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Association Between Preoperative Frailty Using Frailty Index-Laboratory Test and Clinical Outcomes in Older Adults Undergoing Brain Tumor Surgery

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ABSTRACT

This retrospective cohort study aimed to evaluate preoperative frailty in older adults undergoing brain tumor surgery using the laboratory-based frailty index (FI-LAB) and its association with clinical outcomes. Data were from electronic medical records of individuals aged ≥ 65 years who had brain tumor surgery between 2015 and 2022 at a general hospital in Seoul, South Korea. The FI-LAB included 26 preoperative laboratory tests and five vitality parameters. Of the 111 patients (mean age 75.4 years; 55% women; 63.1% had benign tumors), 35.1% exhibited moderate or high frailty. Moderate frailty was associated with higher hospital readmission rates (OR = 1.5; 95% CI, 1.01–1.82), and high frailty was linked to non-home discharge (OR = 2.1; 95% CI, 1.03–2.99). Assessing preoperative frailty with the FI-LAB may help identify risks of readmission or non-home discharge. Future studies with larger samples are needed to validate these findings. Nurses should integrate frailty assessment into practice to improve postoperative outcomes.

1 | Introduction

The prevalence of brain tumors is increasing in older adults (Ilic and Ilic 2023; Purshouse et al. 2024; Siegel et al. 2024). In South Korea in 2021, individuals in their 60s and 70s accounted for nearly 40% of the total brain tumor cases (National Cancer Information Center 2023). As the population of older adults grows, these rates are expected to increase (Varela et al. 2023). The primary treatment approach for brain tumors is surgery (Weller et al. 2021). In older adults undergoing brain tumor surgery, the presence of numerous comorbidities and increased vulnerability to stress can place them at high risk for further complications (Huq et al. 2022). Furthermore, psychological issues such as depression, anxiety, behavioral disorders, and personality changes are recognized as common postsurgical challenges in older patients (Fehrenbach et al. 2021). These complex problems result in various issues, such as the increased burden on family caregivers, financial challenges, and a decline in the patient's quality of life (Ilic and Ilic 2023; Pointon et al. 2023).

Frailty, which is characterized by aging-related changes, physiological decline, and increased susceptibility to various stressors (Dent et al. 2019), significantly predicts clinical outcomes in older adults (Gong et al. 2023). Despite the traditional focus on age and comorbidities in the surgical risk assessments of

Summary

- This study assessed preoperative frailty in older adults undergoing brain tumor surgery at a tertiary academic medical center in South Korea, revealing a high prevalence of frailty in this population.
- Findings demonstrated that high preoperative frailty is associated with increased risks of 90-day hospital readmission and discharge to non-home settings, emphasizing the need for frailty assessment to predict postoperative outcomes.
- The study highlights the potential of the FI-LAB index in identifying high-risk individuals, recommending its integration into clinical practice and encouraging further research to compare its effectiveness with other frailty tools.

older adults, frailty is gaining attention as a predictor of overall physiological decline that may otherwise go unnoticed (George et al. 2021). Previous studies have consistently linked frailty with worse postoperative outcomes in older adults with brain tumors, including prolonged hospital length of stay (LOS) (Casazza et al. 2020; Goshtasbi et al. 2020), higher rates of readmission (Sastry et al. 2020), and increased likelihood of discharge to non-home settings (Bonney et al. 2021; Harland et al. 2020). Beyond medical outcomes, frailty also impacts psychological, social, and financial burdens, as well as challenges in post-discharge complication management (Katiyar et al. 2020).

Frailty is assessed by various methods due to its multiple causes and associated factors (Stewart 2019). A systematic review found that the tools used to assess frailty in patients with brain tumors included the 5-factor modified frailty index, the 11-factor modified frailty index, the Johns Hopkins Adjusted Clinical Groups frailty-defining diagnosis indicator, and the Hopkins Frailty Score (Huq et al. 2022). However, existing frailty assessment tools for patients with brain tumors are based on underlying conditions, symptoms, and functional status. These tools are either self-reported or require extensive time and specialized expertise to administer. Moreover, in previous studies, nurses have stated that frailty screening tools are helpful in daily practice, but that assessment is difficult due to environmental constraints such as lack of time and personnel (Warnier et al. 2021). Among various tools, the frailty index based on laboratory tests (FI-LAB) is easy to administer and highly accessible in clinical settings, enabling its straightforward implementation for patients in the acute phase of surgery.

Recent studies have recognized the FI-LAB to be a crucial factor for predicting mortality, postoperative complications, hospital LOS, and readmission (C. H. Kim, Kang, et al. 2022; Y. Kim, Song, et al. 2022; Sohn et al. 2019). However, there is limited research on preoperative frailty assessment in older adult patients with brain tumors using the FI-LAB. In addition, the impact of frailty (as assessed using the FI-LAB) on clinical outcomes such as hospital LOS, discharge disposition, and readmission has not been extensively examined.

Therefore, the main aim of this study was to evaluate preoperative frailty levels in older adults with brain tumors using the FI-LAB and to explore their association with clinical outcomes, including hospital LOS, discharge disposition, and readmission.

2 | Method

2.1 | Study Design

This retrospective cohort study aimed to use the FI-LAB to evaluate preoperative frailty in older adults who underwent brain tumor surgery and to examine the association of frailty scores with clinical outcomes.

2.2 | Setting and Sample

This study was conducted at a 765-bed a tertiary care hospital in Seoul, South Korea. The study sample consisted of adults aged ≥65 years who underwent brain tumor surgery for primary brain tumors, such as meningioma, glioma, pituitary tumors, and vestibular schwannoma, and who were missing <30% of data for the variables used to calculate the FI-LAB between January 1, 2015, and December 31, 2022. Of note, the period from 2020 to 2021, marked by the COVID-19 pandemic, significantly impacted healthcare and nursing overall. However, the treatment and nursing guidelines for brain tumor patients remained largely unchanged, except for strengthened infection control measures such as visitor restrictions and the use of masks and protective equipment.

To control the effects of potential confounders (e.g., reoperation or heterogeneous primary tumor site) (Cagney et al. 2017; Gupta et al. 2021), patients with a metastatic brain tumor and patients who underwent reoperation after the initial surgery were excluded. We also excluded patients whose records were missing at least 30% of the FI-LAB items (Ellis et al. 2020; Kim, Song, et al. 2022). In total, 111 patients were included in the study, and a patient flow chart describing the process of sample selection is presented in Figure 1.

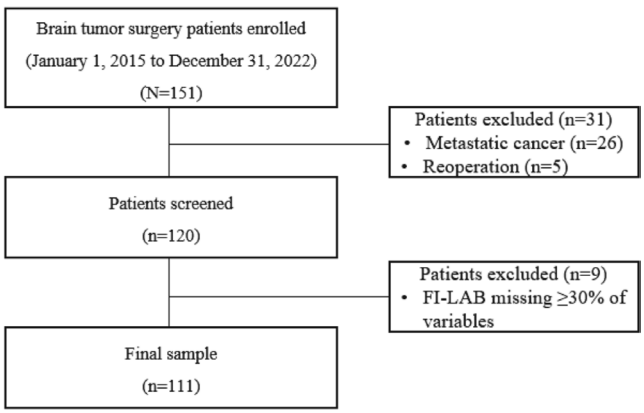

FIGURE 1 | Inclusion flowchart to establish the patient sample in a study of the link between frailty and clinical outcomes. FI-LAB, frailty index based on laboratory test results.

2.3 | Measurement

2.3.1 | Frailty Measurement

In this study, the FI-LAB was used to assess the frailty level of patients undergoing brain tumor surgery, incorporating 26 laboratory test results and 5 vitality indicators (Resendes et al. 2023). The specific list and scope of the 26 laboratory tests and 5 vitality parameters are presented in the Supporting Information S1.

The laboratory test values and vitality indicators were measured within 72 h before surgery. Each item received a score of 0 if it fell within the normal range and a score of 1 if it fell outside the normal range. The FI-LAB score was calculated by summing these scores and dividing by the total number of variables. For example, if 10 out of 26 variables were beyond the normal range, the FI-LAB score would be 0.38 (10/26). As FI-LAB scores can only be computed when fewer than 30% of variables are missing (Ellis et al. 2020; Y. Kim, Song, et al. 2022), the frailty levels of participants with a minimum of 22 items were calculated. Guided by previous research using the FI-LAB to investigate frailty in older adults (Huang et al. 2022; Wang et al. 2019), we categorized frailty as low if the score was <0.2, moderate if the score was 0.2 to <0.35, and high if the score was ≥ 0.35.

2.3.2 | Clinical Outcomes

Clinical outcomes included hospital LOS, unplanned readmissions within 90 days, and discharge disposition. The measurement of LOS was the number of days from admission to discharge. Unplanned readmissions within the 90-day timeframe were identified for cases related to the original surgery, including emergency room visits. Discharge disposition indicated whether the patient was discharged to home. Non-home discharges included transfers to inpatient rehabilitation, home health services, specialized nursing facilities, and other intermediate or long-term care facilities due to additional care needs.

2.3.3 | Baseline Patient Characteristics

Other variables included the patient's age, sex, body mass index (BMI, kg/m^2), smoking status (yes, no), drinking status (yes, no), comorbidity (hypertension, type 2 diabetes, dyslipidemia, kidney disease, liver disease, cardiac disease, lung disease), admission route (outpatient, emergency room), diagnosis (Meningioma, Glioma, Pituitary tumors, Vestibular schwannoma, Others), tumor type (benign, malignant), surgery method (Craniotomy, Brain biopsy, Trans sphenoidal approach), tumor location (Frontal, Parietal, Temporal, Occipital, Pituitary, Cerebellopontine angle, Over 2 location, Others), treatment (only surgery, Concurrent chemo radiotherapy, only chemotherapy, only radiotherapy), Karnofsky Performance Status (KPS), and modified Rankin Scale (mRS). KPS is a scale to assess a patient's independence and health status in daily activities. It is measured on a scale from 0 to 100, with higher scores indicating better health. The mRS assesses the level of functional disability in patients after a stroke or other neurological conditions, with scores ranging from 0 to 6, where a higher score indicates a worse level of functional ability and greater disability.

2.4 | Ethical Considerations and Data Collection

The study protocol was reviewed and approved by the Institutional Review Board of SMG-SNU Boramae Medical Center (IRB No. 20-2023-31). Informed consent was waived because the study involved a retrospective analysis of anonymized data. Using electronic medical records (EMRs) from the respective medical institution, anonymized data of eligible patients were extracted according to the predefined selection criteria.

2.5 | Data Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA).

Prior to analysis, the assumptions of normality, homoscedasticity, and absence of multicollinearity were assessed. Descriptive statistics, including mean, standard deviation, frequency, and percentage were reported for all variables. The chi-square test, Fisher's exact test (used when the sample size is small or the expected frequency in any cell is low), and one-way analysis of variance were used to examine general characteristics, clinical features, and postoperative health outcomes according to frailty levels. Post hoc tests for analysis of variance were conducted using Bonferroni correction, which adjusts the significance level based on the number of comparisons to control the family-wise error rate and reduce the risk of type I error.

To investigate the association of participant frailty levels with postoperative outcomes including hospital LOS, 90-day readmission, and discharge disposition, linear regression analysis and multiple logistic regression analysis were used. Covariates for the regression models were selected based on variables that exhibited significant differences or correlations with the postoperative outcome in the univariate results. The variable input method was used to simultaneously enter the explanatory variables predicted to influence the dependent variable. The goodness of fit for the logistic regression model was assessed using the Hosmer & Lemeshow test, while the goodness of fit for the linear regression model was evaluated using R-squared and the F-test. A two-tailed p-value <0.05 indicated statistical significance.

3 | Results

3.1 | Baseline Patient Characteristics According to Preoperative Frailty Level

A summary of the characteristics of 111 patients is presented in Table 1. The mean age was 75.4 ± 6.9 years, and females comprised 55% ($n=61$) of the sample. Based on FI-LAB scores, 72 patients (64.8%) were classified in the low-frailty group (0.11 ± 0.05), 31 patients (28.8%) in the moderate-frailty group (0.26 ± 0.04), and 8 patients (6.4%) in the high-frailty group (0.41 ± 0.06). The mean BMI was 23.5 ± 5.58 kg/m^2, with 28.8% of participants ($n=32$) classified as overweight and 39.7% ($n=44$) as obese. In our sample, 10.8% ($n=12$) were smokers, and 22.5% ($n=25$) reported alcohol consumption. Hypertension (46.6%, $n=62$), type 2 diabetes (21.1%, $n=28$), and dyslipidemia (19.5%, $n=26$) were the three most prevalent comorbidities.

TABLE 1 | Baseline patient characteristics according to preoperative frailty level.

Variables	Total ($n=111$)	Low frailty[a] ($n=72$)	Moderate frailty[b] ($n=31$)	High frailty[c] ($n=8$)	F or χ^2 (p)
	Mean ± SD or n (%)				
FI-LAB (mean ± SD)	0.17 ± 0.10	0.11 ± 0.05	0.26 ± 0.04	0.41 ± 0.06	202.2 (0.001)
					a < b < c[‡]
Age (years)	75.39 ± 6.88	74.6 ± 7.0	75.6 ± 5.9	81.1 ± 6.86	3.63 (0.031)
					a < c[‡]
65–69	21 (18.9)	16 (22.2)	5 (16.1)	0 (0)	10.52 (0.031)
70–79	59 (53.2)	38 (52.8)	19 (61.3)	2 (25.0)	a, b < c[‡]
≥ 80	31 (27.9)	18 (25.0)	7 (22.6)	6 (75.0)	
Sex					
Female	61 (55.0)	36 (50.0)	19 (61.3)	6 (75.0)	(0.282)[†]
Male	50 (45.0)	36 (50.0)	12 (38.7)	2 (25.0)	
BMI (kg/m^2)	23.5 ± 5.58	23.7 ± 5.8	21.8 ± 6.8	25.0 ± 3.7	6.83 (0.345)
Underweight (< 18.5)	3 (2.7)	2 (2.8)	0 (0)	1 (12.5)	
Normal (18.5–22.9)	32 (28.8)	19 (26.4)	9 (29.0)	4 (50.0)	
Overweight (23–24.9)	32 (28.8)	23 (31.9)	8 (25.8)	1 (12.5)	
Obese (> 25)	44 (39.7)	28 (38.9)	14 (45.2)	2 (25.0)	
Smoking status					
None	99 (89.2)	66 (91.7)	25 (80.6)	8 (100)	3.76 (0.153)
Current	12 (10.8)	6 (8.3)	6 (19.4)	0 (0)	
Drinking status					
None	86 (77.5)	54 (75.0)	25 (80.6)	7 (87.5)	(0.642)[†]
Current	25 (22.5)	18 (25.0)	6 (19.4)	1 (12.5)	
Comorbidities*					
Hypertension	62 (46.6)	34 (69.4)	13 (26.5)	2 (4.1)	(0.463)[†]
Type 2 diabetes	28 (21.1)	18 (64.3)	9 (32.1)	1 (3.6)	(0.621)
Dyslipidemia	26 (19.5)	18 (69.2)	6 (23.1)	2 (7.7)	(0.712)
Kidney disease	1 (0.8)	0 (0.0)	1 (100)	0 (0)	(0.223)[†]
Liver disease	3 (2.3)	2 (66.7)	1 (33.3)	0 (0)	(0.823)[†]
Cardiac disease	9 (6.8)	5 (55.6)	4 (44.4)	0 (0)	(0.285)[†]
Lung disease	4 (3.0)	3 (75.0)	1 (25.0)	0 (0)	(0.827)[†]
Admission route					
Outpatient	92 (82.9)	65 (90.3)	21 (71.4)	6 (75.0)	8.24 (0.012)
Emergency department	19 (17.1)	7 (9.7)	10 (28.6)	2 (25.0)	
Diagnosis					

(Continues)

TABLE 1 | (Continued)

Variables	Total ($n = 111$)	Low frailty[a] ($n = 72$)	Moderate frailty[b] ($n = 31$)	High frailty[c] ($n = 8$)	F or χ^2 (p)
	Mean ± SD or n (%)				
Meningioma	59 (53.2)	44 (61.1)	14 (45.2)	1 (12.5)	(0.028)[†]
Glioma	26 (23.4)	11 (15.3)	9 (29.0)	6 (75.0)	
Pituitary tumors	7 (6.3)	5 (6.9)	2 (6.5)	0 (0)	
Vestibular schwannoma	8 (7.2)	5 (6.9)	2 (6.5)	1 (12.5)	
Others	11 (9.9)	7 (9.7)	4 (12.9)	0 (0)	
Tumor type					
Benign	70 (63.1)	50 (69.4)	18 (58.1)	2 (25.0)	8.13 (0.017)
Malignant	41 (36.9)	22 (30.6)	13 (41.9)	6 (75.0)	
Surgery method					
Craniotomy	88 (79.3)	58 (65.9)	27 (30.7)	3 (3.4)	(0.015)[†]
Brain biopsy	20 (18.0)	12 (60.0)	3 (15.0)	5 (25.0)	
TSA	3 (2.7)	2 (66.7)	1 (33.3)	0 (0)	
Tumor location					
Frontal	35 (31.5)	23 (31.9)	9 (29.0)	3 (37.5)	(0.854)[†]
Parietal	17 (15.3)	12 (16.7)	4 (12.9)	1 (12.5)	
Temporal	16 (14.4)	9 (12.5)	4 (12.9)	3 (37.5)	
Occipital	13 (11.7)	9 (12.5)	3 (9.7)	1 (12.5)	
Pituitary	7 (6.3)	5 (6.9)	2 (6.5)	0 (0)	
CPA	5 (4.5)	2 (2.8)	3 (9.7)	0 (0)	
Over 2 location	13 (11.7)	9 (12.5)	4 (12.9)	0 (0)	
Others	5 (4.5)	3 (4.2)	2 (6.5)	0 (0)	
Treatment					
Only surgery	79 (71.2)	56 (77.8)	18 (58.1)	5 (62.5)	(0.219)[†]
CCRT	12 (10.8)	6 (8.3)	4 (12.9)	2 (25.0)	
Chemo only	9 (8.1)	6 (8.3)	3 (9.7)	0 (0)	
RT only	11 (9.9)	4 (5.6)	6 (19.4)	1 (12.5)	
Preoperative KPS	82.97 ± 16.71	85.97 ± 15.25	79.35 ± 17.30	70.00 ± 20.0	4.57 (0.012) c < a[‡]
≥ 70	88 (79.3)	60 (83.3)	23 (74.2)	5 (62.5)	2.58 (0.275)
< 70	23 (20.7)	12 (16.7)	8 (25.8)	3 (37.5)	
Preoperative mRS	1.47 ± 1.37	1.20 ± 1.22	1.82 ± 1.48	2.50 ± 1.60	5.00 (0.008) a < c[‡]
≥ 2	36 (32.4)	18 (25.0)	13 (41.9)	5 (62.5)	6.39 (0.041)
< 2	75 (67.6)	54 (75.0)	18 (58.1)	3 (37.5)	
Hospital LOS (days)	17.3 ± 14.21	15.5 ± 13.3	20.3 ± 14.9	21.6 ± 17.3	1.80 (0.171)

(Continues)

TABLE 1 | (Continued)

Variables	Total ($n=111$)	Low frailty[a] ($n=72$)	Moderate frailty[b] ($n=31$)	High frailty[c] ($n=8$)	F or χ^2 (p)
	Mean ± SD or n (%)				
Readmission within 90 days					
Yes	19 (17.1)	17 (23.6)	6 (19.3)	1 (12.5)	6.47 (0.032)
No	92 (82.9)	55 (76.4)	25 (80.7)	7 (87.5)	
Discharge to home					
Yes	97 (87.4)	66 (91.7)	26 (83.9)	5 (62.5)	(0.043)[†]
No	14 (12.6)	6 (8.3)	5 (16.1)	3 (37.5)	

Note: *Multiple response. [†]Fisher's exact test. [‡]Bonferroni post hoc test: Values with different superscript letters (a, b, c) within the same row differ significantly at $p<0.05$, based on Bonferroni-corrected post hoc comparisons.
Abbreviations: BMI, body mass index; CCRT, concurrent chemoradiotherapy; CPA, Cerebellopontine angle; FI-LAB, frailty index based on laboratory test results; KPS, Karnofsky Performance Status; LOS, length of stay; mRS, modified Rankin Scale; RT, radiotherapy; SD, standard deviation; TSA, Trans sphenoidal approach.

Most patients were admitted through outpatient clinics, comprising 82.9%, ($n=92$) of the total. The most common diagnosis was meningioma, which represented 53.2% ($n=59$) of the cases. Benign tumors predominated, accounting for 63.1% ($n=70$). The most frequently performed surgical method was craniotomy, conducted in 79.3% ($n=88$) of cases, with the most common tumor location being the frontal region at 31.5% ($n=35$). A total of 71.2% ($n=79$) of patients received only surgical treatment. The mean preoperative KPS was 82.9 ± 16.7, and the mean preoperative mRS was 1.47 ± 1.37. The mean hospital length of stay was 17.3 ± 14.21 days, and the proportion of patients who were not readmitted within 90 days was 82.9% ($n=92$), while those who were discharged home had a higher rate of 87.4% ($n=97$).

Compared with the low-frailty and moderate-frailty groups, individuals in the high-frailty group were older ($p=0.031$), and were more often admitted through the emergency department rather than outpatient clinics ($p=0.012$). Meningioma accounts for a higher percentage of diagnoses in the low-frailty group compared with both the moderate and high-frailty group, while gliomas exhibited an increasing proportion from the low-frailty group to the moderate and high frailty group ($p=0.028$). The proportion of malignancies increased as the frailty group progressed from low-frailty to moderate-frailty and then to high-frailty ($p=0.017$). Craniotomy was performed more frequently in the low-frailty group ($p=0.015$). Individuals in the high-frailty group had lower KPS scores ($p=0.012$), and higher mRS scores ($p=0.008$). Furthermore, in the high-frailty group, the 90-day readmission rate ($p=0.032$) and the proportion of discharges to locations other than home ($p=0.043$) were higher than in the low-frailty and moderate-frailty groups.

3.2 | FI-LAB Parameters by Level of Frailty

A descriptive summary of the FI-LAB parameters across the three frailty levels is presented in Table 2. In the moderate- and high-frailty groups, there were higher levels of alkaline phosphatase ($p=0.006$), neutrophils ($p<0.001$), red cell distribution width ($p<0.001$), and white cell count ($p=0.022$). Conversely, in the low-frailty group, higher values were observed in albumin ($p=0.002$), basophils ($p<0.001$), hematocrit ($p<0.001$), hemoglobin ($p=0.001$), lymphocytes ($p<0.001$), potassium ($p=0.004$), and total calcium levels ($p<0.001$).

3.3 | Association Between the FI-LAB and Clinical Outcomes

The results of covariate-adjusted analysis are presented in Table 3. Prior to conducting multiple regression analysis, multicollinearity among the independent variables was assessed using tolerance and the Variance Inflation Factor (VIF). The VIF values ranged from 1.05 to 3.34, remaining well below the threshold of 10, while tolerance values ranged from 0.299 to 0.948, exceeding the minimum acceptable value of 0.1. These results confirm that there is no issue of multicollinearity. The Durbin-Watson statistic was found to be 1.80, indicating no autocorrelation. After adjusting for covariates (i.e., age), the hospital LOS was longer by 0.20 days ($p=0.032$) in patients with type 2 diabetes than those without type 2 diabetes. Compared with those admitted from outpatient settings, the hospital LOS was longer by 0.26 days ($p=0.011$) for those admitted via an emergency room.

Regarding readmission, the odds ratio (OR) of the moderate-frailty group was 1.5 (95% confidence interval [CI], 1.01–1.82) times higher than that of the low-frailty group. With respect to discharge disposition, the OR of the high-frailty group was 2.1 (95% CI, 1.03–2.99) times higher for non-home discharge than the low-frailty group.

4 | Discussion

Frailty poses significant challenges for older adults, especially those with various comorbid conditions (Sinclair and Abdelhafiz 2022). Despite the growing prevalence of brain tumors and poor long-term prognosis in the older population (Chen et al. 2021; Voisin et al. 2021), there is a paucity

TABLE 2 | FI-LAB parameters according to frailty levels.

Variables (unit)	Total ($n=111$)	Low frailty ($n=72$)	Moderate frailty ($n=31$)	High frailty ($n=8$)	F (p)
Albumin (g/L)	111	4.07 ± 0.28	3.84 ± 0.34	3.81 ± 0.47	6.87 (0.002)
					b, c < a
Alkaline phosphatase (IU/L)	110	69.25 ± 19.26	79.44 ± 36.06	117.73 ± 125.35	5.37 (0.006)
					a, b < c
Alanine transaminase (IU/L)	78	18.09 ± 7.77	18.65 ± 9.21	30.17 ± 12.05	1.64 (0.199)
Aspartate transaminase (IU/L)	78	21.89 ± 5.40	24.12 ± 7.46	30.6 ± 9.33	1.08 (0.343)
Basophils (%)	67	0.44 ± 0.21	0.25 ± 0.18	0.07 ± 0.12	13.27 (0.000)
					b, c < a
TCO_2 (mmol/L)	42	24.83 ± 2.95	25.34 ± 2.93	22.80 ± 4.32	1.10 (0.342)
Bilirubin, total (mg/dL)	78	0.70 ± 0.31	0.64 ± 0.29	0.68 ± 0.30	0.30 (0.739)
Blood urea nitrogen (mg/dL)	78	17.47 ± 4.35	21.24 ± 15.73	21.33 ± 9.91	1.60 (0.210)
Chloride (mmol/L)	77	104.18 ± 2.41	97.22 ± 25.37	101.78 ± 6.40	3.12 (0.058)
Creatinine (mg/dL)	78	0.82 ± 0.21	1.58 ± 3.46	0.72 ± 0.16	1.53 (0.222)
Eosinophils (%)	77	1.87 ± 1.24	1.77 ± 2.51	1.60 ± 3.16	0.07 (0.934)
GFR (mL/min)	67	86.12 ± 19.23	74.68 ± 24.43	86.31 ± 47.59	1.50 (0.231)
Glucose, serum (mg/L)	50	134.07 ± 43.09	151.94 ± 63.81	136.17 ± 27.62	0.69 (0.506)
Hematocrit (%)	111	40.89 ± 3.72	37.99 ± 4.01	36.12 ± 4.85	10.36 (0.000)
					b, c < a
Hemoglobin (g/dL)	111	13.69 ± 1.30	12.84 ± 1.66	12.07 ± 1.96	7.49 (0.001)
					b, c < a
Mean corpuscular hemoglobin	111	30.93 ± 1.39	30.85 ± 1.81	29.84 ± 3.56	1.73 (0.182)
Mean cell volume (fL)	111	92.43 ± 3.84	91.36 ± 3.86	89.15 ± 7.71	2.89 (0.060)
Monocytes (%)	77	5.58 ± 1.42	5.40 ± 2.46	6.08 ± 2.62	0.37 (0.693)
Lymphocytes (%)	74	30.71 ± 9.35	23.12 ± 10.89	14.88 ± 5.27	11.25 (0.000)
					b, c < a
Neutrophils (%)	77	61.32 ± 9.67	69.46 ± 12.57	77.01 ± 9.43	9.65 (0.000)
					a < b, c
Platelet count (1000 cells/μL)	111	226.35 ± 55.14	231.74 ± 69.20	235.45 ± 78.91	0.15 (0.861)
Potassium (mmol/L)	111	4.20 ± 0.30	3.80 ± 0.92	3.89 ± 0.48	5.83 (0.004)
					b < a
Red cell distribution width (%)	111	12.89 ± 0.67	13.44 ± 1.06	14.6 ± 3.03	10.64 (0.000)
					a, b < c
Sodium (mmol/L)	111	139.10 ± 2.07	133.57 ± 26.91	136.43 ± 4.26	1.61 (0.206)
Total calcium (mg/dL)	80	9.03 ± 0.41	8.49 ± 0.61	8.75 ± 0.37	9.91 (0.000)
					b < a
White cell count (thousands)	111	6.91 ± 2.21	7.49 ± 2.99	9.18 ± 3.07	3.96 (0.022)
					a < c

(Continues)

TABLE 2 | (Continued)

Variables (unit)	Total ($n=111$)	Low frailty ($n=72$)	Moderate frailty ($n=31$)	High frailty ($n=8$)	F (p)
Blood pressure- systolic (mmHg)	111	131.66 ± 15.29	129.23 ± 29.60	138.64 ± 13.27	0.89 (0.415)
Blood pressure- diastolic (mmHg)	111	79.16 ± 10.29	76.73 ± 19.95	81.64 ± 16.27	0.54 (0.586)
Pulse (bpm)	111	73.84 ± 12.24	72.31 ± 19.99	80.0 ± 13.3	1.10 (0.338)
O_2 saturation (%)	78	96.80 ± 1.31	96.83 ± 1.47	97.63 ± 1.41	1.31 (0.276)
Temperature (°C)	105	36.55 ± 0.34	35.09 ± 7.16	36.41 ± 0.24	1.57 (0.212)

Note: a: Low frailty; b: Moderate frailty; c: High frailty.
Abbreviations: bpm, beats per minute; FI-LAB, frailty index based on laboratory test results; GFR, glomerular filtration rate.

of studies on the association between frailty and clinical outcomes in older individuals with brain tumor. In this retrospective cohort study, we assessed the preoperative frailty of older adults undergoing brain tumor surgery using routine laboratory data and examined its association with postoperative clinical outcomes, including hospital LOS, 90-day readmission, and discharge disposition, at a tertiary hospital in South Korea.

In our sample, over one-third of the participants fell into the moderate or high frailty categories. Previous studies have reported varying rates of moderate to high frailty (8.2% to 52.3%) in patients undergoing brain tumor surgery across age groups (Bonney et al. 2021; Harland et al. 2020; Huq et al. 2021; Sastry et al. 2020). Cloney et al. (2016) reported an 81.4% prevalence of moderate or high frailty among older adults with brain tumors, which is higher than the prevalence reported in our study. This difference may be attributed to our inclusion of both benign and malignant brain tumor cases, in contrast to previous studies that included only malignant tumors.

We examined the associations of frailty with clinical outcomes, whereas many previous studies concentrated on the link between frailty and mortality in older adults (Ellis et al. 2020; Huang et al. 2022; Y. Kim, Song, et al. 2022; Sohn et al. 2019). While survival rates for brain tumors can vary depending on factors such as location and type of tumor, older people have poorer overall survival rates than younger individuals (Stadler et al. 2024). Survival alone may not fully illustrate the impact of frailty on both short-term and long-term postsurgical hospital courses, as well as on the individual patient's caregiving needs (as reflected in their discharge dispositions).

In our sample, there were significant associations between frailty level and adverse postoperative outcomes, including 90-day readmission and non-home discharge. Our findings are consistent with previous studies that highlighted the association between frailty and postoperative outcomes in brain tumor patients (Asemota and Gallia 2019; Bonney et al. 2021; Cinotti et al. 2018; Sastry et al. 2020). The positive association between frailty and increased postsurgical LOS has been generally well recognized (Y. Kim, Song, et al. 2022; Vermillion et al. 2017) and has been shown in studies involving brain tumor surgery (Cloney et al. 2016; Harland et al. 2020; Huq et al. 2021). A study by Asemota and Gallia (2019) that analyzed a large nationwide sample ($n=115\,317$) in the United States found that postsurgical LOS for frail patients was nearly double that of non-frail individuals. Contrary to prior reports, our study found no significant association between frailty levels and hospital LOS after brain tumor surgery. We speculate that our small sample size might have contributed to the conflicting results. Other factors, such as the heterogeneity in tumor types and surgical sites, might have also influenced our findings. Therefore, our results require cautious interpretation, and further validation with a larger sample is warranted.

Previous studies have used the Johns Hopkins Adjusted Clinical Group (JHACG) tool and the modified Frailty Index-5 (mFI-5) to quantify frailty in brain tumor patients (Huq et al. 2022). The JHACG tool measures frailty by evaluating 10 clinical factors, including malnutrition, dementia, severe visual impairment, pressure injuries, urinary incontinence, fecal incontinence, weight loss, difficulty walking, falls, and lack of social support. Drawbacks of this measure include the need for patient cooperation for direct assessment as well as the investment of resources to implement the tool (e.g., staff training, time investment) (Nidadavolu et al. 2020). The mFI-5, however, measures the presence or absence of major comorbid conditions (e.g., congestive heart failure, chronic obstructive pulmonary disease) as well as functional dependency based on the patient's history (Sastry et al. 2020). Although the mFI-5 may be a simpler tool, its comprehensive assessment of frailty may be limited because it relies primarily on comorbid conditions and self-reported function. Our study revealed that the FI-LAB, based on routinely collected laboratory data, showed a stronger association with adverse outcomes in older adults undergoing brain tumor surgery than previously reported. Notably, preoperative blood tests and vitality assessments are standard components of surgical risk evaluation in this population. Thus, FI-LAB offers a convenient and feasible approach to assessing preoperative frailty, benefiting both patients and healthcare professionals.

Few studies have used the FI-LAB specifically for patients with brain tumors undergoing surgery. According to a systematic literature review investigating the impact of frailty on health outcomes using the FI-LAB (Sapp et al. 2023), most studies using a similar tool were conducted on groups undergoing cardiac-related surgeries (C. H. Kim, Kang, et al. 2022; Lim et al. 2022; Sohn et al. 2019). Therefore, our study supports the feasibility

TABLE 3 | Association of preoperative frailty with clinical outcomes ($n = 111$).

	Hospital length of stay*		Readmission within 90 days†		Discharge disposition†	
Predictors	***β***	***p***	**OR (95% CI)**		**OR (95% CI)**	
Type 2 diabetes						
No (reference)						
Yes	0.20	0.032*	0.50	0.13–1.87	0.56	0.17–1.83
Tumor type						
Benign (reference)						
Malignant	−0.09	0.343	2.17	0.80–5.93	0.39	0.12–1.20
Admission route						
Outpatient (reference)						
ER	0.26	0.011*	0.89	0.23–3.42	0.30	0.08–1.04
KPS						
≥ 70 (reference)	0.43	0.984	1.75	0.24–12.60	0.29	0.04–1.96
< 70						
mRS						
< 2 (reference)						
≥ 2	0.12	0.436	3.73	0.58–23.98	1.27	0.19–8.52
FI-LAB						
Low (reference)						
Moderate	0.18	0.063	1.52	(1.01–1.82)*	0.48	0.13–1.75
High	0.05	0.551	0.34	0.04–3.24	2.17	(1.03–2.99)*
Model fit indicator	$F = 14.3$ (< 0.001)		$\chi^2 = 3.93$, df = 6, $p = 0.686$‡		$\chi^2 = 7.07$, df = 6, $p = 0.320$‡	
	$R^2 = 15.2\%$					
	Adjusted $R^2 = 13.1\%$					

Note: Significance levels: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Adjusted for age. *Multiple linear regression; †Multiple logistic regression. ‡Hosmer & Lemeshow test.
Abbreviations: CI, confidence interval; DM, type 2 diabetes mellitus; ER, emergency room; FI-LAB, frailty index based on laboratory test results; KPS, Karnofsky Performance Status; mRS, modified rankin scale; OR, odds ratio.

and clinical value of applying the FI-LAB to older adults undergoing brain tumor surgery. In our analysis, higher frailty levels were significantly associated with several abnormal laboratory parameters, including low albumin and hemoglobin levels and elevated white blood cell counts. These findings are consistent with existing literature suggesting that such parameters may serve as objective biomarkers of frailty (Cheng et al. 2022; El Assar et al. 2024). For example, hypoalbuminemia has been linked to malnutrition and systemic inflammation—two key physiological components of frailty—and has been identified as an independent predictor of frailty risk in older adults (Yamamoto et al. 2021; Yanagita et al. 2020). Similarly, hemoglobin levels show an inverse relationship with frailty; a cohort study by Steinmeyer et al. (2020) reported that each 1 g/dL increase in hemoglobin was associated with a 14% reduction in the risk of frailty (Steinmeyer et al. 2020), supporting the relevance of anemia as a clinical marker. Taken together, our findings highlight the potential utility of routinely collected laboratory data as objective and accessible indicators for identifying and monitoring frailty.

Individuals undergoing brain tumor surgery frequently experience a range of symptoms, including gait imbalance, hemiparesis, language and communication difficulties, seizures, changes in cognition and personality, visual impairment, and insomnia (Robinson 2016; Tankumpuan et al. 2015). In addition, as the tumor grows, systemic symptoms indicating increased intracranial pressure such as headache, nausea, vomiting, papilledema, and blurred vision may also develop (Palmieri et al. 2021). These symptoms vary significantly in frequency, intensity, quantity, and quality, greatly affecting the individual's quality of life (Rha et al. 2020).

Older adults with brain tumors may experience not only general age-related frailty but also tumor-related frailty, which includes physiological decline caused by tumor burden, cancer-associated cachexia, cancer-related pain, treatment-induced

fatigue, and chronic inflammation (Ernster et al. 2024; Goede 2023; Uslu and Canbolat 2021). Early assessment of frailty is essential for detecting changes in both overall frailty and specific domains of vulnerability throughout the course of treatment and the patient's remaining lifespan. These assessments can support shared decision making by informing discussion about treatment goals and patient preferences, potentially leading to tailored oncologic treatment plans and targeted non-oncologic interventions for managing geriatric impairments (Goede 2023).

In particular, psychological symptoms such as anxiety, depression, and personality changes are common among older adults with brain tumors (Fehrenbach et al. 2021), yet these issues are often overlooked in frailty assessments that focus primarily on physical or physiological indicators. Although our study did not include psychological assessments due to its retrospective design, future frailty models for this population should incorporate the psychological dimension to provide a more comprehensive understanding of vulnerability. In addition, future studies should consider ways to systematically capture psychological factors through the EMR system.

Several limitations of this study should be considered. First, it was conducted at a single institution and only included individuals with records that provided $>70\%$ of the variables. Therefore, selection bias may limit the generalizability of our findings. Second, since only laboratory data and vitality signs were used to assess frailty levels, a comprehensive evaluation of frailty may not have been achieved. Third, this study involved a retrospective analysis of EMR data. It is important to acknowledge the potential influence of unidentified extraneous factors on the results. Fourth, there were instances where test results and vitality signs were not collected on the same day, which might affect the accuracy of the frailty measurements. Fifth, the number of participants in the high frailty group was relatively small ($n=8$), which may have limited the statistical power to detect significant associations. This small sample size could partly explain the absence of statistically significant findings, despite the possibility of clinically meaningful effects. Therefore, the results related to this group should be interpreted with caution. Future studies with larger and more diverse populations are warranted to validate the clinical utility of FI-LAB and to guide the development of frailty-informed care strategies in neurosurgical settings.

5 | Conclusion

Since older adult patients with higher preoperative frailty were more likely to experience 90-day readmission and discharge to a location other than home, we recommend assessing preoperative frailty levels in older adults undergoing brain tumor surgery using routinely collected laboratory data. Preoperative frailty assessment using the FI-LAB can help in the early identification of older adults at high risk for complex postsurgical courses after brain tumor surgery and can assist nurses in the development of tailored preoperative and postoperative care plans. Furthermore, this study affirmed the applicability of the FI-LAB to patients undergoing brain tumor surgery. A comparative study is necessary to compare the FI-LAB to other frailty tools, examining their respective advantages and disadvantages.

6 | Relevance for Clinical Practice

Nurses need to assess and manage frailty in older patients undergoing brain tumor surgery, tailoring their care plans to enhance postoperative recovery. Clinical tools such as the FI-LAB should be integrated into nursing practice, with education on frailty management strengthened.

Author Contributions

S.O.K.: conceptualization, methodology, data curation, investigation, formal analysis, writing – original draft, writing – review and editing. Y.J.S.: writing – original draft, writing – review and editing. J.C.: conceptualization, writing – original draft, writing-review and editing, supervision, funding acquisition. All authors have read and agreed to the final version of the manuscript.

Ethics Statement

The study protocol was reviewed and approved by the Institutional Review Board (IRB) of SMG-SNU Boramae Medical Center (reference number 20–2023-31).

Consent

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to privacy and ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.