



# Transcortical versus Transsylvian Approach for Insular Gliomas: A Systematic Review and Meta-Analysis

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## Abstract

Insular gliomas can be resected via a transcortical (TC) or transsylvian (TS) approach. The TC approach avoids injury to the middle cerebral artery (MCA) and is considered suitable for gliomas with opercular spread. The TS approach is limited by bridging veins and a surgical “blind spot” for larger gliomas. We aimed to compare the TC and TS approaches for the resection of insular gliomas. A systematic review of the literature was performed using PubMed, Scopus, and Web of Science databases from inception to November 20, 2022, following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guidelines. Primary outcomes included the extent of resection (EOR), postoperative deficits, and immediate and delayed complications of both approaches. Summary estimate of proportion, random effects, and confidence intervals (CIs) were calculated using R (statistical package). Sixteen studies with 1,517 patients (56.5% male) were included. The mean age  $\pm$  standard deviation (SD) of patients was  $43.6 \pm 6.8$  years. The predominant presenting symptom was first-onset seizure (62.8%), followed by headache (~10%). There was a slight predominance of right-sided gliomas (52.5%). Pathology revealed a slight abundance of low-grade (WHO grade I or II) histology (51.5%) compared with 48.5% high-grade (WHO grade III or IV). A greater pool proportion of 0.44 (CI: 0.28–0.61) for gross total resection and 0.19 (CI: 0.10–0.34) for partial resection was found for the TC approach compared with the TS approach. For subtotal resection, the TS approach had a higher pooled proportion

## Keywords

- ▶ insular glioma
- ▶ transsylvian
- ▶ transcortical

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(0.47 [CI: 0.40–0.54]) than the TC approach (0.41 [CI: 0.24–0.60]). Postoperative speech deficits (0.04 [95% CI: 0.02–0.11]) and motor deficits (0.10 [95% CI: 0.07–0.15]) were more frequent with the TS approach compared with the TC approach. Our study confirms that the TC approach results in a higher proportion of gross total resection of insular gliomas compared with the TS approach, with fewer postoperative speech and motor deficits.

## Introduction

Insular gliomas account for approximately 25% of all low-grade gliomas (LGGs) and 10% of all high-grade gliomas (HGGs).<sup>1</sup> Hidden under the opercular surfaces, the insula has been implicated in a variety of physiological functions, including emotional processing, interoception, and perception of gustatory, olfactory, and somatosensory stimuli,<sup>2</sup> and high-order cognitive function involved in speech and language processing. Anatomically, the proximity to the middle cerebral artery (MCA) and its branches, the highly eloquent nature of the opercular cortex, and the underlying white matter tracts make the insula a particularly challenging place to operate. In the best of hands, 11% of the patients will experience new temporary motor or language deficits, 4% permanent motor deficits, and 2% permanent language deficits.<sup>3</sup> To reduce operative morbidity, the choice of surgical approach and meticulous perioperative and intraoperative mapping are essential and should be strongly considered.<sup>1</sup>

Several approaches have been described to reach the insula, including transcortical (TC; including transopercular<sup>4</sup> and transfrontal/trans temporal isthmus<sup>5,6</sup>), and transsylvian (TS) approaches.<sup>7</sup> The TC approach involves resection of parts of the cortex to expose the insula, whereas the TS approach takes advantage of the natural Sylvian corridor exposed by splitting the fissure. However, this requires some degree of retraction of the opercular surfaces of the frontal, parietal, and temporal lobes.<sup>7</sup> The TC approach avoids injury to the MCA and its branches and is considered more suitable for resecting insular gliomas with opercular spread.<sup>8</sup> While the TS approach spares opercular tissue, surgical exposure can be limited by bridging veins and the extent of Sylvian split due to anatomical variations, thus affecting surgical freedom.<sup>9</sup>

Following the pioneering work of Yasargil and colleagues,<sup>10</sup> many institutions have adopted surgical treatment for insular gliomas. However, the available literature on glioma surgery primarily consists of case reports<sup>11,12</sup> and case series<sup>9,13,14</sup> reporting the institutional experiences of individual surgeons. Surgical approaches and the use of technical adjuncts differ across institutions, highlighting the need for a comprehensive systematic review. This review aims to compare TC and TS approaches for insular gliomas through a meta-analysis, assessing postoperative deficits, extent of resection (EOR), and both immediate and delayed complications associated with each approach.

## Materials and Methods

A systematic review of the literature was conducted to identify studies describing the surgical management of insular gliomas, and a meta-analysis was performed on outcome measures. The Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) protocol<sup>15</sup> (CRD42024535369) was followed for all stages to identify suitable studies for analysis.

### Data Source and Search Strategy

The literature search was conducted by two independent reviewers (A.S.G. and H.M.Q.), who screened all published articles from inception till November 2022 using the PubMed, Scopus, and Web of Science databases. The key terms used were “insula,” “insular glioma,” “insular tumor,” “insular region,” “insular surgery,” “insular glioma resection,” and “insular glioma treatment,” and the Boolean operators “AND” and “OR” were used. The detailed search strategy is provided in **Supplementary Table S1** (available in the online version). Manual search techniques, including snowballing through references, were also used to identify additional articles.

### Eligibility Criteria

The Population, Intervention, Comparison, and Outcome (PICO) framework for this study was defined as follows:

- P: Adult patients with insular glioma
- I: Transcortical approach
- C: Transsylvian approach
- O: Extent of resection, and immediate/delayed complications of TS versus TC.

### Inclusion Criteria

This study included observational studies involving adult patients ( $\geq 18$  years) with insular glioma who underwent TC or TS approach and reported patient outcomes.

### Exclusion Criteria

Studies without insular glioma and anatomical studies, case reports/series, and abstracts were excluded.

### Study Outcomes

The primary outcomes were EOR, immediate, and delayed complications. EOR was classified according to the method reported by Berger et al.<sup>16</sup> Gross total resection is when there is no postoperative signal abnormality detected and/or 100% resection achieved, subtotal when residual tumor is less than

10 cm<sup>3</sup> or resected less than 100% or specifically between 70% and 90%, while partial resection is when the volume was 10 mL or greater and less than 70%.

### Article Screening

The identified articles were de-duplicated and screened using Rayyan software. Two independent reviewers screened the titles, abstracts, and full texts based on predefined eligibility criteria, with any disagreements resolved by a third reviewer.

### Data Extraction

Data from studies meeting the inclusion criteria were extracted by two authors, including study characteristics (author(s), year of publication, country of origin), study design, sample size, patient, and tumor characteristics (age, gender, tumor laterality, Yasargil et al<sup>10</sup> or Berger and Sanai classification,<sup>17</sup> and pathological grading), and outcomes (EOR, intra- and perioperative complications). A third author then reviewed and verified the data independently. The refined data were then processed using Google Sheets for further analysis.

### Risk of Bias Assessment

Using the U.S. National Institutes of Health (NIH) National Heart, Lung, and Blood Institute Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies,<sup>18</sup> and the NIH Quality Assessment for Case Series,<sup>18</sup> two reviewers (H. A.I. and M.S.) independently evaluated the quality of the articles included in the study. The reviewers responded to each question with a yes, no, or N/A. The articles were then divided into three categories: Ambiguous (bias may exist because not all requirements are met), low (bias is improbable), and high (bias is extremely likely). The quality assessment is detailed in ►Supplementary Table S2 (available in the online version).

### Statistical Analysis

The meta-analysis of proportions was conducted between two groups (TC and TS approaches) by clustering the studies in each group. The summary estimate of proportion was calculated using metaprop (R Statistical Package). A random effects model following the inverse variance method and confidence intervals (CIs) were computed using the Clopper–Pearson method. Funnel plots were graphed to assess publication bias.

## Results

We screened 329 studies, of which 177 underwent full-text review after removal of duplicates and titles and abstract screening. Our final analysis included 16 studies, as outlined in the PRISMA flow diagram (►Fig. 1). Most studies were published between 2000 and 2021, including nine retrospective cohorts, three retrospective observational studies, three retrospective case series, and one prospective case series. These studies were conducted in the United States, France, Germany, China, Italy, Russia, and India (►Fig. 2). Study characteristics are detailed in ►Table 1.

Among 1,517 participants, 858 (56.55%) were males, with the mean age ± SD of 43.66 ± 6.88 years. There were 720 (47.46%) tumors in the right insula and 797 (52.54%) in the left insula. Handedness was noted in some studies, with the majority being right-handed (216 vs. 37; ►Table 2).

The classification systems for insular gliomas varied across the 16 studies. Ten studies used the Berger and Sanai classification, with most cases in Zone 1 (247) and the fewest in Zones 2 and 3 (49). Three studies used Yasargil et al's classification, identifying 18 tumors as type 3A, 31 as type 3B, 57 as type 5A, and 58 as type 5B. Hameed et al<sup>19</sup> categorized tumors as anterior (52 cases), superior (12 cases), posterior (26 cases), inferior (15 cases), and giant (150 cases). Rossi et al's (2021)<sup>20</sup> study did not specify a classification system. Detailed data are provided in ►Table 3.

Tumor histology was categorized into LGGs (WHO grade I or II) and HGGs (WHO grade III or IV), with 786 (51.5%) LGG and 740 (48.5%) HGG tumors. Histological diagnoses included astrocytoma (339 cases), oligodendroglioma (212 cases), glioblastoma (186 cases), and gliosarcoma (3 cases; ►Table 3).

Preoperative deficits included motor, sensory, and speech deficits, seizures, headache, papilledema, and dizziness. Seizures were the most common, affecting 954 (62.88%) patients, followed by headaches (142), speech (120), motor (75), and sensory deficits (62), and increased intracranial pressure (ICP) (3). Li et al<sup>9</sup> (2020) reported dizziness in 52 patients. Preoperative deficits and Karnofsky Performance Status (KPS) Scale are detailed in ►Supplementary Tables S3 and S4 (available in the online version).

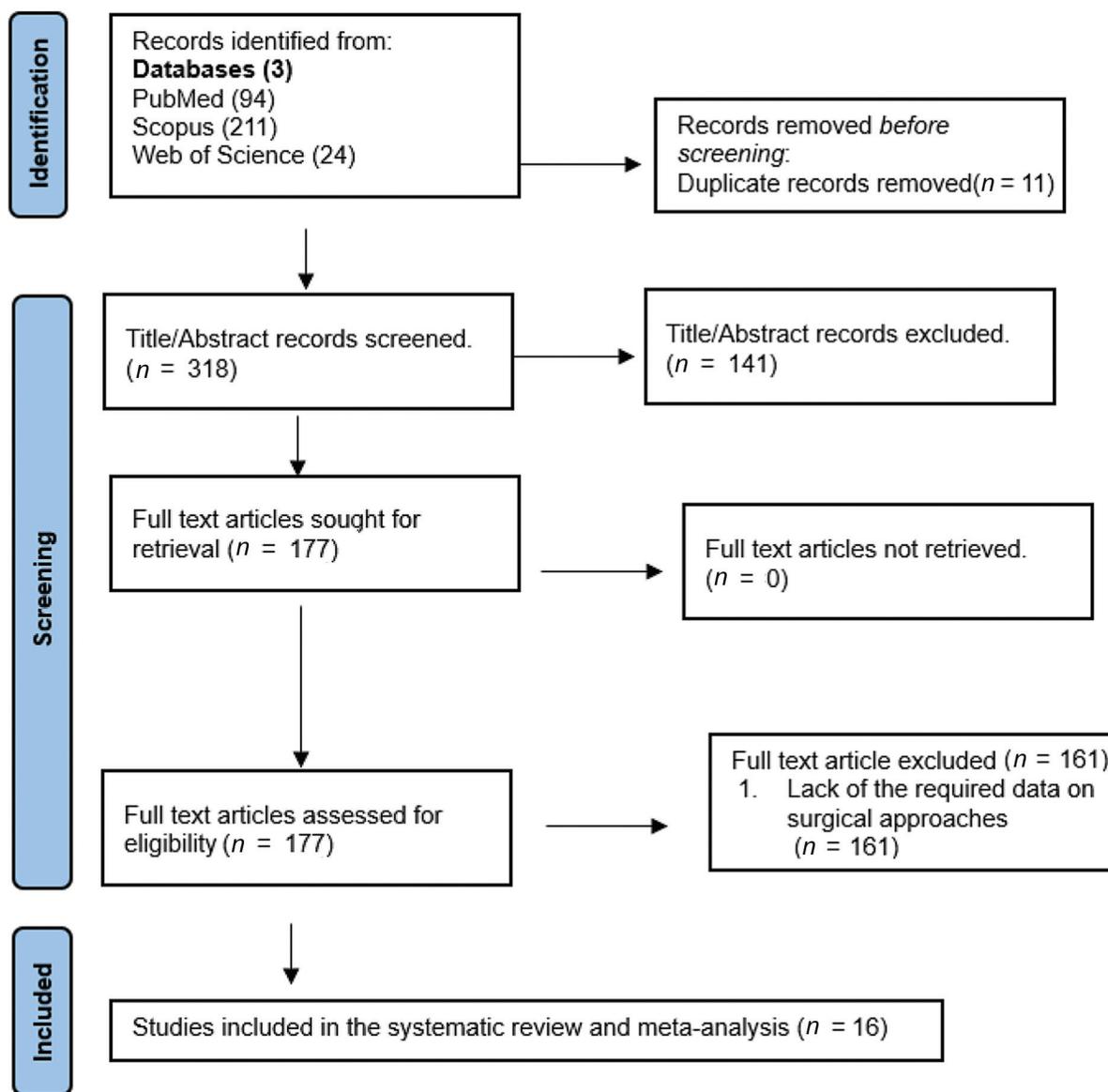
The TC approach was reported in 13 studies, the TS in 6, and both approaches in 3 studies (►Table 4). Intraoperative complications were documented by one study, and immediate postoperative complications ranged from 1.6% to 58%, with intracerebral hemorrhage requiring surgical evacuation in six cases (2.4%) and neurological deficits being the most frequent. Many immediate complications were resolved, but some cases had persistent speech (28 patients) and motor deficits (16 patients), as shown in ►Table 5.

The TC approach showed a higher pooled proportion of gross total resection (0.44 [95% CI: 0.28–0.61]) compared with the TS approach (0.35 [95% CI: 0.19–0.55]). For subtotal resection, the TS approach had a higher pooled proportion (0.47 [95% CI: 0.40–0.54]) than the TC approach (0.41 [95% CI: 0.24–0.60]). For partial resection, the TC approach had a greater pooled proportion (0.19 [95% CI: 0.10–0.34]) compared with the TS approach (0.18 [95% CI: 0.07–0.38]), as shown in ►Fig. 3.

Postoperative speech (0.04 [95% CI: 0.02–0.11]) and motor deficits (0.10 [95% CI: 0.07–0.15]) were more frequent with the TS approach compared with the TC approach. ►Figure 4 outlines the postoperative deficits for both approaches. Publication bias was assessed, and funnel plots are shown in ►Fig. 5.

## Discussion

In a first-of-its-kind meta-analysis, we compared the outcomes of insular glioma resection using the TS and TC



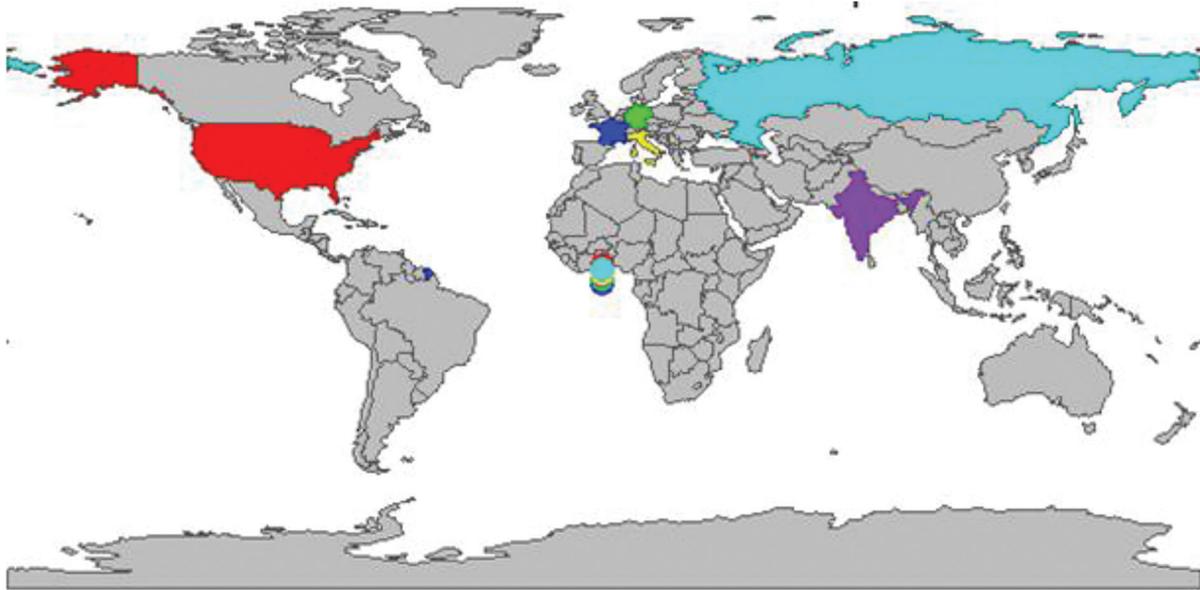
**Fig. 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

approaches. Our findings suggest a higher rate of gross total resection and lower rates of postoperative motor and speech deficits with the TC approach.

Our analysis included 51.5% LGGs and 48% HGGs, mirroring the distribution observed in Sanai et al's<sup>17</sup> study, which reported 54% LGG and 45% HGG. The EOR is an important factor in predicting overall survival (OS) for brain tumor patients. Achieving optimal EOR requires consideration of the tumor's size and location, the patient's overall health and neurological condition, and the expertise of the surgeon. A multivariate analysis by Lacroix et al<sup>21</sup> found that resection of  $\geq 98\%$  of the glioblastoma multiforme is associated with longer OS. Ruella et al<sup>22</sup> (53 patients with insular gliomas) reported that 62.3% of patients achieved  $>90\%$  resection, with 2-year survival rates of 100% for LGG and 46% for HGG. Simon et al<sup>23</sup> (94 insular tumor patients) found a median survival of 5 years for anaplastic astrocytomas (WHO grade

III) and a 5-year survival rate of 80% for anaplastic oligodendroglial tumors, with  $>90\%$  resection achieved in 42% of the cases and 70% to 90% resection in 51% of cases. They reported that extensive resections, as an independent predictor of OS, with the EOR correlating with improved patient outcomes. Similarly, Sanai et al<sup>17</sup> reported that EOR was a significant prognostic factor for OS in 104 patients with insular gliomas. Patients with LGG, tumor resection  $\geq 90\%$  had a 5-year OS rate of 100%, whereas those with resections  $<90\%$  had 84% 5-year OS rate. For HGG, patients with  $\geq 90\%$  resection had a 2-year OS of 91%, compared with 75% for those with  $<90\%$  resection.

The need to preserve surrounding white matter tracts and vasculature makes complete resection of insular tumors challenging; the type of surgical approach and intraoperative mapping are, therefore, crucial to improve EOR.<sup>24</sup> Our meta-analysis identified a higher pooled EOR associated with the



**Fig. 2** Countries of publication.

TC approach compared with the TS approach. Benet et al's<sup>25</sup> study of 16 cadaveric specimens found that the TC approach provided better exposure of the superior insula and surgical freedom compared with the TS approach. In conclusion, the literature suggests that the TC approach is associated with a higher EOR, thus leading to improved OS.

We found a higher proportion of motor deficits associated with the TS approach. Preservation of major vasculatures, including M2 vessels, long M2 perforators, lenticulostriate arteries (LSAs), and major Sylvian veins, is

important in both TC and TS. One possible explanation for the higher proportion of motor deficits in TS is the increased risk of vasculature injury inherent in the TS approach.<sup>26</sup> Structures such as the LSAs arising principally from the inferomedial aspect of the M1 segment are more susceptible to injury in the anterior perforated substance and require careful preservation regardless of the surgical approach. The long insular artery, which supplies the periventricular white matter, is located on the surface of the insula and damage to which results in characteristic corona

**Table 1** Study characteristics

Study	Year	Study design	Country of study	Sample size (n)
1. Duffau et al, 2000 <sup>33</sup>	2000	Prospective case series	France	12
2. Lang et al, 2001 <sup>26</sup>	2001	Retrospective cohort	United States	22
3. Simon et al, 2009 <sup>23</sup>	2009	Retrospective cohort	Germany	94
4. Duffau, 2009 <sup>34</sup>	2009	Retrospective case series	France	51
5. Sanai et al, 2010 <sup>17</sup>	2010	Retrospective observational	United States	104
6. Eseonu et al, 2015 <sup>35</sup>	2015	Retrospective cohort	United States	74
7. Hervey-Jumper et al, 2016 <sup>36</sup>	2016	Retrospective cohort	United States	129
8. Przybylowski et al, 2019 <sup>7</sup>	2019	Retrospective cohort	United States	100
9. Mandonnet, 2019 <sup>37</sup>	2019	Retrospective case Series	France	12
10. Hameed et al, 2019 <sup>19</sup>	2019	Retrospective cohort	China	255
11. Li et al, 2020 <sup>9</sup>	2020	Case series	China	253
12. Singh et al, 2020 <sup>38</sup>	2020	Retrospective observational	India	27
13. Panigrahi et al, 2021 <sup>39</sup>	2021	Retrospective cohort	India	61
14. Rossi et al, 2021 <sup>20</sup>	2021	Retrospective cohort	Italy	95
15. Pallud et al, 2021 <sup>40</sup>	2021	Retrospective observational	France	149
16. Pitskhelauri et al, 2021 <sup>14</sup>	2021	Retrospective cohort	Russia	79

**Table 2** Patient characteristics

Study	Year	Age (mean/median)	Male (n)	Female (n)
1. Duffau et al, 2000 <sup>33</sup>	2000	38	6	6
2. Lang et al, 2001 <sup>26</sup>	2001	36 <sup>a</sup>	7	15
3. Simon et al, 2009 <sup>23</sup>	2009	41.3 <sup>a</sup>	57	37
4. Duffau, 2009 <sup>34</sup>	2009	36	30	21
5. Sanai et al, 2010 <sup>17</sup>	2010	39.8	42	62
6. Eseonu et al, 2017 <sup>35</sup>	2017	54 <sup>a</sup>	42	32
7. Hervey-Jumper et al, 2016 <sup>36</sup>	2016	41	74	55
8. Przybylowski et al, 2019 <sup>7</sup>	2019	62	62	38
9. Mandonnet, 2019 <sup>37</sup>	2019	40	6	6
10. Hameed et al, 2019 <sup>19</sup>	2019	20–78 <sup>b</sup>	161	94
11. Li et al, 2020 <sup>9</sup>	2020	43.67	137	116
12. Singh et al, 2020 <sup>38</sup>	2020	52	20	7
13. Panigrahi et al, 2021 <sup>39</sup>	2021	42.57	41	20
14. Rossi et al, 2021 <sup>20</sup>	2021	40.89	59	36
15. Pallud et al, 2021 <sup>40</sup>	2021	42.7	75	74
16. Pitskhelauri et al, 2021 <sup>14</sup>	2021	39.7 <sup>a</sup>	39	40

<sup>a</sup>Median.<sup>b</sup>Range.

radiata infarction and postoperative hemiparesis.<sup>26–29</sup> The Sylvian vessels are often prone to spasm in the TS approach.<sup>30</sup> In this approach, the cortical MCA branches are identified and preserved early on. In contrast, these branches are often visualized only toward the end of tumor resection with the TC corridor.<sup>31</sup>

Our findings demonstrated that postoperative speech deficits were low in patients with the TC approach for insular glioma resection. In Przybylowski et al's study, a higher postoperative ischemia in radiological findings for the TS was correlated with an increased rate of permanent aphasia, although the TS and TC approaches shared a similar profile of transient deficits (<6 months).<sup>32</sup> As hypothesized by Benet et al, the increased risk of postoperative ischemia can be explained by the need for frontal lobe retraction in the TS and sacrifice of superficial Sylvian veins, sometimes necessary for better exposure.<sup>19,25</sup> Thus, the TC approach serves an advantage in preserving postoperative deficits due to ischemic changes for insular glioma resection.

The rarity and eloquent location of insular gliomas have resulted in a lack of standardization in treatment protocols.<sup>10</sup> The advantages of the TC approach include an increased EOR and provision of favorable postoperative outcomes, which can be considered against the traditional preference for the TS approach in certain cases. Future research should explore the benefits offered by endoscopic techniques and awake craniotomies in improving treatment outcomes further.

### Limitations

Despite following the PRISMA guidelines, our study has some limitations. While rigorous, its exclusion criteria—

non-English publications and studies with fewer than five sample sizes—may have excluded diverse patient data. Variability in surgical techniques, tumor characteristics, and patient demographics among included studies introduces heterogeneity. Short-term follow-up limits the comprehensive evaluation of long-term outcomes like recurrence and functional recovery. Efforts to reduce publication bias may underrepresent studies with non-significant findings, affecting the overall robustness of treatment comparisons. Moreover, the limited number of studies available specifically for TS for inclusion and their predominantly high-income country origin may restrict the generalizability of findings, necessitating cautious interpretation in global health care settings.

### Conclusion

Our study compared the TS and TC approaches for insular glioma resection. The TC approach had a slightly higher proportion of gross total resection, whereas the TS approach resulted in a higher proportion of subtotal resections. Prioritizing safe resection and minimizing postoperative deficits is essential, as motor and language dysfunction rates were higher with the TS approach. Although the TC approach may improve prognosis and outcomes, the limited number of TS studies warrants caution in interpretation. This study highlights the need for further prospective and large sample research to guide surgical decisions and optimize patient outcomes in insular glioma management.

**Table 3** Tumor characteristics

Study	Location of tumor		Yasargil or Berger and Sanai classification of insular glioma	Tumor grading		Histological diagnosis
	Right	Left		Low grade (I and II)	High grade (III and IV)	
Duffau et al, 2000 <sup>33</sup>	10	02	Type 3A: 1 Type 3B: 2 Type 5A: 5 Type 5B: 4	12	00	NA
Lang et al, 2001 <sup>26</sup>	09	13	Insular: 8 Temporal polar-insula: 8 Frontal operculum-insula: 6	11	11	Oligodendroglioma Astrocytoma Glioblastoma
Simon et al, 2009 <sup>23</sup>	54	40	Type 3A: 10 Type 3B: 20 Type 5A: 37 Type 5B: 34	36	64	Oligodendroglioma Astrocytoma Glioblastoma
Duffau, 2009 <sup>34</sup>	37	14	Type 3A: 7 Type 3B: 9 Type 5A: 15 Type 5B: 20	51	00	Oligodendroglioma Astrocytoma
Hervey-Jumper et al, 2016 <sup>36</sup>	61	68	Zone 1: 40 Zone 2: 02 Zone 3: 17 Zone 4: 14 Zone 1 + 2: 4 Zone 1 + 4: 21 Zone 2 + 4: 7 Zone 3 + 4: 12 Giant tumor: 12	70	59	Oligodendroglioma
Przybylowski et al, 2019 <sup>7</sup>	40	60	Zone 1: 21 Zone 2: 21 Zone 3: 30 Zone 4: 18 Giant tumor: 10	32	68	NA
Li et al, 2020 <sup>9</sup>	134	119	Zone 1: 91 Zone 2: 10 Zone 3: 5 Zone 4: 19 Zone 1 + 2: 23 Zone 1 + 4: 55 Zone 2 + 4: 9 Zone 3 + 4: 12 Giant tumor: 29	149	104	NA
Panigrahi et al, 2021 <sup>39</sup>	34	27	Zone 1: 19 Zone 2: 4 Zone 3: 6 Zone 4: 7 Zone 1 + 2: 2 Zone 1 + 4: 13 Zone 2 + 3: 3 Zone 3 + 4: 3 Giant tumor: 4	42	19	Oligodendroglioma Astrocytoma Glioblastoma Gliosarcoma
Rossi et al, 2021 <sup>20</sup>	35	60	NA	69	26	Oligodendroglioma Astrocytoma Glioblastoma
Singh et al, 2020 <sup>38</sup>	14	13	Zone 1, 2, 3, 4 (giant): 8 Zone 1 + 2: 5 Zone 1 + 4: 3 Zone 2 + 3: 5	3	24	Glioblastoma/Gliosarcoma

(Continued)

**Table 3** (Continued)

Study	Location of tumor		Yasargil or Berger and Sanai classification of insular glioma	Tumor grading		Histological diagnosis
	Right	Left		Low grade (I and II)	High grade (III and IV)	
			Zone 3 + 4: 3 Zone 2 + 3 + 4: 3			
Sanai et al, 2010 <sup>17</sup>	46	58	Zone 1: 40 Zone 2: 06 Zone 3: 06 Zone 4: 06 Zone 1 + 2: 4 Zone 1 + 4: 26 Zone 2 + 3: 9 Zone 3 + 4: 4 Giant tumor: 14	70	45	NA
Pallud et al, 2021 <sup>40</sup>	70	79	Zone 1: 10 Zone 2: 6 Zone 3: 3 Zone 4: 6 Zone 1 + 2: 11 Zone 1 + 4: 48 Zone 2 + 3: 4 Zone 3 + 4: 31 Giant tumor: 30	66	75	Oligodendroglioma Astrocytoma Glioblastoma
Mandonnet, 2019 <sup>37</sup>	5	7	Zone 1: 1 Zone 3: 1 Zone 1 + 2: 1 Zone 1 + 4: 2 Giant tumor: 7	12	00	IDH-mutated insular glioma
Pitskhelauri et al, 2021 <sup>14</sup>	30	49	Zone 1: 4 Zone 2: 2 Zone 3: 2 Zone 4: 1 Zone 1 + 2: 1 Zone 1 + 4: 9 Zone 2 + 3: 4 Zone 3 + 4: 1 Giant tumor: 55	18	61	Oligodendroglioma Astrocytoma Glioblastoma Gliosarcoma
Eseonu et al, 2017 <sup>35</sup>	31	43	Zone 1: 21 Zone 2: 6 Zone 3: 7 Zone 4: 2 Zone 1 + 2: 7 Zone 1 + 4: 11 Zone 2 + 3: 8 Zone 3 + 4: 2 Giant tumor: 10	25	49	NA
Hameed et al, 2019 <sup>19</sup>	110	145	Anterior: 52 Superior: 12 Posterior: 26 Inferior: 15 Giant tumor: 150	120	135	Oligodendroglioma Astrocytoma Glioblastoma Gliosarcoma

Abbreviations: IDH, isocitrate dehydrogenase; NA, not available.

**Table 4** Approaches used for insular gliomas among included studies

Study	Surgical approach used for number of cases	
	Transcortical	Transsylvian
1. Lang et al, 2001 <sup>26</sup>	NR	22
2. Duffau et al, 2000 <sup>33</sup>	12	NR
3. Simon et al, 2009 <sup>23</sup>	NR	101
4. Duffau, 2009 <sup>34</sup>	51	NR
5. Mandonnet, 2019 <sup>37</sup>	12	NR
6. Przybylowski et al, 2019 <sup>7</sup>	48	52
7. Hervey-Jumper et al, 2016 <sup>36</sup>	129	NR
8. Li et al, 2020 <sup>9</sup>	253	NR
9. Panigrahi et al, 2021 <sup>39</sup>	23	38
10. Rossi et al, 2021 <sup>20</sup>	95	NR
11. Sanai et al, 2010 <sup>17</sup>	104	NR
12. Pallud et al, 2021 <sup>40</sup>	149	NR
13. Pitskhelauri et al, 2021 <sup>14</sup>	NR	79
14. Eseonu et al, 2017 <sup>35</sup>	74	NR
15. Hameed et al, 2019 <sup>19</sup>	255	NR
16. Singh et al, 2020 <sup>38</sup>	14	13

Abbreviations: NR, not reported.

**Table 5** Complications

Study	Approach	Intraoperative	Immediate postoperative, n (%)	Delayed postoperative (within 7 days)	Delayed postoperative (after 7 days)
Li et al, 2020 <sup>9</sup>	TC	M2 injury: 3 (1.2%) LSA injury: 3 (1.2%)	Hematoma: 4 (1.6%)	Short-term language impairment: 20/23 (87.0%) Short-term motor deficit: 23/28 (82.1%)	Eight patients suffered from long-term neurological deficit (one motor disability and one language disability)
Panigrahi et al, 2021 <sup>39</sup>	TC and TS	NR	TC: 2 (8.6%) TS: 13 (34.2%)	Speech deficits TC: 0 (0%) <sup>a</sup> TS: 5 (13.1%) <sup>a</sup> Motor deficits: TC: 1 (4.3%) <sup>a</sup> TS: 8 (21.1%) <sup>a</sup>	Speech deficits TC: 0 (0%) <sup>b</sup> TS: 4 (10.5%) <sup>b</sup> Motor deficits TC: 0 (0%) <sup>b</sup> TS: 4 (10.5%) <sup>b</sup>
Rossi et al, 2021 <sup>20</sup>	TC	NR	Language deficit: 31 (32.6) Motor deficit: 26 (27.3) Visual deficit: 3 (3.1)	<sup>c</sup> Language deficit: 20 (21.1) Motor deficit: 7 (7.3) Visual deficit: 3 (3.1)	<sup>d</sup> Language: 3 (3.2) Motor: 0 (0) Visual: 2 (2.1)
Sanai et al, 2010 <sup>17</sup>	TC	NR	NR	Eight patients (7.7%) had a new or worsened facial weakness and one-half recovered completely by the 4- to 6-month evaluation. Another two patients demonstrated a partial recovery, whereas the condition of the other two patients remained unchanged. Two patients	Five patients (4.8%) with new-onset dysarthria; four of these patients proceeded to a complete functional recovery by the 4- to 6-month clinical evaluation, and one patient had a partial recovery

(Continued)

**Table 5** (Continued)

Study	Approach	Intraoperative	Immediate postoperative, n (%)	Delayed postoperative (within 7 days)	Delayed postoperative (after 7 days)
				(1.9%) had hemiparesis, which persisted through the 4- to 6-week clinical evaluation. One of these patients recovered completely, while the other retained a permanent deficit.	
Pallud et al, 2021 <sup>40</sup>	TC	NR	NR	Epileptic seizure: 7 (5.78%)	Controlled seizures: 56 (46.28%) Uncontrolled seizures: 21 (17.35%)
Mandonnet, 2019 <sup>37</sup>	TC	NR	Severe dysarthria: 1 (8.33%)	NR	NR
Pitskhelauri et al, 2021 <sup>14</sup>	TS	NR	New neurological deficit was observed in 31 (39.2%) patients: In 8 patients (10.1%), motor impairment; in 13 (16.5%), only speech disorders; and 10 (12.7%) patients had speech and movement disorders	NR	Persistent neurological deficit was evaluated 3 months after surgical treatment and was observed in five (6.3%) patients: One patient (1.3%) with speech disorders and four patients (5.1%) with motor deficits
Eseonu et al, 2017 <sup>35</sup>	TC	NR	New sensory and language deficits were found in (3) 4.1% and (5) 6.8% of patients, respectively	Transient motor deficits were seen in (6) 8.1% of patients	Permanent deficits were seen in (2) 2.7% of patients. At the 6-month follow-up, postoperative seizures were seen in (12) 16% of patients
Hameed et al, 2019 <sup>19</sup>	TC	NR	About 11.05% (19/172) patients developed language impairment, while 13.37% (23/172) developed motor impairment, of whom 68.42% (13/19) and 34.78% (8/23) patients, respectively, recovered on long-term follow-up.		About 8.97% (13/145) postoperatively asymptomatic patients developed late-onset language or motor impairment
Lang et al, 2001 <sup>26</sup>	TS	NR	Postoperative deficits included hemiparesis and dysphasia and occurred after 6 (21%) of the 28 operations	NR	Two motor deficits
Duffau, 2009 <sup>34</sup>	TC	NR	Hemiplegia: 2 (3.92%) Hemiparesis: 17 (33.33%) Dysphasia: 10 (19.60%)	NR	Hemiparesis: 2 (3.92%)

**Table 5** (Continued)

Study	Approach	Intraoperative	Immediate postoperative, n (%)	Delayed postoperative (within 7 days)	Delayed postoperative (after 7 days)
			Arhythmormic syndrome: 7 (13.72%) Foix–Chavany–Marie syndrome: 4 (7.84%)		
Przybylowski et al, 2019 <sup>7</sup>	TC and TS	NR	NR	NR	TS 4–6 weeks: 7 weakness and 3 aphasia 4–6 months: 6 weakness and 1 aphasia Permanent: 6 weakness TC 4–6 weeks: 6 weakness and 2 aphasia 4–6 months: 4 weakness and 2 aphasia Permanent: 4 weakness
Hervey-Jumper et al, 2016 <sup>36</sup>	TC	NR	NR	Language deficits: 21 (16.3%) Motor deficits: 10 (7.8%) Face motor deficits: 12 (9.3%)	Language deficits: 1 (0.8%) Motor deficits: 2 (1.6%) Face motor deficits: 1 (0.8%)
Duffau et al, 2000 <sup>33</sup>	TC	NR	Seven patients (58%) experienced an immediate postoperative deficit (six motor and one linguistic), in one case, remaining in a comatose state for 72 hours.	One case of temporal venous thrombosis and one case of meningitis	Deficit recovery delay of 5 days to 3 months in one case
Simon et al, 2009 <sup>23</sup>	TS	NR	Permanent new/worsened hemiparesis 12 (13%) Permanent new/worsened dysphasia 5 (13%) Other neurological deficits 6 (6%)	NR	Seizure(s): 83 (83%) Neurological deficit at presentation: 23 (23%) Recurrent insular tumors: 12 (12%)
Singh et al, 2020 <sup>38</sup>	TC and TS	NR	Five patients had major postoperative complications (18.5%). These included	NR	NR

(Continued)

**Table 5** (Continued)

Study	Approach	Intraoperative	Immediate postoperative, n (%)	Delayed postoperative (within 7 days)	Delayed postoperative (after 7 days)
			operative site hematoma (3, 11%), and MCA infarct (2, 7%). Four of them required a re-surgery for the evacuation of the hematoma (n = 3) and decompressive craniectomy (n = 1)		

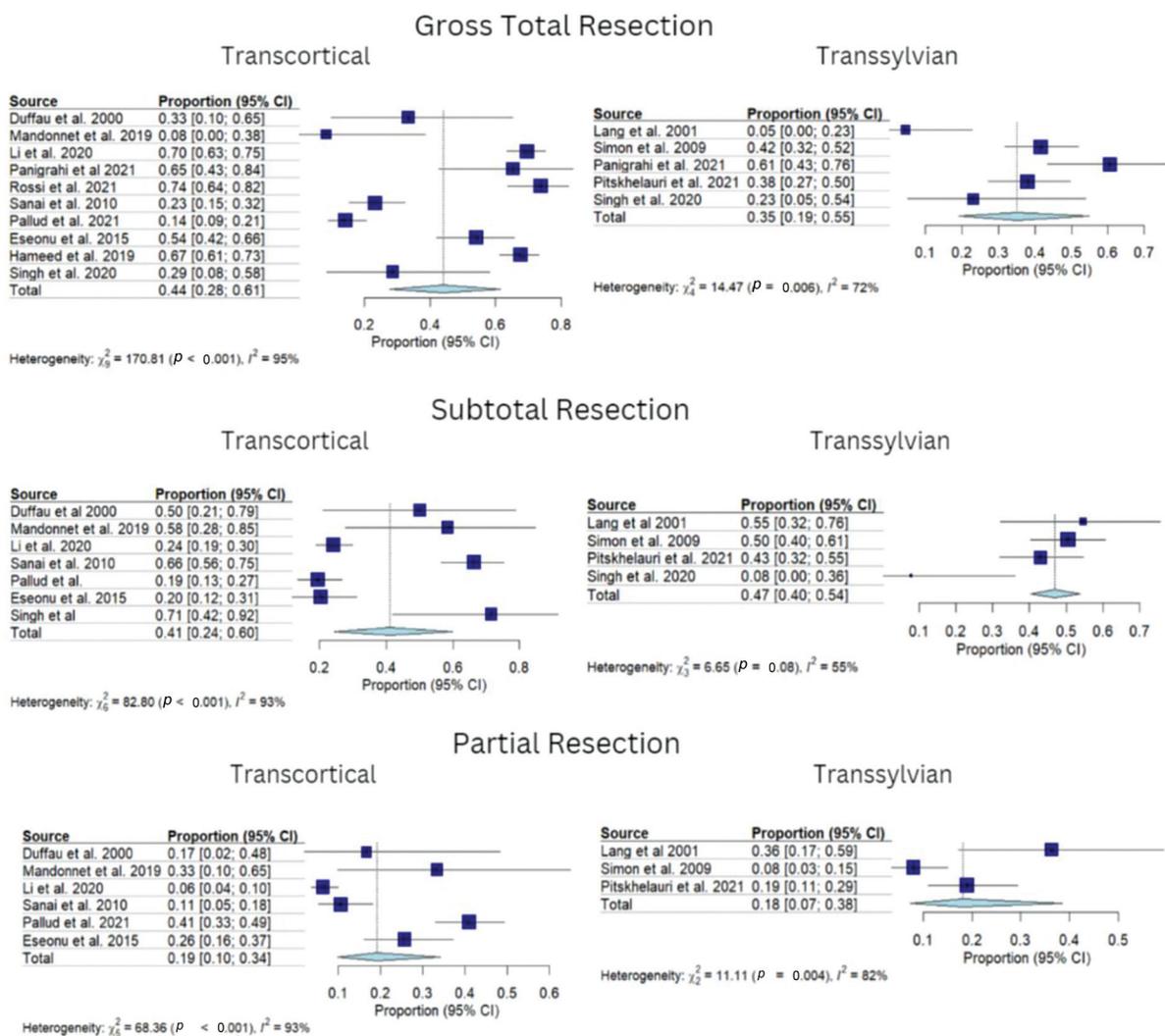
Abbreviations: LSA, lenticulostriate artery; MCA, middle cerebral artery; NR, not reported; TC, transcortical; TS, transsylvian.

<sup>a</sup>Within 3 months.

<sup>b</sup>After 3 months

<sup>c</sup>One-month follow-up.

<sup>d</sup>One-year postop.



**Fig. 3** Forest plots comparing gross total resection, subtotal resection, and partial resection percentages between the two approaches. CI, confidence interval.

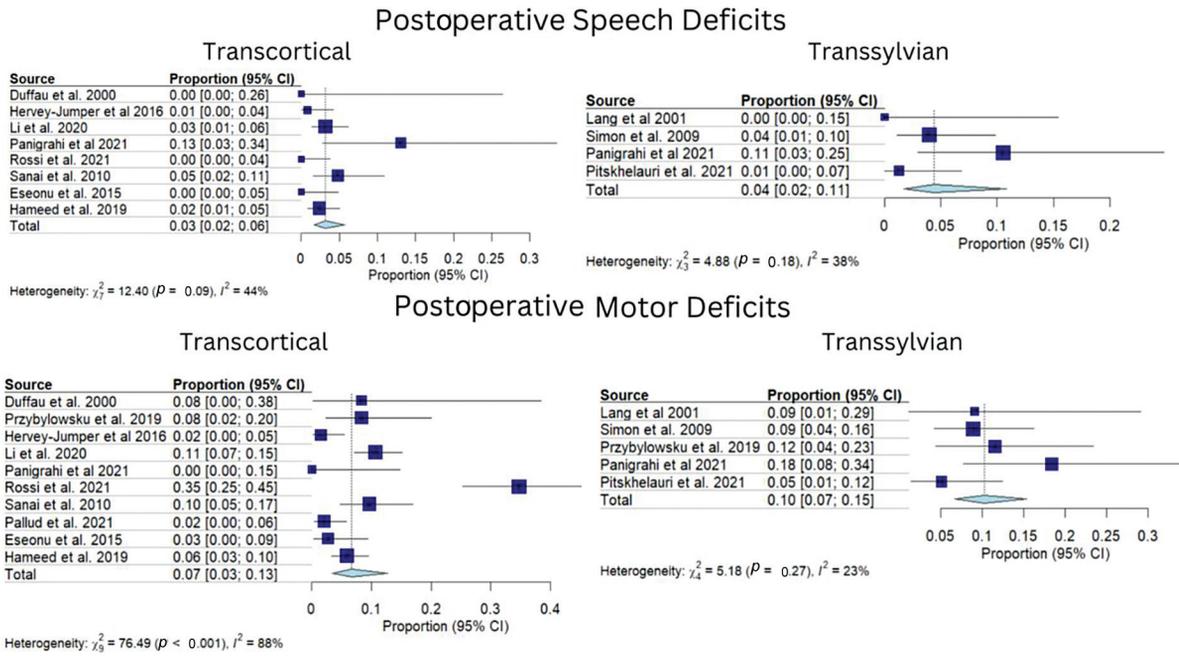


Fig. 4 Forest plots comparing postoperative deficits and motor deficits between the two approaches.

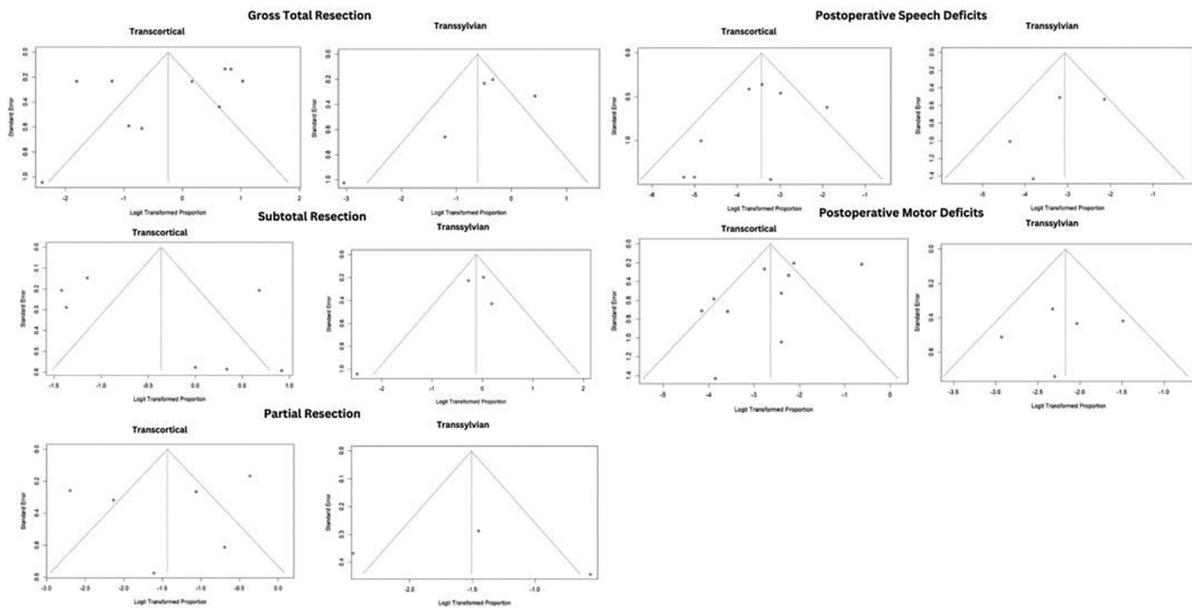


Fig. 5 Funnel plots show publication bias.

**Authors' Contributions**

A.A. contributed to writing the original draft, reviewing and editing the manuscript, and visualization. M.S. was responsible for methodology, supervision, writing, reviewing and editing, project administration, and validation. H.A.I. contributed to conceptualization and to writing the original draft as well as reviewing and editing. H.M.Q. contributed to writing the original draft, reviewing and editing, and visualization. Z.A. and I.B. were involved in investigation, data curation, writing the original draft,

and visualization. A.S.G. contributed to investigation, data curation, and writing the original draft. R.N. contributed to writing the original draft, investigation, and data curation. S.A.K., M.R., and S.A.E. contributed to conceptualization, supervision, project administration, and review. M.O.C. contributed to writing, reviewing, and editing the manuscript.

**Conflict of Interest**

None declared.

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