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Length of hospital stay after craniotomy for tumor: a National Surgical Quality Improvement Program analysis

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OBJECT Although the length of hospital stay is often used as a measure of quality of care, data evaluating the predictors of extended hospital stay after craniotomy for tumor are limited. The goals of this study were to use multivariate regression to examine which preoperative characteristics and postoperative complications predict a prolonged hospital stay and to assess the impact of length of stay on unplanned hospital readmission.

METHODS Data were extracted from the National Surgical Quality Improvement Program (NSQIP) database from 2007 to 2013. Patients who underwent craniotomy for resection of a brain tumor were included. Stratification was based on length of hospital stay, which was dichotomized by the upper quartile of the interquartile range (IQR) for the entire population. Covariates included patient age, sex, race, tumor histology, comorbidities, American Society of Anesthesiologists (ASA) class, functional status, preoperative laboratory values, preoperative neurological deficits, operative time, and postoperative complications. Multivariate logistic regression with forward prediction was used to evaluate independent predictors of extended hospitalization. Thereafter, hierarchical multivariate logistic regression assessed the impact of length of stay on unplanned readmission.

RESULTS The study included 11,510 patients. The median hospital stay was 4 days (IQR 3–8 days), and 27.7% (n = 3185) had a hospital stay of at least 8 days. Independent predictors of extended hospital stay included age greater than 70 years (OR 1.53, 95% CI 1.28%–1.83%, $p < 0.001$); African American (OR 1.75, 95% CI 1.44%–2.14%, $p < 0.001$) and Hispanic (OR 1.68, 95% CI 1.36%–2.08%) race or ethnicity; ASA class 3 (OR 1.52, 95% CI 1.34%–1.73%) or 4–5 (OR 2.18, 95% CI 1.82%–2.62%) designation; partially (OR 1.94, 95% CI 1.61%–2.35%) or totally dependent (OR 3.30, 95% CI 1.95%–5.55%) functional status; insulin-dependent diabetes mellitus (OR 1.46, 95% CI 1.16%–1.84%); hematological comorbidities (OR 1.68, 95% CI 1.25%–2.24%); and preoperative hypoalbuminemia (OR 1.78, 95% CI 1.51%–2.09%, all $p \leq 0.009$). Several postoperative complications were additional independent predictors of prolonged hospitalization including pulmonary emboli (OR 13.75, 95% CI 4.73%–39.99%), pneumonia (OR 5.40, 95% CI 2.89%–10.07%), and urinary tract infections (OR 11.87, 95% CI 7.09%–19.87%, all $p < 0.001$). The C-statistic of the model based on preoperative characteristics was 0.79, which increased to 0.83 after the addition of postoperative complications. A length of stay after craniotomy for tumor score was created based on preoperative factors significant in regression models, with a moderate correlation with length of stay ($\rho = 0.43$, $p < 0.001$). Extended hospital stay was not associated with differential odds of an unplanned hospital readmission (OR 0.97, 95% CI 0.89%–1.06%, $p = 0.55$).

CONCLUSIONS In this NSQIP analysis that evaluated patients who underwent craniotomy for tumor, much of the variance in hospital stay was attributable to baseline patient characteristics, suggesting length of stay may be an imperfect proxy for quality. Additionally, longer hospitalizations were not found to be associated with differential rates of unplanned readmission.

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KEY WORDS brain tumor; craniotomy; length of hospital stay; NSQIP; outcomes; readmission

ABBREVIATIONS ACS = American College of Surgeons; ASA = American Society of Anesthesiologists; INR = international normalized ratio; IQR = interquartile range; NSQIP = National Surgical Quality Improvement Program; PTT = partial thromboplastin time; UTI = urinary tract infection.

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With the passage of the Patient Protection and Affordable Care Act, value-based measures and outcomes have become an important aspect of grading quality of care.[4,20,23,34,35,50,64,66,68–70] Pay-for-performance measures have been proposed throughout medicine, including in surgical disciplines, to reward providers for quality care.[44,46,61] However, quality is an abstract concept that is difficult to directly quantify. Therefore, many policy makers and payers of health care have turned to easily measurable parameters that may serve as a proxy for quality of care.[68] One outcome that has been increasingly used as an indicator of quality, including in surgical and neurosurgical quality improvement programs, is length of hospital stay.[26]

Defined as the number of inpatient days recorded during a hospitalization, length of stay has gained prominence, because the drive for greater resource conservation and improved efficiency of care has created an emphasis on cost containment.[60] As the cost of an inpatient hospitalization continues to rise at twice the rate of inflation,[31] decreasing the length of hospital stay is an attractive target for payers of health care and policy makers. Multiple studies, including those evaluating patients undergoing craniotomy for tumors, have shown that length of hospital stay is independently associated with hospitalization charges.[37] To decrease costs and increase efficiency, organizations have sought to implement protocols designed to decrease length of stay.[60] However, minimization of length of stay to improve quality of care remains a controversial subject: some argue that rapid discharges lead to decreased patient satisfaction, increased emergency department visits, and higher readmission rates.[26,60]

Despite the increasing emphasis on length of stay, data that evaluate the predictors of extended hospitalization in the neurosurgical population are limited.[6] Moreover, no national study to date has specifically evaluated the predictors of prolonged stay following craniotomy for tumor. In this study, a nationally accrued patient population from the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) database was analyzed to evaluate length of stay after craniotomy for tumor. There are many advantages to the use of this data source, including the fact that data are collected prospectively, it is a validated multiinstitutional program, and data are available on many parameters of interest to oncology patients including functional status, comorbidities, prior oncological treatment, and baseline neurological status. The goals of this study were as follows: 1) evaluate what are the preoperative and postoperative predictors of extended hospitalization after craniotomy for tumor, and 2) analyze the impact of length of stay on unplanned hospital readmissions.

Methods

Data Source

Data were retrospectively extracted from the NSQIP database for the years 2007–2013. The NSQIP is a multiinstitutional program in which data are prospectively collected at more than 400 academic and private hospitals by surgical reviewers in accordance with a uniform protocol. The ACS routinely audits data from contributing institutions, and multiple reports have validated the accuracy of data from NSQIP.[56] This data source has been previously used to evaluate patients undergoing neurosurgical intervention,[7,9,11,13,24,28,33,47–49,52,53] including craniotomy for tumor.[1–3,10,14,29,54] The NSQIP database has been exempted as not human subject research by our institutional review board.

Inclusion Criteria

Patients were included who met the following predetermined criteria: 1) age 18 years or older; 2) a postoperative diagnosis of a brain tumor or of a primary extracranial malignancy; 3) a Current Procedural Terminology code indicating they underwent a supratentorial (61500, 61510, 61512) or infratentorial (61518, 61519, 61520, 61521, 61526, and 61530) craniotomy or craniectomy for excision of tumor; 4) the patient's attending surgeon was a neurosurgeon; 5) the disposition was inpatient; and 6) the documented anesthesia type was general anesthesia or monitored anesthesia care. Tumor histology was stratified based on *International Classification of Diseases, Ninth Revision, Clinical Modification* codes for 1) primary brain benign (225, 225.0, 225.9, 228.0, 228.02); 2) primary brain malignant (191.x, 192.9, 194.4); 3) secondary brain (198.3) or extracranial malignancy (150.x–159.x, 161.1, 162.x, 172.x, 174.x, 180.9, 185, 188.9, 189.0, 193, 194.1, 197.x, 198.x, 199.1, 209.x); 4) primary brain of uncertain malignancy (237.1, 237.5, 239.6); 5) meninges benign (225.2); 6) meninges malignant, uncertain, or secondary (192.1, 237.6, 198.4); or 7) cranial nerve benign (225.2, 237.72, 237.73) or malignant (192.0). Patients with pituitary tumors were not included, as these patients were expected to have a shorter hospital stay and are predisposed to different complications.

Patient Stratification

Length of hospital stay is encoded directly in the NSQIP. In the primary analysis, patients were analyzed dichotomously based on the upper quartile of the interquartile range (IQR) for the entire study population. Similar dichotomous characterization of length of stay has been used in other administrative database studies.[6,15,31]

Predictors

Pertinent covariates collected by the NSQIP were extracted. Age, sex, race, and tumor histology were evaluated. Age was evaluated categorically (18–45, 46–55, 56–70, and > 70 years); these divisions were chosen because they were the 5-year intervals approximating the median, lower, and upper quartiles of age of the study population. Given that the surgical risks vary with approaches, patients were stratified by supratentorial versus infratentorial tumor location. American Society of Anesthesiologists (ASA) class was assessed categorically as 1, 2, 3, 4, and 5, or missing. Functional status "prior to the current illness" is collected by NSQIP and stratified as 1) independent, 2) partially dependent, 3) totally dependent, and 4) unknown or missing.

Comorbidities collected by the NSQIP and present in

at least 30 patients were evaluated: smoking (within the last year), alcohol abuse (at least 2 drinks per day), hypertension requiring medication, prior cardiac revascularization, chronic obstructive pulmonary disease, dyspnea, and diabetes (non–insulin dependent and insulin dependent), which were stratified into absent, present, and missing (when applicable). Additionally, the NSQIP combines hypothrombotic conditions into a single comorbidity (bleeding disorders) that includes vitamin K deficiencies, hemophilias, thrombocytopenia, and long-term anticoagulant use; aspirin use is not included within this categorization. Patient height and weight are recorded by the NSQIP; body mass index (BMI) was calculated, and body habitus was classified based on WHO classification as nonobese, underweight (BMI < 18.5 kg/m^2), overweight (BMI 25–29 kg/m^2), Class I obesity (BMI 30–35 kg/m^2), Class II obesity (BMI 36–40 kg/m^2), and Class III obesity (BMI > 40 kg/m^2), or missing.[12]

Pertinent preoperative laboratory values available were extracted and evaluated categorically to appropriately account for missing data. These values and their stratification were sodium (by 135 mEq/L), creatinine (by 1.4 mg/dl), white blood cell count (by 4000/µl, 10,000/µl, and 20,000/µl), hematocrit (by 30% and 40%), platelet count (by 100,000/µl and 150,000/µl), partial thromboplastin time (PTT; by 40 seconds), and international normalized ratio (INR; by 1.4). Impaired sensorium, hemiplegia, and coma are assessments of baseline neurological status that are collected by the NSQIP, the former of which is defined as altered mental status or delirium in the context of the current illness, and "hemiplegia" is defined as paresis or plegia of 1 side of the body present on admission. Coma was infrequently encoded (n = 7) and thus was not used as a covariate. Steroid use, chemotherapy administration (within 30 days), and radiotherapy (within 90 days) were also extracted when recorded.

Admission type and preoperative intubation (within 48 hours) were evaluated. An emergency operation is defined by the NSQIP as any operation whereby the surgeon had deemed it as such. Operative time was extracted and evaluated categorically as < 180, 180–300, and > 300 minutes, as these are the 30-minute intervals closest to the median and upper quartile of the IQR within the entire population.

Because postoperative complications may also impact length of hospital stay, data were extracted on those complications that are collected by NSQIP. Postoperative cerebrovascular accidents are defined as an embolic, thrombotic, or hemorrhagic accident with motor, sensory, or cognitive dysfunction that persists for at least 24 hours. Although data on new postoperative coma are also collected by the NSQIP, given its rarity in this population (n = 17), this was not evaluated. Other medical complications extracted were cardiac (cardiac arrest or acute myocardial infarction); extubation failure; failure to wean off the ventilator for greater than 48 hours; symptomatic pulmonary embolus or deep venous thrombosis; infectious (surgical site infections, pneumonia, urinary tract infections, and sepsis); and postoperative packed red blood cell transfusions (within 72 hours postoperatively).

Additional Outcomes

Discharge disposition and readmission were evaluated among patients discharged alive, which are only available for the years 2011–2013. A nonroutine hospital discharge was defined as any discharge other than home. Among those with a nonroutine hospital discharge, an additional analysis compared patients discharged to institutional care with those discharged to acute rehabilitation, to evaluate whether type of posthospitalization care impacted length of hospital stay. Unplanned readmission to any acute care facility within 30 days was also extracted.

Sensitivity Analysis

Two additional sensitivity analyses were performed. The first evaluated predictors of extended hospitalization after excluding patients with in-hospital mortality. The second analysis was performed on discharge disposition and hospital readmission, evaluating length of hospital stay as a continuous variable, which was logarithmically transformed due to nonnormal distribution with significant skew.

Missing Data

Missing data are a potential limitation of any administrative database, and the NSQIP explicitly denotes if data are missing on any given parameter. Many covariates had missing data in a proportion of patients. For these variables, those with missing data were categorized into a different group to maintain appropriate stratification, but data from this group were not reported separately in multivariate analyses.

Statistical Analysis

Statistical analyses were performed using Stata version 13 (StataCorp). Baseline demographic and preoperative variables were compared using the chi-square test. Multivariate regression modeling with forward prediction was used to evaluate predictors of extended hospital stay, with logistic regression used in the dichotomous analysis and linear regression selected for the continuous sensitivity analysis. Each potential predictor was screened with bivariate analysis, and those significant were included in the final multivariate model. Two different multivariate models were constructed, the first of which only included preoperative and intraoperative characteristics, to evaluate the degree to which length of stay varies by baseline factors. The second model included all significant predictors, including postoperative complications. Thereafter, hierarchical multivariate logistic regression models using all previously defined covariates evaluated the association of hospital stay with discharge disposition and unplanned readmission. C-statistics assessed the discriminatory capacity of logistic regression models, and R^2 was used for linear regression. Subsequently, a length of stay after craniotomy for tumor score was created with all factors significant in multivariate logistic regression with an odds ratio of at least 1.50. Spearman rank correlation was used (due to nonnormal distribution of length of stay) to evaluate the correlation of the score with hospital stay. A p value < 0.05 was defined as significant.

Results

Demographics of Study Population

This study included 11,510 patients, of whom 72.2% (n = 8314) had a hospitalization shorter than 8 days and 27.7% (n = 3185) had a hospital stay of at least 8 days. The median hospital stay in the entire population was 4 days (IQR 3–8 days, range 0–369 days), and the 90th, 95th, and 99th percentiles were 14, 20, and 38 days, respectively (Fig. 1). The demographics and preoperative characteristics of the patients were compared by length of stay (Table 1). The median age of the population was 58 years (IQR 47–67 years), and many key demographics varied by length of stay (Fig. 2).

Predictors of Extended Hospitalization

Multivariate regression modeling with forward prediction was used to evaluate the independent predictors of prolonged hospital stay. First, variables were screened using bivariate logistic regression; all variables were significantly associated with extended hospital stay with the exception of alcohol abuse, preoperative chemotherapy, preoperative radiation therapy, and surgical site infections (data not shown). Variables that were significant in univariate models were used in 2 multivariate logistic regression models: the first exclusively evaluated preoperative and operative characteristics and the second included postoperative complications (Table 2).

As a sensitivity analysis, multivariate linear regression with forward prediction was used to evaluate predictors of a longer hospitalization when evaluated as a continuous variable. Likewise, potential predictors were screened with bivariate analysis, all of which were significantly associated with prolonged hospitalization, except for patient sex, alcohol abuse, and preoperative radiation therapy (data not shown). These variables were then included in 2 multivariate linear regression models, of which the first only included preoperative and operative characteristics, whereas the second also included postoperative complications (Table 3).

An additional analysis was performed using both multivariate logistic and linear regression after excluding patients who died during the index hospitalization (n = 141). Both logistic and linear regressions included the same variables as the primary analysis. In the logistic regression analysis, similar significant associations were found (albeit with slightly different effect sizes), with C-statistics of 0.79 and 0.83 in Models 1 and 2, respectively (data not shown). In the first linear regression model, similar associations were found, except non–insulin-dependent diabetes mellitus was also significantly associated with longer hospital stay (by 5.91%, 95% CI 0.14%–11.68%, p = 0.04). The second linear regression model also saw similar associations, except that Asian race or ethnicity (by 7.82%, 95% CI 0.03%–15.61%, p = 0.05) and anesthesia time > 390 minutes (by 7.73%, 95% CI 0.94%–14.53%, p = 0.03) were also significantly associated with longer hospitalization, whereas white blood cell count > 20,000/μl only trended toward significance (by 8.87%, 95% CI −0.07% to 17.81%, p = 0.05, other data not shown). The R^2 values of the models were 0.22 and 0.29, respectively.

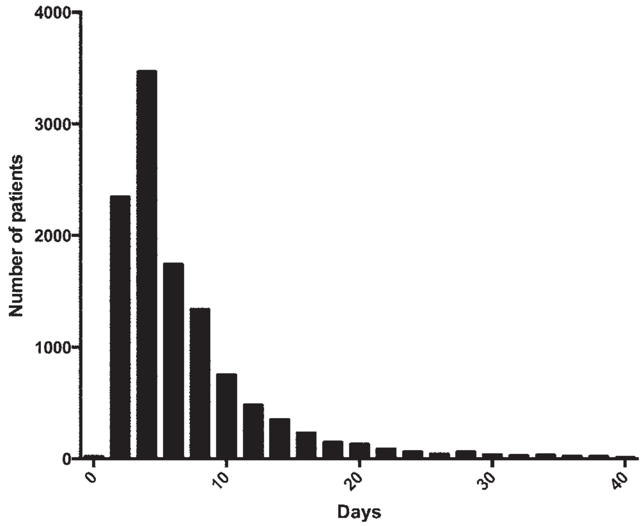

FIG. 1. Histogram showing the distribution of length of stay in the study population. The 99th percentile of hospital stay was 38 days; however, 104 patients had hospital stays greater than 40 days, with the longest being 369 days.

Length of Stay After Craniotomy for Tumor Score

A length of hospital stay score was then created based on 10 preoperative factors that were significant in the multivariate logistic regression model with an odds ratio of at least 1.5 (Table 4). This score allows for partial adjustment for length of stay based on baseline characteristics that are available in the NSQIP. This score had a moderate correlation with recorded length of hospital stay (ρ = 0.43, p < 0.001). The median length of hospital stay after craniotomy for tumor score was 2 (IQR 1–3); 14.3% of patients (n = 1645) had a score of 0, 28.1% (n = 3231) had a score of 1, 26.3% (n = 3029) had a score of 2, 17.0% (n = 1958) had a score of 3, 8.8% (n = 1015) had a score of 4, and 5.5% (n = 632) had a score of at least 5. The median hospital stay was 3 days (IQR 2–4 days) for patients with a score of 0, 4 days (IQR 3–7 days) for those with a score of 1–2, 7 days (IQR 4–11 days) for those with a score of 3–4, and 11 days (IQR 7–16 days for patients with a score of at least 5; Fig. 3).

Discharge Disposition and Readmission

The impact of prolonged hospitalization on discharge disposition and unplanned hospital readmission is evaluated in Table 5. A hospital stay of at least 8 days was associated with increased odds of a nonroutine hospital discharge (OR 4.34, 95% CI 3.82%–4.94%, p < 0.001), but no difference was noted when comparing patients discharged to institutional care (OR 1.13, 95% CI 0.91%–1.42%, p = 0.27) with those whose destination was acute rehabilitation. Additionally, extended hospital stay was not associated with differential odds of a readmission (OR 0.87, 95% CI 0.73%–1.04%, p = 0.13).

Thereafter, a sensitivity analysis of discharge disposition and readmission was performed with hospital stay evaluated as a continuous variable. Increasing stay was

TABLE 1. Demographics of the patients undergoing craniotomy for tumor, stratified by length of hospital stay*

Variable	Total Population (n = 11,510)	Length of Stay < 8 Days (n = 8314)	Length of Stay ≥ 8 Days (n = 3185)	p Value
Age (yrs)				<0.001†
18–45	22.6	24.6	17.1	
46–55	21.7	23.2	17.6	
56–70	39.1	38.2	41.6	
>70	16.7	14.0	23.7	
Sex				0.008†
Female	53.2	54.1	50.9	
Male	46.8	45.9	49.1	
Race				<0.001†
White	71.1	75.1	60.6	
African American	5.8	4.9	8.3	
Hispanic	5.1	4.9	5.7	
Asian	3.4	3.3	3.5	
Unknown, not reported, or missing	14.7	11.9	22.0	
Tumor histology				<0.001†
Primary brain benign	4.5	4.5	4.5	
Primary brain malignant	36.6	36.0	38.0	
Secondary brain	22.7	21.2	26.6	
Brain uncertain	8.4	8.6	8.1	
Meningioma	22.7	24.2	18.8	
Meninges (malignant, metastatic, unknown)	2.0	1.8	2.5	
Schwannoma	3.0	3.6	1.5	
Location				<0.001†
Supratentorial	80.5	81.6	77.7	
Infratentorial	19.5	18.4	22.3	
ASA class				<0.001†
1 & 2	28.2	32.9	15.9	
3	59.2	58.0	62.3	
4 & 5	11.9	8.3	21.2	
Missing	0.8	0.8	0.5	
Preop functional status				<0.001†
Independent	92.5	95.3	85.1	
Partially dependent	6.1	4.0	11.7	
Totally dependent	1.0	0.3	2.6	
Unknown or missing	0.5	0.4	0.6	
Smoking	19.9	19.0	22.3	<0.001†
Alcohol use				0.45
No	28.0	28.3	27.2	
Yes	1.1	1.1	1.3	
Missing	70.9	70.7	71.6	
Hypertension	39.3	36.3	46.9	<0.001†
Prior cardiac surgery or PCI				0.006†
No	27.3	27.8	26.2	
Yes	1.6	1.4	2.2	
Missing	71.0	70.8	71.6	
COPD	4.9	4.3	6.5	<0.001†
Preop dyspnea	5.5	4.9	6.9	<0.001†
Bleeding disorder	2.5	1.8	4.1	<0.001†

(continued)

TABLE 1. Demographics of the patients undergoing craniotomy for tumor, stratified by length of hospital stay* ***(continued)***

Variable	Total Population (n = 11,510)	Length of Stay < 8 Days (n = 8314)	Length of Stay ≥ 8 Days (n = 3185)	p Value
Diabetes mellitus				<0.001†
None	88.6	90.3	84.0	
Noninsulin	7.4	6.6	9.4	
Insulin	4.1	3.1	6.6	
Body habitus				<0.001†
Normal weight	28.8	28.7	29.0	
Underweight	1.9	1.6	2.8	
Overweight	33.4	33.8	32.6	
Class I obesity	19.1	20.0	16.8	
Class II obesity	8.3	8.5	7.6	
Class III obesity	5.5	5.6	5.2	
Missing	3.0	1.9	5.9	
Preop sodium (mEq/L)				<0.001†
≥135	85.6	85.8	85.2	
<135	9.2	7.6	13.2	
Missing	5.2	6.6	1.6	
Preop creatinine (mg/dl)				<0.001†
<1.4	91.6	91.2	92.8	
≥1.4	3.2	2.9	4.1	
Missing	5.1	5.9	3.1	
Preop serum albumin (g/dl)				<0.001†
≥3.5	41.0	40.3	42.8	
<3.5	9.6	6.1	18.9	
Missing	49.4	53.7	38.3	
Preop white blood cell count (cells/µl)				<0.001†
4000–10,000	58.2	61.5	49.5	
>10,000 & <20,000	32.1	27.7	43.7	
>20,000	2.6	2.4	3.3	
<4000	3.0	3.4	2.0	
Missing	4.1	5.0	1.5	
Preop hematocrit				<0.001†
>40%	51.1	54.1	43.3	
30–40%	42.7	40.2	49.4	
<30%	2.8	1.9	4.8	
Missing	3.5	3.8	2.5	
Preop platelet count (platelets/µl)				<0.001†
≥150,000	88.4	88.3	88.9	
125,000–149,000	4.2	4.0	4.8	
100,000–124,000	2.0	1.7	2.8	
<100,000	1.3	1.0	1.9	
Missing	4.1	5.0	1.5	
Preop PTT (sec)				<0.001†
>40	0.7	0.5	1.2	
≤40	71.7	68.6	79.5	
Missing	27.7	30.9	19.3	

(continued)

TABLE 1. Demographics of the patients undergoing craniotomy for tumor, stratified by length of hospital stay* *(continued)*

Variable	Total Population (n = 11,510)	Length of Stay < 8 Days (n = 8314)	Length of Stay ≥ 8 Days (n = 3185)	p Value
Preop INR				<0.001†
>1.4	0.9	0.7	1.4	
≤1.4	82.9	80.2	89.9	
Missing	16.2	19.1	8.7	
Impaired sensorium				<0.001†
No	26.7	27.9	23.6	
Yes	2.3	1.3	4.8	
Missing	71.0	70.8	71.6	
Hemiplegia				<0.001†
No	25.8	27.2	22.2	
Yes	3.1	2.0	6.2	
Missing	71.0	70.8	71.6	
Steroid use	17.4	18.2	15.4	0.002†
Preop chemotherapy (last 30 days)				0.23
No	27.3	27.4	27.1	
Yes	1.7	1.8	1.3	
Missing	71.0	70.8	71.6	
Preop radiation therapy (last 90 days)				0.23
No	28.1	28.4	27.3	
Yes	0.9	0.8	1.1	
Missing	71.0	70.8	71.6	
Admission type				<0.001†
Home	84.8	91.4	67.3	
Other than home	15.3	8.6	32.7	
Preop intubation	1.1	0.4	2.8	<0.001†
Emergency operation	5.7	4.2	9.4	<0.001†
Anesthesia time (mins)				0.049†
<300	19.0	19.3	18.4	
300–390	4.8	5.0	4.1	
>390	7.6	7.3	8.5	
Missing	68.6	68.4	69.0	
Op time (mins)				<0.001†
<180	48.7	48.8	48.5	
180–300	32.2	33.4	29.3	
>300	19.1	17.8	22.2	
Cardiovascular accident	1.1	0.4	3.1	<0.001†
Cardiac complications	0.5	0.3	1.2	<0.001†
Unplanned reintubation	1.6	0.4	4.8	<0.001†
Mechanical ventilation >48 hrs	2.2	0.3	7.4	<0.001†
Pulmonary embolism	0.6	0.1	1.8	<0.001†
DVT	1.2	0.2	3.7	<0.001†
Surgical site infection	2.2	2.1	2.5	0.34
Pneumonia	1.2	0.2	3.8	<0.001†
UTI	1.6	0.2	5.2	<0.001†
Sepsis	2.2	1.1	5.0	<0.001†
Packed cell transfusion	4.8	3.0	9.5	<0.001†

COPD = chronic obstructive pulmonary disease; DVT = deep venous thrombosis; PCI = percutaneous coronary intervention.

* All data are presented as percentages.

† Statistically significant difference by chi-square test.

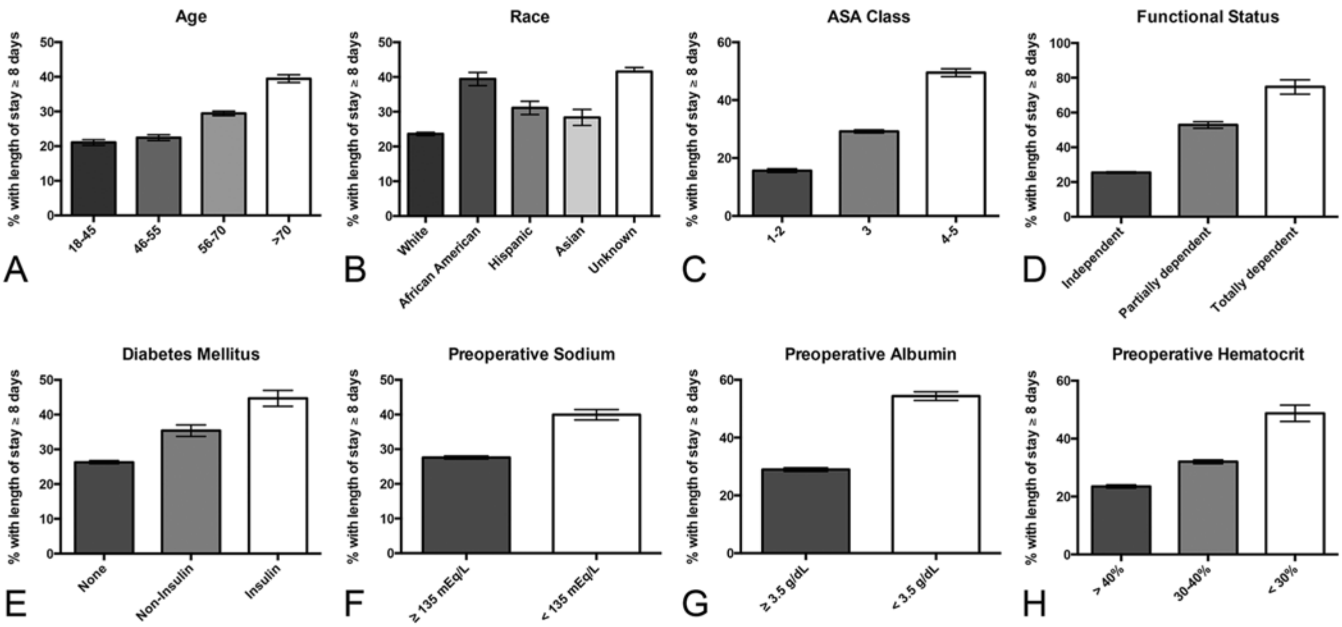

FIG. 2. Graphic presentation of differences in the proportion of patients with length of stay ≥ 8 days based on age **(A)**; race or ethnicity (including unreported, unknown, or missing race or ethnicity) **(B)**; ASA class **(C)**; preoperative functional status **(D)**; comorbid diabetes mellitus **(E)**; preoperative sodium **(F)**; preoperative albumin **(G)**; and preoperative hematocrit **(H)**.

associated with greater odds of a nonroutine hospital discharge (OR 4.19, 95% CI 3.79%–4.64%, p < 0.001, C-statistic 0.85), including increased odds of institutional care placement (OR 1.36, 95% CI 1.15%–1.61%, p < 0.001, C-statistic 0.74) compared with discharge to rehabilitation. However, longer hospitalization was not associated with differential odds of an unplanned readmission (OR 0.97, 95% CI 0.89%–1.06%, p = 0.55, C-statistic 0.65).

Discussion

In this NSQIP analysis, 11,510 patients who underwent craniotomy for tumor were included to evaluate the predictors of extended hospitalization after the procedure. Many preoperative characteristics that are collected by NSQIP including age greater than 70 years, African American or Hispanic race or ethnicity, ASA class, functional status, diabetes mellitus, and hypothrombotic conditions were associated with extended hospital stay. Prior studies have evaluated craniotomy for tumor in older adults, several of which have found that greater age is not an independent risk factor for death or major complications,[18,54] undoubtedly more important outcomes than length of hospital stay. Disparities based on race or ethnicity in neurooncology patients are well documented.[40,41,43] Prior evaluation of the Nationwide Inpatient Sample from 1988 to 2004 by Curry et al. has suggested that postoperative disparities may be primarily due to more severe disease on presentation and reduced access to high-volume care.[17] However, these differences in length of hospital stay may also be related to residual confounding, as disparities in outcomes have also been shown to be attributable to a greater number of and more severe comorbidities.[19] Although the only comorbidities evaluated that were significantly associated with extended hospitalization were insulin-dependent diabetes mellitus and hypothrombotic conditions, higher ASA class and premorbid dependent functional status were potent predictors of length of hospital stay, highlighting the utility of these measures when risk-stratifying patients. Additionally, preoperative hyponatremia, baseline neurological deficits, and an admission other than from home were also found to be significant predictors of prolonged hospitalization, likely due to preoperative morbidity from the intracranial mass.

It is perhaps not surprising that in multivariate regression models, many of the most potent predictors of prolonged hospitalization were postoperative complications.[42] In both linear and logistic regression models, venous thromboembolic events, pneumonia, and prolonged mechanical ventilation were complications with among the highest odds ratios or regression coefficients. Notably, urinary tract infections (UTIs) were also found to be strongly independently associated with longer hospitalization, which in linear regression models increased length of stay by 67%. This emphasizes the importance of minimizing UTIs, and prior reports in neurosurgical patients have shown that the implementation of a UTI quality improvement program including maintenance of sterility during catheter insertion, product standardization, and early discontinuation can significantly decrease the incidence of UTIs.[63] Although the optimal modality of venous thromboembolism prophylaxis—mechanical alone or in conjunction with pharmacological prophylaxis—remains debated, the strong association between length of hospital stay and both deep venous thrombosis and pulmonary emboli emphasizes the importance of this prophylaxis.[5,21,22,51,59]

TABLE 2. Multivariate logistic regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of extended length of hospital stay evaluated dichotomously (stratified by hospital stay of 8 days) following craniotomy for tumor*

	Model 1			Model 2		
Variable	OR	95% CI	p Value	OR	95% CI	p Value
Age (yrs)						
18–45	Ref			Ref		
46–55	0.97	0.83–1.12	0.66	0.93	0.80–1.09	0.40
56–70	**1.18**	**1.02–1.36**	**0.02**	1.12	0.97–1.30	0.12
>70	**1.67**	**1.41–1.99**	**<0.001**	**1.53**	**1.28–1.83**	**<0.001**
Sex						
Female	Ref			Ref		
Male	0.93	0.84–1.03	0.17	0.90	0.81–1.00	0.05
Race						
White	Ref			Ref		
African American	**1.79**	**1.48–2.17**	**<0.001**	**1.75**	**1.44–2.14**	**<0.001**
Hispanic	**1.54**	**1.25–1.89**	**<0.001**	**1.68**	**1.36–2.08**	**<0.001**
Asian	1.17	0.90–1.51	0.25	1.15	0.87–1.51	0.33
Unknown, not reported, or missing	**2.28**	**1.99–2.60**	**<0.001**	**2.31**	**2.01–2.65**	**<0.001**
Tumor histology						
Primary brain benign	Ref			Ref		
Primary brain malignant	0.89	0.71–1.13	0.35	0.85	0.67–1.09	0.20
Secondary brain	0.79	0.62–1.02	0.07	0.77	0.60–1.00	0.05
Brain uncertain	**0.72**	**0.54–0.94**	**0.02**	**0.63**	**0.47–0.84**	**0.002**
Meningioma	**0.71**	**0.55–0.90**	**0.006**	**0.62**	**0.48–0.80**	**<0.001**
Meninges (malignant, metastatic, unknown)	1.05	0.72–1.53	0.80	0.88	0.59–1.30	0.51
Schwannoma	**0.40**	**0.27–0.60**	**<0.001**	**0.39**	**0.26–0.60**	**<0.001**
Location						
Supratentorial	Ref			Ref		
Infratentorial	**1.42**	**1.26–1.61**	**<0.001**	**1.42**	**1.25–1.62**	**<0.001**
ASA class						
1 & 2	Ref			Ref		
3	**1.59**	**1.40–1.79**	**<0.001**	**1.52**	**1.34–1.73**	**<0.001**
4 & 5	**2.41**	**2.03–2.86**	**<0.001**	**2.18**	**1.82–2.62**	**<0.001**
Preop functional status						
Independent	Ref			Ref		
Partially dependent	**2.05**	**1.71–2.46**	**<0.001**	**1.94**	**1.61–2.35**	**<0.001**
Totally dependent	**3.44**	**2.10–5.64**	**<0.001**	**3.30**	**1.96–5.55**	**<0.001**
Smoking	1.06	0.94–1.19	0.37	1.09	0.96–1.23	0.19
Hypertension	1.10	0.99–1.23	0.08	1.10	0.98–1.23	0.10
Prior cardiac surgery or PCI	1.07	0.75–1.54	0.71	1.11	0.76–1.61	0.60
COPD	0.94	0.75–1.17	0.55	0.89	0.70–1.12	0.32
Preop dyspnea	1.02	0.83–1.26	0.82	0.96	0.77–1.20	0.75
Bleeding disorder	**1.53**	**1.15–2.03**	**0.003**	**1.68**	**1.25–2.24**	**0.001**
Diabetes mellitus						
None	Ref			Ref		
Noninsulin	1.19	1.00–1.41	0.06	1.14	0.95–1.38	0.16
Insulin	**1.50**	**1.20–1.87**	**<0.001**	**1.46**	**1.16–1.84**	**0.002**
Body habitus						
Normal weight	Ref			Ref		
Underweight	1.28	0.92–1.77	0.14	1.26	0.89–1.77	0.19

(continued)

TABLE 2. Multivariate logistic regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of extended length of hospital stay evaluated dichotomously (stratified by hospital stay of 8 days) following craniotomy for tumor* ***(continued)***

	Model 1			Model 2		
Variable	OR	95% CI	p Value	OR	95% CI	p Value
Body habitus *(continued)*						
Overweight	1.04	0.93–1.18	0.48	1.03	0.91–1.17	0.67
Class I obesity	**0.84**	**0.72–0.97**	**0.02**	**0.81**	**0.70–0.94**	**0.006**
Class II obesity	0.90	0.75–1.09	0.29	0.86	0.71–1.06	0.16
Class III obesity	0.90	0.72–1.12	0.35	0.87	0.69–1.10	0.25
Preop sodium (mEq/L)						
≥135	Ref			Ref		
<135	**1.26**	**1.08–1.47**	**0.003**	**1.24**	**1.06–1.46**	**0.009**
Preop creatinine (mg/dl)						
<1.4	Ref			Ref		
≥1.4	0.89	0.69–1.15	0.37	0.84	0.64–1.10	0.21
Preop serum albumin (g/dl)						
≥3.5	Ref			Ref		
<3.5	**1.75**	**1.49–2.04**	**<0.001**	**1.78**	**1.51–2.09**	**<0.001**
Preop white blood cell count (cells/µl)						
4000–10,000	Ref			Ref		
>10,000 & <20,000	**1.59**	**1.44–1.76**	**<0.001**	**1.57**	**1.41–1.74**	**<0.001**
>20,000	**1.37**	**1.03–1.81**	**0.03**	1.22	0.90–1.65	0.19
<4000	**0.69**	**0.50–0.94**	**0.02**	0.72	0.52–1.00	0.05
Preop hematocrit						
>40%	Ref			Ref		
30–40%	**1.27**	**1.15–1.41**	**<0.001**	**1.28**	**1.15–1.43**	**<0.001**
<30%	**1.69**	**1.29–2.23**	**<0.001**	**1.49**	**1.12–2.00**	**0.007**
Preop platelet count (platelets/µl)						
≥150,000	Ref			Ref		
125,000–149,000	1.15	0.92–1.43	0.24	1.11	0.88–1.41	0.37
100,000–124,000	1.35	0.99–1.84	0.06	1.24	0.88–1.73	0.22
<100,000	1.41	0.95–2.10	0.09	1.15	0.75–1.77	0.53
Preop PTT (sec)						
>40	Ref			Ref		
≤40	0.60	0.36–1.02	0.06	0.60	0.35–1.02	0.06
Preop INR						
>1.4	Ref			Ref		
≤1.4	0.74	0.46–1.20	0.22	0.72	0.44–1.18	0.19
Impaired sensorium	**1.69**	**1.24–2.31**	**0.001**	**1.73**	**1.25–2.38**	**0.001**
Hemiplegia	**2.40**	**1.84–3.13**	**<0.001**	**2.36**	**1.79–3.11**	**<0.001**
Steroid use	**0.67**	**0.58–0.76**	**<0.001**	**0.62**	**0.54–0.71**	**<0.001**
Admission type						
Home	Ref			Ref		
Other than home	**3.31**	**2.94–3.74**	**<0.001**	**3.40**	**3.00–3.86**	**<0.001**
Preop intubation	**1.98**	**1.24–3.14**	**0.004**	1.02	0.61–1.70	0.95
Emergency operation	0.97	0.80–1.18	0.77	0.90	0.73–1.11	0.32
Anesthesia time (mins)						
<300	Ref			Ref		
300–390	1.01	0.78–1.32	0.93	0.97	0.74–1.28	0.84
>390	1.12	0.89–1.41	0.33	1.18	0.93–1.50	0.18

(continued)

TABLE 2. Multivariate logistic regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of extended length of hospital stay evaluated dichotomously (stratified by hospital stay of 8 days) following craniotomy for tumor* *(continued)*

	Model 1			Model 2		
Variable	OR	95% CI	p Value	OR	95% CI	p Value
Op time (mins)						
<180	Ref			Ref		
180–300	**1.23**	**1.10–1.38**	**<0.001**	**1.15**	**1.02–1.29**	**0.03**
>300	**2.28**	**1.96–2.65**	**<0.001**	**1.77**	**1.51–2.09**	**<0.001**
Cardiovascular accident	—	—	—	**5.67**	**3.42–9.38**	**<0.001**
Cardiac complications	—	—	—	1.29	0.65–2.58	0.47
Unplanned reintubation	—	—	—	**2.11**	**1.26–3.54**	**0.005**
Mechanical ventilation >48 hrs	—	—	—	**11.07**	**6.56–18.70**	**<0.001**
Pulmonary embolism	—	—	—	**13.75**	**4.73–39.99**	**<0.001**
DVT	—	—	—	**7.46**	**4.18–13.31**	**<0.001**
Pneumonia	—	—	—	**5.40**	**2.89–10.07**	**<0.001**
UTI	—	—	—	**11.87**	**7.09–19.87**	**<0.001**
Sepsis	—	—	—	**1.64**	**1.14–2.36**	**0.008**
Postop transfusion	—	—	—	**1.82**	**1.45–2.27**	**<0.001**
C-statistic		**0.79**			**0.83**	

Ref = reference.

* Odds ratios, 95% CIs, and p values that reached statistical significance are in boldface type.

Although many of the postoperative complications collected by the NSQIP had the greatest effect size in multivariate regression models evaluating predictors of prolonged hospitalization, it is notable that their addition to models only slightly improved their discriminatory capacity. The C-statistic of the logistic regression model based only on preoperative and intraoperative characteristics was 0.79 and 0.83, respectively, with the addition of postoperative complications. Likewise, the R^2 from the multivariate regression models increased from 0.22 to 0.29 when complications were included, suggesting that only 7% of the variance in length of hospital stay is attributable to the complications that are evaluated by the NSQIP, whereas 22% is due to baseline and operative characteristics. Therefore, much of the variance in hospital stay in those undergoing craniotomy for tumor may be due to characteristics present at admission and not due to postoperative care. This is in contrast to the results of some studies evaluating length of hospital stay in other surgical disciplines: prior reports analyzing general and cardiac surgical procedures have found a greater variance in length of stay to be attributable to postoperative complications.[16,26] Thus, length of stay may be an imperfect proxy for quality of care in cranial neurosurgical patients.

Nonetheless, pay-for-performance measures and variations on the Center for Medicare and Medicaid Services physician quality reporting system have become a staple of contemporary health care delivery.[8,23,39,45,55,62] However, given that much of the variance of length of hospital stay was found in this study to be related to preoperative factors, pay-for-performance measures using length of hospitalization as an indicator may paradoxically compromise quality of care by removing incentives for treating high-risk patients. Therefore, to partially adjust length of stay for pertinent differences in baseline characteristics, a length of stay after craniotomy for tumor score was proposed in this analysis. Its simple 10-point scale based on easily measurable preoperative characteristics may allow for partial risk stratification when analyzing length of hospital stay.

Furthermore, an analysis of postoperative disposition was performed to evaluate whether discharge type was associated with length of hospital stay. Longer hospitalization (when evaluated both continuously and dichotomously) was significantly associated with a nonroutine hospital discharge in hierarchical analyses including preoperative characteristics and postoperative complications as covariates. Although this association may be partially due to residual confounding, it suggests that hospitalization in patients with brain tumors may be prolonged by the availability of beds at acute rehabilitation or institutional care facilities. A subgroup analysis of patients with a nonroutine hospital discharge was performed to evaluate whether those discharged to institutional care (including skilled nursing facilities or long-term acute care hospitals) had differential associations with hospitalization length compared with patients whose destination was acute rehabilitation. When length of stay was evaluated continuously, there was a significant association with discharge to institutional care, which suggests a particular delay in institutional care placement.

One of the concerns about emphasizing shorter hospitalizations is that it may lead to an increased incidence of unplanned hospital readmissions.[25,27] However, in this analysis, length of stay (when evaluated both continuously and categorically) was not associated with differential odds of

TABLE 3. Multivariate linear regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of longer length of hospital stay evaluated continuously after craniotomy for tumor*

	Model 1			Model 2		
Variable	Coefficient (%)	95% CI	p Value	Coefficient (%)	95% CI	p Value
Age (yrs)						
18–45	Ref			Ref		
46–55	−2.63	−7.08 to 1.81	0.25	−3.06	−7.13 to 1.20	0.16
56–70	**4.68**	**0.47–8.89**	**0.03**	3.52	−0.52 to 7.55	0.09
>70	**17.87**	**12.49–23.25**	**<0.001**	**14.76**	**9.61–19.92**	**<0.001**
Race						
White	Ref			Ref		
African American	**20.06**	**13.72–26.41**	**<0.001**	**18.94**	**12.86–25.01**	**<0.001**
Hispanic	**12.31**	**5.65–18.96**	**<0.001**	**14.39**	**8.02–20.77**	**<0.001**
Asian	**8.58**	**0.43–16.73**	**0.04**	7.68	−0.01 to 15.49	0.06
Unknown, not reported, or missing	**28.97**	**24.60–33.35**	**<0.001**	**27.80**	**23.61–31.99**	**<0.001**
Tumor histology						
Primary brain benign	Ref			Ref		
Primary brain malignant	**−9.75**	**−17.07 to −2.42**	**0.009**	**−10.21**	**−17.22 to −3.20**	**0.004**
Secondary brain	**−15.55**	**−23.34 to −7.75**	**<0.001**	**−14.21**	**−14.21 to −6.75**	**<0.001**
Brain uncertain	**−14.55**	**−23.01 to −6.10**	**0.001**	**−16.96**	**−25.06 to −8.86**	**<0.001**
Meningioma	**−18.35**	**−25.87 to −10.87**	**<0.001**	**−21.14**	**−28.35 to −13.93**	**<0.001**
Meninges (malignant, metastatic, unknown)	−7.48	−19.82 to 4.85	0.23	**−12.78**	**−24.61 to −0.96**	**0.03**
Schwannoma	**−23.19**	**−34.22 to −12.16**	**<0.001**	**−19.56**	**−30.12 to −8.99**	**<0.001**
Location						
Supratentorial	Ref			Ref		
Infratentorial	**13.81**	**9.88–17.75**	**<0.001**	**12.22**	**8.44–16.00**	**<0.001**
ASA class						
1 & 2	Ref			Ref		
3	**10.92**	**7.38–14.46**	**<0.001**	**8.92**	**5.53–12.32**	**<0.001**
4 & 5	**25.50**	**19.63–30.77**	**<0.001**	**19.41**	**14.05–24.76**	**<0.001**
Preop functional status						
Independent	Ref			Ref		
Partially dependent	**30.85**	**24.58–37.12**	**<0.001**	**25.49**	**19.48–31.50**	**<0.001**
Totally dependent	**42.79**	**27.29–58.28**	**<0.001**	**36.39**	**21.54–51.25**	**<0.001**
Hypertension	**4.01**	**0.58–7.44**	**0.02**	**3.92**	**0.63–7.21**	**0.02**
Prior cardiac surgery or PCI	4.63	−7.17 to 16.44	0.31	5.81	−5.50 to 17.11	0.31
COPD	−0.42	−7.56 to 6.74	0.91	−1.93	−8.78 to 4.93	0.58
Preop dyspnea	−0.37	−7.09 to 6.36	0.92	−1.89	−8.33 to 4.56	0.57
Bleeding disorder	**13.68**	**3.98–23.37**	**0.006**	**15.64**	**6.35–24.93**	**0.001**
Diabetes mellitus						
None	Ref			Ref		
Noninsulin	5.54	−0.23 to 11.31	0.06	3.54	−2.00 to 9.07	0.21
Insulin	**12.06**	**4.52–19.60**	**0.002**	**9.26**	**2.02–16.50**	**0.01**
Body habitus						
Normal weight	Ref			Ref		
Underweight	1.51	−9.26 to 12.29	0.68	−0.01	−10.33 to 10.32	0.99
Overweight	0.78	−2.93 to 4.50	0.68	0.27	−3.29 to 3.83	0.88
Class I obesity	−3.68	−8.05 to 0.70	0.10	−4.06	−8.25 to 0.13	0.06
Class II obesity	0.78	−5.08 to 6.64	0.79	3.49	−5.27 to 5.97	0.90
Class III obesity	−1.69	−8.62 to 5.24	0.63	−2.37	−9.02 to 4.27	0.48

(continued)

TABLE 3. Multivariate linear regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of longer length of hospital stay evaluated continuously after craniotomy for tumor* *(continued)*

	Model 1			Model 2		
Variable	Coefficient (%)	95% CI	p Value	Coefficient (%)	95% CI	p Value
Preop sodium (mEq/L)						
≥135	Ref			Ref		
<135	**8.38**	**3.23–13.52**	**0.001**	**7.65**	**2.72–12.57**	**0.002**
Preop creatinine (mg/dl)						
<1.4	Ref			Ref		
≥1.4	−1.89	−10.26 to 6.48	0.66	−3.07	−11.09 to 4.95	0.45
Preop serum albumin (g/dl)						
≥3.5	Ref			Ref		
<3.5	**21.14**	**15.73–26.55**	**<0.001**	**19.55**	**14.37–24.74**	**<0.001**
Preop white blood cell count (cells/µl)						
4000–10,000	Ref			Ref		
>10,000 & <20,000	**15.52**	**12.22–18.82**	**<0.001**	**13.60**	**10.44–16.76**	**<0.001**
>20,000	**14.86**	**5.61–24.11**	**0.002**	**10.57**	**1.70–19.44**	**0.02**
<4000	**−10.83**	**−19.56 to −2.11**	**0.02**	**−9.59**	**−17.94 to −1.23**	**0.03**
Preop hematocrit						
>40%	Ref			Ref		
30–40%	**9.86**	**6.76–12.96**	**<0.001**	**9.16**	**6.19–12.14**	**<0.001**
<30%	**21.05**	**11.72–30.37**	**0.002**	**14.21**	**5.14–23.28**	**0.002**
Preop platelet count (platelets/µl)						
≥150,000	Ref			Ref		
125,000–149,000	1.59	−5.64 to 8.82	0.67	0.15	−6.78 to 7.07	0.97
100,000–124,000	**10.63**	**1.97–21.07**	**0.05**	5.24	−4.77 to 15.25	0.31
<100,000	**15.59**	**2.28–28.91**	**0.02**	5.89	−6.89 to 18.67	0.37
Preop PTT (sec)						
>40	Ref			Ref		
≤40	**−19.15**	**−37.16 to −1.14**	**0.04**	**−19.52**	**−36.77 to −2.27**	**0.03**
Preop INR						
>1.4	Ref			Ref		
≤1.4	**−16.58**	**−32.48 to −0.69**	**0.04**	**−17.37**	**−32.60 to −2.14**	**0.03**
Impaired sensorium	**15.29**	**4.92–25.66**	**0.004**	**14.95**	**5.02–24.88**	**0.003**
Hemiplegia	**24.70**	**15.84–33.55**	**<0.001**	**22.90**	**14.41–31.38**	**<0.001**
Steroid use	**−13.17**	**−17.13 to −9.22**	**<0.001**	**−14.14**	**−17.93 to −10.35**	**<0.001**
Preop chemotherapy (last 30 days)	−10.39	−22.04 to 1.25	0.08	**−12.24**	**−23.39 to −1.08**	**0.03**
Admission type						
Home	Ref			Ref		
Other than home	**45.20**	**40.91–49.49**	**<0.001**	**42.78**	**38.67–46.90**	**<0.001**
Preop intubation	**18.11**	**3.33–32.90**	**0.02**	−12.55	−27.06 to 1.95	0.09
Emergency operation	**15.47**	**8.85–22.10**	**<0.001**	**13.43**	**7.08–19.78**	**<0.001**
Anesthesia time (mins)						
<300	Ref			Ref		
300–390	−0.46	−8.18 to 7.25	0.63	−1.82	−9.21 to 5.57	0.63
>390	5.73	−1.41 to 12.88	0.12	6.83	−0.01 to 13.67	0.05
Op time (mins)						
<180	Ref			Ref		
180–300	**15.73**	**12.20–19.25**	**<0.001**	**12.98**	**9.59–16.36**	**0.001**
>300	**36.89**	**32.10–41.68**	**<0.001**	**26.53**	**21.86–31.20**	**<0.001**

(continued)

TABLE 3. Multivariate linear regression evaluating preoperative and operative predictors (Model 1) and all predictors (Model 2) of longer length of hospital stay evaluated continuously after craniotomy for tumor* ***(continued)***

	Model 1			Model 2		
Variable	Coefficient (%)	95% CI	p Value	Coefficient (%)	95% CI	p Value
Cardiovascular accident	—	—	—	**51.95**	**38.54–65.36**	**<0.001**
Cardiac complications	—	—	—	−1.01	−20.39 to 18.36	0.92
Unplanned reintubation	—	—	—	**15.88**	**2.79–28.98**	**0.02**
Mechanical ventilation <48 hrs	—	—	—	**63.32**	**51.73–74.93**	**<0.001**
Pulmonary embolism	—	—	—	**52.04**	**32.67–71.42**	**<0.001**
DVT	—	—	—	**58.60**	**45.27–71.94**	**<0.001**
Pneumonia	—	—	—	**54.32**	**40.44–68.20**	**<0.001**
UTI	—	—	—	**67.29**	**55.96–78.61**	**<0.001**
Sepsis	—	—	—	9.29	−1.19 to 19.77	0.08
Surgical site infection	—	—	—	**12.78**	**2.91–22.64**	**0.01**
Postop transfusion	—	—	—	**22.34**	**15.52–29.15**	**<0.001**
R^2		**0.22**			**0.29**	

* Odds ratios, 95% CIs, and p values that reached statistical significance are in boldface type.

readmissions. Prior research has suggested that many surgical readmissions, including those for neurosurgical patients, are due to new postdischarge complications rather than exacerbations of prior complications.[30,32,36,38,57,58,65,67]

This study has many notable limitations. Although the NSQIP is an externally validated program that internally audits data, as with all database studies based on *International Classification of Diseases, Ninth Revision* identifiers, there is the potential for miscoding. Additionally, although the NSQIP collects data on many variables pertinent to neurooncology patients, other important factors are not collected that may be associated with extended hospitalization in this patient population, including tumor size, peri-tumor edema, Karnofsky performance status, a composite score evaluating neurological function (such as modified Rankin score) pre- or postoperatively, and many specific neurological complications including CSF leakage, meningitis, and seizures. Nonetheless, the multiinstitutional accruement of patients from across the US provides a broad perspective with a large patient sample size for statistical outcomes analyses, allowing for a multivariate analysis of the predictors of extended hospitalization.

Conclusions

In this NSQIP analysis, 11,510 patients were included to evaluate the predictors of extended hospitalization after craniotomy for resection of tumor. Although postoperative complications were potent predictors of length of stay,

TABLE 4. Components of the length of stay after craniotomy for tumor score

Potential Points	Variable	Stratification
1	Age	>70 yrs
1	Race or ethnicity	African American, Hispanic, or other
1	ASA class	3–5
1	Preop functional status	Partially or totally dependent
1	Comorbidity	Bleeding disorder
1	Preop serum albumin	<3.5 g/dl
1	Preop white blood cell count	>10,000 & <20,000 cells/µl
1	Preop neurological examination	Impaired sensorium
1		Hemiparesis or hemiplegia
1	Admission type	Other than from home
10	Maximum potential score	

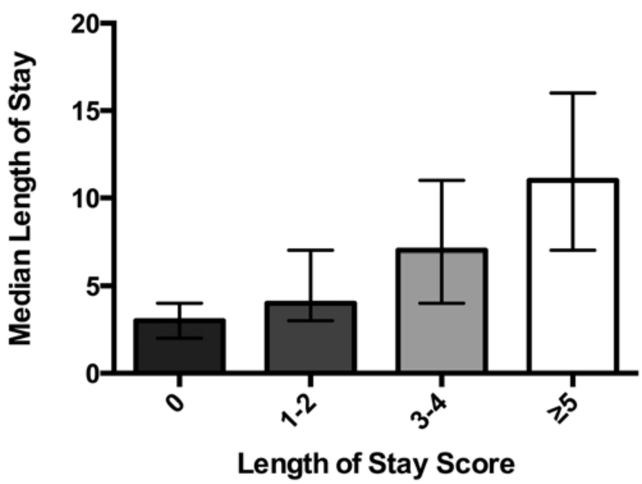

FIG. 3. Graphs showing the variations in the median length of hospital stay (with associated IQR represented by error bars) by length of stay after craniotomy for tumor score.

TABLE 5. The impact of length of hospital stay on discharge disposition and unplanned hospital readmission

Variable	Total Population	Length of Stay < 8 Days (n = 8314)	Length of Stay ≥ 8 Days (n = 3185)	OR	95% CI	p Value	C-statistic
Nonroutine hospital discharge	22.0 (n = 9754)	12.4 (n = 7120)	48.1 (n = 2631)	4.34	3.82–4.94	<0.001*	0.81
Institutional care	36.7 (n = 2150)	30.1 (n = 882)	41.4 (n = 1266)	1.13	0.91–1.42	0.27	0.73
Unplanned readmission	10.6 (n = 9662)	10.6 (n = 6996)	10.7 (n = 2657)	0.87	0.73–1.04	0.13	0.65

* Statistically significant difference by hierarchical multivariate logistic regression, using all covariates in the models.

much of the variance in regression models was attributable to preoperative characteristics. Age greater than 70 years, African American or Hispanic race or ethnicity, higher ASA class, and dependent functional status were significant independent predictors of prolonged hospitalization. Additionally, a length of stay after craniotomy for tumor score was proposed based on preoperative predictors that met statistical significance with a strong effect size in multivariate logistic regression; this scale had moderate correlation with recorded length of stay. A nonroutine hospital discharge disposition was associated with extended hospitalization, suggesting that the availability of rehabilitation or institutional care beds may extend hospital stay. However, length of stay was not significantly associated with hospital readmissions.

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Disclosures

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Author Contributions

Conception and design: Dasenbrock. Acquisition of data: Dasenbrock, Devine. Analysis and interpretation of data: all authors. Drafting the article: all authors. Critically revising the article: all authors. Reviewed submitted version of manuscript: Dunn, Dasenbrock, Liu, Chavakula, Smith, Gormley. Approved the final version of the manuscript on behalf of all authors: Dunn. Statistical analysis: Dasenbrock, Liu, Devine. Study supervision: Dasenbrock.

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