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Predictors of Prolonged Hospital Stay After Craniotomy for Tumor Resection

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Abstract

Purpose:

Prolonged length of hospital stay (LOS) after craniotomy for tumor resection is associated with increased healthcare costs, resource utilization, and postoperative morbidity. Identifying patients at risk for prolonged hospitalization may facilitate perioperative optimization and targeted discharge planning. This study aimed to identify predictors of prolonged inpatient hospital stay following craniotomy for brain tumor resection at a tertiary care center in a low- and middle-income country.

Methods:

A retrospective cohort study was conducted on 390 adult patients who underwent craniotomy for brain tumor resection at a single tertiary care center. Prolonged LOS was defined as hospitalization for ≥ 8 days. Demographic, clinical, radiological, operative, and postoperative variables were analyzed using univariate and multivariable logistic regression to identify independent predictors of prolonged LOS.

Results:

Of the 390 patients, 58 (14.9%) had prolonged hospitalization. On univariate analysis, prolonged LOS was associated with longer SCU/ICU stay, lower Karnofsky Performance Status (KPS), lower Glasgow Coma Scale (GCS), preoperative antiplatelet/anticoagulant use, greater blood loss, longer operative duration, perioperative transfusion, and general anesthesia. On multivariable analysis, emergency admission (OR 2.85, 95% CI 1.33–6.07), transfer from another service (OR 6.07, 95% CI 1.04–35.43), and longer operative duration independently predicted prolonged LOS, while higher preoperative KPS was protective.

Conclusion:

Emergency admission, inter-service transfer, prolonged operative duration, and poor preoperative functional status were independent predictors of prolonged hospital stay after craniotomy for tumor resection. Optimizing functional status, improving operative efficiency, and implementing enhanced recovery pathways may help reduce LOS and improve resource utilization.

Introduction

Length of hospital stay (LOS) is an important metric of perioperative outcomes and a key focus for healthcare policymakers. [1] Prolonged LOS is associated with increased costs, delayed functional recovery and greater resource consumption. [2, 3] It is also closely associated with certain post-operative complications, including nosocomial infections, delirium and venous thromboembolism. [2, 3] However, the relationship is bidirectional: extended hospital stay can increase exposure to hospital-

associated adverse events, but postoperative complications can also increase hospital stay. These factors often necessitate additional diagnostic and therapeutic interventions, thus creating a cascade that increases overall morbidity and the likelihood of unplanned readmissions. [1, 4]

Institutions are implementing protocols to reduce patients' LOS and resource consumption. [5, 6] While enhanced recovery protocols are becoming increasingly common for spinal surgeries, it is of paramount importance to determine whether comparable efficiency in care delivery, with shorter hospitalization, can be achieved in cranial surgeries without compromising quality of care. [5, 8] Early discharge after brain tumor surgery carries significant potential risks and challenges, necessitating stringent patient selection and robust outpatient monitoring. Patients may experience new or worsening deficits, postoperative seizures, altered consciousness, dysphasia, intracranial bleed, hyponatremia or CSF leak. [9, 10, 11] Reducing the length of hospital stay therefore depends on patients' characteristics, disease severity and perioperative events. [5]

Although there is growing evidence on predictors of prolonged LOS after craniotomy for brain tumor resection, most previous studies have been conducted in high-income healthcare systems. Evidence from low- and middle-income countries remains limited. Differences in patient characteristics, perioperative practices, and limited healthcare resources and healthcare infrastructure may influence these predictors, underscoring the need for locally relevant evidence. This study aimed to identify the demographic, clinical, and perioperative factors associated with prolonged postoperative LOS at a tertiary care center in a low- and middle-income country. Additionally, we aimed to identify potentially addressable factors that may help reduce postoperative hospital stay and to evaluate whether prolonged LOS is associated with early emergency readmissions.

Material and Methods

It is a retrospective, single-center, cohort study, conducted after obtaining an exemption from the Ethical Review Committee (2024-9603-28019) at the Department of Surgery, Section of Neurosurgery, Aga Khan University Hospital (AKUH), Karachi. Sample size was calculated using OpenEpi software version 3.01. A sample size of 390 patients undergoing craniotomy was calculated based on an anticipated proportion of prolonged hospital stay of 36%, a precision of 5%, a 95% confidence level, a design effect of 1, and an inflation of 10% to account for incomplete records. (8) Researchers reviewed online hospital databases and patient files of consecutive eligible patients who underwent craniotomy for the resection of brain tumors between January 2019 and December 2023. Postoperative hospital stay was calculated from the date of surgery to the discharge date. All data were first entered into REDCap software and subsequently exported to SPSS version 21 for analysis. Prolonged length of hospital stay (LOS) was defined as a postoperative stay of ≥ 8 days, consistent with the definition used in a previous NSQIP study of patients undergoing craniotomy. [1] Readmission was defined as an unplanned readmission within 30 days of discharge.

Inclusion criteria comprised all patients aged 18 years or older who underwent craniotomy for tumor excision. Patients undergoing any additional surgical procedure during the same admission were excluded.

Normality of the data was assessed using the Shapiro-Wilk test. Continuous variables were reported as mean with standard deviation or median with interquartile range (IQR), and categorical variables as percentages. The Mann-Whitney U test or Student's t-test was used for comparing continuous variables, while Fisher's exact test or the chi-square test was applied for categorical variables. Binary logistic regression analyses were performed to identify factors associated with prolonged hospital stay. Both unadjusted and adjusted odds ratios with their 95% confidence intervals (CIs) were reported. A p-value of < 0.2 at univariable analysis was set as the threshold for entry into the multivariable model, and a p-value of < or equal to 0.05 at multivariable analysis was considered statistically significant

Results

A total of 390 patients were included in the study, comprising 239 (61.3%) males and 151 (38.7%) females. The median age was 42 years (IQR 33–55). Overall, 177 patients (45.4%) had pre-existing comorbidity, most commonly ischemic heart disease, while 213 (54.6%) had no documented comorbidities. The majority of the patients were admitted through the outpatient clinic (86.4%), underwent their first cranial surgery (92.6%), and had no midline shift on preoperative MRI (92.6%). General anesthesia was used in 80.3% of procedures, while 19.7% underwent surgery under scalp block.

Most patients were admitted directly to a ward bed (93.8%), whereas 6.2% required admission to a special care/high dependency unit. High-grade intra-axial tumors were the most common pathological subgroup, followed by low-grade extra-axial lesions. Most patients (79.7%) did not require perioperative blood transfusion, and postoperative complications occurred in only 2.3%. Overall, 12.3% of patients visited the emergency department within 30 days of discharge and 6.9% required hospital readmission.

Table 1
Preoperative and intraoperative characteristics according to postoperative length of stay

		LOS < 8 day	LOS ≥ 8 days	P-value
Comorbidities	None	184 (86.40%)	29 (13.60%)	0.44
	Yes	148 (83.60%)	29 (16.40%)	
Route of admission	Clinic	294 (87.20%)	43 (12.80%)	0.008
	ER	32 (71.10%)	13 (28.90%)	
	Takeover	4 (66.70%)	2 (33.30%)	
Level of inpatient admission	Special care	14 (58.30%)	10 (41.70%)	< 0.001
	Regular ward	318 (86.9%)	48 (13.1%)	
Patients taking any anti-coagulants and anti-platelets preoperatively	No	321 (85.80%)	53 (14.20%)	0.06
	Yes	11 (68.80%)	5 (31.30%)	
First cranial surgery	No	24 (82.80%)	5 (17.20%)	0.71
	Yes	308 (85.30%)	53 (14.70%)	
Midline shift on MRI	No	306 (84.80%)	55 (15.20%)	0.6
	Yes	26 (89.70%)	3 (10.30%)	
Hemorrhage on MRI	No	325 (85.30%)	56 (14.70%)	0.34
	Yes	6 (75.00%)	2 (25.00%)	
Tumor grade	High grade intra-axial lesion (3,4)	114 (87.70%)	16 (12.30%)	0.85
	Low grade intra-axial lesion (1,2)	79 (84.90%)	14 (15.10%)	
	High grade extra-axial lesion (3,4)	3 (75.00%)	1 (25.00%)	

		LOS < 8 day	LOS ≥ 8 days	P-value
	Low grade extra-axial lesion (1,2)	92 (86.80%)	14 (13.20%)	
Blood transfusion	Not done	276 (88.70%)	35 (11.30%)	> 0.99
	Pre-operatively	2 (66.70%)	1 (33.30%)	
	Intra-operatively	44 (83.00%)	9 (17.00%)	
	Post-operatively within 72 hours	5 (45.50%)	6 (54.50%)	
	Post-operatively after 72 hours	2 (40.00%)	3 (60.00%)	
	Intraoperatively and post-operatively within 72 hours	3 (50.00%)	3 (50.00%)	
	Intraoperatively and post-operatively after 72 hours	0 (0.00%)	1 (100.00%)	
Type of anesthesia	General anesthesia	260 (83.10%)	53 (16.90%)	0.02
	Scalp block (awake surgery)	72 (93.50%)	5 (6.50%)	
Volume of intra-operative blood loss (ml)		400 (200–650)	500(200–812)	0.18
Duration of surgery (mins)		220 (175–285)	261.5(163–366)	0.05
Values are presented as n (row percentage) or median (interquartile range), unless otherwise indicated. Percentages were calculated using available data.				

Table 2
Postoperative characteristics and 30-day outcomes according to postoperative length of stay

		Less than 8 days	8 or more days	P-value
Postoperative complications during hospital stay.	None	328 (86.10%)	53 (13.90%)	0.001
	Yes	4 (44.40%)	5 (55.60%)	
Was patient transferred to another service post-operatively?	No	331 (85.80%)	55 (14.20%)	0.001
	Yes	1 (25.00%)	3 (75.00%)	
Type of service transferred to post-operatively (if applicable)	Other surgical specialty	1 (100.00%)	0 (0.00%)	0.5
	Medical specialty	0 (0.00%)	2 (100.0%)	
	Other	0 (0.00%)	1 (100.0%)	
Emergency visits within 30 days post-operatively	No	294 (86.00%)	48 (14.00%)	0.215
	Yes	38 (79.20%)	10 (20.80%)	
Readmission within 30 days of discharge	No	313 (86.20%)	50 (13.80%)	0.025
	Yes	19 (70.40%)	8 (29.60%)	
Values are presented as n (row percentage) or median (interquartile range), unless otherwise indicated. Percentages were calculated using available data.				

Overall, 58 patients (14.9%) had a prolonged hospital stay (≥ 8 days). Patients admitted to special care were more likely to have prolonged LOS than those admitted directly to the ward (41.7% vs. 13.1%, $p < 0.001$). General anesthesia was associated with a higher proportion of prolonged stay compared with patients who received scalp block for awake surgery (16.9% vs. 6.5%, $p = 0.02$). Postoperative complications (55.6% vs. 13.9%, $p = 0.001$) and transfer to another inpatient service (75.0% vs. 14.2%, $p = 0.001$) were also significantly associated with prolonged LOS. Non-parametric analysis showed that patients with prolonged LOS had a longer median operative duration than those with shorter LOS (261.5 versus 220 minutes, $p = 0.05$). No in-hospital mortality was reported in this cohort. Postoperative morbidity was low, with only nine patients (2.3%) developing postoperative complications. Thirty-day readmission was more frequent among patients with prolonged LOS than among those with shorter LOS (13.8% vs 5.7%, $p = 0.025$)

In univariable logistic regression analysis, emergency department admission was significantly associated with prolonged LOS. Direct admission to the special care unit, lower Karnofsky Performance Status (KPS), longer operative duration, perioperative blood transfusion, postoperative complications, postoperative transfer to another inpatient service and general anesthesia were associated with higher odds of prolonged LOS(Table 3).

Table 3
Univariable logistic regression analysis of factors associated with prolonged postoperative length of stay

Variables	Unadjusted OR (95% CI)	P-value
Age	1.012 (0.992, 1.032)	0.243
Female	1.047 (0.592, 1.853)	0.874
Comorbidities (Yes)	1.243 (0.711, 2.173)	0.445
Admission (Clinic admission Ref)	2.778 (1.352, 5.705)	0.011*
• Admission (ER)	3.419 (0.608, 19.23)	0.005
• Admission (Take over from other service)		0.163
Level of admission (special care)	4.732 (1.990, 11.25)	< 0.001*
KPS score	0.111 (0.018, 0.680)	0.017*
GCS score	3.567 (0.829, 15.35)	0.088*
Antiplatelet/Anticoagulant (Yes)	2.753 (0.920, 8.240)	0.070*
Is this first surgery of brain (Yes)	0.826 (0.302, 2.260)	0.710
Midline shift (Yes)	0.642 (0.188, 2.194)	0.480
Hemorrhage (Yes)	1.935 (0.381, 9.827)	0.426
Grade (low grade extra-axial: ref)	0.922 (0.428, 1.988)	0.852
• High-grade intra-axial	1.165 (0.524, 2.590)	0.836
• Low-grade intra-axial	2.190 (0.213, 22.55)	0.709
• High grade extra -axial		0.510
Blood loss	1.000 (1.000, 1.001)	0.127*
Duration of surgery	1.004 (1.002, 1.006)	0.001*
Transfusion	3.943 (0.348, 44.61)	< 0.01*
• Pre-op	1.613 (0.763, 3.585)	0.268
• Intra-op	9.463 (2.744, 32.69)	0.241
• Post-op within 72 hours	11.82 (1.910, 73.25)	< 0.01
• Post-op after 72 hours	7.886 (1.532, 40.59)	0.008
• Intra-op & post-op within 72 hours		0.014
*p-value < 0.2 is considered cut-off for inclusion in the multivariable model		

Variables	Unadjusted OR (95% CI)	P-value
General anesthesia, (ref: awake craniotomy)	2.935 (1.131, 7.616) 1	0.027*
Postoperative complications Yes	7.736 (2.103, 29.73)	0.003*
Transfer from another service (Yes)	18.05 (1.845, 176.7)	0.013*
*p-value < 0.2 is considered cut-off for inclusion in the multivariable model		

Variables with a p-value < 0.20 in univariable analysis were then analyzed using a multivariable logistic regression model, and backward stepwise elimination was employed. (Table 4).

Table 4
Multivariable logistic regression analysis of factors associated with prolonged postoperative length of stay

Variables	Adjusted OR (95% CI)	P-value*
Admission (Clinic)		0.006
• From ER	2.845 (1.33, 6.07)	0.007
• Transferred from other specialty	6.07 (1.04, 35.4)	0.045
Duration of surgery	1.005 (1.002, 1.007)	< 0.001
KPS	0.041 (0.004, 0.430)	0.008
*P value < 0.05 is considered significant by multivariable analysis.		

After adjustment for potential confounders, route of admission, operative duration, and preoperative functional status (KPS) remained independent predictors of prolonged hospital stay. Compared with patients admitted through the outpatient clinic, those admitted via the emergency department had nearly threefold higher odds of prolonged hospitalization, while patients transferred from another specialty had approximately six fold higher odds.

Longer operative duration was independently associated with an increased likelihood of prolonged hospital stay. In contrast, higher preoperative KPS was associated with lower odds of prolonged hospitalization indicating that better preoperative functional status was associated with lower odds of extended length of stay.

Discussion

We investigated the predictors of prolonged hospital stay in patients undergoing craniotomy for tumor resection at a tertiary care center in Pakistan, providing context-specific insights relevant to low- and middle-income country (LMIC) healthcare systems. Our study showed that 14.9% experienced an

extended LOS of 8 days or more. This is comparable to another study conducted in the USA showing similar hospital LOS in patients who underwent craniotomy for tumor resection. [8] The factors contributing to prolonged LOS were transfer from another specialty on admission, emergency department admission, longer operative duration and lower preoperative KPS.

As healthcare systems have shifted towards value-based care and cost-efficiency, LOS has become a critical metric for assessing healthcare quality, resource utilization, and patient outcomes [8, 12]. Previous studies also identified emergency department admission and postoperative transfer to non-neurosurgical services as independent predictors of prolonged LOS, which is consistent with our results. [8] An important independent factor was the duration of surgery, with patients in the prolonged-stay group undergoing significantly longer operations, with a median time of 261.5 minutes vs. 220 minutes in patients who didn't have prolonged LOS. Each incremental increase in operative time was associated with a greater likelihood of extended hospitalization. Duration of surgery may partly reflect tumour complexity and surgical approach, although potentially avoidable workflow delays may also contribute. This is consistent with findings from previous studies, where prolonged operating times have been correlated with increased risk of infection, blood loss, anesthetic exposure, and postoperative complications, all of which may delay recovery and thus increase LOS. [1]

Our results reinforce existing evidence that functional status is a key prognostic indicator for both surgical and oncological outcomes. [13, 14] Lower KPS is not only associated with increased perioperative risk but also with slower mobilization, rehabilitation challenges, and higher susceptibility to complications. [13] Optimizing patients preoperatively, through measures such as physical conditioning and nutritional support, could potentially mitigate this risk. [13, 14] In the univariate analysis, several other clinically meaningful associations were observed. Postoperative complications were strongly correlated with prolonged LOS, with over half of the patients who experienced complications remaining hospitalized beyond 8 days. This aligns with the findings of Bardach et al., who reported that postoperative complications are among the strongest predictors of increased LOS in neurosurgical patients [15]. Similarly, perioperative blood transfusions, especially those administered within 72 hours postoperatively, dramatically increased the odds of prolonged LOS—nearly tenfold. This underlines the importance of meticulous intraoperative hemostasis and judicious transfusion strategies, especially in patients with borderline hematologic parameters preoperatively.

Interestingly, patients who underwent awake craniotomy had notably shorter hospital stays compared to those who received general anesthesia. While the absolute number of awake cases may have been lower, this trend is consistent with the literature suggesting that awake procedures, where feasible, allow for more rapid neurological assessments, fewer anesthetic-related complications, and earlier mobilization [16]. We also observed a statistically significant association between 30-day readmission rates and prolonged index hospital stays. This suggests that patients requiring longer hospitalizations may be inherently more vulnerable to adverse events even after discharge. Interestingly, this contrasts with findings by Hormuzdiyar H. Dasenbrock et al., who found no association between prolonged LOS and 30-day unplanned readmissions [1]. The discrepancy may be attributed to institutional variations in

discharge planning, follow-up protocols, and post-discharge support services. In another study by Shaheryar F Ansari et al it was reported that decreased LOS over time has been associated with an increased readmission rate at the population level. However, a prolonged LOS was associated with a higher risk of readmission at the individual level, and this was attributed to patient comorbidities. [17]

Our analysis highlights several potential strategies to reduce prolonged hospital stays. Preoperative optimization, such as improving patients' functional status through rehabilitation, nutritional support, or addressing reversible deficits, may play a key role. Enhancing surgical efficiency by streamlining operative workflows, minimizing intraoperative interruptions, and ensuring experienced surgical teams could help reduce operative time and improve outcomes. The implementation of Enhanced Recovery After Surgery (ERAS) protocols has been shown to reduce length of stay and postoperative complications while enhancing functional recovery, including higher postoperative Karnofsky Performance Status (KPS), as demonstrated in recent meta-analyses [11, 14]. Finally, better discharge planning and coordination, particularly for patients transferred from other services, may help prevent delays and further reduce hospital length of stay.

As a single-center retrospective analysis, its findings may have limited generalizability and are subject to information bias, missing data, and residual confounding despite statistical adjustment. The relatively small number of patients with prolonged hospital stay limited the stability of the multivariable model, and external validation is lacking. In addition, important factors such as surgeon experience and tumor characteristics could not be fully accounted for. Our institution is a major tertiary referral center that frequently manages patients with advanced disease, significant neurological deficits, and complex clinical presentations. Consequently, lower KPS, emergency admissions, and inter-service transfers may partly reflect the complexity of the underlying patient population rather than independent determinants of prolonged length of stay. Likewise, prolonged operative duration may act as a surrogate for tumor complexity, anatomical location, and technical difficulty; important factors that are challenging to quantify accurately in a retrospective study.

Conclusion

While many of the identified independent predictors are non-modifiable, early recognition of high-risk patients may facilitate targeted preoperative optimization, implementation of enhanced recovery pathways, and proactive discharge planning. However, as a major tertiary referral center, our institution manages a highly complex patient population, and both patient and tumor complexity are difficult to accurately quantify in a retrospective study. Future prospective multicenter studies incorporating standardized measures of tumor complexity, case severity, and surgical complexity are needed to validate these findings, develop robust prediction models, and identify interventions that can safely reduce postoperative length of stay while maintaining optimal patient outcomes.

Declarations

Ethics approval

This retrospective study was conducted following an exemption from the Ethical Review Committee of Aga Khan University Hospital, Karachi, Pakistan (ERC No. 2024-9603-28019).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

Z.J. contributed to the conception and design of the study, acquisition of data, interpretation of data and drafting of the article. A.S. contributed to the acquisition of data, interpretation of data and drafting of the article.A.K. and R.S. contributed to the acquisition of data and drafting of the article. H.F.A. contributed to revising the article critically for important intellectual content. N.Z. contributed to data analysis.S.K.B. contributed to the conception and design of the study, revising the article critically for important intellectual content, and final approval of the version to be published.

Data Availability

The data supporting the findings of this study were obtained from hospital medical records. Due to patient confidentiality and institutional restrictions, the data are not publicly available. De-identified data may be available from the corresponding author upon reasonable request, subject to appropriate ethical and institutional approvals.

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