Neurosurgical Review (2026) 49:35
https://doi.org/10.1007/s10143-025-03980-6

REVIEW

Predictors and implications of 30-day readmissions following craniotomy for brain tumors: A systematic review and meta-analysis

Neslihan Nisa Gecici[1,2] · Kenan Kerem Ozcinar[3] · Allyson Andrews[4] · Riya M. Dange[5] · Ahmed Habib[1,2] · Jaime Mullin[1,2] · Pascal O. Zinn[1,2]

Received: 4 June 2025 / Revised: 24 October 2025 / Accepted: 16 November 2025

Abstract

Thirty-day readmission rates are commonly used as quality indicators (QIs) due to their feasibility and financial impact on healthcare systems. However, their validity in neurosurgical oncology remains uncertain. This study evaluates 30-day readmission rates following craniotomies for brain tumor resection, focusing on causes, predictors, and their impact on overall survival (OS). A systematic review and meta-analysis were conducted following PRISMA guidelines. PubMed, Cochrane, Scopus, and Web of Science databases were queried for studies reporting 30-day readmission rates in craniotomies for brain tumors. Meta-analysis with random-effects modeling was performed for pooled readmission rates, causes, predictors, and survival outcomes. Individual patient data (IPD) for overall survival were available for glioblastoma patients from four studies and were reconstructed from Kaplan–Meier curves to assess the association between readmission and survival. Eleven studies involving 132,791 patients yielded a pooled 30-day readmission rate of 13% (95% CI: 11%–16%). Neurological (50%) and infectious (25%) causes were the most common readmission indications. Surgical site infections accounted for 11% (7%–16%) and thromboembolic events for 12% (9%–16%) of all readmissions. Preoperative characteristics, including functional status, were consistent predictors of readmission. Among glioblastoma patients, reconstructed IPD from four studies demonstrated that readmitted patients had significantly shorter median overall survival compared with non-readmitted patients (6.4 vs. 8.7 months, $p<0.0001$). Thirty-day readmission rates provide insights into neurosurgical oncology care but have limitations as standalone QIs. A combination of QIs would offer a more comprehensive and accurate assessment of care quality. Efforts to reduce readmissions should address modifiable risk factors, such as preventing SSIs and thromboembolic events, and optimizing perioperative care.

Keywords Readmission · Quality indicators · Neurosurgery · Tumor · Craniotomy

Introduction

Over the years, numerous quality indicators (QIs) have been developed across various medical specialties, including neurosurgery, with the goal of enhancing the quality of care while minimizing healthcare costs [1, 2]. The 30-day readmission rate has become a widely utilized quality indicator due to its feasibility for monitoring through routine administrative data and its significant contribution to healthcare expenditures, making it a critical focus for hospital administrators and policymakers [3, 4]. Readmissions place a significant financial burden on the healthcare system, with annual costs estimated at $17.4 billion for Medicare and $41.2 billion for the overall U.S. healthcare system [4–7]. To address this issue, several initiatives have been introduced, including reimbursement penalties under the Patient

✉ Jaime Mullin
mullinja2@upmc.edu

✉ Pascal O. Zinn
zinnpo@upmc.edu

1 Department of Neurological Surgery, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

2 Hillman Cancer Center, University of Pittsburgh Medical Center, 5115 Centre Avenue, Pittsburgh, PA 15213, USA

3 Bahcesehir University Faculty of Medicine, Istanbul, Turkey

4 Biomedical Master's Program, School of Medicine, University of Pittsburgh, Pittsburgh, PA, USA

5 School of Medicine, University of Pittsburgh, Pittsburgh, PA, USA

Published online: 29 November 2025

Protection and Affordable Care Act, designed to incentivize hospitals to enhance the quality of care [8].

Whether readmission rates accurately reflect the quality of care in neurosurgery remains controversial [3, 4]. Some studies suggest that early readmissions serve as opportunities for timely intervention to prevent further severe complications and improve long-term patient outcomes [9–11]. Conversely, other studies indicate that readmissions can disrupt recovery and negatively impact prognosis [3, 5, 12–14]. In patients with glioblastoma, a few studies have specifically reported reduced overall survival associated with 30-day readmissions, with these findings derived from adjusted analyses that controlled for both preoperative and postoperative factors [3, 5, 12, 14].

A comprehensive evaluation is essential to assess the validity of 30-day readmission rates as a QI in neurosurgical oncology, given the distinct characteristics of this patient population—marked by the complexity of brain tumor biology, a high burden of comorbidities, the intricacy of neurosurgical interventions, and the variability in postoperative management and adjuvant therapies—that set them apart from other patient populations in neurosurgery. Existing studies have primarily included all neurosurgical cases, which may not accurately capture the outcomes for oncological patients [4]. In this study, we aim to provide a comprehensive analysis of 30-day readmissions following craniotomies for tumor resection. Specifically, we seek to determine the overall rate and causes of readmissions, identify key predictors, and evaluate the implications of these events on patient outcomes as well as the validity of the 30-day readmission rate as a QI in neurosurgical oncology.

Methods

Literature review

This study was registered with PROSPERO (CRD42024607268). A systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [15]. PubMed, Cochrane, Scopus, and Web of Science databases were queried for eligible articles using the following search string: (“readmission*” OR “patient readmission” OR “readmission rate”) AND (“craniotomy” OR “brain tumor surgery” OR “surgery” OR “neurosurgery”) AND (“brain tumor” OR “glioma” OR “metastasis” OR “brain neoplasms”) AND (“risk factors” OR “predictors”).

Study selection

Studies were included if they met the following criteria: (i) retrospective or prospective design with at least 100 patients with brain tumors undergoing craniotomy, and (ii) reported data on 30-day readmission rates. Exclusion criteria included reviews and meta-analyses; studies involving vascular, functional, pediatric, or trauma cases; non-English publications; studies with insufficient outcome data; and studies with overlapping cohorts. Two authors independently conducted title and abstract screening, followed by full-text review. Any conflicts were resolved by a third author.

Data extraction

The following data were extracted from the articles: study design, data source, data collection period, patient demographics, 30-day readmissions, causes of readmissions, predictors and their odds ratios (ORs) with 95% confidence intervals (CIs), and hazard ratios (HRs) with 95% CIs for the association of 30-day readmission with overall survival.

The primary outcome measure was 30-day readmission rate, calculated as the number of readmissions within 30 days of discharge divided by total number of cases. The secondary outcomes were causes of 30-day readmissions, predictors of readmission, and the association between 30-day readmission and overall survival (OS).

Data were extracted by two authors and independently verified by a third author.

Risk of bias assessment

Risk of bias assessment was performed using the Joanna Briggs Institute (JBI) checklists for case series and randomized controlled trials.

Statistical analysis

Meta-analysis with random-effects modeling was performed for readmission rates, causes of readmission, and hazard ratios for overall survival. A logistic generalized linear mixed model (GLMM) was applied to account for within- and between-study variability and to include studies with zero or complete event rates without continuity correction. Heterogeneity was summarized using I^2 statistics, with I^2 >75% indicating substantial heterogeneity.

To assess survival outcomes associated with 30-day readmissions, individual patient data (IPD) were reconstructed from Kaplan-Meier curves reported in the included studies. This

was performed using a previously validated method described by Guyot et al., which involves extracting digitized survival curves and converting them into numerical data [16]. First, the Kaplan-Meier curves were digitized using WebPlotDigitizer, and the coordinates of the survival probabilities over time were extracted [17]. The number-at-risk data, when available, were used to enhance the accuracy of the reconstruction by aligning the extracted survival probabilities with the reported time intervals. The extracted data were then processed to estimate individual survival times and censoring indicators, ensuring that the reconstructed IPD accurately reflected the original survival distributions. A pooled Kaplan-Meier curve was generated using the reconstructed IPD from all available studies. Median overall survival (OS) was calculated and compared between patients who experienced 30-day readmissions and those who did not. A p-value < 0.05 was considered statistically significant. Statistical analyses were performed using RStudio.

Results

A total of 11 studies were identified as meeting the eligibility criteria (Fig. 1). [3, 5, 12–14, 18–23] An aggregate of 132,791 patients were included, with study sample sizes ranging from 276 to 57,621 patients (Table 1). Five studies used data from a single institution [3, 5, 12, 13, 22], and the remaining 6 used data from a large database [18–21, 23]. The majority of the studies defined 30-day readmissions as readmissions occurring within 30 days of discharge, while three studies defined it as within 30 days of surgery [3, 18, 23]. All studies included only patients who underwent surgery for primary malignant brain tumors, except for four studies that included both malignant and benign tumors [18, 20, 22, 23]. The JBI criteria-based assessment revealed that all the studies included had a low risk of bias (Supplementary File 1).

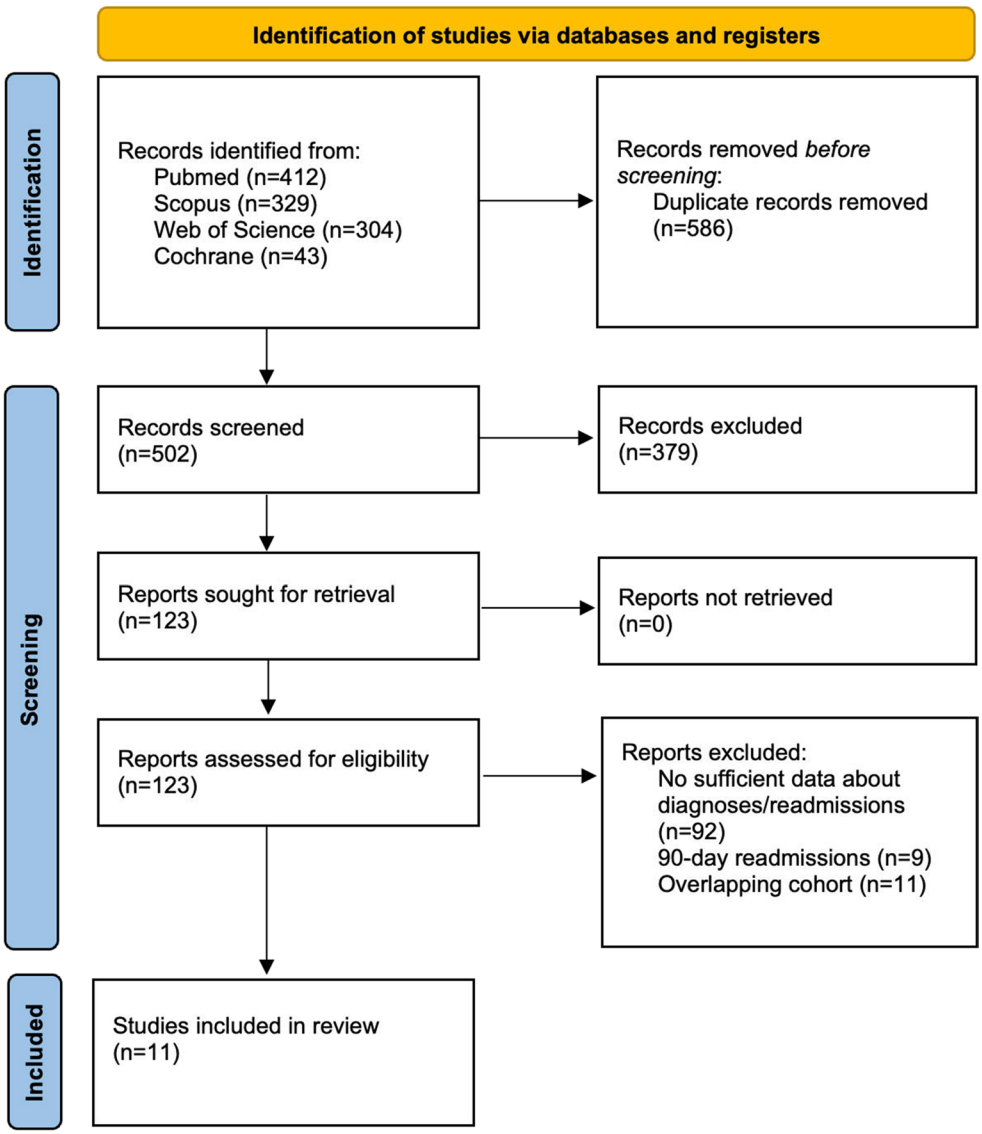

Fig. 1 PRISMA flow diagram

Table 1 Study characteristics

Authors & Year	Study Design	Data Source	Included Pathologies	Data Collection Period	No. of Patients	No. of Readmissions (%)
Botros et al. −2022	Retrospective	Single center	Glioblastoma	2009–2019	418	69 (17%)
Caplan et al. −2019	Prospective	Neurosurgery Quality Improvement Initiative EpiLog tool	Malignant and benign brain tumors	2017–2018	311	57 (18%)
Dickinson et al. −2015	Retrospective	Single center	Glioblastoma	2003–2011	362	27 (7%)
Kasper et al. −2023	Retrospective	Single center	Glioblastoma	2014–2020	276	37 (13%)
Mallela et al. −2020	Retrospective	Single center	Glioblastoma	2004–2016	666	136 (20%)
Marcus et al. −2014	Retrospective	California Office of Statewide Health Planning & Development (OSHPD) database	Malignant primary brain tumors	1995–2010	18,506	2641 (14%)
Moghavem et al. −2015	Retrospective	Agency for Healthcare Research and Quality, Healthcare Cost and Utilization Project, State Inpatient Databases (SIDs) for California, Florida, and New York	Malignant and benign brain tumors	2010–2011	19,178	3250 (17%)
Rumalla et al. −2020	Retrospective	Nationwide Readmissions Database	Malignant brain tumors	2010–2014	57,621	4189 (7%)
Sander et al. −2021	Retrospective	Single center	Malignant and benign brain tumors	2015–2017	903	83 (9%)
Zohdy et al. −2023	Retrospective	American College of Surgeons National Surgical Quality Improvement Program (NSQIP) database	Malignant and benign brain tumors	2012–2019	31,776	3420 (11%)
Nuno et al. −2014	Retrospective	Surveillance, Epidemiology and End Results (SEER) Medicare database	Glioblastoma	1991–2007	2774	437 (16%)
Total					132,791	14,346

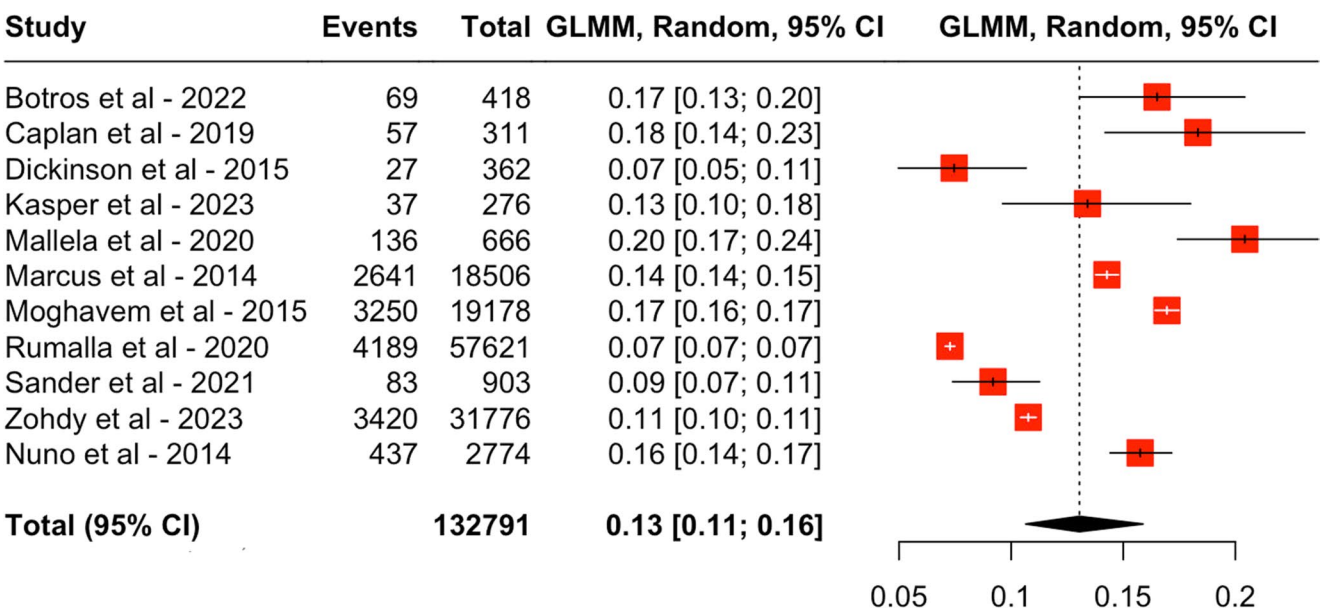

Fig. 2 Pooled rate of 30-day readmissions

Thirty-day readmissions

The pooled 30-day readmission rate for the 11 studies was 13% (95% CI: 11% −16%) and ranged between 7% and 20% (Fig. 2). Jackknife sensitivity analysis was conducted, in which individual studies were sequentially excluded to assess their impact on the 30-day readmission rate according to the a priori threshold; none of the exclusions resulted in a change greater than 0.5%. In addition, no significant differences in readmission rates were found based on the data

source ($p = 0.86$), and heterogeneity remained unchanged. In a separate subgroup analysis restricted to seven studies that included only malignant brain tumors, the pooled readmission rate was 13% (95% CI, 10%–17%), with no significant difference between groups ($p = 0.9$). The inverse funnel plot for publication bias showed symmetry, and Egger's test ($p = 0.51$) did not reveal significant evidence of publication bias.

Causes of readmissions

With the exception of two [13, 18], all included studies reported the causes of readmissions. Neurological causes, including seizures, hydrocephalus, intracranial hemorrhage (ICH), and new neurological deficits, accounted for 50% (95% CI: 42%–58%) of all readmissions (Fig. 3). Among the studies with available data, the pooled rates of readmissions due to seizures, hydrocephalus, and ICH were 9% (6%–14%), 6% (5%–9%), and 1% (0%–11%), respectively [3, 5, 12, 19–21, 23]. Readmissions due to infectious causes made up 25% (19%–33%) of all readmissions, with surgical site infections accounting for 11% (7%–16%)[3, 5, 12, 19, 20, 23]. Medical causes, defined as non-neurological and non-infectious complications such as thromboembolic events, cardiovascular issues, and causes due to other systemic comorbidities, represented 19% (10%–34%) of all readmissions. Among these, the pooled rate of readmissions due to deep vein thrombosis (DVT) or pulmonary embolism (PE) was 12% (9%–16%)[3, 5, 12, 19, 20, 23]. In subgroup analyses restricted to studies that included only malignant brain tumors, the distribution of readmission causes did not differ significantly from the overall cohort (all $p > 0.5$), except for hydrocephalus, which occurred more frequently in this subgroup (8% [7%–9%] vs. 5% [4%–6%], $p < 0.01$).

Additionally, three studies reported data on the preventability of readmissions [3, 5, 22]. Based on the available data, 57% (44%–68%) of all readmissions were classified as preventable. The criteria for preventability varied slightly across studies but generally included complications such as postoperative infections including surgical site infections, thromboembolic events, seizures, and other postoperative issues considered avoidable with optimal perioperative care. In contrast, non-preventable readmissions were typically attributed to tumor progression or side effects of adjuvant therapy (e.g. cerebral edema or neutropenic fever secondary to radiation or chemotherapy), medical conditions unrelated to the neurosurgical procedure (e.g. coronary artery disease, viral bronchitis), nonadherence to medications or cases where patients adhered to treatment protocols but experienced breakthrough events such as seizures or mental status changes.

Predictors of readmissions

All included studies investigated predictors for readmissions. The analytical methods reported by the included studies to identify predictors of readmission included univariable and multivariable logistic regression, as well as bivariate analyses using the Welch t-test and Pearson chi-square test.

Age was examined in six studies, with two identifying increasing age as a significant predictor of 30-day readmissions, while three reported no such association (Table 2) [22, 23]. Interestingly, Botros et al. reported a slight decrease in readmission risk with increased age and attributed this trend to their institutional practice of discharging patients at high risk of readmission to inpatient rehabilitation, where complications are managed accordingly [5]. Sex was found to be a significant predicting factor in 2 of the 7 studies that examined it; males were more likely to be readmitted in the hospital after neurosurgery than females [20, 21]. Race was investigated by 4 out of 12 studies as a possible readmission factor, and only one study found a significant association [3, 14, 19, 20]. Moghavem et al. demonstrated that African American and Hispanic patients have a higher risk for readmission compared to white patients [20].

Functional status, assessed in seven studies, was identified as a consistent predictor of readmission in five [3, 5, 12,

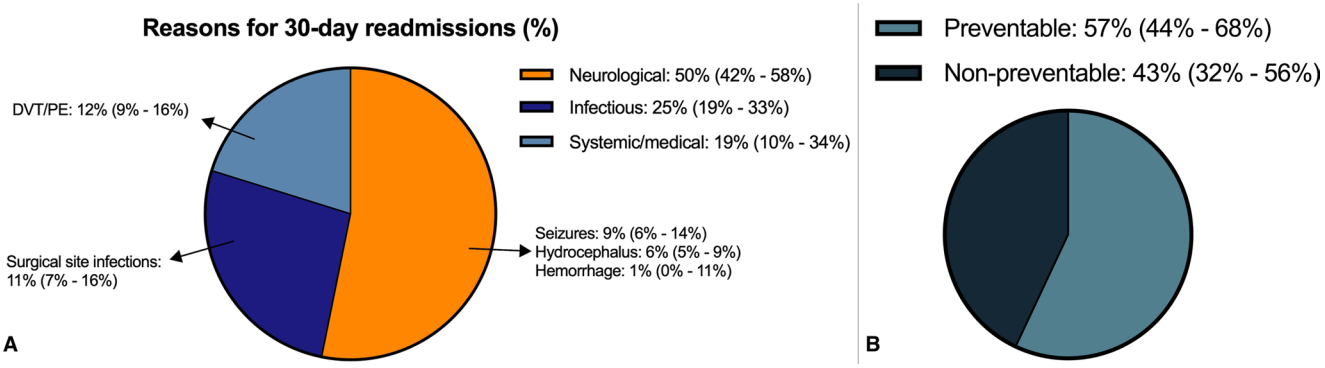

Fig. 3 Reasons for 30-day readmissions (**A**) and preventability (**B**) of readmissions following craniotomies for brain tumors

Table 2 Preoperative factors associated with 30-day readmissions

	Age	Sex	Race	Functional Status	Comorbidities (Y/N)	HTN	DM	CVD/Stroke	CPD	Preoperative Neurological deficit (Y/N)	Cognitive deficit	Motor deficit
Botros et al. – 2022	S	NS	X	S	X	X	X	X	X	X	S	X
Caplan et al. – 2019	NS	NS	X	NS	NS	X	X	X	X	X	X	X
Dickinson et al. – 2015	X	X	NS	S	X	X	X	X	X	X	X	X
Kasper et al. – 2023	NS	NS	X	NS	X	X	X	X	X	NS	NS	NS
Mallela et al. – 2020	X	X	X	S	X	X	X	X	X	X	X	X
Marcus et al. – 2014	X	NS	NS	X	X	NS	NS	NS	NS	X	X	X
Moghavem et al. – 2015	NS	S	S	X	X	NS	S	X	NS	X	X	X
Rumalla et al. – 2020	X	S	X	S	S	X	X	X	X	X	X	X
Sander et al. – 2021	S	X	X	X	X	X	X	NS	X	X	X	X
Zohdy et al. – 2023	S	X	X	S	X	S	X	X	X	S	X	X
Nuno et al. – 2014	X	X	NS	X	X	X	X	X	X	X	X	X

S statistically significant association with 30-day readmissions, *NS* not statistically significant, *X* the variable not included in the model for readmission risk assessment or result unclear. *HTN* hypertension, *DM* diabetes mellitus, *CVD* cerebrovascular disease, *CPD* chronic pulmonary disease

13, 18, 21, 23]. Among these, decreased KPS scores were associated with an increased risk of readmission in three studies [3, 5, 13]. Rumalla et al. demonstrated an association between readmission and the Elixhauser Comorbidity Index, and Zohdy et al. reported an increased readmission risk in patients with frailty [21, 23]. Additionally, Botros et al. highlighted a significant association between readmission risk and higher mFI-5 scores, alongside KPS [5]. Comorbidities, including hypertension, diabetes, and preoperative neurological deficits were inconsistently associated with readmissions.

Admission type was assessed in five studies, with mixed results regarding its significance (Table 3) [3, 5, 14, 20, 21]. Notably, Moghavem et al. reported an increased risk of readmission with emergent index admissions, whereas Rumalla et al. observed a decreased risk of readmission with non-elective index admissions [20, 21]. Eight studies examined length of stay (LOS) during the index admission as a predictor of hospital readmission. Three of these studies identified LOS as a significant predictor, specifically demonstrating a positive correlation between LOS >7 days and increased readmission rates [19, 21, 22]. The significance of discharge disposition was highlighted in three out of six studies that examined this factor, with non-home discharge being significantly associated with an increased risk of readmission [3, 5, 12, 14, 18, 21]. Although postoperative complications were inconsistently associated with readmissions across the studies that examined them, hydrocephalus, surgical site infections (SSIs), and thromboembolic events such as deep vein thrombosis (DVT) or pulmonary embolism (PE) were found to significantly increase the likelihood of readmission in several studies [5, 12, 13, 19]. Patients covered by public insurance programs, such as Medicare or Medicaid, were found to have a higher risk of readmission compared to those with private insurance in all four studies that assessed insurance type as a predictor of readmission [18–21]. Hospital teaching status and volume were not associated with readmissions [19, 20].

Thirty-day readmission impact on overall survival

Four of the eleven studies investigated the association between survival and 30-day readmission. All of these only included patients with glioblastoma [3, 5, 12, 14]. These studies consistently reported that patients who experienced 30-day readmission had significantly shorter median OS compared with those who were not readmitted. In each study, multivariable Cox regression analyses adjusted for relevant confounders also demonstrated that 30-day readmission was independently associated with decreased overall survival. Kaplan-Meier curves and available number-at-risk data from these studies were used to reconstruct

Table 3 Postoperative and institutional factors associated with 30-day readmissions

	Admission type	Insurance type	LOS (index surgery)	Complications (Y/N)	DVT/PE	Intracranial hematoma	Seizure	SSI	Hydrocephalus/VPS	New deficit	Discharge disposition	Hospital type
Botros et al. – 2022	NS	X	NS	X	NS	NS	NS	X	X	NS	NS	X
Caplan et al. – 2019	X	S	NS	NS	NS	NS	NS	X	X	NS	S	X
Dickinson et al. – 2015	NS	X	NS	X	X	X	X	X	X	X	S	X
Kasper et al. – 2023	X	X	NS	S	X	X	X	X	X	S	NS	X
Mallela et al. – 2020	X	X	X	X	S	X	X	S	S	X	X	X
Marcus et al. – 2014	X	S	S	NS	S	X	NS	NS	S	NS	X	NS
Moghavem et al. – 2015	S	S	X	X	X	X	X	X	X	X	X	NS
Rumalla et al. – 2020	S	S	S	X	X	X	X	X	X	X	S	X
Sander et al. – 2021	X	X	S	X	X	X	X	X	X	X	X	X
Zohdy et al. – 2023	X	X	X	X	X	X	X	X	X	X	X	X
Nuno et al. – 2014	NS	X	NS	NS	X	X	X	X	X	X	NS	X

S statistically significant association with 30-day readmissions, *NS* not statistically significant, *X* the variable not included in the model for readmission risk assessment or result unclear. *LOS* length of stay, *DVT/PE* deep vein thrombosis/pulmonary embolus, *SSI* surgical site infection, *VPS* ventriculoperitoneal shunt

a pooled Kaplan-Meier curve, which demonstrated that readmitted patients had significantly lower median OS compared to non-readmitted patients (6.4 vs. 8.7 months, $p < 0.0001$) (Fig. 4 and A) [16]. Furthermore, a meta-analysis of hazard ratios from these studies identified 30-day readmission as a significant risk factor for decreased survival (HR: 2.05 [1.31–3.18] (Fig. 4 and B).

Discussion

This study revealed a pooled 30-day readmission rate of 13% (95% CI: 11%–16%) following craniotomy for brain tumors, with significant inter-study heterogeneity. Despite conducting sensitivity and subgroup analyses based on data source, cohort size and study period, heterogeneity remained high. Potential explanations for this variability may include the reliance on CPT or ICD codes in some of the included studies, which may not fully capture all of the readmissions, and shown to have inaccuracies. Additionally, most studies only accounted for readmissions to the index hospital, with only three studies also including non-index hospital readmissions [12, 19, 20]. Notably, Moghavem et al. reported that fewer than half of readmitted patients in their study returned to the index hospital, with the majority presenting to non-index facilities [20]. These findings suggest that while the readmission rate is a measurable outcome, its utility as an isolated quality indicator in neurosurgical oncology is limited due to these inherent challenges, necessitating more comprehensive measurement strategies that account for patient and contextual factors.

Our findings align with prior literature emphasizing the limitations of 30-day readmissions as a standalone quality metric in neurosurgery. Schipmann et al. highlighted that many quality indicators, including readmission rates, are influenced by baseline patient characteristics rather than true measures of surgical care quality [1]. Readmission rates, while convenient for administrative tracking and reimbursement purposes, may not accurately reflect preventable complications or suboptimal care. Instead, their interpretation must be adjusted for patient complexity and institutional factors. Furthermore, studies have shown that risk adjustment strategies are necessary when utilizing readmission rates, as hospitals treating high-risk patients may exhibit higher readmission rates independent of care quality [1].

Nonetheless, our study identifies areas for targeted improvement in patient care. Approximately 57% of readmissions were classified as preventable in studies with available data, which defined preventability as discrepancies in medical care. However, this definition may not be generalizable across institutions. Instead, examining the

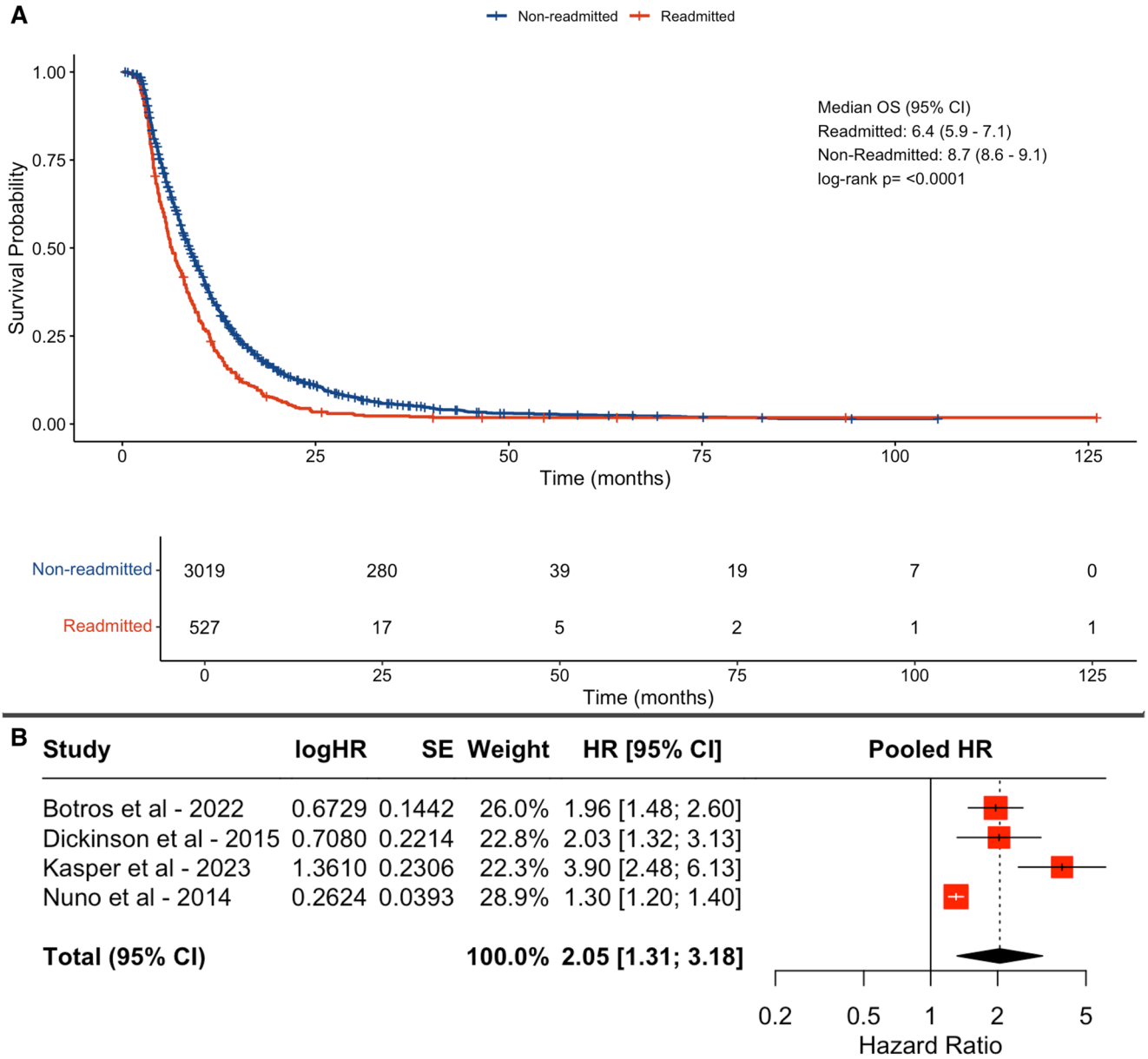

Fig. 4 Survival outcomes and pooled hazard ratio for 30-day readmissions. (**A**) Reconstructed Kaplan-Meier curve using digitized individual patient data. (**B**) Forest plot of hazard ratios for overall survival

causes of readmissions and focusing on actionable events may yield a more effective approach. For instance, SSIs were identified as one of the major causes of readmissions due to infectious complications, accounting for 11% (7%–16%). Given that these complications may be preventable with proper technique and appropriate use of prophylactic antibiotics in some cases, modifications in clinical practice, along with improvements in patient education and follow-up care, hold promise, particularly for at-risk patient groups. Similarly, thromboembolic events, another substantial contributor to readmissions (12%, 95% CI: 9% −16%), can be targeted through anticoagulation. Although the risks of chemoprophylaxis should be weighed against its benefits on an individual basis, recent studies suggests that anticoagulation may not substantially increase the risk of hemorrhagic complications.

This study also explored the predictors of readmission. While some of the factors found to be significantly differed among studies, preoperative functional status emerged as a consistent predictor, with measures such as decreased KPS, dependent functional status, and frailty associated with increased readmission risk [3, 5, 13, 21, 23]. These findings could present a valuable opportunity for implementing targeted initiatives for preoperative risk stratification

and rehabilitation and enhanced discharge planning. Specifically, frailty or functional status could serve as pivotal metrics for preoperative risk stratification. Existing literature supports the potential benefits of prehabilitation in improving postoperative outcomes for frail and dependent patients across various medical fields [24–27]. While the impact of delaying surgery for prehabilitation on survival is not yet fully understood, prior studies have emphasized the functional advantages of prehabilitation for patients with brain tumors [27–29]. Similarly, prehabilitation in surgical oncology has been associated with fewer postoperative complications and reduced early readmissions [30, 31]. In addition, randomized trials in lung cancer patients demonstrated significant functional benefits from short prehabilitation programs without increasing mortality risk [5, 32]. This concept warrants further exploration in the context of neurosurgical oncology.

The association between 30-day readmissions and reduced OS was noted in several of the included studies on glioblastoma patients, and our reconstructed Kaplan-Meier analysis corroborated these findings [3, 5, 12, 14]. Patients readmitted within 30 days had a median overall survival of 6.4 months compared to 8.7 months for those who were not readmitted. While a causal or correlative relationship cannot be inferred based on this data only, a plausible explanation is that readmissions may contribute to delays in initiating or continuing adjuvant therapies, thereby adversely affecting outcomes [5, 33]. This is consistent with findings from Pollom et al., who demonstrated that delays in initiating radiotherapy were associated with reduced OS in glioblastoma patients [34]. Additionally, other patient- and disease-related factors, such as the disease state at the time of surgery, additional comorbidities, and in-hospital adverse events and complications, may also influence overall survival in this population. Thus, 30-day readmission rates may serve as a proxy for overall survival but should be interpreted within the broader clinical context.

Limitations

This study has several limitations. First, the findings are derived from retrospective studies, which may be prone to reporting bias and variability in data quality. Second, heterogeneity in study designs, patient populations, and tumor pathology may have influenced the pooled estimates. Although subgroup analyses restricted to malignant brain tumors were performed to enhance comparability, variability in inclusion criteria and outcome definitions remains a potential source of bias. Third, institutional differences in discharge and postoperative care practices likely influenced readmission rates and could not be fully accounted for using study-level data. Finally, several studies lacked detailed reporting on factors such as anticoagulation use, postoperative complications, and preventability of readmissions, limiting the depth of subgroup and sensitivity analyses.

Conclusion

While 30-day readmission rates offer insights into the quality of care in neurosurgical oncology, their validity as a standalone metric is limited by significant variability and contextual factors. Incorporating multiple quality indicators, as well as patient-related factors such as functional status and frailty indices, may provide a more holistic and accurate assessment of care quality for this complex patient population. Efforts to reduce readmission rates should focus on targeted interventions, including optimizing perioperative care and addressing modifiable risk factors. Future studies should aim to standardize reporting practices and explore the nuanced relationship between readmissions, care quality, and survival.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10143-025-03980-6.

Acknowledgements None.

Author contributions NNG: Conceptualization, Methodology, Data collection, Formal analysis, Writing-Original draft. KKO: Conceptualization, Methodology, Data collection, Writing-Reviewing and Editing. AA: Data collection, Writing-Reviewing and Editing. RMD: Data collection, Writing-Reviewing and Editing. AH: Data collection, Writing-Reviewing and Editing. JM: Supervision, Methodology, Writing-Reviewing and Editing POZ: Conceptualization, Methodology, Supervision, Writing-Reviewing and Editing.

Funding None.

Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval Not applicable. This is a systematic review and meta-analysis.

Disclosures The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

Consent to participate Not applicable. This is a systematic review and meta-analysis.

Competing interests The authors declare no competing interests.

Clinical trial number Not applicable. This is a systematic review and meta-analysis.

References

1. Schipmann S, Schwake M, Sundstrøm T, Holling M, Stummer W (2024) Quality indicators in cranial neurosurgery: current insights and critical evaluation - a systematic review. Neurosurg Rev 47(1):815. https://doi.org/10.1007/s10143-024-03066-9
2. Kerezoudis P, Alvi MA, Spinner RJ, Meyer FB, Habermann EB, Bydon M (2019) Predictors of unplanned returns to the operating room within 30 days in neurosurgery: insights from a National Surgical Registry. World Neurosurg 123:e348–e370. https://doi.org/10.1016/j.wneu.2018.11.171
3. Dickinson H, Carico C, Nuño M et al (2015) Unplanned readmissions and survival following brain tumor surgery. J Neurosurg 122(1):61–68. https://doi.org/10.3171/2014.8.Jns1498
4. Cusimano MD, Pshonyak I, Lee MY, Ilie G (2017) A systematic review of 30-day readmission after cranial neurosurgery. J Neurosurg 127(2):342–352. https://doi.org/10.3171/2016.7.Jns152226
5. Botros D, Khalafallah AM, Huq S et al (2022) Predictors and impact of postoperative 30-Day readmission in Glioblastoma. Article. Neurosurgery 91(3):477–484. https://doi.org/10.1227/neu.0000000000002063
6. Jencks SF, Williams MV, Coleman EA (2009) Rehospitalizations among patients in the Medicare fee-for-service program. N Engl J Med 360(14):1418–28. https://doi.org/10.1056/NEJMsa0803563
7. Bailey MK, Weiss AJ, Barrett ML, Jiang HJ (2006) Characteristics of 30-Day All-Cause hospital Readmissions, 2010–2016. Healthcare cost and utilization project (HCUP) statistical briefs. Agency for Healthcare Research and Quality (US)
8. Rosenbaum S (2011) The patient protection and affordable care act: implications for public health policy and practice. Public Health Rep 126(1):130–5. https://doi.org/10.1177/003335491112600118
9. Shah MN, Stoev IT, Sanford DE et al (2013) Are readmission rates on a neurosurgical service indicators of quality of care? J Neurosurg 119(4):1043–9. https://doi.org/10.3171/2013.3.Jns121769
10. James Z, Leach PA, Hayhurst C (2019) Is 30-day readmission an accurate measure of morbidity in cranial meningioma surgery? Br J Neurosurg 33(4):379–382. https://doi.org/10.1080/02688697.2019.1600658
11. Schipmann S, Suero Molina E, Windheuser J et al (2020) The 30-day readmission rate in neurosurgery-a useful indicator for quality assessment? Acta Neurochir (Wien) 162(11):2659–2669. https://doi.org/10.1007/s00701-020-04382-x
12. Kasper J, Wach J, Vychopen M et al (2023) Unplanned 30-day readmission in glioblastoma patients: implications for the extent of resection and adjuvant therapy. Cancers (Basel). https://doi.org/10.3390/cancers15153907
13. Mallela AN, Agarwal P, Goel NJ et al (2020) An additive score optimized by a genetic learning algorithm predicts readmission risk after glioblastoma resection. J Clin Neurosci 80:1–5. https://doi.org/10.1016/j.jocn.2020.07.048
14. Nuño M, Ly D, Ortega A et al (2014) Does 30-day readmission affect long-term outcome among glioblastoma patients? Neurosurgery Feb 74(2):196–204 discussion 204-5. https://doi.org/10.1227/neu.0000000000000243
15. Page MJ, McKenzie JE, Bossuyt PM et al (2021) The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 372:n71. https://doi.org/10.1136/bmj.n71
16. Guyot P, Ades AE, Ouwens MJNM, Welton NJ (2012) Enhanced secondary analysis of survival data: reconstructing the data from published Kaplan-Meier survival curves. BMC Med Res Methodol 12(1):9. https://doi.org/10.1186/1471-2288-12-9
17. Rohatgi A (2018) WebPlotDigitizer
18. Caplan IF, Sullivan PZ, Kung D et al (2019) LACE plus Index as Predictor of 30-Day Readmission in Brain Tumor Population. *World Neurosurgery*. Jul ;127:E443-E448. https://doi.org/10.1016/j.wneu.2019.03.169
19. Marcus LP, McCutcheon BA, Noorbakhsh A et al (2014) Incidence and predictors of 30-day readmission for patients discharged home after craniotomy for malignant supratentorial tumors in California (1995–2010). J Neurosurg 120(5):1201–1211. https://doi.org/10.3171/2014.1.Jns131264
20. Moghavem N, Morrison D, Ratliff JK, Hernandez-Boussard T (2015) Cranial neurosurgical 30-day readmissions by clinical indication. J Neurosurg 123(1):189–197. https://doi.org/10.3171/2014.12.Jns14447
21. Rumalla K, Lin M, Orloff E et al (2020) Effect of comorbid depression on surgical outcomes after craniotomy for malignant brain tumors: a nationwide readmission database analysis. World Neurosurg 142:E458–E473. https://doi.org/10.1016/j.wneu.2020.07.048
22. Sander C, Oppermann H, Nestler U, Sander K, Von Dercks N, Meixensberger J (2021) Causes and predictors of unplanned readmission in cranial neurosurgery. World Neurosurg 149:E622–E635. https://doi.org/10.1016/j.wneu.2021.01.123
23. Zohdy YM, Skandalakis GP, Kassicieh AJ et al (2023) Causes and predictors of unplanned readmission in patients undergoing intracranial tumor resection: a multicenter analysis of 31,776 patients. World Neurosurg 178:e869–e878. https://doi.org/10.1016/j.wneu.2023.08.063
24. Silver JK, Baima J, Mayer RS (2013) <article-title update="added">Impairment-driven cancer rehabilitation: an essential component of quality care and survivorship. CA Cancer J Clin 63(5):295–317. https://doi.org/10.3322/caac.21186
25. Lindbäck Y, Tropp H, Enthoven P, Abbott A, Öberg B (2018) PREPARE: presurgery physiotherapy for patients with degenerative lumbar spine disorder: a randomized controlled trial. Spine J 18(8):1347–1355. https://doi.org/10.1016/j.spinee.2017.12.009
26. Nielsen PR, Andreasen J, Asmussen M, Tønnesen H (2008) Costs and quality of life for prehabilitation and early rehabilitation after surgery of the lumbar spine. BMC Health Serv Res 8:209. https://doi.org/10.1186/1472-6963-8-209
27. Worrell SL, Kirschner ML, Shatz RS, Sengupta S, Erickson MG (2021) Interdisciplinary approaches to survivorship with a focus on the low-grade and benign brain tumor populations. Curr Oncol Rep 23(2):19. https://doi.org/10.1007/s11912-020-01004-8
28. Daksla N, Nguyen V, Jin Z, Bergese SD (2022) Brain prehabilitation for oncologic surgery. Curr Oncol Rep 24(11):1513–1520. https://doi.org/10.1007/s11912-022-01312-1
29. Rivera-Rivera PA, Rios-Lago M, Sanchez-Casarrubios S (2017) Cortical plasticity catalyzed by prehabilitation enables extensive resection of brain tumors in eloquent areas. J Neurosurg 126(4):1323–1333. https://doi.org/10.3171/2016.2.Jns152485
30. Silver JK, Baima J (2013) Cancer prehabilitation: an opportunity to decrease treatment-related morbidity, increase cancer treatment options, and improve physical and psychological health outcomes. Am J Phys Med Rehabil Aug 92(8):715–727. https://doi.org/10.1097/PHM.0b013e31829b4afe
31. Dewberry LC, Wingrove LJ, Marsh MD (2019) Pilot prehabilitation program for patients with esophageal cancer during neoadjuvant therapy and surgery. J Surg Res 235:66–72. https://doi.org/10.1016/j.jss.2018.09.060
32. Liu Z, Qiu T, Pei L et al (2020) Two-week multimodal prehabilitation program improves perioperative functional capability in patients undergoing thoracoscopic lobectomy for lung cancer: a randomized controlled trial. Anesth Analg 131(3):840–849. https://doi.org/10.1213/ane.0000000000004342

33. Chen SY, Stem M, Gearhart SL et al (2019) Readmission adversely affects survival in surgical rectal cancer patients. World J Surg 43(10):2506–2517. https://doi.org/10.1007/s00268-019-05053-4
34. Pollom EL, Fujimoto DK, Han SS, Harris JP, Tharin SA, Soltys SG (2018) Newly diagnosed glioblastoma: adverse socioeconomic factors correlate with delay in radiotherapy initiation and worse overall survival. J Radiat Res 59(1):i11–i18. https://doi.org/10.1093/jrr/rrx103