac events, or respiratory compromise. Foley catheters were placed only if patients were unable to void postoperatively. There was a case manager dedicated to vascular patients, and the normal expectation is to discharge patients on the first postoperative day (POD).

Variables. Standard demographic data, cardiovascular comorbidities and medications, indication for CEA, repeat CEA, contralateral carotid occlusion, EEG changes, patch angioplasty, and intraoperative shunting were recorded prospectively. Additionally, we retrospectively collected, via medical record review, clinical characteristics (history of congestive heart failure [CHF], chronic renal insufficiency, preadmission status), perioperative data (total operating room time, CEA case volume per surgeon, drain placement), postoperative course (need for ICU, need for Foley catheter, postoperative LOS, and discharge destination), postoperative in-hospital complications (transient ischemic attack or stroke, bleeding or hematoma, cardiac arrhythmia, seizure, myocardial infarction, pneumonia, respiratory failure requiring reintubation, renal failure, CHF exacerbation, wound infection, pulmonary embolism, carotid thrombosis, dysphagia, and need for reoperation), and long-term outcomes (1-year hospital readmission and 1-year mortality).

Chronic renal insufficiency was defined as preoperative serum creatinine >2.0 mg/dL. A high CEA case volume was defined as ≥18 CEA procedures per year per surgeon.[5] Stroke was defined as the persistence of a neurological deficit beyond 24 hours, as defined by a consulting neurologist. A disabling stroke was one that significantly impaired outcome, while a non-disabling stroke produced no significant functional disability.[6] The primary end point was ELOS, defined as discharge on POD 2 or later. Secondary end points were discharge on or after POD 3, unplanned readmission (URA) within 30 days of discharge, any hospital readmission over 1 year, and overall survival at 1 year.

Statistical analysis. We examined associations with the primary end point of ELOS using two-tailed Student *t*-tests for continuous variables (Mann-Whitney *U* tests for nonparametric continuous variables) and χ^2 tests for categorical variables (Fisher exact tests for nonparametric categorical variables). Each variable that was statistically significant at the $P < .05$ level on univariable analysis was included in a stepwise multivariable logistic regression model for the outcome of ELOS. We calculated mortality and hospital readmission rates by ELOS using the Kaplan-Meier method, with unadjusted differences evaluated using the log-rank test. Analyses resulting in values of $P < .05$ were considered significant. SAS 9.3 (SAS Inc, Cary, NC) was used for all statistical analyses.

Table I. Baseline characteristics of patients undergoing carotid endarterectomy (*CEA*)

Baseline characteristics	*No. (%)*
Median age, years (IQR)	70.1 (64-77)
Female gender	349 (39.0)
Caucasian	850 (95.0)
Past medical history	
Diabetes	271 (30.3)
Smoking	246 (27.5)
Hypertension	736 (82.2)
Coronary artery disease	390 (43.6)
CHF	58 (6.5)
Prior coronary artery bypass graft	179 (20.1)
COPD	89 (9.9)
Chronic kidney disease (serum Cr >2.0 mg/dL)	37 (4.1)
End-stage renal disease	3 (0.3)
Indication	
Asymptomatic	586 (65.4)
Transient ischemic attack	122 (13.6)
Recent stroke	95 (10.6)
Amaurosis fugax	92 (10.3)
Contralateral occlusion	58 (6.5)
Reoperative CEA	22 (2.5)
Preadmit	102 (11.4)

CHF, Congestive heart failure; *COPD*, chronic obstructive pulmonary disease; *Cr*, creatinine; *IQR*, interquartile range.

RESULTS

Study cohort. Eight hundred forty patients underwent 897 CEA procedures during the study period. Baseline characteristics are reported in Table I. Median age was 70.1 years (interquartile range [IQR], 64-77 years). Three hundred forty-nine (38.9%) procedures were in females and 309 (34.7%) were for symptomatic disease. One hundred forty-two (15.8%) patients were octogenarians and eight (0.9%) were nonogenarians. In 102 (11.4%) cases, patients were admitted prior to the day of CEA ("preadmitted"), while the rest were admitted on the day of surgery. Median follow-up was 3.4 years (IQR, 1.2-5.2 years).

Operative details. Operative details for the entire cohort are shown in Table II. Most cases were done under general anesthesia (99.1%) with EEG monitoring (94.3%). One hundred four (12.2%) patients had EEG changes. One hundred sixty-three (18.2%) had intraoperative shunts. Drains were placed in 236 (26.4%) cases. Median operating room time was 2.8 hours (IQR, 2.3-3.3 hours).

Perioperative mortality and morbidity. One hundred twenty-four patients (13.9%) required transfer to the ICU postoperatively, usually in the setting of hypotension (n = 69; 55.6%) or hypertension (n = 38; 30.6%).

Table II. Operative details of patients undergoing carotid endarterectomy (CEA)

Operative characteristics	*No. (%)*
General anesthesia	886 (99.1)
EEG monitor	842 (94.3)
EEG changes	104 (12.2)
Shunt	163 (18.2)
Patch angioplasty	883 (98.5)
Drain	236 (26.4)
Median operating room time, hours (IQR)	2.8 (2.3-3.3)

EEG, Electroencephalography; *IQR,* interquartile range.

One hundred thirty-two patients (14.8%) required Foley placement. Of these, 92 (69.7%) were males. Median and mean postoperative LOS were 1 day (IQR, 1-2 days) and 2.4 ± 4.4 days, respectively. The range was 1 to 66 days. Most patients (n = 837; 93.7%) were discharged to home. Of these, 312 (34.9%) were discharged with visiting nurse services. Fifty-eight (6.5%) had a 30-day postdischarge URA. There was no association between ELOS and URA (6.0% vs 7.0%; $P = .59$).

As shown in Table III, 9.9% (n = 89) of patients suffered one or fewer in-hospital complication and 2.8% (n = 25) suffered two or more in-hospital complications. Among patients who had a complication, mean and median number of complications was 1.3 ± 0.7 and 1 (IQR, 1-2), respectively. The most frequent complication was bleeding or hematoma, which occurred in 4.1% (n = 37) of cases. Three percent (n = 27) of patients required reoperation, usually for a bleeding complication (n = 24; 88.9%). As shown in Table IV, there were 15 postoperative strokes (1.7%), six of which occurred after initial discharge, two of which were disabling, and none of which were fatal. Cause of death was known in three of the five patients who died within 30 days of CEA (ruptured thoracoabdominal aortic aneurysm, *C. difficile* sepsis, and ischemic colitis). Thirty-day stroke or death rate and 1-year death rate were 2.2% and 3.5%, respectively.

Extended postoperative LOS. The distribution of postoperative LOS is shown in Fig 1. Four hundred fourteen patients (46.2%) had ELOS. One hundred seventy (19.1%) and 107 (11.9%) patients were discharged on POD 3 or later (ELOS 3) and on POD 4 or later (ELOS 4), respectively.

Factors associated with ELOS on univariable analysis are shown in Table V. Patients in the ELOS group were more likely to be older (median age, 72.0; IQR, 64-78 years vs 70.0; 64-76 years; $P < .01$), female (44.3% vs 34.6%; $P < .01$), non-Caucasian (6.8% vs 3.5%; $P = .03$), diabetic (34.1% vs 27.1%; $P = .02$), smokers (31.7% vs 23.8%; $P < .01$), and to have a history of chronic obstructive pulmonary disease (COPD; 13.4% vs 6.9%; $P < .01$) and/or CHF (9.9% vs 3.3%; $P < .01$). They were also more likely to be preadmitted (17.9% vs 5.8%; $P < .01$), to have symptomatic carotid disease (41.2% vs 29.0%; $P < .01$), and intraoperative EEG changes (17.0% vs 7.7%; $P < .01$). Patients with ELOS were more likely to

Table III. Frequency of in-hospital morbidity after carotid endarterectomy (CEA)

In-hospital morbidity	*No. (%)*
At least one in-hospital complication	89 (9.9)
Two or more in-hospital complications	25 (2.8)
In-hospital complications	
Transient ischemic attack	6 (0.7)
Stroke	12 (1.3)
Bleeding/hematoma	37 (4.1)
Arrhythmia	19 (2.1)
Seizure	2 (0.2)
Myocardial infarction	11 (1.2)
Pneumonia	9 (1.0)
Respiratory failure	7 (0.8)
Renal failure	7 (0.8)
CHF	4 (0.5)
Wound infection	9 (1.0)
Pulmonary embolism	1 (0.1)
Carotid thrombosis	2 (0.2)
Dysphagia	15 (1.7)
Reoperation	27 (3.0)

CHF, Congestive heart failure.

Table IV. Perioperative stroke and death

	No. (%)
30-day stroke	15 (1.7)
30-day death	5 (0.6)
30-day stroke or death	21 (2.2)
1-year death	31 (3.5)
1-year restenosis/thrombosis	7 (.7)

have been operated on by an attending surgeon who did not have a high CEA case volume (48.9% vs 41.7%; $P = .03$), at an operating room start time after 12:00 pm (32.2% vs 22.9%; $P < .01$), and for longer total operating room time (median, 3.0 hours [IQR, 2.4-3.5] vs 2.6 hours [IQR, 2.3-3.2]; $P < .01$). Postoperatively, patients with ELOS were more likely to require ICU care (25.5% vs 4.2%; $P < .01$) and to have urinary retention requiring Foley catheter placement (21.8% vs 8.8%; $P < .01$). Additionally, patients with ELOS were more likely to have had postoperative complications (0.3 ± 0.6 [range, 0-4] vs 0.04 ± 0.2 [range, 0-3]; $P < .01$) or need reoperation (5.1% vs 1.3%; $P < .01$).

Variables independently associated with ELOS in the multivariable analysis were divided into preoperative, intraoperative, and postoperative factors and are presented in Table VI. Preoperative factors were preadmission status (odds ratio [OR], 3.3; 95% confidence interval [CI], 1.9-5.7; $P < .01$), history of CHF (OR, 2.1; 95% CI, 1.1-4.2, $P = .03$), female gender (OR, 1.9; 95% CI, 1.4-2.6; $P < .01$), and history of COPD (OR, 1.7; 95% CI, 1.0-2.9; $P = .04$). Operative factors were EEG change (OR, 1.9; 95% CI, 1.2-3.2; $P < .01$), operating room start time after 12:00 pm (OR, 1.7; 95% CI, 1.2-2.4; $P < .01$), and total operating room time (OR, 1.5 per hour; 95% CI, 1.2-1.9; $P < .01$). Postoperative factors were

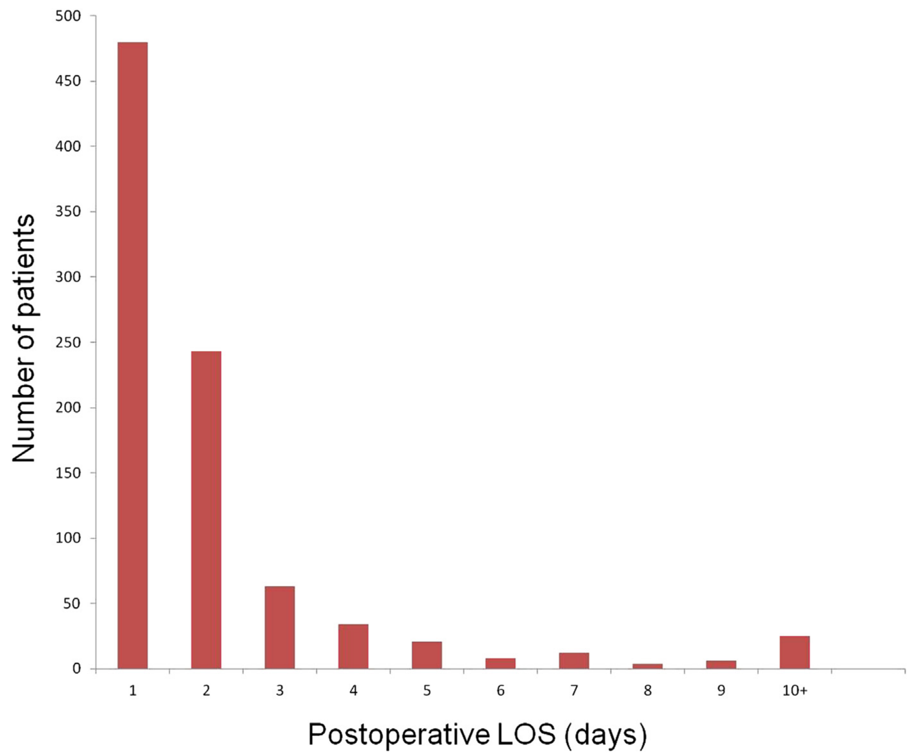

Fig 1. Frequency distribution of postoperative length of stay (*LOS*) after carotid endarterectomy (CEA).

transfer to ICU (OR, 5.4; 95% CI, 3.1-9.4; $P < .01$), number of in-hospital postoperative complications (OR, 3.7; 95% CI, 2.2-6.5; $P < .01$), and Foley catheter placement (OR, 2.1; 95% CI, 1.3-3.4; $P < .01$).

There was no correlation between ELOS and URA within 30 days of discharge (6.0% vs 7.0%; $P = .55$). However, as shown in Fig 2, *A*, there was a significant association between ELOS and 1-year postdischarge hospital readmission (planned or unplanned) between 31 days and 1 year (93.6% vs 84.7%; $P < .01$, log-rank test) and decreased survival in the ELOS group over 1 year (98.3% vs 95.1%; log-rank test, $P < .01$; Fig 2, *B*).

DISCUSSION

In this analysis of prospectively collected data at a single institution, we found that 46.2% (95% CI, 43%-49%) of patients were discharged on POD 2 or later during the 10-year study period, notwithstanding the institution's longstanding inclination for discharge on POD 1. Preoperative patient characteristics, intraoperative variables, and postoperative events all contributed to ELOS. We identified a number of potentially modifiable risk factors for ELOS, including timing of the case after 12:00 pm and urinary retention. We also observed that ELOS was associated with long-term morbidity and mortality.

Among preoperative risk factors, we found female gender and history of CHF or COPD to be predictive of ELOS in accordance with prior literature suggesting a gender difference in outcomes after CEA[7-10] and worse outcomes after carotid revascularization in patients with heart failure or COPD.[11-14] Women in our cohort had median postoperative LOS 1 day longer than men ($P < .01$) and had 1.9 times the odds of ELOS compared with men. Patients with either CHF or COPD had approximately twofold odds of ELOS, even after adjusting for other factors. We were surprised to see the correlation between operating room start time after 12:00 pm and ELOS. It does not appear to be secondary to complications in the late-start cohort, as there was no significant correlation between a late start time and the occurrence of in-hospital postoperative complications ($P = .59$). It would be interesting to parse out this correlation further in a prospective fashion. Due to our referral pattern, many of our patients live outside the local area. A common scenario for patients leaving the operating room late in the day is that the morning of POD 1 is spent monitoring for headache or titrating blood pressure or pain medication; often, patients are not ready for discharge until the following day. Potential risk modification includes starting the case before 12:00 pm.

Intraoperative variables associated with ELOS included longer operating room time and intraoperative EEG changes. The association between longer operating room time and ELOS is concordant with prior reports on CEA[11,15,16] and any major vascular surgery.[17] Increased operating room time is likely a marker for more complex patients who required lengthier anesthesia and nursing care or for more complex carotid disease that required a longer operative time and hence posed risks for

Table V. Univariate analysis of patient characteristics based on extended length of stay (*ELOS*) after carotid endarterectomy (*CEA*)

	Total cohort (N = 897)	*No ELOS (n = 484) (53.9%)*	*ELOS (n = 413) (46.2%)*	P *value*
Median age, years (IQR)	69.3 (64-76)	70 (64-76)	72 (64-78)	**.006**
Female gender	349 (39.1)	166 (34.6)	183 (44.3)	**.003**
Non-Caucasian	45 (5.0)	17 (3.5)	28 (6.8)	**.03**
Diabetes mellitus	271 (30.3)	130 (27.1)	141 (34.1)	**.02**
Current smoker	245 (27.4)	114 (23.8)	131 (31.7)	**.008**
Hypertension	735 (82.3)	397 (82.7)	338 (81.8)	.73
Prior coronary artery bypass graft	179 (20.0)	96 (20.0)	83 (20.1)	.97
CHF	57 (6.4)	16 (3.3)	41 (9.9)	**<.0001**
COPD	89 (10.0)	33 (6.9)	56 (13.4)	**.0009**
Chronic kidney disease (serum Cr ≥2.0 mg/dL)	37 (4.1)	15 (3.1)	22 (5.3)	.10
Dialysis	3 (0.3)	1 (0.2)	2 (0.5)	.60
Symptomatic carotid stenosis	309 (34.6)	139 (29.0)	170 (41.2)	**.0001**
Surgeon with low CEA volume (<18/year)	402 (45.0)	200 (41.7)	202 (48.9)	**.03**
Preadmit status	102 (11.4)	28 (5.8)	74 (17.9)	**<.0001**
Operating room start time after 12:00 pm	243 (27.2)	110 (22.9)	133 (32.2)	**.002**
Median operating room time, hours (IQR)	2.8 (2.3-3.3)	2.6 (2.3-3.2)	3.0 (2.4-3.5)	**<.0001**
EEG changes	103 (12.1)	35 (7.7)	68 (17)	**<.0001**
Shunt	163 (18.4)	77 (15.9)	86 (20.8)	.15
Drain	236 (26.4)	119 (24.8)	117 (28.4)	.22
Foley catheter	132 (14.8)	42 (8.8)	90 (21.8)	**<.0001**
Postoperative ICU	124 (13.9)	20 (4.2)	104 (25.2)	**<.0001**
Postoperative hypertension requiring continuous intravenous vasoactive medication	38 (4.3)	5 (1.0)	33 (8.0)	**<.0001**
Postoperative hypotension requiring continuous intravenous vasoactive medication	69 (7.7)	17 (3.5)	52 (12.6)	**<.0001**
Discharge to facility	56 (6.3)	7 (1.5)	49 (11.9)	**<.0001**
Mean ICU LOS (if in ICU postoperative), days ± SD (range)	2.4 ± 3.2 (0-32)	1.6 ± 0.7 (0-2)	2.5 ± 3.4 (0-32)	**.02**
Median total LOS, days (IQR)	3 (2-4)	2 (2-2)	3 (3-5)	**<.0001**
At least 1 in-hospital postoperative morbidity	89 (10.0)	12 (2.5)	77 (18.6)	**<.0001**
Mean number of complications ± SD (range)	0.15 ± 0.5 (0-4)	.04 ± 0.2 (0-3)	0.3 ± 0.6 (0-4)	**<.0001**
Postoperative transient ischemic attack	6 (0.7)	0	6 (1.5)	**.001**
Postoperative stroke	12 (1.3)	2 (0.4)	10 (2.4)	**.01**
Postoperative hematoma	37 (4.1)	9 (1.9)	28 (6.8)	**.0002**
Postoperative arrhythmia	19 (2.1)	0	19 (4.6)	**<.0001**
Postoperative myocardial infarction	11 (1.2)	1 (0.2)	10 (2.4)	**.003**
Postoperative pneumonia	9 (1.0)	2 (0.4)	7 (1.7)	.09
Postoperative respiratory failure	7 (0.8)	1 (0.2)	6 (1.5)	**.04**
Postoperative renal failure	7 (0.8)	1 (0.2)	6 (1.5)	**.04**
Postoperative CHF	4 (0.5)	0	4 (1.0)	.05
Postoperative wound infection	9 (1.0)	2 (0.4)	7 (1.7)	.09
Early carotid thrombosis	2 (0.2)	0	2 (0.5)	.21
Postoperative dysphagia	15 (1.7)	0	15 (3.6)	**<.0001**
Reoperation	27 (3.0)	6 (1.3)	21 (5.1)	**.0008**

CHF, Congestive heart failure; *COPD,* chronic obstructive pulmonary disease; *Cr,* creatinine; *EEG,* electroencephalography; *ELOS,* extended length of stay; *ICU,* intensive care unit; *IQR,* interquartile range; *LOS,* length of stay; *SD,* standard deviation.
Data are presented as median (IQR), mean ± SD (range), or number (%). $P < .05$ were considered significant and are shown in bold.

postoperative complications or increased LOS. Similarly, we found intraoperative EEG changes to be associated with ELOS. Although intraoperative factors are difficult to modify, these findings of their association with ELOS may prove useful for discharge planning.

Postoperative variables associated with ELOS included postoperative complications, ICU admission, and urinary retention. We found that even a single postoperative complication was a strong predictor of prolonged LOS (OR, 7.1; 95% CI, 3.6-14.2; $P < .01$), while the type of complication may be less significant. Our rate of hematoma formation (4.1%) is high, but it includes both patients who were managed conservatively and who required re-exploration, and as such, it is comparable to other rates of hematoma formation reported in the literature. There was a 5.5% hematoma rate in the North American Symptomatic Carotid Endarterectomy Trial (NASCET).[18] Similarly, the New York Carotid Artery Surgery study reported a 5.5% hematoma formation rate in 9308 cases.[19] We do not advocate for more frequent drain placement, as this was previously shown in a randomized prospective fashion not to decrease hematoma formation or the rate for reoperation.[20] Need for reoperation alone did not necessarily increase LOS, presumably because most reoperations

Table VI. Multivariate analysis of extended length of stay (ELOS) after carotid endarterectomy (CEA)

Variable	*Adjusted OR*	*95% CI*	P *value*
Preoperative factors			
Preadmit	3.3	1.9-5.7	<.0001
CHF	2.1	1.1-4.2	.03
Female gender	1.9	1.4-2.6	.0001
COPD	1.7	1.0-2.9	.04
Operative factors			
Electroencephalography change	1.9	1.2-3.2	.009
Operating room start time after 12:00 pm	1.7	1.2-2.4	.002
Total operating room time	1.5	1.2-1.9	.0004
Postoperative factors			
Postoperative ICU	5.4	3.1-9.4	<.0001
Number of in-hospital complications	3.7	2.2-6.5	<.0001
Foley catheter	2.1	1.3-3.4	.002

CHF, Congestive heart failure; *CI,* confidence interval; *COPD,* chronic obstructive pulmonary disease; *ICU,* intensive care unit; *OR,* odds ratio.

occurred on the same day of surgery. Patients requiring a postoperative ICU stay had five-fold odds of ELOS. It is our practice to transfer any patient requiring continuous intravenous blood pressure medication infusion to the ICU for hemodynamic monitoring. It is possible for many of these patients to be weaned off intravenous medications within several hours, thus rendering the need for continued ICU-level care unnecessary. In these stable patients who would otherwise be cleared for discharge to home on POD 1, an ICU stay may be a barrier for hospital discharge and could be a reason for extended LOS, as ICU nurses and physicians are usually unfamiliar with the discharge process. An improved discharge process from the ICU, a more efficient process for transfer out of the ICU for discharge, or establishment of an intermediate-care unit or step-down unit for short-stay ICU patients who need "low-risk monitoring" may facilitate timely discharge in these patients.[21] Finally, given the high rates of urinary retention and the correlation with ELOS, we have now changed our practice such that Foley catheters are routinely placed in all males over the age of 65 undergoing CEA, with a plan for a future study on the outcomes of ELOS and catheter-related urinary tract infection in patients before and after the initiation of the new Foley catheterization protocol.

Finally, preadmission was strongly associated with ELOS in our study. It is our routine practice to admit all patients to the hospital on the day of surgery for elective CEAs. As such, preadmitted patients are either symptomatic patients transferred from another institution; patients who are in the hospital for another reason and subsequently develop symptoms referable to carotid disease; or patients who need inpatient preoperative monitoring, evaluation, or optimization. This includes inpatients who are initially seen by a neurologist and are later referred to a vascular surgeon. In this study, 85 (83.3%) of all preadmitted patients were symptomatic vs 224 (28.3%) of nonpreadmitted patients. For these reasons, our finding that preadmission status is associated with increased postoperative LOS potentially represents confounding by indication. In discharge planning, preadmission status should represent a flag for more likely increased LOS.

In our study, nearly half of patients had ELOS. This was higher than we anticipated, but nationally, the proportion of patients with extended postoperative LOS after CEA is also high: Glaser et al[11] reported a 17.5% rate of ELOS after CEA in 8860 patients from 2003 to 2011 at 22 centers in the Vascular Study Group of New England. In the 2011 American College of Surgeons National Surgical Quality Initiative Program (NSQIP) database, 17.4% of all patients undergoing CEA performed by a vascular surgeon are discharged on POD 2 or later, and 11.2% are discharged on POD 3 or later (unpublished). While our absolute rate of ELOS may not be widely generalizable, our analysis of the reasons for ELOS is still applicable.

Changes in health care reimbursement policies over the past two decades have prompted hospitals to adopt strategies that decrease health care resource utilization. Beginning in the mid-1990s, there was an abundance of literature describing the safety and cost benefits of multiple changes in the practice of CEA, including a shift towards admission the day of surgery for elective CEA, selective carotid angiography, cervical block anesthesia, and clinical pathways involving selective postoperative ICU monitoring and discharge on the first POD. This body of literature demonstrated that in the modern era, patients undergoing uncomplicated CEA can be discharged safely and feasibly on the first POD.[22] Indeed, in our study, 792 patients (88.6%) were same-day admits, and 480 (53.5%) were discharged on POD 1. Furthermore, the reported mean postoperative LOS after CEA has significantly decreased in numerous practice settings.[9,12,23-31] Unlike other institutions,[12,29] we did not observe a linear trend in LOS over time.

That even a single day of increased LOS after CEA is associated with increased morbidity and mortality over 1 year has not been previously reported and deserves further investigation into causes of death and reasons for hospital readmission over 1 year. The fact that ELOS was not correlated with unplanned 30-day readmission and was not an independent predictor of mortality in a Cox proportional hazards model (data not shown) suggests that the severity of comorbid disease, rather than the CEA procedure itself, was likely responsible for morbidity and mortality after discharge.

There are several limitations to this study. First, our practices, clinical pathways, and referral patterns may limit the generalizability of our findings to other institutions. We have a low threshold not to discharge patients with postoperative headache, as it may be a possible symptom of cerebral hyperperfusion. We also carefully monitor patient blood pressures prior to discharge with a goal to keep systolic blood pressures less than 140 mm Hg unless contraindicated. However, a nationally representative

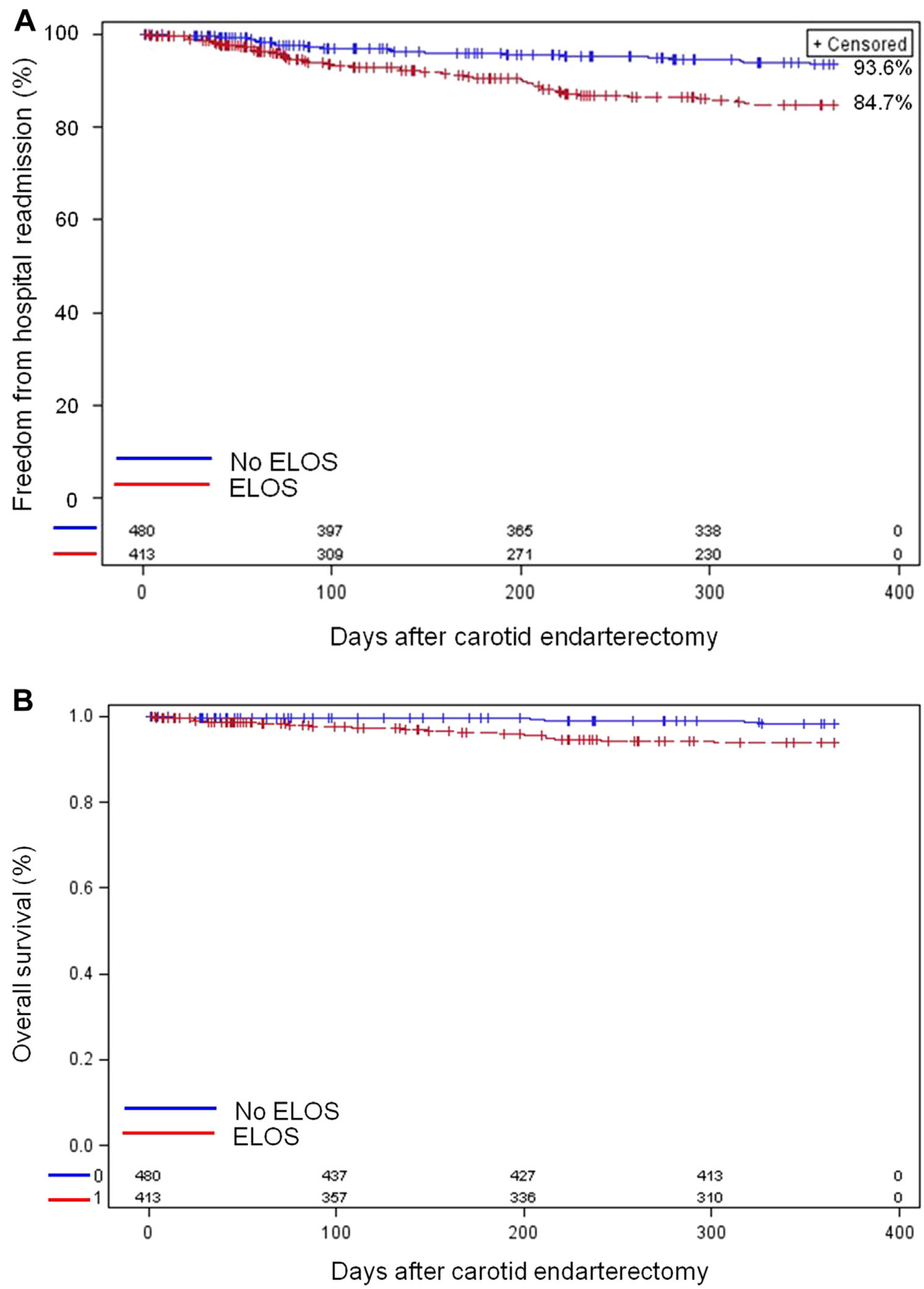

Fig 2. A, Decreased hospital readmission among patients with extended postoperative length of stay (*ELOS*) after carotid endarterectomy (CEA). Log-rank $\chi^2 = 15.4$; $P < .01$. **B,** Decreased survival over 1 year among patients with ELOS. Log rank $\chi^2 = 10.1$; $P < .01$.

sample from the 2011 American College of Surgeons National Surgical Quality Improvement Program database also had surprisingly high rates of extended postoperative LOS. Second, as a retrospective study, data that were not collected for the prospective database or for clinical use were unavailable for inclusion in the analysis. We expect that this would lead to nondifferential missing data and bias our results toward the null. We have no data on preoperative patient functional status, availability of transportation, and adequacy of home care, all of which could conceivably significantly influence time to discharge. We were also unable to capture discrete reasons for extended LOS in most cases, since this information is only variably captured in discharge summaries. Finally, we do not have any cost accounting data on postoperative CEA care and how much cost savings we can expect from measures to reduce LOS. However, our findings may inform future cost-effectiveness studies.

CONCLUSIONS

In summary, this work adds to the evidence that postoperative factors (particularly the number of complications) remain as important as preoperative patient characteristics in determining risk for increased LOS.[16] We anticipate that simple interventions on modifiable risk factors will significantly decrease the proportion of patients requiring a single extra day of postoperative care. These include early Foley catheter placement and removal on the day of surgery to prevent urinary retention in at-risk males and scheduling CEA cases to start in the morning rather than after 12:00 pm. Intraoperative and postoperative efforts to prevent and mitigate adverse events may decrease the number of patients with increased LOS. Finally, increased LOS following CEA may be a harbinger for increased risk of long-term readmission and mortality.

AUTHOR CONTRIBUTIONS

Conception and design: KH, AM, JM, MS, RB, LN, CO, MB
Analysis and interpretation: KH, AM, MS, RB, LN, CO, MB
Data collection: KH, AM, JM, RB
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Critical revision of the article: KH, AM, JM, MS, RB, LN, CO, MB
Final approval of the article: KH, AM, JM, MS, RB, LN, CO, MB
Statistical analysis: KH, AM, MS
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