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Neuropsychological Outcomes After Insular Tumor Resection: Focus on Neurologically Intact Patients Following Transsylvian–Transinsular Resection in the Dominant Hemisphere

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Abstract

Background

Gliomas of the dominant insular lobe represent functionally critical tumors in which overt neurological deficits may be absent despite involvement of language-related and associative networks. In such cases, standard neurological examination does not always adequately reflect the status of higher cognitive functions, underscoring the importance of neuropsychological assessment for a comprehensive evaluation of functional outcomes following surgical treatment.

Objective

To evaluate neuropsychological outcomes in patients with gliomas of the dominant insular lobe, with particular emphasis on a functional analysis of the subgroup undergoing resection via the transsylvian–transinsular approach, aiming to identify subclinical cognitive alterations in the absence of clinically significant neurological deficits.

Materials and Methods

A prospective, single-center observational cohort study was conducted between January 2023 and December 2025. Thirty-one patients aged 18–52 years were included. Hemispheric dominance was determined clinically based on handedness. All tumors were classified as gliomas according to the WHO classification (LGG/HGG). In 12 patients, the tumor was located in the left insular lobe; among them, 8 patients underwent resection via the transsylvian–transinsular approach, which was applied in individuals with a clinically preserved preoperative neurological status allowing standardized neuropsychological assessment. The extent of resection comprised subtotal resection (STR) in 9 patients and gross total resection (GTR) in 3 patients. Neuropsychological evaluation was performed in all patients during the preoperative and postoperative periods; in patients with transient motor aphasia, testing was conducted after regression of the speech deficit. One illustrative clinical case is presented using intraoperative images.

Results

In the early postoperative period, transient neurological disturbances were observed in three patients with dominant insular tumors who underwent resection via the transsylvian–transinsular approach: motor deficits in two patients and motor aphasia in one patient. No new permanent neurological deficits were identified compared with the preoperative status, and all transient deficits completely resolved during follow-up.

Neuropsychological assessment revealed cognitive alterations in a subset of patients both in the early postoperative period and during subsequent follow-up, including patients with clinically preserved or recovered neurological status. The profile and severity of neuropsychological impairments varied across patients and time points, as detailed in the corresponding tables.

Conclusion

Within the framework of this prospective study, it was demonstrated that a clinically preserved neurological status after surgical treatment of dominant insular gliomas does not necessarily reflect the integrity of higher

cognitive functions. Despite the absence of permanent motor or language deficits, neuropsychological assessment identified cognitive alterations in a subset of patients, including those with an otherwise neurologically intact clinical presentation. In this context, neuropsychological testing proved to be more sensitive than standard neurological examination in detecting subclinical cognitive impairments following tumor resection via the transsylvian–transinsular approach.

INTRODUCTION

Insular gliomas are among the most challenging tumors to treat surgically due to their deep-seated location, close anatomical relationships with cortical and subcortical functional networks, and marked variability of the vascular architecture [1–3, 7, 21]. The insula constitutes a key component of the limbic and paralimbic systems and plays an essential role in the regulation of language, executive, affective, and integrative cognitive functions [1, 2, 10, 11, 15, 17]. Historically, the high rate of postoperative complications led to a cautious attitude toward aggressive surgical management of tumors in this region, particularly when located in the dominant hemisphere [18, 20, 21, 38, 39].

Advances in microsurgical techniques, improved understanding of the topographic and microanatomy of the insular region, and the introduction of functionally oriented surgical concepts have substantially changed the management of insular gliomas [2, 3, 10, 16, 22, 23]. Contemporary clinical series demonstrate that, with careful patient selection and appropriate choice of surgical approach, a meaningful extent of resection can be achieved with an acceptable rate of neurological morbidity [9, 14, 25, 28, 33, 38]. In this context, the transsylvian–transinsular approach is regarded as an anatomically sound corridor to insular tumors, allowing minimization of cortical injury while providing direct visualization of vascular and subcortical structures [4, 21, 29, 30, 33, 34, 48].

Despite their location within the dominant hemisphere, insular gliomas frequently present without clinically evident neurological deficits [10, 13, 16]. This phenomenon has been attributed both to the slow-growing nature of these tumors, enabling functional reorganization, and to the distributed organization of language and cognitive networks [10–12, 16]. As a result, standard neurological examination may fail to detect functional impairment even when eloquent structures are involved, thereby limiting its sensitivity for assessing functional outcomes after surgical treatment [9, 24, 37].

In recent years, increasing attention has been directed toward neuropsychological methods as more sensitive tools for the evaluation of higher cortical functions [11, 13, 37, 45, 46]. Neuropsychological testing allows the detection of subclinical cognitive impairments that are not identified during routine neurological examination but may significantly affect daily functioning and quality of life [37, 44]. Nevertheless, data on neuropsychological outcomes following resection of dominant insular gliomas remain limited, as most published studies primarily focus on gross neurological complications, extent of resection, and oncological outcomes [9, 14, 24, 33, 52].

Transient postoperative disturbances, including motor and language deficits, warrant particular attention, as their underlying pathophysiological mechanisms remain incompletely understood [9, 24, 41, 42]. In addition to direct cortical or subcortical injury, increasing emphasis has been placed on venous factors, especially in the perisylvian region, where even minor disturbances of venous drainage may result in reversible functional

deficits [3, 26, 35, 40]. Analysis of such clinical scenarios requires integration of intraoperative findings, neuroimaging data, and functional outcomes.

In light of these considerations, a comprehensive approach to the evaluation of functional outcomes after surgical treatment of dominant insular gliomas appears warranted, incorporating not only standard neurological examination but also systematic neuropsychological assessment [11, 16, 37, 49, 51]. The present study aims to analyze neuropsychological outcomes in patients with dominant insular gliomas following surgical treatment, with an in-depth functional analysis of the subgroup undergoing resection via the transsylvian–transinsular approach and a particular focus on identifying subclinical cognitive impairments in the absence of clinically significant neurological deficits.

MATERIALS AND METHODS

Study Design and Ethical Considerations

A prospective observational cohort study was conducted at a single specialized neurosurgical center—the Republican Specialized Scientific and Practical Medical Center of Neurosurgery (Tashkent, Uzbekistan). The study protocol was approved by the local institutional ethics committee and was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013 revision). Written informed consent for surgical treatment and the use of clinical data for research purposes was obtained from all patients prior to inclusion in the study.

Patient Characteristics

Between January 2023 and December 2025, a total of 31 patients with insular gliomas who underwent surgical treatment were prospectively evaluated. In 12 patients, the tumor was located in the dominant insular lobe. Among them, 8 patients underwent tumor resection using the transsylvian–transinsular approach, and this subgroup constituted the primary study cohort **(table. 1).**

Patients with a clinically preserved preoperative neurological status were included, allowing standardized neuropsychological assessment. Patients with significant preoperative neurological deficits that could compromise the reliability of cognitive evaluation were excluded from the neuropsychological outcome analysis.

Table 1
Clinical, Demographic, and Surgical Characteristics of Patients with Insular Tumors According to Hemispheric Dominance.

Non-Dominant							
№	**Side**	**KPS Score**	**Education level**	**Location**	**Approach**	**STR/GT**	**WHO Grade**
1	Rt	100	1	Medial extension	T-T	STR	II
2	Rt	90	2	Medial extension	T-T	STR	II
3	Rt	90	2	Pure insular	T-T	STR	II
4	Rt	100	2	Pure insular	T-T	STR	II
5	Rt	100	2	Pure insular	T-T	GT	II
6	Rt	90	3	Lateral extension	T-T	STR	III
7	Rt	90	2	Pure insular	T-T	STR	II
8	Rt	100	2	Medial extension	T-T	STR	II
9	Rt	100	1	Pure insular	T-T	STR	II
10	Rt	100	2	Lateral extension	T-F	GT	II
11	Rt	100	3	Lateral extension	T-F	GT	II
12	Rt	100	2	Lateral extension	T-F	GT	II
13	Rt	90	2	Lateral extension	T-F	STR	III
14	Rt	100	1	Lateral extension	T-F	GT	III
15	Rt	100	1	Lateral extension	T-T	STR	II
16	Rt	100	2	Lateral extension	T-T	STR	II
17	Rt	80	2	Lateral extension	T-T	GT	II
18	Rt	90	1	Multiregional	Combined	STR	III
19	Rt	90	2	Multiregional	Combined	STR	III
Dominant							
20	Lt	100	1	Pure insular	T-T	STR	II
21	Lt	100	2	Pure insular	T-T	GT	II
22	Lt	100	1	Medial extension	T-T	STR	II
23	Lt	90	2	Medial extension	T-T	STR	III
24	Lt	100	2	Pure insular	T-T	GT	II
25	Lt	100	1	Pure insular	T-T	STR	II

Non-Dominant							
№	**Side**	**KPS Score**	**Education level**	**Location**	**Approach**	**STR/GT**	**WHO Grade**
26	**Lt**	**100**	**3**	**Medial extension**	**T-T**	**STR**	**II**
27	Lt	100	2	Pure insular	T-T	STR	II
28	Lt	90	3	Lateral extension	TO + AS	STR	II
29	Lt	100	2	Lateral extension	TO + AS	STR	II
30	Lt	100	1	Lateral extension	TO + AS	GT	II
31	Lt	100	2	Lateral extension	TO + AS	STR	III

Determination of the Dominant Hemisphere

The dominant hemisphere was determined clinically based on handedness, in accordance with widely accepted clinical practice. Only patients with clearly identifiable hemispheric dominance were included in the analysis, allowing reliable interpretation of functional and neuropsychological outcomes.

Preoperative Neuroimaging

All patients underwent a standardized preoperative neuroimaging protocol, including contrast-enhanced brain MRI (T1-weighted images), T2- and FLAIR-weighted sequences, diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), and MR angiography using a 3D time-of-flight (3D-TOF) technique. The acquired imaging data were used for anatomical tumor assessment, surgical approach planning, and evaluation of the relationships between the lesion and adjacent vascular and subcortical structures.

Surgical Technique

Surgical procedures were performed using two anesthetic protocols depending on the selected surgical strategy. Resections carried out via the transsylvian–transinsular approach were performed under general anesthesia, whereas patients operated on under awake conditions underwent an awake craniotomy protocol with intraoperative language mapping. Among the 12 patients with dominant insular gliomas, tumor resection was performed via the transsylvian–transinsular approach in 8 patients and using awake craniotomy in 4 patients.

For the transsylvian–transinsular approach, microsurgical dissection of the Sylvian fissure was performed without cortical incision. Depending on tumor location and individual vascular anatomy, two dissection trajectories were employed: a medial-to-lateral approach in 5 patients and a lateral-to-medial approach in 3 patients.

In patients with tumors located in the non-dominant hemisphere, the choice of surgical approach was determined by tumor location, extent, and relationships with cortical and subcortical structures. According to anatomical characteristics, the following approaches were used: transsylvian–transinsular (n = 9), transfrontal (n = 5), transtemporal (n = 3), and combined approaches (n = 2). All procedures in this group were performed under general anesthesia in accordance with the principles of functionally oriented microsurgery.

In all procedures performed via the transsylvian–transinsular approach, intraoperative neurophysiological monitoring with motor evoked potential (MEP) recording was utilized to assess the functional integrity of subcortical motor pathways. Neuronavigation was not employed; instead, individualized preoperative three-dimensional planning based on neuroimaging data was used to define optimal surgical corridors and to evaluate the relationships between the tumor and adjacent vascular and subcortical structures.

Assessment of the Extent of Resection

The extent of tumor resection was assessed based on early postoperative contrast-enhanced MRI performed on the second postoperative day. Gross total resection (GTR) was defined as the absence of residual tumor on postoperative neuroimaging, whereas subtotal resection (STR) was recorded when residual tumor tissue was present.

Within the subgroup of patients with dominant insular gliomas, subtotal resection was achieved in 9 patients, including 6 cases treated via the transsylvian–transinsular approach, while gross total resection was achieved in 3 patients, 2 of whom underwent surgery using the transsylvian–transinsular approach.

Postoperative Neuroimaging

All patients underwent non-contrast computed tomography of the brain within the first postoperative day to exclude hemorrhagic complications. Follow-up contrast-enhanced MRI was performed on the second postoperative day to assess the extent of resection and to identify ischemic or structural changes.

Neurological Assessment

Neurological status was assessed preoperatively, in the early postoperative period, and during follow-up. New neurological deficits were defined as impairments not present in the preoperative period. Transient and permanent neurological deficits were analyzed separately.

Neuropsychological Assessment

Neuropsychological assessment was performed in all patients during the preoperative and postoperative periods using standardized and validated test batteries aimed at evaluating language functions, executive functions, attention, and memory, in accordance with international recommendations. Assessment of language functions included naming and verbal productivity tasks, such as the Boston Naming Test and tests of phonemic and semantic verbal fluency. Executive functions and attention were evaluated using the Trail Making Test (parts A and B) and tasks assessing cognitive control, whereas memory was examined using the Digit Span (forward and backward) and verbal memory tests. Neuropsychological testing was conducted at

standardized follow-up time points; in patients with transient speech disturbances, repeat assessment was performed after clinical resolution of aphasia.

Postoperative testing was carried out under conditions of stable clinical status. In a patient with transient motor aphasia, neuropsychological assessment was performed only after complete resolution of the speech deficit. In patients with a history of epileptic seizures, testing was conducted during the interictal period; assessment was postponed in the presence of recent seizures or postictal symptoms.

Statistical Analysis

Given the exploratory nature of the study, the limited sample size, and the primarily descriptive focus of the analysis, statistical data processing was predominantly descriptive. Quantitative variables are presented as means or medians with corresponding ranges, whereas qualitative data are reported as absolute values and percentages. Formal statistical comparisons and hypothesis testing were not performed, as the aim of the study was to identify general trends and patterns of functional changes rather than to establish causal relationships.

RESULTS

Overall cohort characteristics

In the studied prospective series of 31 patients, the tumor was localized in the dominant insular lobe in 12 patients. Within this subgroup, surgical intervention was performed using a transsylvian–transinsular approach in 8 patients; these patients were included in the analysis of neuropsychological outcomes. Preoperatively, the neurological status of all patients in this subgroup was assessed as clinically intact.

In the early postoperative period, motor deficits were observed in two patients, and one patient developed transient motor aphasia. In all cases, these neurological disturbances were temporary and fully resolved during subsequent follow-up. Compared with the preoperative condition, no new permanent neurological deficits were identified.

Illustrative clinical case

As an illustrative clinical case, we present a patient with a tumor of the left (dominant) insular region, selected based on a combination of anatomical and clinico-radiological characteristics as well as specific features of the intraoperative course. The tumor demonstrated predominantly medial growth from the insular lobe with close proximity to subcortical structures, which determined the high functional relevance of the surgical intervention.

The patient was followed dynamically for two years; according to MRI performed 2 years and 4 months prior to surgery, a slowly progressive tumor lesion was identified, without a pronounced mass effect and in the absence of a clinically significant neurological deficit ***(fig. 1).***

This case was also selected because of an intraoperative technical particularity—injury to a small cortical vein during dissection of the Sylvian fissure. In the remaining cases of the studied series, no intraoperative technical complications were observed. The presented case illustrates the potential challenges of microsurgical dissection in the perisylvian region and emphasizes the importance of detailed analysis of venous anatomy when performing a transsylvian–transinsular approach

Preoperative contrast-enhanced magnetic resonance imaging revealed a tumor of the insular region with predominantly medial extension, spreading toward the subcortical structures without clear evidence of their gross infiltration. The lesion was characterized by a heterogeneous structure and well-visualized margins on T2- and FLAIR-weighted sequences, while no marked mass effect or compression of the surrounding anatomical structures was observed. The relationships between the tumor and the adjacent subcortical white matter tracts and vascular structures were considered close, which was of critical importance for planning the surgical approach ***(fig. 2).***

According to 3D time-of-flight (3D-TOF) MR angiography, the major intracranial arterial structures were clearly visualized, without evidence of compression, stenosis, or tumor invasion, indicating preservation of the primary arterial blood supply within the affected region.

Diffusion tensor imaging (DTI) demonstrated displacement of the adjacent white matter tracts as a result of the tumor-related mass effect, while their structural integrity was preserved, with no signs of tract disruption or marked fiber destruction. These findings were of key importance for the selection of the surgical strategy and for planning a safe transsylvian–transinsular approach ***(fig. 3).***

Intraoperative findings

Tumor resection was performed via a transsylvian–transinsular approach. Microsurgical dissection of the Sylvian fissure enabled the creation of a direct corridor to the lesion without the need for a cortical incision.

During surgery, injury to a small cortical vein in the perisylvian region was noted ***(fig. 4).*** No arterial injuries were recorded. The tumor was removed within the preplanned extent while preserving the subcortical structures. Intraoperative neurophysiological monitoring with motor evoked potentials was employed during the resection phase, including subcortical stimulation. As functionally eloquent white matter pathways were approached, responses to subcortical stimulation were elicited, indicating close proximity of the motor tracts and serving as the basis for terminating further resection in that direction. Consequently, the extent of resection was limited by functional boundaries, allowing achievement of the planned resection volume without injury to the subcortical white matter tracts (subcortical stimulation threshold ≤ 3–5 mA; preservation of motor evoked potentials without significant amplitude or latency changes).

Postoperative imaging results

Postoperative computed tomography performed within the first 24 hours after surgery revealed no evidence of intracranial hemorrhage or significant cerebral edema ***(fig. 5).***

Contrast-enhanced magnetic resonance imaging of the brain performed on the second postoperative day confirmed the achieved extent of resection, with no evidence of residual tumor tissue within the resection area. Additionally, no signs of ischemic changes, hemorrhagic complications, or pathological contrast enhancement

were identified in the adjacent cortical or subcortical structures, indicating preservation of regional blood supply and functionally eloquent anatomical structures (fig. 6).

Neurological and neuropsychological outcomes

In the early postoperative period, two patients developed moderate motor deficits (up to 3 points on the MRC scale), which completely resolved within two weeks, whereas one patient developed transient motor aphasia without an associated motor deficit, with full recovery of speech function within five days of follow-up ***(table. 2)***.

Table. 2. Neurological outcomes after surgical treatment of insular gliomas according to hemispheric dominance and type of surgical approach.

Outcome	Hemisphere	Surgical approach	Pre-op	Post-op day 3	Post-op day 7	Week 4	Month 3	Year 1
Motor deficit	Dominant	Transsylvian transinsular (n=8)	0	2 (25%)	1 (12.5%)	1 (12.5%)	0	0
		Awake surgery (n=4)	1 (25%)	2 (50%)	2 (50%)	1 (25%)	0	0
	Non-dominant	Transsylvian–transinsular (n=9)	2 (22.2%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	1 (11.1%)	0
		Transfrontal (n=5)	0	0	0	0	0	0
		Transtemporal (n=3)	1 (33.3%)	1 (33.3%)	1 (33.3%)	0	0	0
		Combined approach (n=2)	1 (50%)	1 (50%)	1 (50%)	1 (50%)	1 (50%)	1 (50%)
Language deficit	Dominant	Transsylvian–transinsular (n=8)	0 (%)	1 (12.5%)	0	0	0	0
		Awake Surgery (n=4)	0	1 (25%)	0	0	0	0

Neuropsychological assessment performed after resolution of aphasia revealed subclinical cognitive changes that were not accompanied by clinically significant neurological deficits. The profile of the identified neuropsychological impairments did not fully correlate with the findings of standard neurological examination.

Preoperatively, seizure disorder was present in a subset of patients in both hemispheres. Following surgical treatment, a progressive reduction in seizure frequency was observed over the course of follow-up, with the most pronounced improvement at 3 months and 1 year after the intervention ***(table. 3).***

Table 3. Seizure outcomes before and after surgical treatment of insular gliomas according to hemisphere and surgical approach.

Hemisphere	Surgical approach	Pre-op	Post-op day 3	Post-op day 7	Week 4	Month 3	Year 1
Dominant hemisphere	**Transsylvian–transinsular (n = 8)**	6 (75%)	3 (37.5%)	2 (25%)	2 (25%)	1 (12.5%)	1 (12.5%)
	Awake surgery (n = 4)	3 (75%)	2 (50%)	1 (25%)	1 (25%)	1 (25%)	0 (0%)
Non-dominant hemisphere	**Transsylvian–transinsular (n = 9)**	5 (55.6%)	3 (33.3%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	1 (11.1%)
	Transfrontal (n = 5)	2 (40%)	1 (20%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)
	Transtemporal (n = 3)	2 (66.7%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	0 (0%)
	Combined approach (n = 2)	2 (100%)	2 (100%)	2 (100%)	2 (100%)	1 (50%)	1 (50%)

At 3 months after surgery, favorable seizure control (Engel class I) was achieved in the majority of patients, regardless of the affected hemisphere and the surgical approach used, with further improvement or stabilization of outcomes by 1 year of follow-up ***(table. 4).***

Table 4. Seizure control according to the Engel classification in the long-term period after resection of insular gliomas.

Hemisphere	Surgical approach	Month 3	Year 1
Dominant	Transsylvian–transinsular (n = 8)	7 (87.5%)	7 (87.5%)
Dominant	Awake surgery (n = 4)	3 (75%)	4 (100%)
Non-dominant	Transsylvian–transinsular (n = 9)	8 (88.9%)	8 (88.9%)
Non-dominant	Other approaches (n = 10)	7 (70%)	8 (80%)

In patients with gliomas of the dominant insular lobe, neuropsychological impairments were already present in the preoperative period and demonstrated worsening in the early postoperative phase. Language, executive, and mnemonic functions were most frequently affected, with the greatest severity of deficits observed on postoperative day 7. Subsequently, a trend toward partial regression of cognitive disturbances was noted; however, in a substantial proportion of patients, impairment in at least one cognitive domain persisted even at 1 year of follow-up, despite the absence of clinically significant neurological deficits ***(table. 5).***

Table 5. Dynamics of neuropsychological impairments across cognitive domains in patients with gliomas of the dominant insular lobe.

Cognitive domain	Surgical approach	Pre-op	Post-op day 7	Week 4	Month 3	Year 1
Language	Transsylvian–transinsular (n=8)	1 (12.5%)	4 (50%)	3 (37.5%)	2 (25%)	1 (12.5%)
	Awake surgery (n=4)	1 (25%)	3 (75%)	2 (50%)	1 (25%)	1 (25%)
Memory	Transsylvian–transinsular (n=8)	2 (25%)	5 (62.5%)	4 (50%)	3 (37.5%)	2 (25%)
	Awake surgery (n=4)	1 (25%)	2 (50%)	2 (50%)	1 (25%)	1 (25%)
Attention / Executive	Transsylvian–transinsular (n=8)	2 (25%)	6 (75%)	5 (62.5%)	4 (50%)	3 (37.5%)
	Awake surgery (n=4)	1 (25%)	3 (75%)	2 (50%)	2 (50%)	1 (25%)
Visuospatial / Praxis	Transsylvian–transinsular (n=8)	1 (12.5%)	3 (37.5%)	2 (25%)	1 (12.5%)	1 (12.5%)
	Awake surgery (n=4)	0 (0%)	1 (25%)	1 (25%)	0 (0%)	0 (0%)
≥1 cognitive domain impaired	Transsylvian–transinsular (n=8)	3 (37.5%)	7 (87.5%)	6 (75%)	5 (62.5%)	4 (50%)
	Awake surgery (n=4)	2 (50%)	4 (100%)	3 (75%)	2 (50%)	2 (50%)

In patients with gliomas of the nondominant insular lobe, neuropsychological impairments were identified predominantly in the domains of memory, attention, and executive functions, with an increase in their frequency in the early postoperative period. The most pronounced and persistent cognitive changes were observed in patients operated on using transtemporal and combined approaches. Subsequently, partial regression of these impairments was noted; however, in a subset of patients, involvement of at least one cognitive domain persisted even at 1 year of follow-up, underscoring the functional significance of the nondominant insular region ***(table. 6).***

Table 6. Neuropsychological impairments across cognitive domains in patients with gliomas of the nondominant insular lobe according to surgical approach.

Cognitive domain	Surgical approach	Pre-op	Post-op day 7	Week 4	Month 3	Year 1
Memory	Transsylvian–transinsular (n=9)	2 (22.2%)	4 (44.4%)	3 (33.3%)	2 (22.2%)	1 (11.1%)
	Transfrontal (n=5)	1 (20%)	1 (20%)	1 (20%)	0 (0%)	0 (0%)
	Transtemporal (n=3)	1 (33.3%)	2 (66.7%)	2 (66.7%)	1 (33.3%)	1 (33.3%)
	Combined approach (n=2)	1 (50%)	2 (100%)	2 (100%)	1 (50%)	1 (50%)
Attention / Executive	Transsylvian–transinsular (n=9)	3 (33.3%)	4 (44.4%)	4 (44.4%)	3 (33.3%)	2 (22.2%)
	Transfrontal (n=5)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)
	Transtemporal (n=3)	1 (33.3%)	2 (66.7%)	2 (66.7%)	1 (33.3%)	1 (33.3%)
	Combined approach (n=2)	1 (50%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)
Visuospatial / Praxis	Transsylvian–transinsular (n=9)	1 (11.1%)	2 (22.2%)	2 (22.2%)	1 (11.1%)	1 (11.1%)
	Transfrontal (n=5)	0 (0%)	1 (20%)	0 (0%)	0 (0%)	0 (0%)
	Transtemporal (n=3)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	0 (0%)
	Combined approach (n=2)	1 (50%)	2 (100%)	2 (100%)	1 (50%)	1 (50%)
≥1 cognitive domain impaired	Transsylvian–transinsular (n=9)	3 (33.3%)	6 (66.7%)	5 (55.6%)	4 (44.4%)	3 (33.3%)
	Transfrontal (n=5)	2 (40%)	2 (40%)	2 (40%)	1 (20%)	1 (20%)
	Transtemporal (n=3)	2 (66.7%)	3 (100%)	3 (100%)	2 (66.7%)	1 (33.3%)
	Combined approach (n=2)	1 (50%)	2 (100%)	2 (100%)	2 (100%)	2 (100%)

Histopathological findings

Histological examination of tumor tissue in all 31 patients confirmed the diagnosis of diffuse gliomas in accordance with the World Health Organization (WHO) classification. Low-grade gliomas (LGG) were identified in 19 patients, whereas high-grade gliomas (HGG) were diagnosed in 12 patients. Astrocytic variants predominated in the histological structure of the tumors, which is consistent with data from large international series on insular gliomas. In the illustrative clinical case, histological analysis revealed a fibrillary astrocytoma, correlating with the prolonged preclinical course of the disease and the findings of preoperative neuroimaging *(fig. 7)*.

Summary of functional outcomes

Thus, despite the absence of persistent clinical neurological deficits after surgery, neuropsychological assessment enabled the identification of cognitive changes in a subset of patients, including those who were clinically intact. All transient neurological disturbances fully resolved, and postoperative neuroimaging revealed no ischemic or hemorrhagic complications.

DISCUSSION

This prospective single-center study demonstrates that the absence of persistent postoperative neurological deficits after surgical treatment of insular gliomas—particularly those located in the dominant hemisphere—does not preclude the presence of clinically relevant neuropsychological impairments. Despite favorable neurological and epileptological outcomes associated with the transsylvian–transinsular approach and awake surgery, systematic neuropsychological evaluation revealed a high prevalence of subclinical cognitive changes, predominantly affecting language, executive, and mnemonic functions.

Neurological preservation and cognitive vulnerability

The neurological outcomes obtained in the present study are consistent with data from large series reporting a low incidence of permanent motor and speech deficits after resection of insular gliomas when modern microsurgical techniques and function-oriented strategies are employed [9, 24, 33, 38]. However, in contrast to most published studies that primarily focus on overt neurological outcomes, our findings demonstrate a pronounced dissociation between a clinically intact neurological status and impairment of higher cognitive functions.

Even in patients without persistent motor or speech deficits, neuropsychological testing revealed abnormalities in one or more cognitive domains. These findings underscore the vulnerability of distributed cortico-subcortical networks involved in attention, executive control, and memory—functions that are not routinely assessed during standard neurological examination. Similar observations have previously been reported only sporadically and mainly in the context of awake surgery [10, 13, 37], whereas systematic evaluation of neuropsychological outcomes following the transsylvian–transinsular approach remains limited.

Dominant hemisphere and domain-specific effects

The most pronounced and persistent neuropsychological changes in our series were observed in patients with tumors involving the dominant hemisphere. Language and executive functions were the most vulnerable domains, in accordance with current concepts of the insula as a key hub within perisylvian language and associative networks [2, 11, 16]. Although partial regression of cognitive impairments was noted during follow-up, deficits persisted for up to one year in a subset of patients, indicating limited compensatory capacity of these functional systems.

Awake surgery allowed minimization of clinically evident speech disturbances, corroborating the findings of Duffau et al. [12, 13]. Nevertheless, despite preserved spontaneous speech, impairments in executive and mnemonic domains were detected in some patients. This suggests that focal language mapping, while effective in preventing overt aphasic deficits, does not fully protect broader cognitive networks.

Surgical approach and functional trade-offs

In our series, the transsylvian–transinsular approach demonstrated high neurological safety and satisfactory seizure control, in line with reports by other authors [32, 33, 43]. However, early neuropsychological impairments were observed in the majority of patients, and complete recovery was not universal, indicating the presence of functional trade-offs even with anatomically sparing approaches.

In the nondominant hemisphere, cognitive changes were generally less pronounced but were absent only when limited surgical approaches were employed. The most unfavorable neuropsychological outcomes were associated with combined approaches, likely reflecting more extensive involvement of cortical and subcortical associative pathways and a greater length of the surgical corridor [27, 36].

Seizure control and cognitive outcomes

Surgical treatment in the present series achieved a high level of seizure control, consistent with the literature [31, 47, 50]. However, attainment of a favorable epileptological outcome (Engel class I) was not necessarily accompanied by preservation of cognitive function. Thus, epileptological success cannot be considered a surrogate marker of full functional recovery, particularly in tumors located within functionally eloquent regions.

Pathophysiological considerations

The illustrative clinical case in our study highlights the potential role of venous factors in the development of transient functional disturbances. The temporal association between injury to a small cortical vein in the perisylvian region and the occurrence of transient motor aphasia—despite the absence of arterial ischemia on postoperative neuroimaging—suggests a possible venous mechanism contributing to functional vulnerability. Similar anatomical and clinical observations have previously been emphasized in studies addressing venous drainage of the insular region [3, 21, 26]. Nevertheless, it should be emphasized that a definitive causal relationship cannot be established within the framework of the present study.

LIMITATIONS AND CLINICAL IMPLICATIONS

Study limitations

The present study has several limitations. First, it was conducted at a single center and included a limited number of patients with dominant-hemisphere involvement, which restricts the scope of statistical analysis. Second, functional lateralization was determined clinically based on handedness, without mandatory use of functional MRI or the Wada test, which does not exclude atypical organization of language networks. Third, the neuropsychological analysis was descriptive and exploratory in nature, without the construction of multivariate models. Finally, any pathophysiological interpretations, including the proposed role of venous factors, are based on associative observations.

Clinical implications

The findings of this study have important practical implications. Neuropsychological testing should be considered an essential component of functional outcome assessment after surgical treatment of insular gliomas, even in the absence of clinically overt neurological deficits. During preoperative planning and intraoperative mapping, it is advisable to take into account not only motor and language functions but also executive and mnemonic domains. In addition, preoperative patient counseling should include discussion of the risk of subclinical cognitive changes. In the future, integration of functional neuroimaging and cognitive rehabilitation programs may contribute to improved long-term functional outcomes.

CONCLUSION

The present study demonstrates that in the surgical treatment of insular gliomas—particularly those located in the dominant hemisphere—the absence of persistent neurological deficits and the achievement of favorable seizure control are not equivalent to preservation of higher cognitive functions. Even when function-oriented strategies are employed, including the transsylvian–transinsular approach and awake surgery, a substantial proportion of patients exhibit subclinical and, in some cases, persistent neuropsychological impairments, predominantly affecting language and executive domains.

These findings highlight the limitations of standard neurological examination as the sole tool for assessing functional outcomes and support the need for systematic incorporation of neuropsychological testing into pre- and postoperative follow-up protocols. A comprehensive functional approach that integrates cognitive aspects should be regarded as a key element in evaluating the results of surgical treatment of insular gliomas and in further refinement of neurosurgical strategies.

Declarations

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Ethics approval and consent to participate

The study protocol was approved by the local institutional ethics committee of the Republican Specialized Scientific and Practical Medical Center of Neurosurgery (Tashkent, Uzbekistan) and was conducted in accordance with the Declaration of Helsinki (2013 revision). Written informed consent was obtained from all participants prior to inclusion in the study. All patients were evaluated preoperatively and were deemed capable of ethically and medically providing informed consent for participation in the research.

Consent for publication

Written informed consent for publication of clinical details and clinical images was obtained from all patients included in this study. In cases where patients had cognitive impairment or lacked full decision-making capacity, written informed consent for publication was obtained from their family members or legal guardians.

Data availability

All data generated or analyzed during this study are included in this published article.

Competing interests

The authors declare that they have no competing interests.

Author Contribution

J.Y. conceived and designed the study. J.Y., U.A., and G.K. contributed to patient management, data collection, and clinical evaluation. J.Y. performed the surgical procedures and supervised the study. A.C. contributed to conceptual development, interpretation of results, and critical revision of the manuscript for important intellectual content. J.Y. drafted the main manuscript text. All authors reviewed, edited, and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

References

1. Yasargil MG, von Ammon K, Cavazos E, Doczi T, Reeves JD, Roth P. Tumours of the limbic and paralimbic systems. *Acta Neurochir (Wien).* 1992;118(1–2):40–52. https://doi.org/10.1007/BF01400725
2. **Türe U, Yaşargil DCH, Al-Mefty O, Yaşargil MG.** Topographic anatomy of the insular region. *Journal of Neurosurgery.***1999**;90(4):720–733. https://doi.org/10.3171/jns.1999.90.4.0720
3. **Rhoton AL Jr.** The cerebral veins. *Neurosurgery.* 2002;51(4 Suppl):S159–205. PMID: 12234449. https://doi.org/10.1227/01.NEU.0000028228.51706.2D
4. **Cikla U, Swanson KI, Turan Y, Baskaya MK.** Transsylvian resection of dominant insular gliomas: demonstration of microsurgical techniques in pure insular versus insulo-opercular gliomas—3-dimensional operative video. *Operative Neurosurgery.***2017;**13(6):760. https://doi.org/10.1093/ons/opx056
5. Alimohamadi M, Shirani M, Shariat Moharari R, Pour-Rashidi A, Ketabchi M, Khajavi M, Arami M, Amirjamshidi A. Application of awake craniotomy and intraoperative brain mapping for surgical resection of insular gliomas of the dominant hemisphere. *World Neurosurg.* 2016;92:151–158. https://doi.org/10.1016/j.wneu.2016.04.079
6. Baran O, Akgun MY, Kemerdere R, Akcil EF, Tanriverdi T. Long-term clinical and seizure outcomes of insular gliomas via trans-opercular approach. *Clin Neurol Neurosurg.* 2018;173:52–57. https://doi.org/10.1016/j.clineuro.2018.08.001
7. Barbosa BJAP, Dimostheni A, Teixeira MJ, Tatagiba M, Lepski G. Insular gliomas and the role of intraoperative assistive technologies: results from a volumetry-based retrospective cohort. *Clin Neurol Neurosurg.* 2016;149:104–110. https://doi.org/10.1016/j.clineuro.2016.08.001
8. Chen LF, Yang Y, Ma XD, Yu XG, Gui QP, Xu BN, Zhou DB. Optimizing the extent of resection and minimizing the morbidity in insular high-grade glioma surgery by high-field intraoperative MRI guidance. *Turk Neurosurg.* 2017;27(5):696–706. https://doi.org/10.5137/1019-5149.JTN.18346-16.1
9. Di Carlo DT, Cagnazzo F, Anania Y, Duffau H, Benedetto N, Morganti R, Perrini P. Post-operative morbidity ensuing surgery for insular gliomas: a systematic review and meta-analysis. *Neurosurg Rev.* 2020;43(3):987–997. https://doi.org/10.1007/s10143-019-01113-4
10. Duffau H. A personal consecutive series of surgically treated 51 cases of insular WHO Grade II glioma: advances and limitations. *J Neurosurg.* 2009;110(4):696–708. https://doi.org/10.3171/2008.8.JNS08741

11. Duffau H. Surgery of insular gliomas. *Prog Neurol Surg.* 2018;30:173–185. https://doi.org/10.1159/000464393
12. Duffau H. Awake mapping with transopercular approach in right insular–centered low-grade gliomas improves neurological outcomes and return to work. *Neurosurgery.* 2022;91(1):182–190. https://doi.org/10.1227/neu.0000000000001966
13. Duffau H, Moritz-Gasser S, Gatignol P. Functional outcome after language mapping for insular World Health Organization Grade II gliomas in the dominant hemisphere: experience with 24 patients. *Neurosurg Focus.* 2009;27(2):E7. https://doi.org/10.3171/2009.5.FOCUS0938
14. Eseonu CI, ReFaey K, Garcia O, Raghuraman G, Quinones-Hinojosa A. Volumetric analysis of extent of resection, survival, and surgical outcomes for insular gliomas. *World Neurosurg.* 2017;103:265–274. https://doi.org/10.1016/j.wneu.2017.04.002
15. Hameed NUF, Qiu T, Zhuang D, et al. Transcortical insular glioma resection: clinical outcome and predictors. *J Neurosurg.* 2019;131(3):706–716. https://doi.org/10.3171/2018.4.JNS18424
16. Hervey-Jumper SL, Berger MS. Insular glioma surgery: an evolution of thought and practice. *J Neurosurg.* 2019;130(1):9–16. https://doi.org/10.3171/2018.10.JNS181519
17. Hervey-Jumper SL, Li J, Osorio JA, Lau D, Molinaro AM, Benet A, Berger MS. Surgical assessment of the insula. Part 2: Validation of the Berger–Sanai zone classification system for predicting extent of glioma resection. *J Neurosurg.* 2016;124(2):482–488. https://doi.org/10.3171/2015.4.JNS1521
18. Ius T, Pauletto G, Isola M, et al. Surgery for insular low-grade glioma: predictors of postoperative seizure outcome. *J Neurosurg.* 2014;120(1):12–23. https://doi.org/10.3171/2013.9.JNS13728
19. Kawaguchi T, Kumabe T, Saito R, et al. Practical surgical indicators to identify candidates for radical resection of insulo-opercular gliomas. *J Neurosurg.* 2014;121(5):1124–1132. https://doi.org/10.3171/2014.7.JNS13899
20. Khatri D, Das K, Gosal J, et al. Surgery in high-grade insular tumors: oncological and seizure outcomes from 41 consecutive patients. *Asian J Neurosurg.* 2020;15(3):537–544. https://doi.org/10.4103/ajns.ajns_18_20
21. Lang FF, Olansen NE, DeMonte F, Gokaslan ZL, Holland EC, Kalhorn C, Sawaya R. Surgical resection of intrinsic insular tumors: complication avoidance. *J Neurosurg.* 2001;95(4):638–650. https://doi.org/10.3171/jns.2001.95.4.0638
22. Leroy HA, Strachowksi O, Tuleasca C, et al. Microsurgical resection of fronto-temporo-insular gliomas in the non-dominant hemisphere under general anesthesia using adjunct intraoperative MRI and no cortical/subcortical mapping: a series of 20 consecutive patients. *Sci Rep.* 2021;11(1):6994. https://doi.org/10.1038/s41598-021-86165-7
23. Li Z, Li G, Liu Z, et al. Transcortical approach for insular gliomas: a series of 253 patients. *J Neurooncol.* 2020;147(1):59–66. https://doi.org/10.1007/s11060-020-03390-2
24. Lu VM, Goyal A, Quinones-Hinojosa A, Chaichana KL. Updated incidence of neurological deficits following insular glioma resection: a systematic review and meta-analysis. *Clin Neurol Neurosurg.* 2019;177:20–26. https://doi.org/10.1016/j.clineuro.2018.12.013
25. Majchrzak K, Bobek-Billewicz B, Tymowski M, et al. Surgical treatment of insular tumours with tractography, functional magnetic resonance imaging, transcranial electrical stimulation and direct

subcortical stimulation support. *Neurol Neurochir Pol.* 2011;45(4):351–362. https://doi.org/10.1016/S0028-3843(14)60106-7

26. Moshel YA, Marcus JDS, Parker EC, Kelly PJ. Resection of insular gliomas: the importance of lenticulostriate artery position. *J Neurosurg.* 2008;109(5):825–834. https://doi.org/10.3171/JNS/2008/109/11/0825
27. Murrone D, Maduri R, Afif A, et al. Insular gliomas: a surgical reappraisal based on a systematic review of the literature. *J Neurosurg Sci.* 2019;63(5):566–580. https://doi.org/10.23736/S0390-5616.17.04045-0
28. Pallud J, Zanello M, Moiraghi A, et al. Surgery of insular diffuse gliomas—Part 1: transcortical awake resection is safe and independently improves overall survival. *Neurosurgery.* 2021;89(4):565–578. https://doi.org/10.1093/neuros/nyab254
29. Panigrahi M, Doshi S, Chandrasekhar YBK, Vooturi S. Avoiding complications in surgical resection of insular gliomas—single surgeon experience. *Neurol India.* 2021;69(4):904–909. https://doi.org/10.4103/0028-3886.325334
30. Papadopoulou A, Kumar NS. Prognostic factors and resectability predictors in insular gliomas: a systematic review. *J Neurol Surg A Cent Eur Neurosurg.* 2024;85(1):74–87. https://doi.org/10.1055/s-0043-1769128
31. Pepper J, Cuthbert H, Scott T, et al. Seizure outcome after surgery for insular high-grade glioma. *World Neurosurg.* 2021;154:e718–e723. https://doi.org/10.1016/j.wneu.2021.07.114
32. Pitskhelauri D, Bykanov A, Konovalov A, et al. Transsylvian insular glioma surgery: new classification system, clinical outcome in a consecutive series of 79 cases. *Oper Neurosurg (Hagerstown).* 2021;20(6):541–548. https://doi.org/10.1093/ons/opab051
33. Przybylowski CJ, Baranoski JF, So VM, Wilson J, Sanai N. Surgical morbidity of transsylvian versus transcortical approaches to insular gliomas. *J Neurosurg.* 2020;132(6):1731–1738. https://doi.org/10.3171/2018.12.JNS183075
34. Przybylowski CJ, Hervey-Jumper SL, Sanai N. Surgical strategy for insular glioma. *J Neurooncol.* 2021;151(3):491–497. https://doi.org/10.1007/s11060-020-03499-4
35. Rao AS, Thakar S, Sai Kiran NA, et al. 3D-CISS sequences enhance the utility of 3D-TOF MRA in delineating lenticulostriate arteries in insular gliomas: a prospective clinicoradiologic analysis. *World Neurosurg.* 2018;109:e426–e433. https://doi.org/10.1016/j.wneu.2017.09.199
36. Renfrow JJ, Julian B-Q, Brown DA, Tatter SB, Laxton AW, Lesser GJ, Strowd RE, Parney IF. A review on the surgical management of insular gliomas. *Can J Neurol Sci.* 2023;50(1):1–9. https://doi.org/10.1017/cjn.2021.248
37. Rossi M, Gay L, Conti Nibali M, et al. Challenging giant insular gliomas with brain mapping: neurosurgical, neurological, neuropsychological and quality-of-life results in a large mono-institutional series. *Front Oncol.* 2021;11:629166. https://doi.org/10.3389/fonc.2021.629166
38. Sanai N, Polley M-Y, Berger MS. Insular glioma resection: assessment of patient morbidity, survival, and tumor progression. *J Neurosurg.* 2010;112(1):1–9. https://doi.org/10.3171/2009.6.JNS0952
39. Simon M, Neuloh G, von Lehe M, Meyer B, Schramm J. Insular gliomas: the case for surgical management. *J Neurosurg.* 2009;110(4):685–695. https://doi.org/10.3171/2008.7.JNS17639

40. Singh A, Das KK, Khatri D, et al. Insular glioblastoma: surgical challenges, survival outcomes and prognostic factors. *Br J Neurosurg.* 2023;37(1):26–34. https://doi.org/10.1080/02688697.2020.1859089
41. Skrap M, Mondani M, Tomasino B, et al. Surgery of insular nonenhancing gliomas: volumetric analysis of tumoral resection, clinical outcome, and survival in a consecutive series of 66 cases. *Neurosurgery.* 2012;70(5):1081–1093. https://doi.org/10.1227/NEU.0b013e31823f5be5
42. Sughrue M, Bonney PA, Burks JD, et al. Multilobar insular-involving gliomas: results with hyperaggressive resection. *Cureus.* 2017:e1623. https://doi.org/10.7759/cureus.1623
43. Sughrue ME, Othman J, Mills SA, Bonney PA, Maurer AJ, Teo C. Keyhole transsylvian resection of infiltrative insular gliomas: technique and anatomic results. *Turk Neurosurg.* 2016;26(4):475–483. https://doi.org/10.5137/1019-5149.JTN.14534-15.0
44. Sun GC, Shu XJ, Zheng XQ, et al. The transfrontal isthmus approach for insular glioma surgery. *J Neurosurg.* 2023;139(1):20–28. https://doi.org/10.3171/2022.8.JNS22923
45. Sun GC, Zhao K, Shu XJ, et al. Resection of insular glioma through the transfrontal limiting sulcus approach. *Oper Neurosurg (Hagerstown).* 2022;22(6):400–408. https://doi.org/10.1227/ons.0000000000000146
46. Tang C, Zhang Z, Chen L, et al. Subgroup characteristics of insular low-grade glioma based on clinical and molecular analysis of 42 cases. *J Neurooncol.* 2016;126(3):499–507. https://doi.org/10.1007/s11060-015-1989-5
47. Wang DD, Deng H, Hervey-Jumper SL, Molinaro AA, Chang EF, Berger MS. Seizure outcome after surgical resection of insular glioma. *Clin Neurosurg.* 2018;83(4):709–718. https://doi.org/10.1093/neuros/nyx486
48. Wang P, Wu MC, Chen SJ, Xu XP, Yang Y, Cai J. Microsurgery resection of intrinsic insular tumors via transsylvian surgical approach in 12 cases. *Cancer Biol Med.* 2012;9(1):44–47. https://doi.org/10.3969/j.issn.2095-3941.2012.01.008
49. Wang Y, Wang Y, Fan X, et al. Putamen involvement and survival outcomes in patients with insular low-grade gliomas. *J Neurosurg.* 2017;126(6):1788–1794. https://doi.org/10.3171/2016.5.JNS1685
50. Zhang JJY, Lee KS, Wang DD, Hervey-Jumper SL, Berger MS. Seizure outcome after resection of insular glioma: a systematic review, meta-analysis, and institutional experience. *J Neurosurg.* 2022:1–12. https://doi.org/10.3171/2022.8.JNS221067
51. Zhuang DX, Wu JS, Yao CJ, et al. Intraoperative multi-information-guided resection of dominant-sided insular gliomas in a 3-T intraoperative MRI integrated neurosurgical suite. *World Neurosurg.* 2016;89:84–92. https://doi.org/10.1016/j.wneu.2016.01.067
52. Simon M, Hagemann A, Gajadin S, et al. Surgical treatment for insular gliomas: a systematic review and meta-analysis. *Brain Spine.* 2024;4:102828. https://doi.org/10.1016/j.bas.2024.102828

Figures

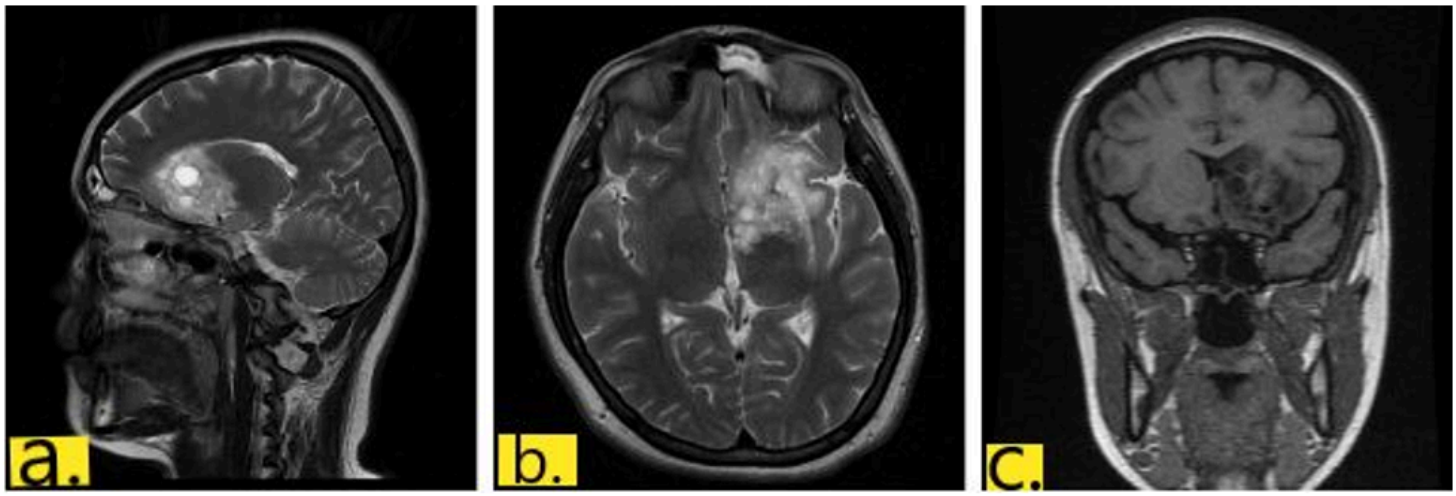


Figure 1

Brain MRI (T2-weighted and T1-weighted images) obtained 2 years and 4 months prior to surgical treatment. Sagittal T2-weighted image: a hyperintense lesion in the projection of the left insular region without a pronounced mass effect ***(a).*** Axial T2-weighted image: tumor involvement of the left insular lobe with features of slow growth ***(b).***Coronal T1-weighted image: absence of gross structural deformation and clinically significant compression of the surrounding brain regions ***(c).***

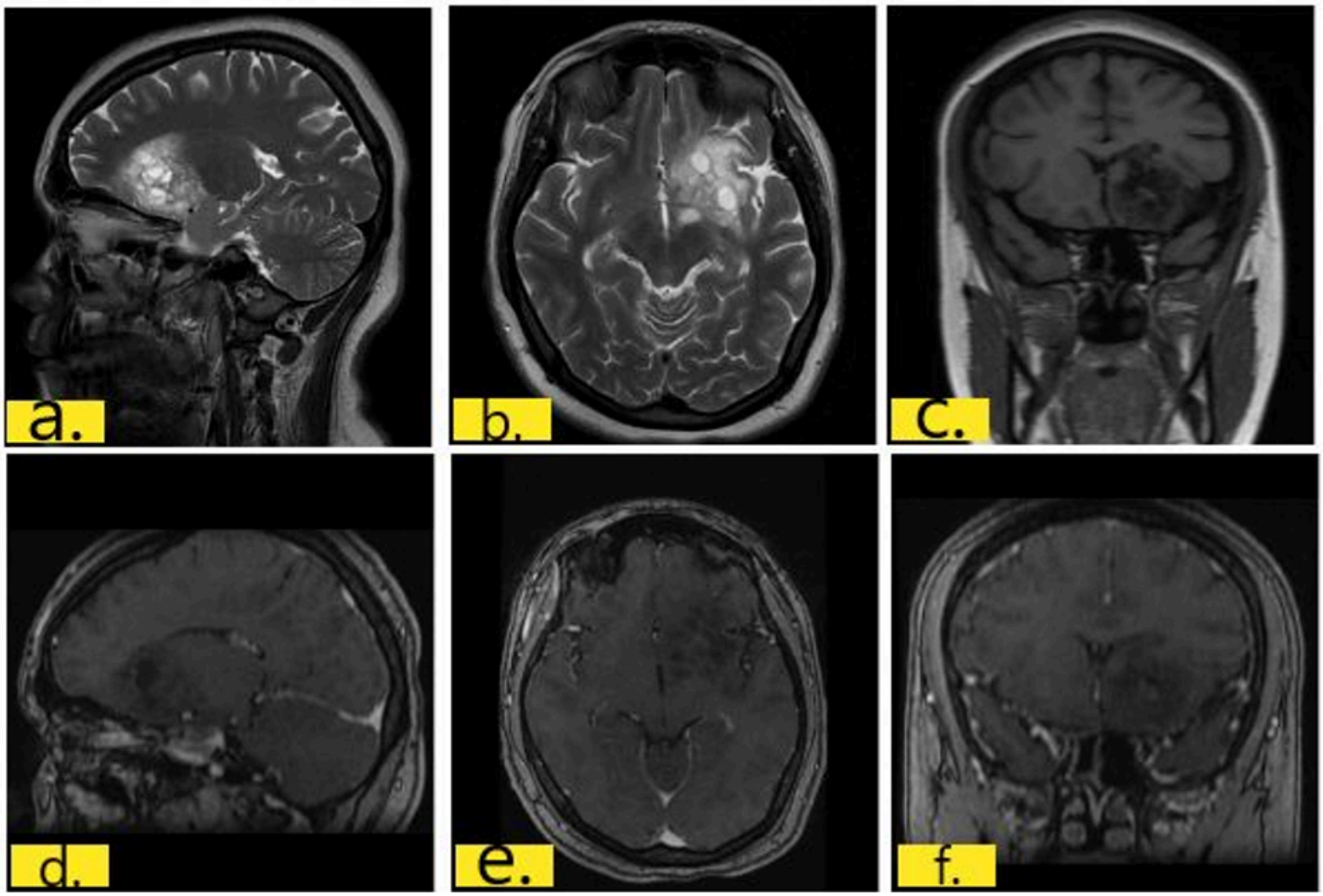


Figure 2

Preoperative contrast-enhanced brain MRI. Sagittal T2-weighted image: a tumor of the left insular region with medial extension ***(a).***Axial T2-weighted image: glioma of the left dominant insular lobe involving deep regions without a pronounced mass effect ***(b).*** Coronal T1-weighted image: topographic relationship between the tumor and adjacent subcortical structures ***(c).*** Sagittal contrast-enhanced T1-weighted image: absence of clear signs of intense contrast enhancement ***(d).*** Axial contrast-enhanced T1-weighted image: heterogeneous contrast enhancement pattern of the tumor ***(e).*** Coronal contrast-enhanced T1-weighted image: confirmation of medial tumor extension without evidence of gross infiltration of the surrounding structures ***(f).***

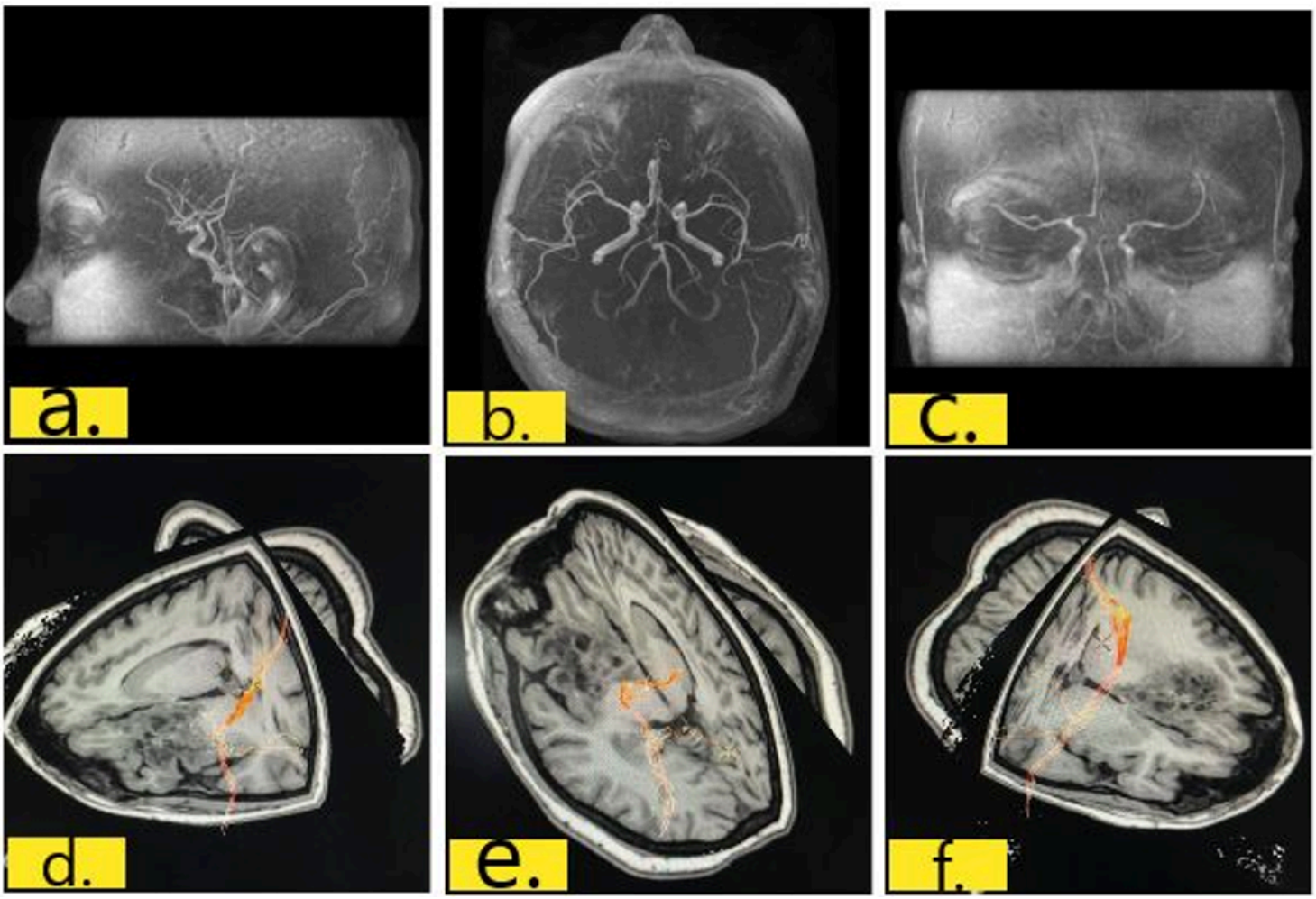


Figure 3

Preoperative 3D time-of-flight (3D-TOF) MR angiography and diffusion tensor imaging (DTI). 3D-TOF MR angiography, lateral view: visualization of the major arterial vessels without signs of compression or tumor invasion ***(a).*** 3D-TOF MR angiography, axial view: preserved configuration of the arterial circle of the brain base and its branches ***(b).*** 3D-TOF MR angiography, frontal view: absence of stenosis or displacement of major arterial structures ***(c).***DTI tractography, sagittal view: displacement of white matter tracts within the zone of tumor growth with preserved tract integrity ***(d).*** DTI tractography, oblique view: relationship between the tumor and adjacent subcortical tracts without evidence of tract destruction ***(e).*** DTI tractography, alternative view: spatial displacement of fibers in the region of the left dominant insular lobe ***(f).***

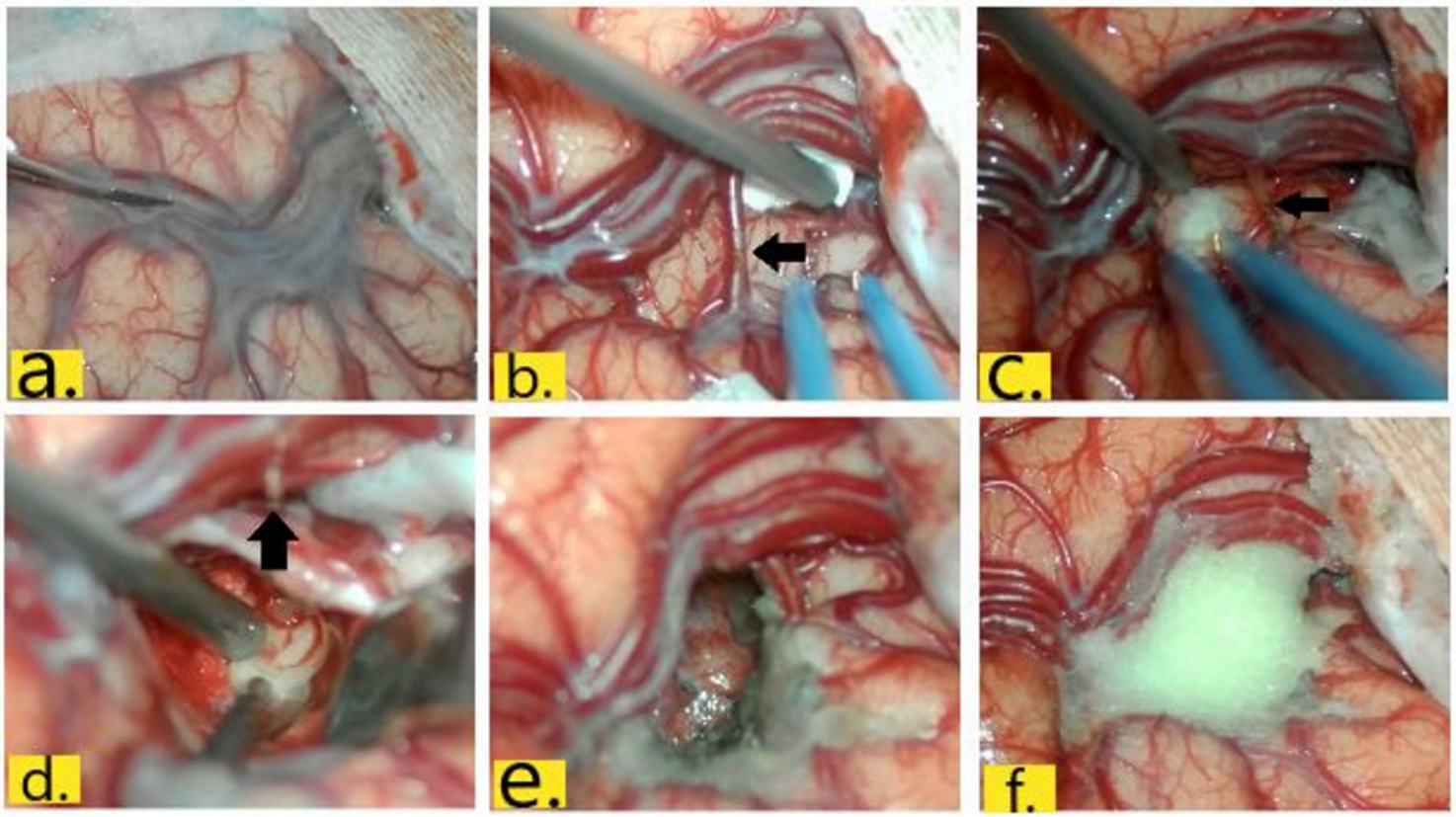


Figure 4

Intraoperative stages of the transsylvian–transinsular approach. Initial stage of microsurgical dissection of the Sylvian fissure with visualization of the cortical surface and superficial venous structures ***(a).*** Continuation of Sylvian fissure dissection; the arrow indicates a small cortical vein in the perisylvian region ***(b).*** Formation of the transinsular surgical corridor with exposure of tumor tissue; the arrow marks the zone of venous relationships ***(c).***Magnified view of the perisylvian region: injury to a small cortical vein (arrow) during microsurgical manipulation ***(d).*** Tumor resection stage through the established transinsular approach with visualization of the resection cavity ***(e).*** Final intraoperative view after tumor removal, showing hemostasis and coverage of the resection cavity with hemostatic material ***(f).***

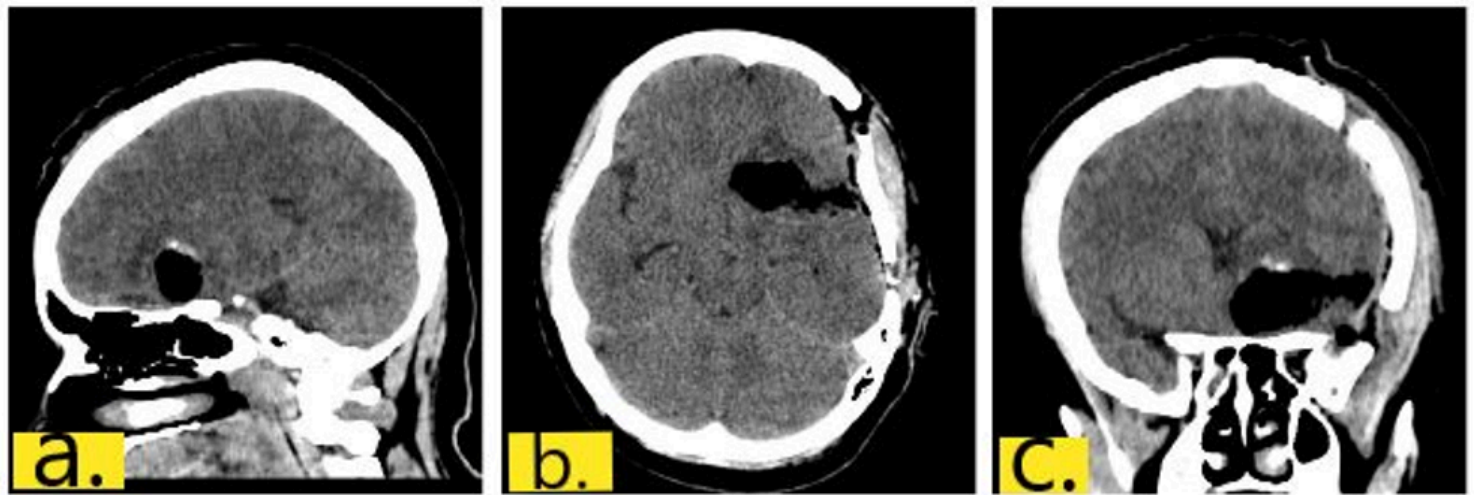


Figure 5

Postoperative brain computed tomography *(postoperative day 1).* Sagittal CT reconstruction: visualization of the resection cavity in the projection of the left insular region without signs of acute hemorrhage ***(a).*** Axial CT slice: postoperative resection cavity with mild pneumocephalus, without evidence of mass effect or compression of surrounding structures ***(b).*** Coronal CT reconstruction: absence of intraparenchymal hemorrhage and significant cerebral edema in the surgical field ***(c).***

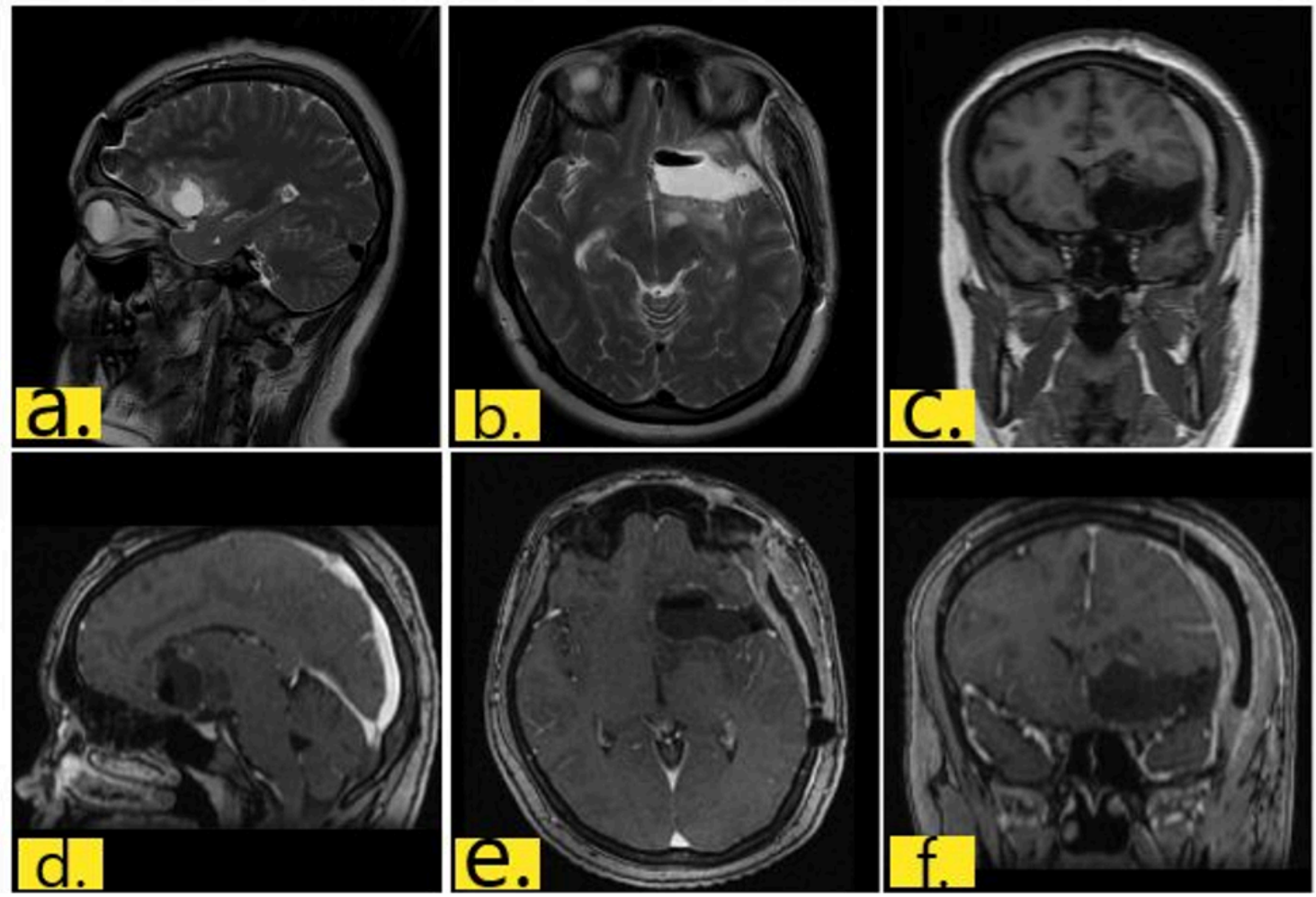


Figure 6

Postoperative contrast-enhanced brain MRI. Sagittal T2-weighted image: postoperative resection cavity in the projection of the left insular region without signs of marked perifocal edema ***(a).*** Axial T2-weighted image: clear visualization of the resection cavity without evidence of mass effect or compression of adjacent structures ***(b).*** Coronal T1-weighted image: anatomical relationship between the resection zone and subcortical structures after tumor removal ***(c).*** Sagittal contrast-enhanced T1-weighted image: absence of pathological contrast enhancement within the resection area ***(d).***Axial contrast-enhanced T1-weighted image: confirmation of the achieved extent of resection with no evidence of residual tumor tissue ***(e).*** Coronal contrast-enhanced T1-weighted image: absence of ischemic or hemorrhagic changes in the adjacent cortical and subcortical regions ***(f).***

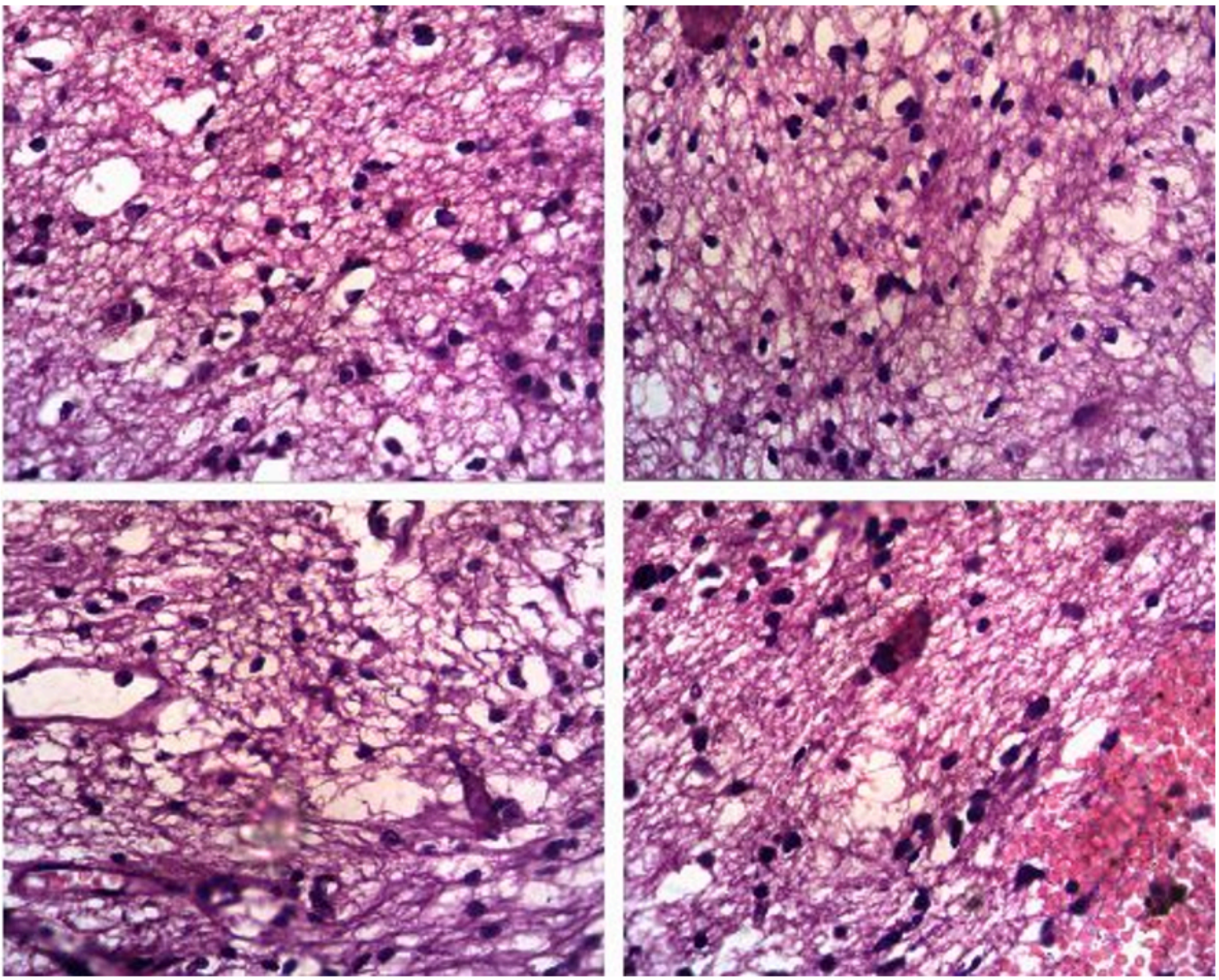


Figure 7

Microscopic appearance of a fibrillary astrocytoma (WHO Grade II). The histological section demonstrates astrocytic tumor cells within a fibrillary matrix, with moderate nuclear atypia and absence of necrosis and microvascular proliferation (hematoxylin and eosin staining).