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Physical Health-Related Quality of Life and Postsurgical Outcomes in Brain Tumor Resection Patients

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Abstract

Background Patient-reported outcome measures (PROMs) have gained traction in assessing patients' health around surgery. Among these, the 29-item Patient-Reported Outcomes Measurement Information System (PROMIS-29) is a widely accepted tool for evaluating overall health, yet its applicability in cranial neurosurgery remains uncertain.

Objective This study aimed to evaluate the predictive value of preoperative PROMIS-29 scores for postoperative outcomes in patients undergoing brain tumor resection.

Materials and Methods We identified adult patients undergoing brain tumor resection at a single neurosurgical center between January 2018 and December 2021. We analyzed physical health (PH) summary scores to determine optimal thresholds for predicting length of stay (LOS), discharge disposition (DD), and 30-day readmission. Bivariate analyses were conducted to examine the distribution of PH scores based on patient characteristics. Multivariate logistic regression models were employed to assess the association between preoperative PH scores and short-term postoperative outcomes.

Results Among 157 patients (mean age 55.4 years, 58.0% female), 14.6% exhibited low PH summary scores. Additionally, 5.7% experienced prolonged LOS, 37.6% had nonroutine DDs, and 19.1% were readmitted within 30 days. Bivariate analyses indicated that patients with low PH summary scores, indicating poorer baseline PH, were more likely to have malignant tumors, nonelective admissions, and adverse outcomes. In multivariate analysis, low PH summary scores independently predicted increased odds of prolonged LOS (odds ratio [OR] = 6.09, $p = 0.003$), nonroutine DD (OR = 4.25, $p = 0.020$), and 30-day readmission (OR = 3.93, $p = 0.020$).

Conclusion The PROMIS-29 PH summary score serves as a valuable predictor of short-term postoperative outcomes in brain tumor patients. Integrating this score into clinical practice can enhance the ability to anticipate meaningful postoperative results.

Keywords

- PROMIS-29
- length of stay
- discharge disposition
- readmission
- brain tumors

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Introduction

Approximately 84,000 individuals receive a new diagnosis of brain and other central nervous system tumors in the United States each year, resulting in about 19,000 deaths annually from this disease.[1] Patients facing brain tumors often experience significant challenges in their health-related quality of life (HRQoL), primarily due to symptoms stemming from focal neurological deficits and the adverse effects of treatment on cognitive function.[2–4] Traditionally, assessments of quality of life (QoL) within this patient group have relied on physician-reported measures such as the Karnofsky Performance Status (KPS) and the Eastern Cooperative Oncology Group Scale (ECOG) of Performance Status.[5,6] However, these instruments may not fully capture patients' actual QoL experiences, as they are determined by health care providers rather than the patients themselves.[7]

The establishment of the Patient-Centered Outcomes Research Institute following the Affordable Care Act has prompted a shift toward patient-centered care and the utilization of patient-reported outcome measures (PROMs) to evaluate health care quality.[8–11] Unlike traditional measures like KPS and ECOG, PROM-based tools enable assessment of treatment response from the patient's viewpoint.[12,13] While numerous HRQoL measures have been employed in brain tumor research, a systematic review by Dirven et al[14] underscored the need for further clarification regarding the clinical validity and utility of these tools. The 29-item Patient-Reported Outcomes Measurement Information System (PROMIS-29), established by the National Institutes of Health, aims to enhance PROM-based research.[15] This extensively validated instrument evaluates seven health domains, including physical function, fatigue, pain, depressive symptoms, anxiety, ability to engage in social roles/activities, and sleep disturbance, providing normalized summary scores for both physical (PH) and mental health.[16]

Recognizing the potential influence of HRQoL on outcomes in brain tumor patients, we aimed to explore the role of preoperative PROMIS-29 PH summary scores in predicting short-term postoperative outcomes among this patient population.

Methods

Our study received approval from our institutional review board (IRB), and we adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines[17] to ensure the presentation of findings without potential bias.

Patient Selection

We conducted a retrospective review of electronic medical records from January 1, 2018 to December 31, 2021, focusing on adult patients (age > 18 years) who underwent craniotomy for intracranial tumors by consultant neurosurgeons with at least 5 years of operating experience at the consultant level, at a single academic institution. We excluded patients with prior neurosurgical intervention for an intracranial tumor. Using the REDCap software system (Nashville, Tennessee, United States), we administered the PROMIS-29 instrument via email correspondence associated with the patient's preoperative clinic visit approximately 1 month before elective surgery. Patients who did not complete a baseline PROMIS-29 instrument preoperatively were excluded.

Data Collection

After screening, we collected various patient variables, including age, sex, race, ethnicity, health insurance type, diagnosis, marital status, admission type, American Society of Anesthesiologists (ASA) score, duration of surgery (hours from incision to closure), hospital length of stay (LOS), discharge disposition (DD), and 30-day readmission. Prolonged LOS was defined as representing the top quartile of this parameter.[18,19] Nonroutine discharge was defined as any discharge to rehabilitation, skilled nursing facility, or hospice. We recorded preoperative PROMIS-29 responses within REDCap and converted raw scores in each domain to T-scores using the Assessment Center Application Program Interface (http://www.assessmentcenter.net). These T-scores were then used to calculate summary scores using the method described by Hays et al.[20]

Statistical Analysis

All statistical analyses were performed using RStudio statistical software, version 3.3.2 (The R Foundation, Vienna, Austria). Continuous variables were presented as mean and standard deviations, analyzed using the Student's *t*-test. Categorical variables were presented as frequencies and percentages; these variables were analyzed via the chi-squared test. Bivariate analyses were conducted to identify differences in baseline characteristics between patients with low preoperative PH summary scores and those with higher scores. Multivariate logistic regression models were used to quantify the relationship between preoperative PH summary scores and postoperative LOS, DD, and 30-day readmission, adjusted for various patient demographics.

Receiver operating characteristic (ROC) curves were generated to assess the relationship between preoperative PH summary scores and prolonged LOS, DD, or 30-day readmission, with optimal PH summary score cutoffs identified using the Youden index.[21] We compared the predictive value of preoperative PH summary scores to previously validated predictors using ROC curves and calculated the *c*-statistic for each curve. DeLong's test was used to assess differences in *c*-statistics between models.

To assess the risk of selection bias, analyses were conducted to compare demographic characteristics, exposure, and outcome metrics between patients included in the study and those excluded due to not completing the PROMIS survey.

Results

Patient Demographics

We identified a cohort of 157 patients who underwent brain tumor surgery, with an average age of 55.4 ± 15.4 years. Most

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Table 1 Baseline characteristics

Characteristic ($n = 157$)	Total cohort Mean ± SD or n (%)
Mean age (y)	55.39 ± 15.42
Sex	
Male	66 (42.0)
Female	91 (57.9)
Race	
White	100 (63.7)
African American	35 (22.3)
Other	22 (14.0)
Ethnicity	
Hispanic/Latino	5 (3.2)
Not Hispanic/Latino	152 (96.8)
Insurance	
Private	109 (69.4)
Medicare	42 (26.8)
Medicaid	6 (3.8)
Diagnosis	
Benign	89 (56.7)
Meningioma	14 (8.9)
Low-grade glioma	5 (3.2)
Pituitary adenoma	52 (33.1)
Vestibular schwannoma	2 (1.3)
Other	16 (10.2)
Malignant	68 (43.3)
Glioblastoma	26 (16.6)
Metastases	27 (17.2)
Other	15 (9.6)
Marital status	
Married	103 (65.6)
Not married	54 (34.4)
Admission type	
Nonelective	54 (34.4)
Elective	103 (65.6)
ASA	
I–II	45 (28.7)
III–IV	112 (71.3)
Duration of surgery (number of hours from incision to closing)	
< 3	103 (65.5)
> 3	54 (34.4)
Karnofsky Performance Score	
100	31 (19.7)
< 100	69 (43.9)
PROMIS-29 scores	
Physical function	45.52 (10.5)
Anxiety	53.70 (10.4)
Depression	49.50 (10.3)
Fatigue	52.08 (11.8)
Sleep	50.81 (9.5)
Ability to function in social activities	50.32 (11.1)
Pain interference	35.96 (15.8)
Pain intensity (raw score)	3.01 (3.0)
Length of stay	
Prolonged	39 (24.8)
Nonprolonged	118 (75.2)
Discharge disposition	
Routine	98 (62.4)
Nonroutine	59 (37.6)
Readmission within 30 days	30 (19.1)

Abbreviations: ASA, American Society of Anesthesiology; PROMIS-29, Patient-Reported Outcomes Measurement Information System 29-item; SD, standard deviation.

of these patients were female (58.0%), Caucasian (63.7%), married (65.6%), admitted electively (65.6%), privately insured (69.4%), classified with an ASA score of III to IV (71.3%), and diagnosed with a benign brain tumor (56.7%). Among them, 39 patients (24.8%) experienced a prolonged LOS defined as ≥ 8.37 days, while 59 patients (37.6%) had a nonroutine discharge, and 30 patients (19.1%) were readmitted within 30 days. ►**Table 1** summarizes the baseline characteristics of the patients included in our study. The IRB, acting as a Health Insurance Portability and Accountability Act (HIPAA) Privacy Board, granted approval for the waiver of informed consent for this retrospective, HIPAA-compliant investigation.

Bivariate Analyses

ROC curves depicting the relationship between PH summary score and postoperative outcomes revealed varying Youden indices (►**Fig. 1**). Therefore, we approximated an optimal cutoff for distinguishing low versus high PH summary scores by averaging and rounding to the nearest whole number for practical interpretation in clinical settings. The defined optimal cutoff was –1. Since the PH summary score is calculated as a T-score, a value of –1 corresponds to a cumulative PH score of one standard deviation below that of the normal population. Patients were categorized into a low preoperative PH summary score (< –1) group ($n = 23$) and a high preoperative PH score (≥ –1) group ($n = 134$). Bivariate analyses indicated that patients in the low PH score group were more likely to have malignant tumors ($n = 16$ [69.6%], $p = 0.010$) and nonelective

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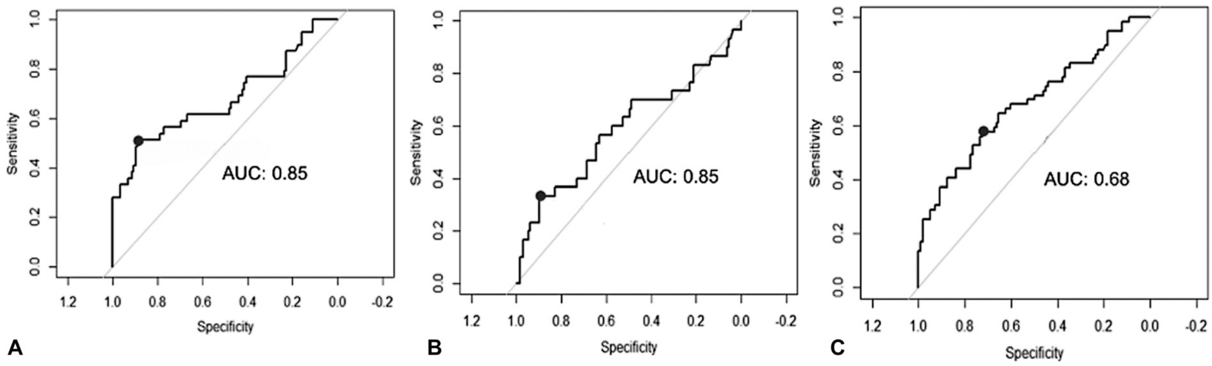

Fig. 1 Receiver operator characteristic (ROC) curves representing multivariate logistic regression models with physical health (PH) summary score as the independent variable for (**A**) prolonged length of stay, (**B**) discharge disposition, and (**C**) readmission within 30 days. The marked point on each curve represents the optimum threshold based on the Youden index calculation. AUC, area under the curve.

admissions ($n=15$ [65.2%], $p=0.002$) compared to their counterparts in the high PH score group ($n=52$ [38.8%], $n=39$ [29.1%], respectively).

Regarding the outcomes of interest, patients with low PH scores were significantly more prone to prolonged LOS ($n=6$ [26.1%], $p<0.001$) compared to those with high PH scores ($n=3$ [2.2%]). Similarly, individuals with low PH scores were more likely to experience a nonroutine discharge ($n=17$ [73.9%], $p<0.001$) compared to patients with high PH scores ($n=42$ [31.3%]). Moreover, those with low PH scores exhibited a significantly higher 30-day readmission rate ($n=10$ [43.5%], $p=0.003$) compared to their counterparts with high PH scores ($n=20$ [14.9%]) (►**Table 2**). The PH summary score also demonstrated excellent predictive correlation with all major outcomes, including LOS (*c*-statistic 0.85; 95% confidence interval [CI] 0.79–0.93), DD LOS (*c*-statistic 0.85; 95% CI 0.81–0.92), and 30-day readmission (*c*-statistic 0.68; 95% CI 0.61–0.75).

Adjusted Multivariate Analyses

Multivariate logistic regression models aimed at identifying risk factors for postoperative outcomes revealed that both low PH summary score and nonelective admission were associated with prolonged LOS (odds ratio [OR] $=6.09$, $p=0.003$ and OR $=28.28$, $p<0.001$, respectively), nonroutine discharge (OR $=4.25$, $p=0.020$ and OR $=4.83$, $p=0.004$, respectively), and 30-day readmission (OR $=3.93$, $p=0.020$ and OR $=3.14$, $p=0.046$, respectively). Additionally, age (per 1-year increase) was associated with a nonroutine discharge (OR $=1.08$, $p=0.001$) (►**Table 3**).

Analyses to Assess Selection Bias

No significant differences were observed in demographic characteristics, PROMIS score, or outcome metrics between the patients included in the study and those excluded due to incomplete PROMIS survey participation.

Discussion

This study was the first to evaluate the utility of the PROMIS-29 summary PH score in predicting clinical outcomes among adult brain tumor patients. Significant associations were observed between preoperative PH summary scores and prolonged LOS, DD, and 30-day readmission in bivariate and multivariate analyses among adult operative brain tumor patients.

This report is not the first neuro-oncology-focused article to utilize PROMIS-29 in its study design. For instance, Lai et al, in a retrospective review of 199 children with primary brain tumors (benign and malignant) from multiple institutions across the United States, reported a significant correlation between PROMIS-29 subscale scores and the well-validated Symptoms Distress Scale.[22] However, our study is the first to correlate preoperative PH summary scores with short-term postoperative outcomes in brain tumor patients.

Prolonged LOS

LOS has been shown to be an important indicator of a patient's ability to recover postoperatively as well as a solid proxy for the cost of care and resource consumption.[23–25] Our study was the first to demonstrate a statistically significant association between preoperative PH summary score and prolonged LOS in patients undergoing brain tumor resection. A possible explanation for this association is that reduced self-reported physical functioning may lead the patient to take a longer period of time to mobilize and achieve a sufficient functional level for discharge. Immobility from reduced physical functioning may also increase the risk of postoperative complications, such as nosocomial pneumonia and pulmonary embolism, thereby prolonging hospital stay further.[26] Low PH score may be a reflection of increased frailty; indeed, a previous study has demonstrated a relationship between objective composite frailty scores and prolonged LOS. Huq et al found that each point-increase in mFI-5 score prolonged the LOS by 1.38 days in a cohort of 1,692 brain tumor patients in a single institution in the United States.[27] Frailty has also been shown to be significantly associated with lower scores on PH-related QoL summary scales.[28] While this overlap may introduce redundancy in the clinical utility of both instruments, using PROMs as an adjunct to objective frailty measures (which are often based on comorbidities) provides a unique perspective on the lived experience of impaired physical function in patients.

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Table 2 Bivariate analyses of baseline characteristics by PH scores in adult brain tumor patients

Characteristics	Low PH score[a] ($n = 23$)	High PH score[a] ($n = 134$)	*p*-Value
Mean age (y)	58.3 ± 12.4	54.89 ± 15.9	0.250
Sex			
Male	9 (39.1)	57 (42.5)	
Female	14 (60.9)	77 (57.5)	0.940
Race			
White	17 (73.9)	83 (61.9)	
African American	3 (13.0)	32 (23.9)	
Other	3 (13.0)	19 (14.2)	0.470
Ethnicity			
Hispanic/Latino	1 (4.4)	4 (2.9)	
Not Hispanic/Latino	22 (95.7)	130 (97.0)	1.000
Insurance			
Private	14 (60.9)	95 (70.9)	
Medicare	8 (34.8)	34 (25.4)	
Medicaid	1 (4.4)	5 (3.7)	0.620
Diagnosis			
Benign	7 (30.4)	82 (61.2)	
Malignant	16 (69.6)	52 (38.8)	***0.010***
Marital status			
Married	14 (60.9)	89 (66.4)	
Not married	9 (39.1)	45 (33.6)	0.780
Admission type			
Nonelective	15 (65.2)	39 (29.1)	
Elective	8 (34.8)	95 (70.9)	***0.002***
ASA			
I–II	21 (91.3)	131 (97.8)	
III–IV	2 (8.7)	3 (2.2)	0.320
Duration of surgery (number of hours from incision to closing)			
< 3	12 (52.2)	78 (58.2)	
> 3	11 (47.8)	56 (41.8)	0.413
Length of stay			
Prolonged	6 (26.1)	3 (2.2)	
Nonprolonged	17 (73.9)	131 (97.8)	***< 0.001***
Discharge disposition			
Routine	6 (26.1)	92 (68.7)	
Nonroutine	17 (73.9)	42 (31.3)	***< 0.001***
Readmission within 30 days	10 (43.5)	20 (14.9)	***0.003***

Abbreviations: ASA, American Society of Anesthesiology; PH, physical health.
Note: Significant *p*-Values are bold, red, and italicized.
[a]Low PH score is defined as a *z*-score of < -1, while a high PH score is a *z*-score of ≥ -1.

Nonroutine Discharge

In addition, the findings presented herein show a low PH summary score was associated with higher rates of nonroutine discharge. It is possible that low self-reported physical functioning reflects increased frailty, and frailer patients likely require a higher level of care after hospitalization,

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Table 3 Multivariate logistic regression analyses of baseline characteristics in adult brain tumor patients

Short-term postoperative outcome	Prolonged LOS		Nonroutine DD		Readmission within 30 days	
	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value	OR (95% CI)	*p*-Value
Low PH summary score[a]	6.09 (1.89, 21.08)	***0.003***	4.25 (1.34, 15.12)	***0.020***	3.93 (1.24, 12.69)	***0.020***
Age (per 1-year increase)	1.00 (0.97, 1.05)	0.970	1.08 (1.03, 1.13)	***0.001***	0.99 (0.95, 1.04)	0.750
Admission type (Ref: elective)						
Nonelective	28.28 (7.73, 132.51)	$<$ ***0.001***	4.83 (1.70, 14.65)	***0.004***	3.14 (1.04, 10.12)	***0.046***

Abbreviations: CI, confidence interval; DD; discharge disposition; LOS, length of stay; OR, odds ratio; PH, physical health; Ref, reference.
Note: Significant *p*-Values are bold, red, and italicized.
[a]Low PH score is defined as a *z*-score of ≤ -1, while a high PH score is a *z*-score of > -1.

thus increasing the likelihood of discharge to a rehabilitation center or nursing facility. There were multiple objective frailty measures being shown to predict nonroutine discharge in brain tumor patients who underwent resection. In a retrospective cohort review involving 7,209 patients from the Nationwide Readmissions Database, Bonney et al demonstrated that frailty, as measured by the Johns Hopkins Adjusted Clinical Groups frailty indicator tool, was associated with twice the odds of nonroutine discharge compared to nonfrail patients.[29] Similarly, a U.S.-based multicenter analysis with 30,951 brain tumor patients undergoing craniotomy found that increasing frailty (measured by the Risk Analysis Index-Administrative tool) was an independent predictor of nonroutine discharge.[30]

30-Day Readmission

This study also demonstrated that a low PH summary score increases nearly 30-day readmission rate by fourfold. To reiterate, this relationship may be explained by the suggestion that lower physical HRQoL reflects higher levels of frailty, which in turn increases the likelihood of postoperative complications necessitating prompt postoperative readmission. A recent retrospective review of the American College of Surgeons National Surgical Quality Improvement Program Participant Use File, involving 8,397 adults undergoing brain tumor resection, found that high mFI-5 scores were associated with a 1.3-fold increase in the odds of 30-day readmission.[31] Another recent study of 238 brain tumor patients from multiple Ontario-based hospitals showed that a single unit increase in an established postoperative complication risk prediction index, which incorporates the Charlson Comorbidity Index physical frailty score, have high predictive accuracy for 30-day readmission rate with a ROC *c*-statistic of 0.77.[32]

Limitations

As with other brain tumor studies, the main limitation of this study was the heterogeneity of the patient population. Despite including only patients with primary brain tumor, this study was unable to further compare patients by specific histology, location, or treatment types. Moreover, the PROMIS-29 score was only measured at one preoperative period. Thus, it was not possible to correlate variables such as progression of illness, neuroanatomical location, and related comorbidities (seizures, aphasia, apraxia, ataxia, and hemiparesis) with the PROMIS-29 score. Therefore, it was not possible to comment on the change in scores over the course of the brain tumor disease or whether it was driven by particular symptomology in this patient population, representing an area for future research. A replicable study with a larger multi-institutional cohort over a longer time period is necessary to assess the validity and reliability of our results. Lastly, the present study only examined the association between PH summary score and three postoperative outcome metrics (prolonged LOS, DD, readmission). Studies looking at other postoperative outcomes, such as hospital charges, remission rate, and mortality, may be helpful to further elucidate the utility of PROMIS-29 in brain tumor patients.

Conclusion

This study highlights the significance of the PROMIS-29 PH summary score as a predictive indicator for hospital LOS, DD, and readmission rates in patients undergoing brain tumor surgery. Through additional research, integrating the PROMIS-29 questionnaire into preoperative assessments could prove invaluable in tailoring patient counseling, allocating resources effectively, and implementing targeted interventions to enhance postoperative outcomes.

Ethical Approval

This study has been approved by the appropriate ethics committee and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All persons gave their informed consent prior to their inclusion in the study. The data can be made available from the author on reasonable request.

Conflict of Interest

None declared.

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