A Consensus Definition of Supratotal Resection for Anatomically Distinct Primary Glioblastoma: An AANS/CNS Section on Tumors Survey of Neurosurgical Oncologists

Maureen Rakovec
Johns Hopkins University School of Medicine
Adham M. Khalafallah
University of Miami Miller School of Medicine: University of Miami School of Medicine
Oren Wei
Johns Hopkins University
David Day
Johns Hopkins University
Jason P. Sheehan
University of Virginia Health System
Jonathan H. Sherman
West Virginia University
Debraj Mukherjee (dmukher1@jhmi.edu)
Johns Hopkins University School of Medicine https://orcid.org/0000-0002-5403-8237

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Abstract

Introduction:

Supratotal resection (SpTR) of glioblastoma may be associated with improved survival, but published results have varied in part from lack of consensus on the definition and appropriate use of SpTR. A previous small survey of neurosurgical oncologists with expertise performing SpTR found resection 1-2 cm beyond contrast enhancement was an acceptable definition and glioblastoma involving the right frontal and bilateral anterior temporal lobes were considered most amenable to SpTR. The general neurosurgical oncology community has not yet confirmed the practicality of this definition.

Methods

Seventy-six general neurosurgical oncology members of the AANS/CNS Tumor Section were surveyed using a crowdsourcing approach. Participants were presented with 11 definitions of SpTR and rated each definition’s appropriateness. Participants additionally reviewed magnetic resonance imaging for 10 anatomically distinct glioblastomas and assessed the tumor location's eloquence, perceived equipoise of enrolling patients in a randomized trial comparing gross total to SpTR, and their personal treatment plans.

Results

Fifty-two neurosurgeons (73.2%) agreed that resection 1-2 cm beyond contrast enhancement was an acceptable definition for SpTR. Cases were divided into three anatomically distinct groups by perceived equipoise between gross total and SpTR. The best clinical trial candidates were right anterior temporal (n=58, 76.3%) and right frontal (n=55, 73.3%) glioblastomas.

Conclusion

Support exists within the neurosurgical oncology community to adopt the proposed consensus definition of SpTR of glioblastoma and to treat right anterior temporal and right frontal glioblastomas using SpTR. A smaller proportion of general neurosurgical oncologists than SpTR experts consider SpTR feasible in the left anterior temporal lobe.

Introduction

Glioblastoma (GBM) is the most common adult primary central nervous system cancer, accounting for 45.6% of all primary brain malignancies with an annual incidence of 3.1 per 100,000 [1, 2]. It is highly aggressive with histopathological characteristics including necrosis, endothelial proliferation, anaplasia, and high mitotic rates [3]. GBM is also resistant to current treatment protocols. The median survival of

GBM patients is only approximately 15 months following the standard of care: surgery, radiotherapy, and temozolomide [1, 4].

GBM's tendency to infiltrate the parenchyma beyond contrast-enhancing regions seen on magnetic resonance imaging (MRI) contributes to its aggressiveness [1, 5]. While gross total resection (GTR) of gadolinium-enhancing tumor is correlated with increased survival time and decreased disease progression compared to subtotal resection (STR) or biopsy, recurrence is usually inevitable at or near the primary resection site [6–10]. Encouraged by studies that established a relationship between supratotal resection (SpTR) of low grade gliomas and improved overall survival (OS) without increased incidence of new, post-operative deficits, neurosurgical oncologists have begun to use this technique with IDH-wildtype GBM [11, 12].

Recent systematic reviews have demonstrated that SpTR of GBM can improve OS, likely by excising non-contrast enhancing neoplastic cells in high-signal, T2 fluid-attenuated inversion recovery (FLAIR) regions on MRI [11, 13–15]. However, authors observed heterogeneity in the magnitude of OS improvement achieved using SpTR, attributable to differences in how SpTR was defined. Further, a delicate balance between tumor burden reduction and preservation of neurologic function must be achieved when SpTR is used. This has encouraged its use in relatively non-eloquent areas of the brain, though the effect of tumor location on OS after SpTR has not yet been definitively established.

Our group has previously used crowdsourcing, a technique that draws on the collective knowledge of a community, to address the need for a single definition for SpTR in GBM, as well as to produce consensus on the anatomical locations most amenable to this technique [16]. Based on the judgment of 21 members of the neurosurgical oncology community with expertise performing SpTR to treat GBM, we previously proposed GTR plus resection 1 to 2 cm beyond contrast-enhancement as an appropriate consensus definition of SpTR, with GBMs in the right frontal, right anterior temporal, and left anterior temporal lobes being the best SpTR candidates. This study again uses crowdsourcing while investigating potential support for a SpTR strategy in GBM among a larger, more general neurosurgical oncology community.

Methods

Survey Creation

A comprehensive literature search identified eleven definitions for SpTR of GBM and four definitions of eloquence (**Supplement**) [14, 17–31]. To investigate the anatomic locations where SpTR was considered an appropriate treatment for GBM, preoperative MRI data was sourced from 10 de-identified adult (≥18 years) GBM patients (**Supplement**). This study was exempt from obtaining patient consent; all radiographic data was de-identified as required by Health Insurance Portability and Accountability Act (HIPAA) regulations and institutional review board protocol (IRB00196609).

Survey Distribution and Data Collection

The survey and its responses were created, distributed, and stored using Qualtrics software, Version XM (Qualtrics, Provo, UT). An invitation to participate in a 72-question online survey (**eAppendix**) was sent via email to all members of the AANS/CNS Section on Tumors in two waves between January 20 and February 25, 2021. Demographic information was collected from each participant (**Supplement**). To reduce survey fatigue, participants were informed that they could complete the survey in multiple sittings.

For each of the eleven definitions of SpTR, survey respondents were asked if they strongly agreed, agreed, disagreed, or strongly disagreed that it was appropriate to use in a potential future clinical trial assessing SpTR for GBM. They then identified which of four definitions of eloquence was consistent with how they described areas of the brain; if no option was appropriate, they provided their own definition under the option "other."

For each of the ten anatomically distinct GBM cases, survey respondents reviewed MR images and categorized the eloquence of the tumor's location, indicated whether it would be reasonable to randomize it to SpTR or GTR, and identified their personal treatment plan and any adjunct perioperative techniques they would use (**Supplement**). Consensus on each case's eloquence, equipoise, or treatment plan was defined as at least 70% agreement among the respondents, following past conventions [32, 33].

Statistical Analysis

Statistical analyses were performed with R version 4.0.3 and Microsoft Excel 2021. P values <0.05 were considered statistically significant (**Supplement**). A "resectability index" (RI) was calculated for each case to quantify and compare the perceived level of resectability of each GBM [34] (**Supplement**).

Results

Demographic Characteristics of Survey Respondents

A total of 76 neurosurgical oncologists completed the survey, representing 34.0% of the 223 members of the AANS/CNS Tumor Section invited to participate who opened the survey. The cohort's median time practicing neurosurgery was 10 years (interquartile range, IQR 5-25 years, Table 1). Most respondents (n=61, 80.3%) practiced in an academic setting; ten (13.2%) were employed at a community hospital, and 11 (17.7%) worked in private practice. The scope of practice of most neurosurgeons surveyed included intra-axial tumors (n=60, 78.9%). A total of 32 participants (42.1%) formally completed a neuro-oncology fellowship. The median number of SpTRs for GBM performed by the cohort annually and in total were 2 (IQR 0.8-5) and 20 (IQR 5-50), respectively.

Table 1
Practice characteristics of neurosurgeons who participated in this crowdsourcing survey.

Variable	All respondents (n=76)
Years in Practice*	
Mean (SD)	15.4 (12.8)
Median (IQR)	10 (5-25)
Practice Setting, n (%)	
Academic hospital	61 (80.3)
Community hospital	10 (13.2)
Academic-affiliated private practice	7 (9.2)
Private practice with partners	4 (8.5)
Practice Focus, n (%)	
Intra-axial tumors	60 (78.9)
Skull base tumors	40 (52.6)
General neurosurgery	33 (43.4)
Spine tumors	19 (25.0)
Neuro-oncology Fellowship, n (%)	
Yes	32 (42.1)
No	44 (57.9)
Intraoperative Techniques Utilized, n (%)	
Functional MRI	59 (80.8)
Diffusion Tensor Imaging	56 (76.7)
Awake craniotomy with speech mapping	53 (72.6)
Asleep motor mapping	55 (75.3)
Awake craniotomy with motor mapping	51 (69.9)
5-ALA fluorescence guided surgery	38 (52.1)
Ultrasound	44 (60.3)
MRI	23 (31.5)

*Missing 5 for years in practice, 7 for annual and total SpTR counts

Variable	All respondents (n=76)
Intraoperative Mapping Training, n (%)	
Yes	37 (48.7)
No	39 (51.3)
SpTR of GBM Performed, Median (IQR)*	
Annually	2 (0.8-5)
Total	20 (5-50)
*Missing 5 for years in practice, 7 for annual and total SpTR counts	

Table 2

A. Agreement and disagreement among 76 neurosurgical oncologists regarding 11 published definitions of SpTR for GBM. **2B.** The neurosurgical oncologists were also provided with four published definitions of eloquence and asked to indicate how they defined eloquent brain structures.

2A. Definitions of SpTR*	**Disagree or Strongly Disagree, n (%)**	**Agree or Strongly Agree, n (%)**
Extent of T2 FLAIR Resection		
Any decrease in post-op FLAIR volume	32 (45.1)	39 (54.9)
GTR + >25% of FLAIR abnormality region	37 (52.1)	34 (47.9)
GTR + >45-50% of FLAIR abnormality region	43 (62.3)	26 (37.7)
GTR + >54% of FLAIR abnormality region	44 (62.9)	26 (37.1)
GTR + >75% of FLAIR abnormality region	39 (55.7)	31 (44.3)
GTR + 100% of FLAIR abnormality region	27 (37.5)	45 (62.5)
Other Extent of Resection Definitions		
Any resection beyond GTR	21 (29.2)	51 (70.8)
GTR + resection of edematous tissue involved radiographically normal gyrus	22 (31.0)	49 (69.0)
GTR + any resection of non-contrast enhanced disease	**14 (19.7)**	**57 (80.3)**
Resection 1-2 cm beyond contrast enhancement	**19 (26.8)**	**52 (73.2)**
GTR + resection of surrounding non-eloquent, radiographically normal cortex and white matter	38 (52.8)	34 (47.2)
2B. Definitions of Eloquence*		Agree, n (%)
Reference areas of the brain that speak to readily identifiable neurologic function and, if injured, result in a disabling neurologic deficit.		**50 (67.6)**
Areas of the brain are eloquent if they are functional as determined by intraoperative functional mapping.		16 (21.6)
Areas of the brain are eloquent if they are functional as determined by preoperative functional MRI.		1 (1.4)
All areas of the brain are eloquent.		5 (6.8)
Other**		2 (2.7)
*Missing 1 for SpTR definitions, Missing 3 for eloquence definitions **"Other" includes "Combination of 1 and 3—cortex defined by functional mapping, subcortical structures defined by known anatomical reference" and "1, 2, and 3"		

Definitions of SpTR and Eloquence

Most neurosurgeons surveyed (n=57, 80.3%) agree or strongly agree that GTR plus resection of any non-contrast enhanced disease is an appropriate definition for SpTR (Table 2A). Compared to the cohort of expert neurosurgical oncologists who previously provided their opinions on this definition, a two proportion z-test demonstrated that a similar fraction agreed or strongly agreed that it was fitting (Experts: n=18, 85.7%; Tumor Section: n=57, 80.3%; p=0.575) [33]. GTR plus resection 1-2 cm beyond contrast-enhancing disease was the second most commonly endorsed definition, with 52 (73.2%) neurosurgeons agreeing or strongly agreeing with this definition of SpTR. There were no significant relationships between demographic variables, including time in practice, practice setting, or SpTRs performed in the last year or in total, and support for this definition. When asked to indicate how they defined eloquence, over two-thirds of the cohort chose “reference areas of the brain that speak to readily identifiable neurologic function and, if injured, result in a disabling neurologic deficit” (n=50, 67.6%, Table 2B). Only five (6.8%) neurosurgeons surveyed considered the entire brain eloquent.

Agreement Among Surgeons on Eloquence of GBM Location and Treatment Plan

There was consensus that GBMs in the left thalamic (97.3%) and right occipital (70.7%) regions were eloquent (Figure 1). Right anterior temporal (62.7%) and right frontal (58.7%) GBMs were considered located in non-eloquent regions by the majority of the cohort. There was no significant difference between the fractions of the cohort that described the right anterior temporal and right frontal GBMs in non-eloquent locations in a two proportion z-test (p=0.174). Neurosurgeons who considered the entire brain eloquent were more likely to label the right cerebellar GBM as near-eloquent (p=0.0235) relative to those who define eloquence as “distinct areas of the brain with readily identifiable neurologic function”; there were no other correlations between surgeons’ definition of eloquence and the perceived eloquence of the cases.

Figure 2 illustrates the treatment plans for each case and corresponding RI and variance calculations. The majority of the cohort agreed that right anterior temporal and right frontal GBMs were amenable to SpTR (69.3% and 58.7%, respectively). A smaller percentage (40.0%) chose SpTR as their treatment plan for the left anterior temporal GBM; neurosurgeons who described this location as eloquent or near-eloquent were significantly less likely in chi-square analysis to recommend SpTR as the treatment plan (p=0.039). However, the cohort still agreed that an aggressive treatment plan such as SpTR or GTR should be pursued for this GBM, as demonstrated by its relatively high RI value (4.37). A significant number of those who would resect these three GBMs indicated that they would utilize 5-Aminolevulinic acid (5-ALA) fluorescence as an intra-operative adjunct (right anterior temporal: n=42; right frontal: n=48; left anterior temporal: n=50; **Supplement**). The cohort was most divided on the optimal treatment plan for the right insular GBM; this case had the lowest sum of squares and therefore the greatest variance between proposed treatment plans (684).

Agreement Among Surgeons Regarding Equipoise Between SpTR and GTR

When asked which cases would be amenable to enrollment in a clinical trial that would randomize patients to either SpTR or GTR, the neurosurgical oncologists reached consensus that right anterior temporal (n=58, 76.3%) and right frontal (n=55, 73.3%) GBMs would probably or definitely be appropriate (Table 3). Though not reaching the 70% threshold for consensus, a significant percentage of the cohort (n=48, 64.0%) also considered the left anterior temporal GBM to be a randomization candidate. Consensus within the cohort was greatest to not randomize patients with a left thalamic GBM to such a clinical trial (n=63, 84.0%) as indicated by its high sum of squares (2168.0).

Table 3

A crowdsourcing approach revealed consensus among neurosurgeons regarding the equipoise of GTR or SpTR for anatomically distinct GBMs. A higher total sum of squares indicates greater agreement between surgeons to randomize patients to SpTR or GTR. Group A: >70% strong consensus to randomize, Group B: no overwhelming consensus, Group C: >70% strong consensus to not randomize.

Case #	Tumor Location	Probably or Definitely No, N (%)	Maybe, N (%)	Probably or Definitely Yes, N (%)	Total Sum of Squares
Group A					
2	R Ant Temporal	13 (17.1)	5 (6.6)	58 (76.3)	1632.7
4	R Frontal	7 (9.3)	13 (17.3)	55 (73.3)	1368.0
Group B					
9	L Ant Temporal	14 (18.7)	13 (17.3)	48 (64.0)	794.0
8	R Occipital	28 (37.3)	14 (18.7)	33 (44.0)	194.0
7	R Parietal	28 (37.3)	13 (17.3)	34 (45.3)	234.0
1	R Cerebellum	35 (46.1)	10 (13.2)	31 (40.8)	360.7
5	R Post Temporal	30 (40.0)	18 (24.0)	27 (36.0)	78.0
6	R Insular	36 (48.0)	15 (20.0)	24 (32.0)	222.0
3	L Frontal	39 (51.3)	13 (17.1)	24 (31.6)	340.7
Group C					
10	L Thalamus	63 (84.0)	5 (6.7)	7 (9.3)	2168.0
R: Right; L: Left; Ant: Anterior; Post: Posterior					
*Missing 1 for cases 4-10					

Variations in the Applicability of SpTR by GBM Location Between General Neurosurgical Oncologists and Experienced SpTR Providers

Previously, 21 neurosurgical oncologists with experience performing SpTR for GBM provided their opinions on the appropriateness of SpTR as a treatment plan for the 10 cases included in this survey [16].

Compared to the experts, a significantly smaller fraction of AANS/CNS Tumor Section members recommended SpTR as their treatment plan of choice for GBMs in two locations (**Supplement**). For the right frontal GBM, 18 (85.7%) SpTR experts chose SpTR as their treatment option, while a significantly smaller fraction of the Tumor Section cohort (n=44, 58.7%) recommended SpTR (p=0.023). Notably, a similar fraction of experts and generalists recommended SpTR for the right anterior temporal GBM (Experts: n=14, 70%; Tumor Section: n=52, 69.3%; p=0.999). SpTR was chosen as the preferred treatment for the left anterior temporal GBM by 15 (78.9%) neurosurgeons in the expert cohort and 30 (40.0%) in the Tumor Section cohort (p=0.004).

Discussion

This survey demonstrates crowdsourcing's ability to provide insights into complex neurosurgical debates. The neurosurgical oncologists who completed this survey varied significantly in their practice setting and focus, as well as their personal experience performing SpTR for GBM. However, consensus was still reached in this large, diverse group of neurosurgical oncologists on a number of questions about SpTR for GBMs in specific anatomical regions. This encourages further use of the "wisdom of the crowd" approach to inform decisions regarding patient care where no one treatment has been conclusively proven superior [32, 34].

These results also provide support for our previously proposed consensus definition of SpTR for GBM [16]. There is a considerable need to adopt a single definition, as the multitude of definitions currently in use has obscured the impact of SpTR on OS in GBM. The 2018 systematic review and meta-analysis by Jackson et al. including 11 studies and 810 patients reported a survival benefit with SpTR over GTR in 9 of 11 studies (SpTR median OS 12-54 months; GTR median OS 11-17.5 months) [14]. However, the authors noted significant heterogeneity between the methods used in the included studies, and secondarily elected to divide studies into three subgroups based on their definition of SpTR, including extent of T2 FLAIR resection, extended anatomical resection, and intra-operative 5-aminolevulinic acid (5-ALA) fluorescence-guided resection. Meta-analysis in the more homogenous extended anatomical resection subgroup demonstrated a statistically significant 35% lower risk of mortality among 88 GBM patients who underwent SpTR versus 95 patients who received GTR (HR = 0.65, 95% CI 0.47–0.91; p = 0.003). This study, the largest systematic review to date on the efficacy of SpTR, supports the selection of a single, anatomically-based definition for SpTR.

Similar to our previous survey of 21 neurosurgical oncologists with experience performing SpTR for GBM, "GTR plus any resection of non-contrast enhanced disease" was the most commonly positively endorsed definition, with a similar fraction of each cohort agreeing or strongly agreeing that it was an acceptable definition for SpTR. However, as previously discussed, this definition would not standardize clinical research involving SpTR, provide a quantifiable benchmark for what can and cannot be classified as SpTR, or allow a neurosurgeon to determine when SpTR has been achieved using intraoperative navigation [16]. For these reasons and in light of the corpus of literature that demonstrates GBMs most often recur within 2 cm of the original contrast-enhancing tumor's margins, we recommend that "GTR

plus resection 1-2 cm beyond contrast enhancement" be implemented as a standardized definition of SpTR for GBM in clinical practice and future research studies [15, 21, 35–40]. A consensus of the AANS/CNS Tumor Section members who completed this survey support the adoption of this definition.

Similar to the results of surveying neurosurgical oncologists with expertise performing SpTR for GBM, the AANS/CNS Tumor Section cohort considered right frontal and right anterior temporal GBMs to be located in non-eloquent regions, amenable to SpTR, and appropriate to enroll in a clinical trial comparing SpTR to GTR. Of note, while the Tumor Section cohort found the right frontal GBM appropriate to enroll in a SpTR vs. GTR clinical trial by consensus, it was mildly more reticent to choose SpTR as the treatment they would personally perform relative to the right anterior temporal GBM; while 52 (69.3%) neurosurgeons thought SpTR was the best treatment for the right anterior temporal GBM, a smaller though still considerable fraction (n=44, 58.7%) would perform SpTR of the right frontal GBM. This trend does not appear to be associated with the relative perceived eloquence of the involved tissues but may be because the practice of performing lobectomy for GBM in the right temporal lobe is relatively well-known and supported by literature that demonstrates improved survival without increased frequency of post-operative deficits, while studies on the effect of SpTR specifically in the right frontal lobe are less common [41–43].

When previously surveyed, the 21 SpTR experts also agreed by consensus that the left anterior temporal GBM was amenable to SpTR vs. GTR randomization. This current cohort of more general neurosurgical oncologists, however, did not reach the 70% threshold for consensus. Compared to those with SpTR expertise (n=15, 78.9%), a significantly smaller fraction of neurosurgical oncologists from the Tumor Section designated SpTR as their chosen treatment for this GBM (n=30, 40.0%, p=0.004). This relative reluctance of the general neurosurgical oncologists to perform SpTR in this area may be related to the perceived eloquence of surrounding tissue, which includes Broca's and Wernicke's areas, visual fibers, and auditory cortex. Inadvertently injuring adjacent tissue involved in language could have a severe impact on quality of life, but such deficits have also been associated with decreased survival [44, 45]. These risks can be reduced by performing an awake craniotomy with speech mapping for the resection of left anterior temporal GBMs [12, 46, 47]. Of the 72 respondents who selected which intraoperative adjunctive methods they would employ during the resection of a left anterior temporal GBM, 32 (44.4%) indicated that they would use this technique; 53 of 76 survey respondents (72.6%) reported that they routinely perform awake craniotomies with speech mapping in their practice. Increasing this modality's usage during the resection of left anterior temporal GBMs may encourage the wider neurosurgical community to consider performing SpTR for GBM in this region.

While this crowdsourcing survey is valuable for demonstrating consensus among the broader neurosurgical community on the preferred treatment of right frontal and anterior temporal GBMs, it is equally useful for revealing the anatomic locations of GBM where there is less agreement on optimal treatment. The proposed treatments for right insular GBM varied widely within the AANS/CNS Tumor Section cohort. While some felt that pursuing SpTR was reasonable, others recommended less aggressive interventions including LITT and SRS; even a simple majority could not agree on a treatment plan.

Historically, neurosurgeons have been hesitant to resect insular tumors due to this cortex's eloquence, complex shape, and relationship to the internal and middle cerebral arteries [48]. However, as the relationship between extent of resection and OS in insular high-grade gliomas has become clearer, increasing extent of resection while reducing morbidity using improved microsurgical and intraoperative adjunctive techniques has become increasingly recommended [6, 7, 48, 49]. Alimohamadi et al., for instance, demonstrated the potential of adjuncts including fMRI, diffusion tensor imaging (DTI), and awake craniotomy with intraoperative speech and motor mapping to yield high extent of resection without increased mortality or new major neurologic morbidities [50]. Hervey-Jumper and Berger reinforce that awake craniotomy with cortical and subcortical stimulation mapping during insular glioma resection results in lower rates of neurological deficit than resections performed without mapping (with: 4.3%; without: 19%; p=0.008) [48]. Again, further study and more widespread adoption of these techniques may encourage more aggressive intervention for insular GBMs and longer survival times for these patients.

Limitations

The individuals who completed this survey were recruited via email invitation and were not financially compensated. If these neurosurgeons chose to participate because they hold strong opinions about SpTR, the internal validity of the results may have been influenced by response bias.

Participants were asked to make decisions about the treatment of GBM patients using only anatomical information. However, when making decisions about surgical treatment of GBM, clinical factors are necessarily taken into account. The cases included in this study were taken from non-elderly and functional patients, which may limit the applicability of the results to older or less robust populations. In addition, extent of resection is often dependent intra-operatively on data from 5-ALA fluorescence or other adjuncts. This information was not provided on the survey in order to directly investigate the relationship between proposed treatment plans and anatomy alone; however, this constraint also limited the results' generalizability.

Conclusion

Support exists among the general neurosurgical oncology community to adopt resection 1-2 cm beyond contrast enhancement as a standardized definition for future clinical work and research studies investigating SpTR for GBM. GBMs involving the right frontal and right anterior temporal lobes are considered most amenable to SpTR by a group of general neurosurgical oncologists. A discrepancy exists between the proportion of SpTR experts and general neurosurgical oncologists who consider SpTR feasible in the left anterior temporal lobe. These results support planning prospective studies, including future clinical trials, to reinforce the clinical utility of SpTR for GBMs in the right frontal and right anterior temporal lobes, and encourages further research and discussion about the applicability of SpTR to GBMs in the left anterior temporal lobe.

Declarations

Reporting Guidelines: We found no applicable reporting guidelines that would apply to this article. By following the EQUATOR reporting guidelines decision tree, (http://www.equatornetwork.org/wp-content/uploads/2013/11/20160226-RG-decision-tree-for-Wizard-CC-BY-26- February-2016.pdf), we found that none of the most popular checklists are appropriate for our study design.

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Data Availability: The datasets generated during and/or analysed during the current study are available from the corresponding authors on reasonable request.

Ethics Approval: This study was reviewed and approved by the Johns Hopkins institutional review board (IRB00196609).

Consent to Participate and Publish: This study was exempt from obtaining patient consent from patients whose radiographic data was used to generate the survey, as all data was de-identified as required by Health Insurance Portability and Accountability Act (HIPAA) regulations and institutional review board protocol (IRB00196609). Informed consent was obtained from all participants who completed the crowdsourcing survey.

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Figures

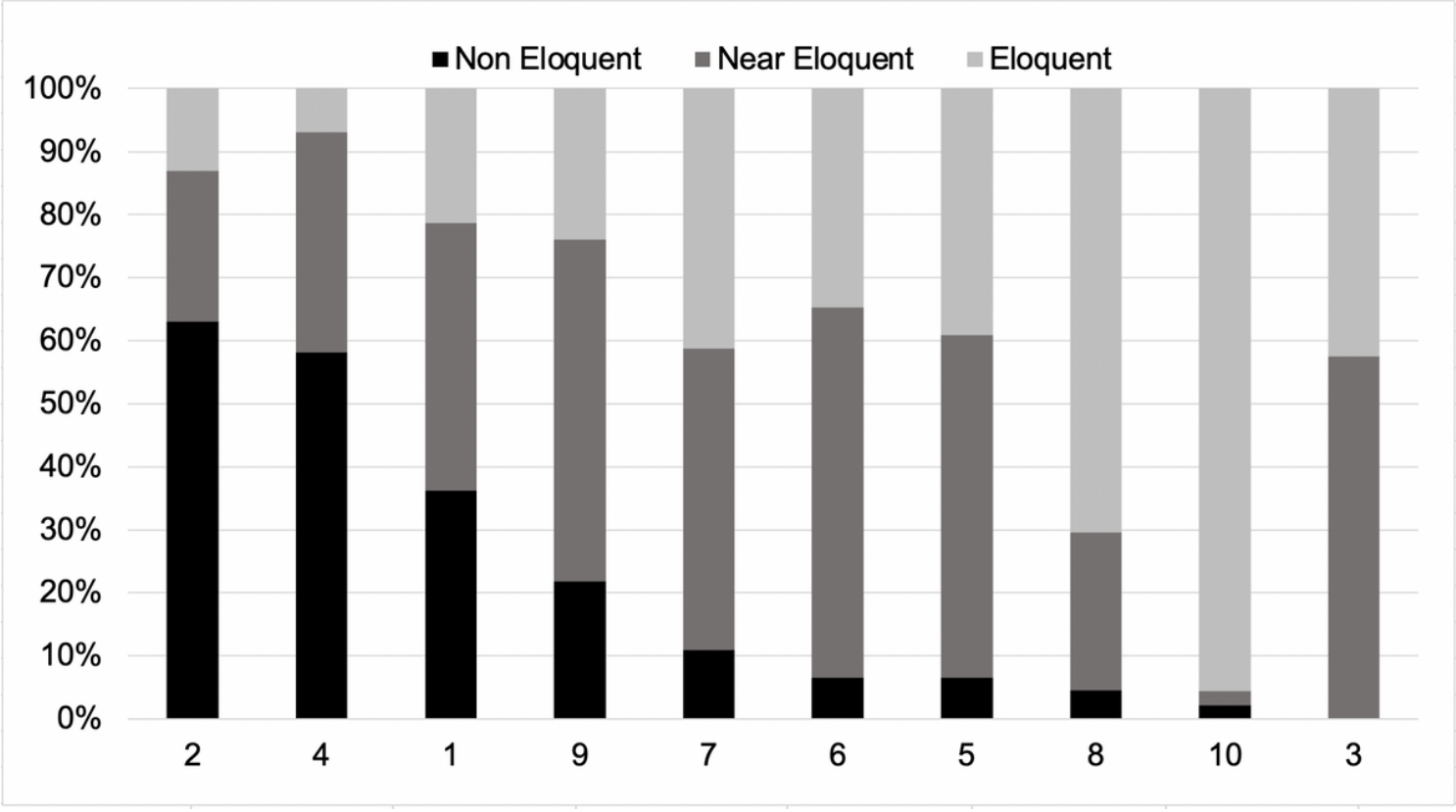

Figure 1

The percentage of neurosurgical oncologists who rated each GBM's location as non-eloquent, near eloquent, or eloquent. R: Right; L: Left; Ant: Anterior; Post: Posterior

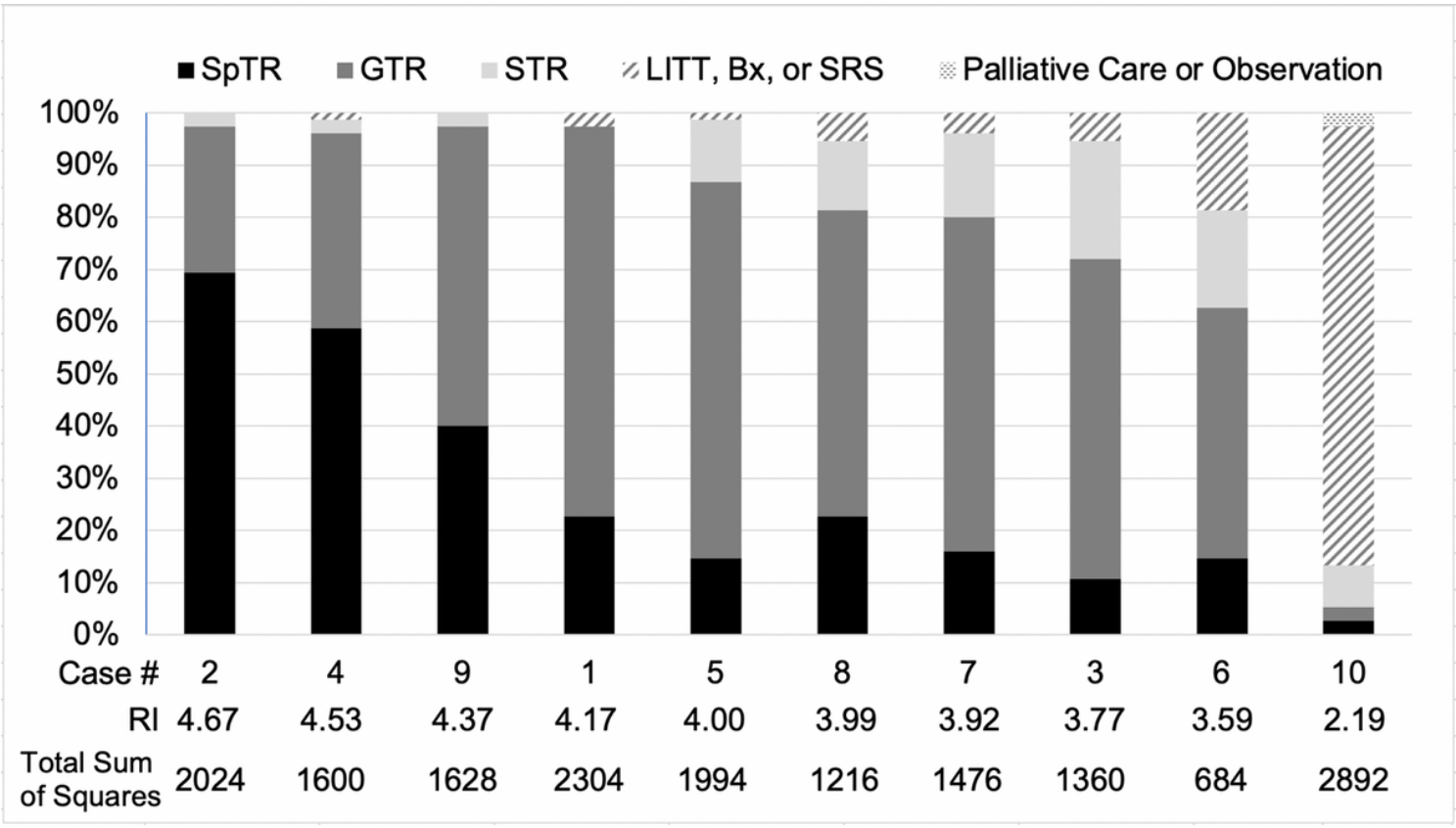

Figure 2

The percentage of neurosurgical oncologists who selected palliative care or observation; laser interstitial thermal therapy (LITT), stereotactic biopsy, excisional biopsy (Bx), or stereotactic radiosurgery (SRS); subtotal resection (STR); gross total resection (GTR); or supratotal resection (SpTR) for each case. The resectability index (RI) and total sum of squares for each case are listed below. A higher RI value represents a GBM that is considered on average to be amenable to more aggressive treatment, such as SpTR; a higher total sum of squares indicates greater agreement between surgeons on proposed treatment plan. Differences between cases' RIs are statistically significant as determined by ANOVA ($p < 0.0005$). R: Right; L: Left; Ant: Anterior; Post: Posterior

Supplementary Files

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