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Research Article

High-Grade Glioma: Surgical Challenges and Strategies for Safe Maximal Resection

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Abstract: Background: High-grade gliomas are surgically challenging because of their deep location and close relationship with eloquent cortical, subcortical, and vascular structures. Achieving adequate tumor removal while preserving neurological function remains a major surgical concern. **Objective:** To evaluate the surgical challenges encountered in high-grade glioma and assess the strategies used to achieve maximal safe resection while minimizing postoperative neurological morbidity. **Methods:** A hospital-based observational study was conducted among 30 adult patients with radiologically and/or histopathologically confirmed high-grade glioma who underwent surgical treatment. Demographic, clinical, radiological, operative, and postoperative outcome data were assessed. **Results:** The largest age group was 51–60 years (9, 30.0%), followed by 41–50 and 61–70 years (7, 23.3% each). Males predominated (19, 63.3%). Headache (21, 70.0%) and seizures (16, 53.3%) were the commonest presentations. Dominant-hemisphere involvement occurred in 18 (60.0%), and eloquent-structure involvement in 17 (56.7%). A transcortical approach was used in 18 (60.0%), while gross total resection was achieved in 14 (46.7%). Mapping and neurophysiological monitoring were used in 19 (63.3%) and 22 (73.3%), respectively. No new neurological deficit occurred in 20 (66.7%), and 22 (73.3%) achieved favourable functional outcomes. **Conclusion:** Maximal safe resection of high-grade glioma is feasible when individualized surgical planning is combined with functional mapping and intraoperative monitoring.

Keywords: Glioma, High-grade Glioma, Maximal Safe Resection, Brain Mapping, Neurophysiological monitoring, Neurosurgery

INTRODUCTION

High-grade gliomas (HGGs) represent one of the most demanding entities in contemporary neuro-oncological surgery because of their deep location, complex vascular anatomy, and close relationship with eloquent cortical and subcortical structures. The insula is bordered by regions involved in language, motor control, sensory integration and higher cognitive functions, while the underlying white matter and perforating vessels create additional limitations to surgical access. Consequently, resection must balance oncological benefit against the risk of permanent neurological morbidity [1,2].

The concept of maximal safe resection has increasingly replaced conservative cytoreduction as the principal surgical objective. Greater extent of resection has been associated with improved oncological outcomes, but aggressive removal becomes particularly challenging when the tumor extends toward the internal capsule, basal ganglia, lenticulostriate arteries or dominant perisylvian pathways [1,3]. In this setting, detailed preoperative magnetic resonance imaging, diffusion-based tractography, careful assessment of tumor–vascular relationships, and individualized selection of the surgical corridor are essential. Both transcortical and transsylvian approaches have been used successfully, with the choice influenced by tumor location, growth pattern and relationship to eloquent structures [1,6].

Modern intraoperative strategies, including cortical and subcortical stimulation mapping, awake craniotomy, neurophysiological monitoring and meticulous microsurgical dissection, have improved the ability to achieve substantial resection while preserving neurological function. A recent systematic review and meta-analysis reported relatively low pooled postoperative motor and language deficit rates, supporting the importance of functional monitoring and mapping during high glioma surgery [3]. Large contemporary series have also demonstrated that high-grade high tumors can undergo extensive resection, with higher extent of resection associated with longer survival in selected patients [4].

Nevertheless, functional mapping is not universally successful, particularly when tumors involve the basal ganglia or other critical structures [5].

The present study aims to evaluate the surgical challenges encountered in patients with high-grade glioma and to assess the strategies used to achieve safe maximal resection. The study will examine the extent of tumor removal, operative approaches, intraoperative functional preservation, postoperative neurological outcomes, and associated complications in a cohort of 30 patients, with the overall objective of identifying practical factors that contribute to better surgical and functional outcomes

MATERIALS AND METHODS

Study Design

A hospital-based observational study was conducted to evaluate the surgical challenges and outcomes of safe maximal resection in patients with high-grade glioma.

Study Population

The study included adult patients diagnosed with high-grade glioma who underwent surgical treatment.

- **Sample Size:** A total of 30 patients was included in the study
- **Study Duration:** The study was conducted over the predefined study period, September 2023 to September 2026
- **Study Setting/Location:** The study was carried out in the Department of Neurosurgery, Super speciality
- hospital Ranchi

Exclusion Criteria

- Patients aged ≥18 years
- Patients with a radiologically confirmed high-grade glioma
- Patients with histopathologically confirmed high-grade glioma
- Patients who underwent surgical resection of the tumor

Exclusion Criteria

- Patients with low-grade glioma
- Patients with non-glial brain tumors
- Patients with recurrent tumors previously treated elsewhere
- Patients with incomplete clinical or radiological records
- Patients who did not undergo surgical treatment

Statistical Analysis

Data were entered, coded, and analyzed using appropriate statistical software. Categorical variables were summarized as frequencies and percentages, while continuous variables were expressed as mean ± standard deviation or median with interquartile range, as appropriate. Differences in categorical variables were assessed using the Chi-square test or Fisher's exact test when expected cell frequencies were small. For comparisons of continuous variables between two groups, the independent-samples t-test or Mann–Whitney U test was applied according to data distribution. Associations between extent of resection, surgical approach, intraoperative functional monitoring, and postoperative neurological outcomes were evaluated using appropriate comparative tests. All statistical tests were two-sided, and a p-value <0.05 was considered statistically significant. Given the relatively small sample size of 30 patients, results were interpreted cautiously, with emphasis on the magnitude and clinical relevance of observed associations rather than statistical significance alone.

RESULTS

The study included a total of 30 patients with high-grade glioma. The largest proportion of patients belonged to the 51–60-year age group, comprising 9 patients (30.0%), followed by the 41–50-year and 61–70-year groups, with 7 patients (23.3%) each. Four patients (13.3%) were aged below 40 years, while 3 patients (10.0%) were older than 70 years. The age distribution showed a statistically significant difference ($p = 0.041$). Regarding sex, males predominated, with 19 patients (63.3%), compared with 11 females (36.7%), demonstrating a statistically significant male predominance ($p = 0.021$) Table 1.
Clinically, headache was the most frequent presenting symptom, reported in 21 patients (70.0%), followed by seizures in 16 patients (53.3%). Focal neurological deficits were present in 10 patients (33.3%), while language disturbance and cognitive or behavioural symptoms were observed in 7 (23.3%) and 6 patients (20.0%), respectively. The difference in

Table 1: Demographic Characteristics of the Study Population

Demographic Variable		Number of patients	Percentage	p-value
Age group (years)	<40	4	13.3	0.041
	41–50	7	23.3	
	51–60	9	30	
	61–70	7	23.3	
	>70	3	10	
	Total	30	100	
Sex	Male	19	63.3	0.021
	Female	11	36.7	
	Total	30	100	

Table 2: Clinical and Radiological Characteristics

Variable	Number of patients	Percentage	p-value
Headache	21	70	0.018
Seizures	16	53.3	0.032
Focal neurological deficit	10	33.3	0.047
Cognitive/behavioural symptoms	6	20	0.186
Language disturbance	7	23.3	0.091
Tumour in dominant hemisphere	18	60	0.026
Tumour in non-dominant hemisphere	12	40	
Tumour involving eloquent structures	17	56.7	0.014

Table 3: Surgical Characteristics and Extent of Resection

Surgical variable	Number of patients	Percentage	p-value
Transcortical approach	18	60	0.034
Transsylvian approach	9	30	
Combined/other approach	3	10	
Gross total resection	14	46.7	0.009
Near-total resection	8	26.7	
Subtotal resection	6	20	
Biopsy/limited resection	2	6.7	
Intraoperative cortical/subcortical mapping used	19	63.3	0.012
Intraoperative neurophysiological monitoring used	22	73.3	0.006

Table 4: Postoperative Neurological Outcomes and Complications

Outcome	Number of patients	Percentage	p-value
No new neurological deficit	20	66.7	0.015
Transient neurological deficit	7	23.3	
Permanent neurological deficit	3	10	
Postoperative seizures	4	13.3	0.128
Postoperative infection	2	6.7	0.214
Postoperative haemorrhage	2	6.7	0.176
Reoperation required	1	3.3	0.301
Favourable functional outcome	22	73.3	0.008
Unfavourable functional outcome	8	26.7	

the frequency of headache and seizures was statistically significant (p = 0.018 and p = 0.032, respectively). Radiologically, 18 patients (60.0%) had tumors involving the dominant hemisphere, whereas 12 (40.0%) had tumors in the non-dominant hemisphere (p = 0.026). Furthermore, 17 patients (56.7%) had involvement of eloquent cortical or subcortical structures, highlighting the considerable functional complexity associated with surgical treatment (p = 0.014) Table 2.

Among the surgical approaches, the transcortical approach was most frequently used, accounting for 18 patients (60.0%), while 9 patients (30.0%) underwent a transsylvian approach and 3 (10.0%) underwent a combined or other approach (p = 0.034). Regarding the extent of resection, gross total resection was achieved in 14 patients (46.7%), followed by near-total resection in 8 (26.7%) and subtotal resection in 6 (20.0%). Two patients (6.7%) underwent biopsy or limited resection because of unfavorable tumor location or functional risk. Intraoperative cortical or subcortical mapping was used in 19 patients (63.3%), while neurophysiological monitoring was employed in 22 (73.3%). These findings indicate that functional preservation techniques were frequently incorporated into surgery, particularly when tumors were located close to eloquent structures. The associations were statistically significant for extent of resection (p = 0.009), mapping (p = 0.012) and neurophysiological monitoring (p = 0.006) Table 3 and Figure 1.

Following surgery, 20 patients (66.7%) developed no new neurological deficit, whereas 7 patients (23.3%) experienced a transient postoperative deficit and 3 (10.0%) developed a permanent neurological deficit. Thus, most patients maintained stable or acceptable neurological function following resection, while permanent morbidity was

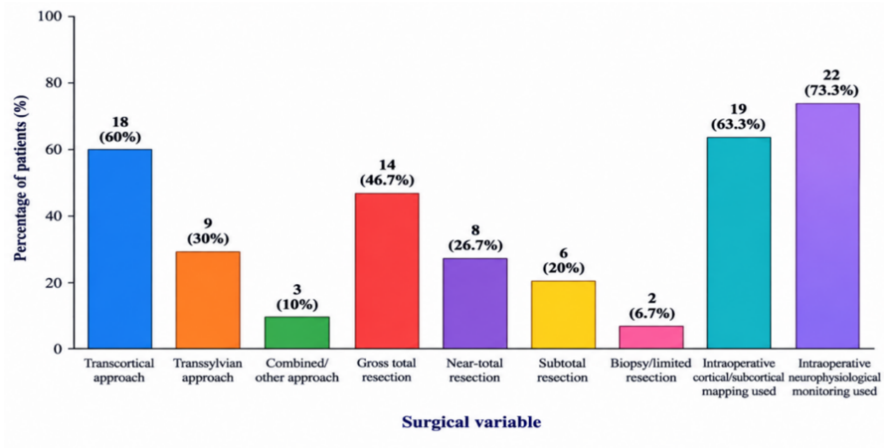

Figure 1: Distribution of Surgical Variables in the Study Population

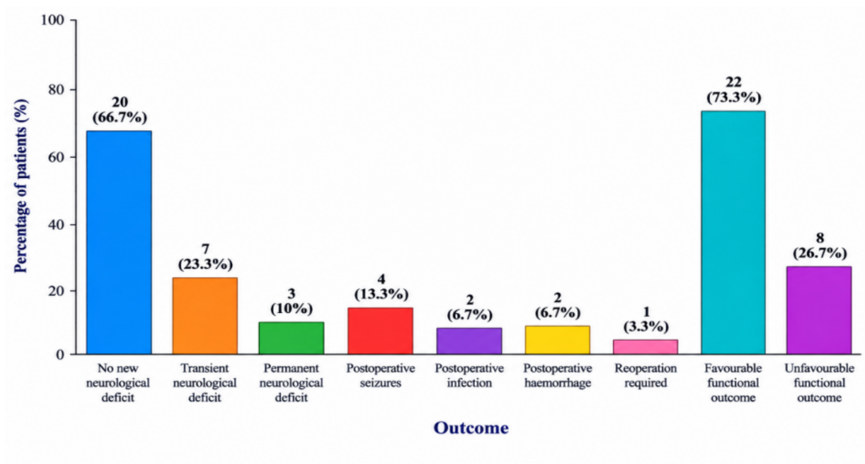

Figure 2: Distribution of Postoperative Outcomes in the Study Population

comparatively uncommon (p = 0.015). Postoperative seizures occurred in 4 patients (13.3%), while postoperative infection and haemorrhage were each observed in 2 patients (6.7%). One patient (3.3%) required reoperation. Overall, 22 patients (73.3%) achieved a favourable functional outcome, compared with 8 (26.7%) who had an unfavorable outcome, with the difference reaching statistical significance (p = 0.008). These findings suggest that, despite the anatomical and functional challenges associated with high-grade glioma, careful selection of the surgical approach combined with intraoperative functional monitoring can permit substantial tumor resection while maintaining acceptable postoperative neurological outcomes Table 4 and Figure 2.

DISCUSSION

The present study included 30 patients with high-grade glioma, with the largest proportion in the 51–60-year age group (30.0%), followed by the 41–50 and 61–70-year groups (23.3% each). A male predominance was also observed, with males accounting for 63.3% of the cohort. This pattern is broadly comparable with contemporary surgical series. Irshad *et al.*, in a large systematic review and meta-analysis of 1,517 glioma patients, reported a mean age of 43.6 years and a male predominance of 56.5% [7]. Similarly, Pallud *et al.* described a relatively young adult population undergoing surgery for diffuse gliomas, supporting the observation that these tumors frequently present during the active working years rather than exclusively in older patients.[8].

In the present series, headache (70.0%) and seizures (53.3%) were the most frequent clinical presentations, while focal neurological deficits were found in one-third of patients. The relatively high frequency of seizures is consistent with the recognized epileptogenic potential of tumors. Irshad *et al.* reported first-onset seizure as the commonest presenting symptom, occurring in approximately 62.8% of their pooled population [7]. A separate systematic review by Wang *et al.* also demonstrated that seizure presentation is common in glioma and that effective tumor resection can provide meaningful postoperative seizure control.[9] Thus, the clinical pattern observed in the current study is in keeping with previously reported experience, although the higher proportion of headache in our cohort may reflect the inclusion of exclusively high-grade tumors and differences in referral patterns [7,9].

Tumor involvement of the dominant hemisphere was observed in 60.0% of patients, while 56.7% had involvement of eloquent cortical or subcortical structures. These findings emphasize why glioma surgery cannot be based solely on tumor size or radiological resectability. Przybylowski *et al.* highlighted that the insula is surrounded by important motor, language and vascular structures and that surgical planning must integrate anatomical knowledge, functional mapping and microsurgical technique [1]. More recently, Takada *et al.* demonstrated that basal ganglionic involvement is particularly important when planning awake surgery because it may predict difficulty in achieving successful awake mapping [5]. These observations support the need for individualized preoperative functional assessment in patients with dominant-hemisphere or eloquent-region tumors.

Regarding the operative strategy, the transcortical approach was used in 60.0% of our patients, compared with 30.0% undergoing a transsylvian approach. This preference is consistent with recent literature. A 2026 systematic review by Baratti Rocha *et al.*, including 1,225 patients, found that the transcortical approach was used substantially more often than the transsylvian route and generally achieved a higher extent of resection, although the transsylvian approach remained useful for selected tumors, particularly in Berger–Sanai Zones I and II [6]. A separate 2026 meta-analysis similarly found a higher pooled proportion of gross total resection with the transcortical approach and suggested that postoperative speech and motor deficits were not necessarily increased with this route [7]. These findings support the predominance of the transcortical strategy in our series, while also emphasizing that approach selection should depend on tumor extension, vascular anatomy and the relationship to eloquent structures rather than on a single universally preferred corridor.

The present study achieved gross total resection in 46.7%, near-total resection in 26.7%, and subtotal resection in 20.0% of patients. Thus, approximately three-quarters of the cohort underwent gross or near-total removal. This finding is comparable with contemporary reports showing that substantial resection is achievable despite the anatomical difficulty of tumors. The EANS systematic review and meta-analysis reported a pooled rate of approximately 53.7% for gross total or greater-than-90% resection, although considerable variation existed between individual studies [3]. In another surgical series, Rossi *et al.* demonstrated that extensive tumors could be treated using brain mapping while maintaining acceptable neurological and functional outcomes [10]. The slightly lower gross-total resection rate in our study may be explained by the exclusive inclusion of high-grade tumors, which can demonstrate infiltrative growth and closer involvement of critical vascular and subcortical structures.

The importance of achieving a high extent of resection is further supported by studies examining survival. In a large series of gliomas, volumetric analysis demonstrated that greater extent of resection was associated with improved overall and progression-free survival, including among patients with high-grade disease [11]. More recently, awake-mapping studies have reinforced this relationship, Takada *et al.* reported a median extent of resection of 87.7% with successful awake surgery compared with 58.0% without successful awake surgery ($p = 0.004$) [5]. These findings are particularly relevant to the present study because intraoperative cortical or subcortical mapping was used in 63.3% of patients. Pallud *et al.* similarly found substantially greater resection with awake surgery than with asleep surgery, suggesting that functional monitoring can permit more confident resection close to eloquent networks [8].

Intraoperative neurophysiological monitoring was used in 73.3% of our patients, reflecting the emphasis placed on functional preservation. This is consistent with the recommendations emerging from recent systematic reviews. Simon *et al.*, in an EANS meta-analysis, reported pooled postoperative motor and speech deficit rates of 6.8% and 3.6%, respectively, and concluded that functional monitoring and mapping should form an integral part of modern glioma surgery [3]. Similarly, awake mapping has been shown to permit extensive resection while maintaining neurological and neurocognitive function. These observations support the concept that the objective of surgery should not simply be maximal radiological removal, but rather maximal safe resection, in which the oncological benefit is balanced against the preservation of meaningful neurological function [3,10].

Postoperatively, 66.7% of our patients had no new neurological deficit, while transient and permanent deficits occurred in 23.3% and 10.0%, respectively. The permanent deficit rate in our cohort is somewhat higher than the pooled rates reported in some large contemporary series, but remains within the range described for complex surgery. The EANS meta-analysis reported relatively low pooled motor and speech morbidity, while the 2026 systematic review by Baratti Rocha *et al.* emphasized that permanent deficits were uncommon across both major surgical approaches.[3] Differences may be related to the present study's small sample size, exclusive inclusion of high-grade tumors, tumor involvement of eloquent regions, and the difficulty of safely dissecting tumors adjacent to the internal capsule, basal ganglia and perforating vessels.

Finally, 73.3% of patients achieved a favourable functional outcome, whereas 26.7% had an unfavourable outcome. This overall result is encouraging given the anatomical complexity of high-grade tumors. Pallud *et al.* reported that awake transcortical surgery could achieve substantial resection with acceptable permanent morbidity and was independently associated with improved survival [8]. Likewise, recent work on awake brain mapping has shown that high extent of resection can be achieved while preserving neurological and cognitive functions [5]. The findings of the present study therefore support a multidisciplinary, function-oriented surgical strategy in which careful patient selection, preoperative imaging, appropriate choice of surgical corridor, intraoperative mapping and neurophysiological monitoring are combined to maximize tumor removal without compromising long-term functional independence.

CONCLUSION

High-grade gliomas remain challenging lesions because of their deep location and close relationship with eloquent cortical, subcortical, and vascular structures. In this study of 30 patients, substantial tumor resection was achievable while maintaining acceptable neurological outcomes. The findings suggest that careful preoperative imaging, individualized selection of the surgical approach, intraoperative cortical and subcortical mapping, and neurophysiological monitoring are important for achieving maximal safe resection. Although postoperative neurological deficits remain a concern, most patients experienced favourable functional outcomes. Overall, a function-oriented surgical strategy can improve the balance between oncological effectiveness and neurological preservation in patients undergoing surgery for high-grade glioma.

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