

Review Article

Awake Craniotomy with Intraoperative Language Mapping for Left Insular Gliomas

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Abstract

Background: Gliomas of the dominant insula are encased by perisylvian language cortex, subcortical language tracts, and lenticulostriate perforators. Awake craniotomy with direct electrical stimulation (DES) mapping is the principal strategy for maximising resection while preserving language.

Objective: To synthesise published literature on awake language mapping for left insular glioma.

Methods: Narrative review of anatomical/classification, technique, mapping-methodology, resection/survival, complication, and comparative awake-versus-asleep studies.

Findings: The Berger-Sanai classification predicts resectability and morbidity; Zone I tumours achieve the highest median resection (86%). Resection near 90% corresponds to 5-year survival of 100% versus 84% (grade II) and 2-year survival of 91% versus 75% (grade III/IV). Stimulation mapping raises gross-total resection from 58% to 75% and lowers late deficits from 8.2% to 3.4%. Dedicated series report 73-100% resection with minimal permanent morbidity.

Conclusions: Awake DES mapping enables aggressive, function-sparing resection of dominant insular gliomas and should be standard practice where feasible.

Keywords: Insular glioma; Awake craniotomy; Language mapping; Direct electrical stimulation; Extent of resection

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Introduction

The insula, buried beneath the frontal, temporal, and parietal opercula within the Sylvian fissure, was long considered surgically inaccessible. Yasargil's 1992 description of the transsylvian approach to limbic and paralimbic tumours [1] revitalised interest in resecting this region, but insular gliomas remain among the most anatomically constrained of hemispheric tumours: they abut the perisylvian language network, the corticospinal and language-relevant subcortical tracts, the basal ganglia, and the lenticulostriate perforators supplying the

internal capsule [2]. In the dominant (typically left) hemisphere, this proximity to language cortex and white-matter language pathways makes function-preserving resection particularly demanding.

Extent of resection (EOR) is a major determinant of survival across glioma grades, and this relationship is especially well documented for insular tumours [3]. Because insular anatomy cannot be reliably inferred from imaging alone, and because eloquent cortex is displaced and reorganised around the tumour in ways that vary between patients, real-time functional localisation is essential. Awake craniotomy with intraoperative direct electrical stimulation (DES) mapping allows the surgeon to identify and preserve language- and motor-eloquent cortex and subcortical pathways while resecting to individualised functional boundaries rather than to a fixed anatomical margin [4,5]. The earliest prospective randomised comparison of awake versus general-anesthesia craniotomy for eloquent-cortex lesions, though not restricted to insular disease, established the methodological template that later insular-specific comparative work has followed [6]. This narrative review synthesises the literature on anatomical classification, awake mapping technique, oncological and functional outcomes, and complications of this approach for dominant-hemisphere insular gliomas.

Insular Anatomy and Surgical Classification

Yasargil's original classification grouped limbic-paralimbic tumours by pattern of spread (Types 3 and 5) [1]. The subsequently developed Berger-Sanai classification, dividing the insula into four zones by a line along the Sylvian fissure and a perpendicular plane through the foramen of Monro, has become the dominant framework because it maps directly onto surgically relevant structures: the perisylvian language network (Zones I-III), primary sensorimotor cortex (Zone II), Heschl's gyrus (Zone III), and the deep lenticulostriate

arteries bordering all zones medially [3,7]. This scheme predicts both EOR and operative morbidity with high inter-rater reliability, and Zone I tumours consistently achieve the highest median EOR (86%), reflecting their distance from the lenticulostriate perforators and internal capsule [8]. Detailed morphometric comparison of the transsylvian and transcortical corridors shows the transcortical approach affords greater surgical freedom to the posterior insula (Zones II-III), while the transsylvian route is favoured for anterior, Zone I disease [9]. Preoperative appreciation of zone, laterality, and lenticulostriate position is now regarded as prerequisite to surgical planning [2,10].

Rationale for Awake Mapping in Insular Surgery

Because the dominant insula sits beneath and adjacent to language cortex, and because subcortical language bundles such as the arcuate fasciculus, inferior fronto-occipital fasciculus, and uncinate fasciculus course through or near the insular white matter, resection guided only by anatomical landmarks or preoperative functional imaging carries substantial risk of permanent aphasia [11]. Awake craniotomy allows continuous, real-time language and motor testing throughout tumour removal, so that resection is tailored to each patient's individual functional map rather than a population-average template. Meta-analytic evidence across glioma locations shows that intraoperative stimulation mapping (ISM) increases radiologically confirmed gross-total resection from 58% (95% CI 48-69%) without mapping to 75% (95% CI 66-82%) with mapping, while simultaneously lowering late severe neurological deficits from 8.2% to 3.4% [12]. For insular disease specifically, where the anatomical margin for error is narrower than almost anywhere else in the supratentorial brain, this combination of greater resection and lower morbidity is the central rationale for awake surgery [13,14].

Intraoperative Language and Cognitive Mapping

Technique

Modern practice most often uses an asleep-awake-asleep (AAA) or monitored-anesthesia-care (MAC) protocol: the craniotomy is performed under sedation or light general anesthesia, the patient is awakened for cortical and subcortical mapping and resection, and, in AAA protocols, resedated for closure [15,16]. Deras and colleagues' prospective series of 140 gliomas in eloquent areas demonstrated that controlled-ventilation AAA anesthesia is compatible with reliable intraoperative testing and low anesthetic-complication rates, establishing much of the modern AAA protocol [16]. A systematic review comparing the two anesthetic strategies found MAC associated with fewer procedure failures and shorter operative time, while AAA was associated with a lower incidence of intraoperative seizure [17]. Cortical mapping with low-frequency bipolar DES identifies essential language and motor sites, which are preserved as anatomical boundaries; subcortical DES is then used during resection to identify and protect the underlying white-matter tracts, since injury to these pathways—rather than to cortex alone—is the principal cause of permanent postoperative deficit [4,11]. Sanai and colleagues' 250-patient series established that this cortical-and-subcortical mapping strategy yields durable postoperative language preservation in the great majority of patients while permitting more extensive resection than mapping of cortex alone [5]. For dominant insular gliomas specifically, awake protocols combining picture-naming, counting, and motor tasks with multimodal preoperative planning (functional MRI, diffusion tensor tractography) have been described as both feasible and safe, even during a surgical team's learning phase, with extents of resection ranging from 73% to 100% and no mortality or major new postoperative deficit in a dedicated ten-patient dominant-insula cohort [18].

Extent of Resection and Oncological Outcomes



Table 1: Extent of resection and survival outcomes across insular glioma surgical series reviewed here [3,14,18,25,20,24,19].					
Series	N	Grade	Approach	Extent of resection	Key survival/f functional finding
Sanai et al. 2010	70 (WHO II); 45 (III/IV)	II and III/IV	Transcortical/transylvian	Median 90%+ in favourable subgroup	5-yr OS 100% vs 84% (II); 2-yr OS 91% vs 75% (III/IV) by EOR
Skrap et al. 2012	66	Nonenhancing (II)	Awake mapping	Volumetric, aggressive	Reduced permanent deficit vs historical series
Alimohammadi et al. 2016	10	7 LGG, 3 HGG	Awake, dominant insula	73-100%	No mortality or major new deficit; seizure improved in 3/4
Ius et al. 2014	52 (insular subset)	Low-grade	Awake mapping	EOR-dependent	Greater EOR predicted postoperative seizure freedom
Pallud et al. 2021	Insular diffuse glioma cohort	Mixed grade	Transcortical awake	Maximal safe	Awake resection independently improved overall survival
Wang et al. 2018	109	Mixed grade	Institutional series	EOR threshold ~81%	68% seizure-free at 1 yr; EOR strongest predictor

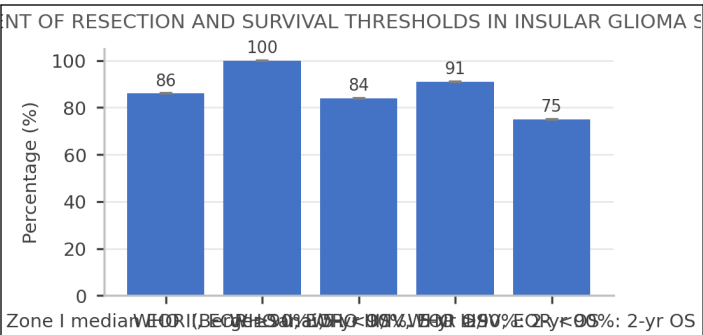


Figure 1: Berger-Sanai Zone I median extent of resection (86%) and extent-of-resection survival thresholds for WHO grade II (100% vs 84% 5-year overall survival at ≥90% vs <90% resection) and grade III/IV (91% vs 75% 2-year overall survival at ≥90% vs <90% resection) insular gliomas [8,3].

The relationship between EOR and survival is unusually strong for insular gliomas. In a series of 70 WHO grade II

insular gliomas, resection ≥90% was associated with 100% 5-year overall survival, versus 84% for resection <90%; EOR also predicted radiographic and malignant progression-free survival [3]. In 45 patients with WHO grade III-IV insular tumours, resection ≥90% conferred 91% 2-year survival compared with 75% for lesser resection [3]. These findings have been reproduced in larger transcortical series, in which EOR correlated with survival in both low- and high-grade disease [10,19]. A dedicated series of 66 nonenhancing insular gliomas demonstrated that aggressive, mapping-guided resection dramatically reduced permanent deficit relative to historical experience while achieving favourable oncological outcomes [14]. Comparing anesthetic strategy directly, a transcortical awake-surgery cohort found that awake resection of insular diffuse gliomas was independently associated with improved overall survival relative to asleep technique [20], although a smaller comparative series found extent of resection, neurological outcome, and survival broadly similar between awake and general-anesthesia groups for insular glioma specifically, with survival for grade <4 tumours at 100% at both 1 and 2 years in each group [21]. Across insular glioma studies more broadly, negative prognosticators include putaminal or paralimbic extension and higher tumour grade, while greater EOR, IDH mutation, and higher performance status are consistently favourable [19].

Neurological and Functional Outcomes

Beyond survival, awake DES mapping is associated with favourable functional outcomes. In perirolandic gliomas, a comparative series found awake craniotomy achieved more complete resections, better postoperative neurological function, and shorter hospitalisation than resection under general anesthesia [22]. A recent systematic review and meta-analysis of awake craniotomy versus general anesthesia across 2689 high-grade glioma patients found awake surgery associated with improved

overall survival (hazard ratio 0.70), a roughly 43% relative reduction in neurological deficits, and a modest but significant EOR advantage (mean difference +4.4%), translating into a median survival benefit of approximately 4.1 months [23]. Seizure control is a major functional outcome for insular disease given its epileptogenicity: in a 109-patient institutional series, 68% of patients were seizure-free at one year, and greater EOR was the strongest independent predictor of seizure freedom, with an EOR threshold near 81% associated with substantially higher seizure-free rates [24]. Earlier seizure-outcome analyses of insular low-grade glioma likewise identified extent of resection as the principal modifiable predictor of postoperative seizure control [25].

Complications

Despite the anatomical risk of the region, pooled complication rates after insular glioma resection are lower than the region's reputation might suggest when mapping is used. A systematic review and meta-analysis of postoperative morbidity following insular glioma surgery found permanent motor and language deficit rates of approximately 4% and 2% respectively [26], figures consistent with the broader ISM meta-analysis showing late severe deficits of 3.4% with mapping [12]. Early transient deficits are more common—commonly cited in the 30-40% range across awake insular series—but the great majority resolve by three months, reflecting reversible operative brain retraction, edema, or vascular spasm rather than permanent tract injury [8,14]. Vascular injury to the lenticulostriate perforators remains the most feared complication because it can produce fixed hemiparesis independent of mapping fidelity, underscoring the importance of identifying these vessels early, tracing their course along the medial insular surface, and respecting them as the medial resection boundary rather than attempting to dissect beyond it [2]. Awake testing does not eliminate this vascular risk, since

perforator injury is a mechanical rather than a functional-mapping failure, but continuous neurological assessment does allow earlier intraoperative recognition of an evolving deficit than is possible under general anesthesia with neurophysiological monitoring alone. Seizures, both intraoperative and as a presenting or postoperative symptom, are common given the insula's inherent epileptogenicity, and anesthetic protocol choice (AAA versus MAC) measurably affects intraoperative seizure incidence [17,16]. Comparative series and meta-analyses suggest that these complication profiles are not worse—and are often more favourable—under awake protocols than under general anesthesia for the same tumour location, reinforcing the case for awake mapping as the default rather than the exceptional approach in dominant insular disease [6,21,23].

Table 2: Comparative awake-versus-general-anesthesia studies relevant to insular and eloquent-area glioma surgery [6,12,22,21,23].					
Study (year)	Design	N	Comparison	Key finding	Source
Gupta et al. 2007	Prospective RCT	Eloquent-cortex lesions	Awake vs general anesthesia	Better cytoarchitecture/neuro improvement with GA in this trial	gupta 2007
De Witt Hamer et al. 2012	Meta-analysis	90 studies pooled	ISM vs no mapping	GTR 75% vs 58%; late severe deficit 3.4% vs 8.2%	dewitthamer2012
Eseonu et al. 2017	Single-surgeon comparative	Perirolandic gliomas	Awake vs general anesthesia	Greater GTR, better function, shorter stay with awake	eseonu2017
Gravestijn et al. 2018	Retrospective comparative	Insular glioma cohort	Awake vs general anesthesia	Similar EOR, neuro outcome, and survival between groups	gravesteijn 2018
Nowacka et al. 2026	Meta-analysis	2689 (11 studies)	Awake vs general anesthesia, HGG	OS HR 0.70; ~43% fewer deficits; EOR +4.4%	nowacka2026

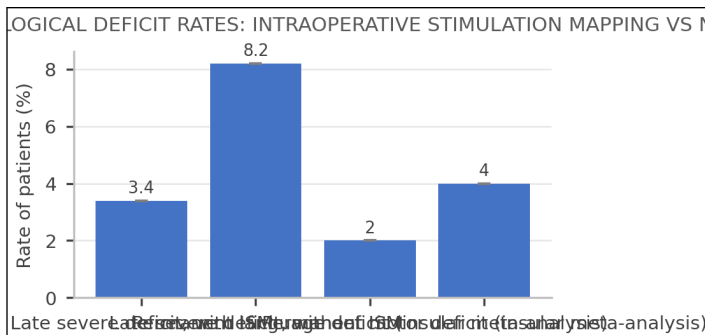


Figure 2: Permanent neurological deficit rates with versus without intraoperative stimulation mapping (ISM) across glioma surgery generally (late severe deficit 3.4% vs 8.2%) [12], and pooled permanent language (2%) and motor (4%) deficit rates specific to insular glioma resection [26].

Conclusion

The published literature on dominant insular glioma surgery converges on a consistent picture: the Berger-Sanai classification meaningfully predicts resectability and risk; extent of resection is the strongest modifiable driver of survival and seizure control; and awake craniotomy with cortical-subcortical DES language mapping is the technique best supported for achieving maximal resection while minimising permanent neurological morbidity in this anatomically constrained region. Comparative and meta-analytic data, though still dominated by observational cohorts, favour awake over asleep resection for survival, functional outcome, and deficit avoidance, with a single randomised trial and several matched comparisons providing corroborating, if not yet definitive, evidence. Continued refinement of anesthesia protocols, subcortical mapping paradigms, and multimodal preoperative planning is likely to further narrow the gap between oncological aggressiveness and functional preservation in this challenging tumour location.

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