Journal of Neuro-Oncology (2026) 176:129
https://doi.org/10.1007/s11060-025-05383-5

RESEARCH

Connectomics in brain tumor surgery: large-scale clinical feasibility and hypothesis-generating tractometry findings

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Received: 17 November 2025 / Accepted: 12 December 2025

Abstract

Background Maximal tumor resection with neurological preservation is central to brain tumor surgery. This study evaluates the integration of an artificial intelligence-based connectomics platform for surgical planning, with exploratory tractometry analysis of postoperative white matter changes.

Methods We retrospectively reviewed 192 consecutive brain tumor surgeries performed between April 2023 and April 2025 using preoperative connectomic mapping (Quicktome, Omniscient Neurotechnology). Functional outcomes were assessed with Karnofsky Performance Status (KPS). In an opportunistic subgroup ($n=13$), paired pre- and postoperative imaging enabled tractometry (Cleartome). Fractional anisotropy (FA) was measured across six major tracts, and three hemispheric FA asymmetry indices were calculated: difference in average FA (Diff FA), asymmetry index (AI), and percentage asymmetry (%Asym).

Results The cohort included intra-axial and extra-axial tumors. Median KPS remained stable at 3 months after surgery. In the tractometry subgroup, 12 of 13 patients showed postoperative shifts toward improved interhemispheric FA symmetry in at least one tract. Left-hemisphere cases most often showed changes in the uncinate fasciculus (UF) and inferior fronto-occipital fasciculi (IFOF) (median AI = −0.68 and −0.20, respectively), while right-hemisphere cases demonstrated alterations in the superior longitudinal fasciculus (SLF) (median AI = +5.13; %Asym =-8.43). The corticospinal tract (CST) and IFOF improved in 61.5% of analyzed cases. Tract-based asymmetry indices captured subtle connectivity changes not evident in raw FA values alone.

Conclusions Routine clinical use of AI-guided connectomics in brain tumor surgery was feasible, with stable short-term functional outcomes. Tract-based hemispheric FA asymmetry metrics suggested postoperative microstructural alterations; findings remain preliminary and warrant further prospective validation.

Keywords Connectome · Tractography · Brain networks, fractional anisotropy · Cognition · Quicktome

Introduction

Contemporary brain tumor surgery seeks to maximize resection while preserving neurological function, a principle commonly termed the "onco-functional balance" [1, 2]. Traditionally, surgical eloquence has been defined by cortical landmarks corresponding to sensory, motor, or language functions. Advances in functional neuroimaging and network neuroscience have expanded this classical definition to include higher-order networks, such as the default mode network (DMN), salience network, and central executive network (CEN), which underpin cognition, executive control, and social-emotional processing [3–7]. Disruption of these distributed systems can significantly impact postoperative quality of life.

This evolving perspective has prompted a shift away from a purely localizationist framework toward a network-based model of brain function, in which behavior arises from interactions across distributed systems rather than isolated cortical regions [8–10]. Both the extent of tumor resection and the preservation of function independently influence survival and long-term outcomes [11–14]. Accordingly,

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neurosurgical planning in experienced centers now frequently incorporates advanced imaging and intraoperative mapping modalities such as diffusion weighted imaging (DWI), functional magnetic resonance imaging (fMRI), and magnetoencephalography (MEG) [15–18]. However, these approaches primarily emphasize focal tract preservation and provide limited means to quantify network-level alterations across the perioperative course.

Artificial intelligence-driven connectomics platforms, such as Quicktome (Omniscient Neurotechnology), address this limitation by generating individualized structural and functional network maps derived from diffusion-weighted and resting-state fMRI data, anchored to the Human Connectome Project Multi-Modal Parcellation (HCP-MMP) atlas [19]. Prior work has demonstrated their value for preoperative surgical planning, particularly in identifying canonical and non-canonical eloquent networks [20–24]. Less is known about their potential for postoperative assessment of structural network changes.

In this study, we describe the large-scale clinical implementation of connectomics in a consecutive series of patients undergoing brain tumor resection. As a secondary, exploratory analysis, we examined a small subgroup with paired pre- and postoperative imaging using tract-based fractional anisotropy (FA) asymmetry indices. These indices—difference in average FA (Diff FA), asymmetry index (AI), and percentage asymmetry (%Asym)—provide relative measures of hemispheric balance and may be more sensitive than absolute FA values for detecting subtle postoperative microstructural alterations. We hypothesized that tumor resection would be associated with shifts in FA asymmetry indices toward reduced hemispheric imbalance, reflecting postoperative network-level change. Given the limited cohort size and variability in imaging intervals, these analyses are intended as hypothesis-generating rather than definitive.

Methods

Patient selection

We conducted a retrospective, institutional review board–approved study of consecutive patients undergoing brain tumor surgery at the two tertiary neurosurgical centers (Lenox Hill Hospital and North Shore University Hospital) of our institution between April 2023 and April 2025. Inclusion criteria were: (1) successful preoperative processing with Quicktome Neurological Visualization Software v2.1.0 (Omniscient Neurotechnology, Sydney, Australia), and (2) availability of core clinical variables (demographics, tumor features, operative details, disposition). Cases were excluded for failed connectome processing or incomplete records. Functional status was assessed using Karnofsky Performance Status (KPS) at baseline and at the routine ~ 3-month postoperative visit. Discharge disposition (home, acute rehabilitation, subacute rehabilitation, hospice) was recorded.

Connectomic mapping and tractometry

Neuroimaging was acquired on a 3.0 T Siemens MAGNETOM Vida MRI scanner (Siemens Medical Solutions USA Inc., Malvern, PA, USA). A T1-weighted anatomical scan (MPRAGE, TR/TE: shortest, FOV: 256 mm, slice thickness: 1.00 mm, 190 slices, no slice gap) and a 30-direction diffusion weighted scan (TE/TR: shortest, FOV: 240 mm, voxel size: 2.00 mm^3 isotropic, slice thickness: 2.00 mm, slices: 90, no slice gap, diffusion scheme: bipolar, b-values: 0, 1000) were obtained. When resting-state fMRI was performed, blood oxygen level dependent (BOLD) echo-planar imaging was acquired (FoV: 240 mm, slice thickness: 3.00 mm, TE: 30 msec, TR: shortest, slices 45, slice gap: 0%, flip angle: 90◦, base resolution: 80, phase resolution 100). Patients were instructed to rest quietly with eyes open. BOLD time series were extracted from 360 cortical regions and 17 subcortical structures for seed-based connectivity analysis.

Diffusion and functional MRI data were processed with Quicktome software using the same imaging pipeline as previously described [23]. T1- weighted, diffusion-weighted, and resting-state BOLD datasets were uploaded to the platform for analysis in a HIPAA compliant cloud-based environment. Diffusion data underwent skull stripping, motion and eddy current correction, and gradient distortion correction. FA maps were generated using a diffusion tensor fit, followed by estimation of a single-fiber white-matter response function and constrained spherical deconvolution (CSD) to compute voxel-wise fiber orientation distributions. Whole-brain deterministic tractography with random seeding in white-matter voxels above an FA threshold produced a patient-specific streamline set, which was used to construct structural connectivity based on the HCP-MMP atlas.

Quicktome generated individualized structural/functional maps anchored to the HCP-MMP atlas. Structural connectivity was derived from CSD-based tractography, and resting-state fMRI seed maps were incorporated when available. Canonical and higher-order networks (salience, central executive, default mode, dorsal/ventral attention) were displayed. Six major white-matter tracts were assessed bilaterally: corticospinal tract (CST), superior longitudinal fasciculus (SLF), inferior longitudinal fasciculus (ILF), uncinate fasciculus (UF), arcuate fasciculus (AF), and inferior fronto-occipital fasciculus (IFOF). Processing was completed within routine preoperative planning timelines without measurable workflow delay. Connectome outputs were available to the surgical team during preoperative planning; the present study was not designed to determine whether connectomics altered surgical strategy or outcomes.

Tract-based asymmetry analysis

An opportunistic subgroup of 13 patients had analyzable paired pre- and postoperative imaging suitable for tractometry ($n = 13$). Availability was limited by scan site and protocol roll-out during the study period. Cases were excluded if there was intervening cranial surgery between scans. Tractometry was performed with Cleartome (pre-release; Omniscient Neurotechnology), which provided tract-specific FA for each hemisphere across the six tracts.

For each tract, we computed three FA-based hemispheric asymmetry indices:

1. Difference in Average FA (Diff FA): This measure captures the absolute difference in average FA between hemispheres, where a larger absolute value indicates greater interhemispheric asymmetry. It is computed as:

$$Diff\ FA = R - L$$

2. Asymmetry Index (AI): The AI quantitatively assesses hemispheric asymmetry as a normalized percentage, where positive values indicate higher FA in the right hemisphere, and negative values indicate higher FA in the left hemisphere. It is calculated using:

$$AI = \left(\frac{R - L}{R + L}\right) x\ 100$$

3. Percentage of Asymmetry (%Asym): This metric expresses asymmetry as a standardized percentage difference relative to the right hemisphere. Positive values indicate higher FA on the left, while negative values indicate higher FA on the right hemisphere. Greater absolute values indicate stronger lateralization. Equation:

$$\%Asym = \left(\frac{L}{R} x\ 100\right) - 100$$

These relative indices are intended to mitigate interindividual variability and known hemispheric asymmetries and are interpreted as markers of microstructural imbalance, not direct measures of function [25]. By convention, positive AI values reflect rightward FA dominance, whereas positive %Asym values indicate leftward FA dominance.

Assessment of surgical impact

The primary descriptive outcome for the full cohort was clinical feasibility of routine connectomics integration across consecutive surgeries, summarized alongside short-term functional status (KPS). In the tractometry subgroup, the descriptive endpoint was within patient pre/post change in hemispheric asymmetry per tract. A shift toward reduced hemispheric imbalance was defined a priori as a decrease in the absolute magnitude of AI and/or %Asym (i.e., movement toward zero). Laterality stratified summaries (left- vs. right-hemisphere lesions) were prespecified. Postoperative imaging intervals (days from surgery to MRI) varied according to clinical care and were recorded; this variability is considered a key limitation.

Statistical analysis

Continuous variables are reported as median (interquartile range) and categorical variables as counts (percentages). Within-patient pre/post comparisons for tract indices used the Wilcoxon signed-rank test. Given the exploratory, hypothesis-generating nature and small sample, no correction for multiple comparisons was applied; p-values are therefore nominal.

Results

Patient population

A total of 192 surgeries performed on 173 patients met inclusion criteria (Table 1). Nineteen procedures (9.9%) were repeat operations analyzed as separate surgical events. The study cohort was 53.8% male with a median age of 62.0 years (interquartile range [IQR] 49.0–69.0 years). Most tumors were intra-axial (84.9%), and extra-axial lesions (15.1%) were meningiomas. Among intra-axial pathologies, glioblastoma (42.2%) was the most frequent, followed by metastatic lesions (12.5%)—predominantly lung primary—and astrocytomas (8.9%). Tumors were more often left-hemispheric (53.6%) than right (36.5%). Midline locations (corpus callosum, brainstem, or midline dura) comprised 7.3%. By lobe, frontal predominated (43.2%), followed by the parietal (18.2%) and temporal (17.7%).

Preoperative connectomic mapping was incorporated into planning for all included cases, spanning intra-axial and extra-axial pathologies across diverse locations (Fig. 1). Functional outcomes, as assessed by median KPS, remained

Table 1 Patient characteristics

Variable	No. (%)
Patient-Level Demographics	
Total No. of Patients	173
Male	93 (53.8%)
Female	80 (46.2%)
Median Age [IQR]	62 [49.0–69.0]
Operative-Level Characteristics	
Total no. of Surgeries	192
Repeat Surgeries	19 (9.9%)
Median Preoperative KPS	80
Median 3-Month Postoperative KPS	80
Discharge Disposition	
Home	121 (63.0%)
Acute Rehab	49 (25.5%)
Subacute Rehab	17 (8.9%)
Hospice	2 (1.0%)
Tumor Characteristics	
Intra-Axial Lesions	163 (84.9%)
Extra-Axial Lesions	29 (15.1%)
Laterality	
Left-sided	103 (53.6%)
Right-sided	70 (36.5%)
Midline	14 (7.3%)
Bilateral	5 (2.6%)
Tumor Location	
Frontal	83 (43.2%)
Parietal	35 (18.2%)
Temporal	34 (17.7%)
Occipital	6 (3.1%)
Corpus Callosum	3 (1.6%)
Cerebellum	8 (4.2%)
Other[¶]	20 (10.4%)
Pathology	
Metastatic disease	44 (22.9%)
Primary Brain Tumors	148 (77.1%)
Glioblastoma	81 (42.2%)
Meningioma	29 (15.1%)
Astrocytoma[†]	17 (8.9%)
Oligodendroglioma	10 (5.2%)
Other Tumors[*]	11 (5.6%)
WHO Grade	
WHO Grade 1	5 (2.6%)
WHO Grade 2	18 (9.4%)
WHO Grade 3	17 (8.9%)
WHO Grade 4	73 (38.0%)
IDH Status	
IDH Wildtype	66 (34.4%)
IDH Mutant	28 (14.5%)
MGMT Status	
MGMT Unmethylated	34 (17.7%)

¶Other tumor location includes deep, brainstem, insula, pituitary, cavernous sinus, ventricular system, skull base, and diffuse. †Astrocytoma includes histologic astrocytoma and low-grade glioma *Other Rare Tumors includes Central Neurocytoma, Chordoma, Neurenteric Cyst, Ganglioglioma, Ependymoma, Olfactory Schwannoma, Vestibular Schwannoma, Papillary Glioneuronal Tumor, and Pituitary Tumor

stable postoperatively, with a median KPS of 80 preoperatively and at the 3-month follow-up, indicating short-term preservation of functional status in this consecutive, connectomics planned series. Discharge disposition was home in 63.0%, acute rehabilitation in 25.5%, subacute rehabilitation in 8.9%, and hospice in 1.0%.

Tractometry subgroup (exploratory)

An opportunistic subgroup ($n=13$) had analyzable paired pre- and postoperative imaging suitable for tractometry (Tables 2 and 3). Availability reflected scan site and protocol roll-out; postoperative imaging intervals varied by clinical need and are reported per patient (Table 3).

Across the six prespecified tracts (CST, SLF, ILF, UF, AF, IFOF), 12 of 13 patients exhibited a postoperative shift in at least one tract's hemispheric FA asymmetry index consistent with reduced interhemispheric imbalance (i.e., movement of AI and/or %Asym toward zero) (Fig. 2). Patterns differed by laterality.

Left-hemisphere lesions ($n=5$) most often showed postoperative shifts within the UF and IFOF (e.g., median AI shifts modestly negative; median %Asym modestly positive), consistent with reduced left-right imbalance in these ventral semantic pathways. The median AI and %Asym in the UF was −0.68, and +1.28, respectively. The median AI and %Asym in the IFOF was −0.20 and +0.36, respectively.

Right hemisphere lesions ($n=8$) most often demonstrated postoperative shifts within the SLF with the median AI shifting positive (+5.13), and the median %Asym shifting negative (–8.43) reflecting a rightward change in SLF asymmetry.

When summarized across the entire subgroup, long-range association/projection tracts such as the CST and/or IFOF showed asymmetry reduction in 61.5% of cases (any index). By contrast, the SLF demonstrated a cohort-level increase in AI (median 2.11 to 5.06) across all 13 patients, which reached nominal significance ($p=0.0125$, Wilcoxon signed-rank, uncorrected). This indicates a rightward shift in SLF hemispheric asymmetry at the group level, independent of tumor location. Given small sample size, variable postoperative timing, and no correction for multiple comparisons however, this finding should be viewed as hypothesis generating.

Interindividual variability

Tract-specific changes varied substantially across patients, even within shared anatomical regions and laterality. For example, ILF %Asym ranged from–18.81 to +32.04, and AF AI ranged from −6.10 to +12.18 postoperatively. This heterogeneity underscores the individualized nature of

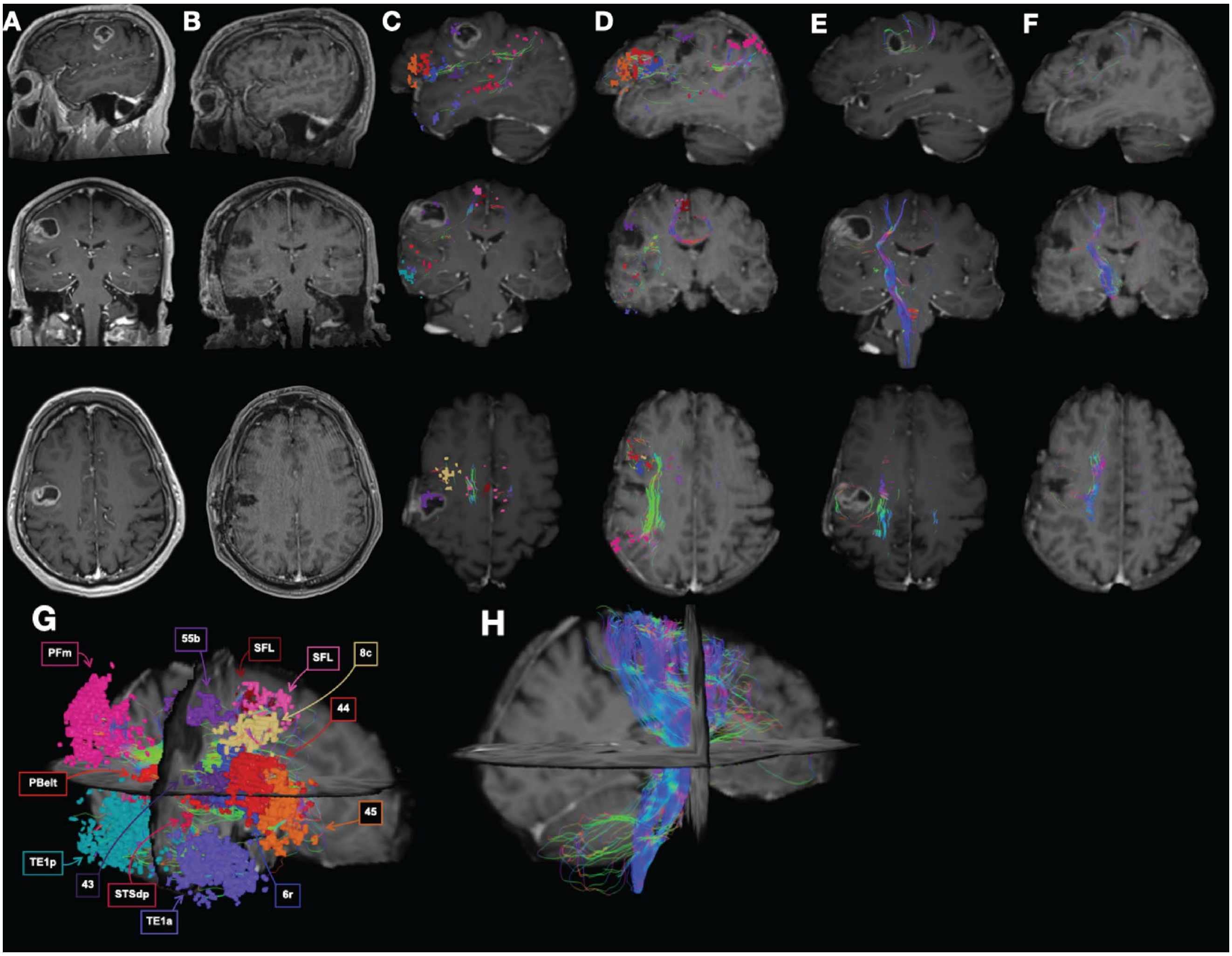

Fig. 1 **A**: Multi-planar reconstructions of a thin cut T1 Post MRI sequence 1 day prior to resection in a 69 year-old male. **B**: Same sequence from the post-op day 1 MRI. Pathology was consistent with Glioblastoma WHO Grade IV. **C**: DWI sequences from the preoperative MRI in part A were used to identify structural connectomics parcels related to language function around the lesion, to aid with planning a surgical approach. **D**: Those same parcels are shown based on DWI sequences from the postoperative MRI. Tracts between parcels are shown in green. **E-F**: depict the corticospinal tract based upon ROI gating in the pons from the same pre-operative (**E**) and post-operative (**F**) MRIs as above. **G-H**: depict 3D reconstructions of these parcels/tracts with corresponding labels. All visualizations are based on QuickTome (TM) software

postoperative white-matter microstructural alteration after tumor resection and supports a patient-specific connectomic assessment rather than reliance on group means.

Across indices, asymmetry-based metrics appeared more sensitive than absolute FA to detect small, postoperative microstructural alterations, particularly within ventral semantic (UF/IFOF) and fronto-parietal (SLF) pathways (Fig. 3). However, interpretation beyond "microstructural alteration" should be cautioned as FA is an indirect measure influenced by edema, gliosis, fiber crossing, acquisition differences, and scan timing. This exploratory analysis should be validated prospectively with standardized intervals and neurocognitive correlation.

Discussion

Contemporary neurosurgical oncology increasingly acknowledges maximal cytoreduction and neurological preservation as determinants of patient survival and quality of life [2, 11–14, 26]. This dual mandate has accelerated a conceptual shift from traditional localizationist approaches toward a network-based model, recognizing that brain functions arise from dynamic interactions across distributed cortical and subcortical networks [3–5, 7–9, 27]. Advances in structural and functional connectivity mapping have facilitated identification and preservation of canonical (e.g., motor, language) and non-canonical eloquent areas,

Table 2 Tractometry data

	All	Right tumors	Left tumors
	N=13	*N*=8 (61.54%)	*N*=5 (38.46%)
CST			
Diff FA	0.01	0.03	0
AI	2.23	3.82	0.32
%Asym	-3.2	-6.93	0.33
SLF			
Diff FA	0.02	0.03	0.01
AI	3.76	5.13	1.98
%Asym	-6.15	-8.43	-3.83
ILF			
Diff FA	-0.01	0.02	-0.01
AI	2.97	3.47	1.80
%Asym	-5.38	-5.68	-4.22
UF			
Diff FA	0	0	0.01
AI	-0.25	-0.25	-0.68
%Asym	0.52	0.52	1.28
AF			
Diff FA	0.01	0.03	0.01
AI	2.7	4.25	1.47
%Asym	-4.61	-6.36	-2.86
IFOF			
Diff FA	0.02	0.03	0.01
AI	2.32	3.78	-0.20
%Asym	-5.4	-6.59	0.36

* Data are presented as median unless indicated otherwise. CST = Corticospinal tract, FA = Fractional anisotropy, Diff FA = Average FA Difference, AI = Asymmetry Index, %Asym = Percentage of Asymmetry, SLF = Superior Longitudinal Fasciculus, ILF = Inferior Longitudinal Fasciculus, UF = Uncinate Fasciculus, AF = Arcuate Fasciculus, IFOF = Inferior Fronto- Occipital Fasciculus.

including those underpinning executive, attentional, and emotional domains [5, 19].

In this study, we report a large, single-institution experience demonstrating that artificial intelligence-guided connectomics can be incorporated into routine preoperative planning for brain tumor surgery across diverse pathologies and locations. In this consecutive series (192 surgeries), short-term functional status (KPS) remained stable, suggesting that clinical integration of connectome maps is feasible at scale without an apparent detriment to early functional outcomes. The present study was not designed to determine whether connectomics changed surgical approach or improved outcomes as those questions require controlled designs and are the focus of ongoing work.

Any intracranial tumor can be understood as a perturbing element within a densely interconnected network architecture of the brain [27]. Even extra-axial lesions such as meningiomas may exert large-scale network effects through mechanisms including edema, vascular compromise, and brain invasion. Patients with such lesions often exhibit cognitive deficits that cannot be explained solely by focal mass effect or cortical displacement [28]. For these reasons, we included meningiomas showing cognitive or behavioral alterations in our connectomic analysis, as their integration provides insights into the broader spectrum of network disruption across tumor pathologies.

Historically, connectomic platforms have emphasized preoperative applications. We expanded their utility by incorporating tract-based FA asymmetry analysis for postoperative assessment of white matter integrity. FA, a diffusion MRI-derived measure, quantifies directional diffusion along axons and serves as a marker of microstructural health [29]. Reduced FA values correlate with axonal disruption and cognitive impairment in glioma patients [30]. However, absolute FA values exhibit substantial variability due to factors such as age, tumor pathology, anatomical location, and natural hemispheric asymmetries, complicating direct interpretations [31–33]. To overcome these limitations, we employed hemispheric asymmetry indices (FA Diff, AI, and %Asym), which normalize interindividual and interhemispheric variability, and may better detect subtle postoperative microstructural changes.

Our exploratory tractometry analysis in a small, opportunistic subgroup ($n = 13$) suggests that hemispheric FA asymmetry indices (Diff FA, AI, %Asym) may be more sensitive than absolute FA to postoperative microstructural alteration at the tract level. Across patients, 12/13 exhibited a postoperative shift in at least one tract toward reduced interhemispheric imbalance, with laterality-linked patterns (UF/IFOF in left-hemisphere lesions; SLF in right-hemisphere lesions). Such postoperative shifts could reflect relief of mass effect/edema and early network-level reorganization as hemispheric indices have precedent in diffusion imaging literature as sensitive markers of white matter laterality in both healthy and pathological populations [25, 34–37].

As such, while a cohort-level rightward shift in SLF AI reached nominal significance, given the sample size, variable imaging intervals, and lack of correction for multiple comparisons, this observation should be regarded as hypothesis-generating.

Importantly, our findings complement prior reports that have largely emphasized preoperative connectomics—extending those observations by (i) demonstrating operational feasibility across a large consecutive cohort and (ii) proposing tract-level hemispheric asymmetry indices as candidate markers for postoperative change. This aligns with the broader shift from localizationist models toward network-aware, patient-specific planning that considers canonical and higher-order systems implicated in cognition and quality of life.

Interestingly, the SLF observation warrants cautious context. Prior studies have linked SLF microstructure (particularly SLF I/II) with motor recovery after stroke, suggesting a

Table 3 Tractometry data for all patients

	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt6	Pt 7	Pt 8	Pt 9	Pt 10	Pt 11	Pt 12	Pt 13
Pathology	Glioblastoma	Anaplastic pleomorphic xanthoastrocytoma	Metastasis	Low grade glioma	Glioblastoma	Glioblastoma	Meningioma	Metastasis	Anaplastic Astrocytoma	Glioblastoma	Glio-blas-toma	Metas-tasis	Glio-blas-toma
Side	Right	Left	Right	Left	Left	Left	Left	Right	Left	Left	Right	Left	Right
Location	Fronto-parietal	Parietal	Parietal	Fron-tal	Frontal	Temporal	Temporal	Frontal	Fronto-parietal	Parieto-occipital	Pari-eto-occip-ital	Frontal	Pari-etal
Preop KPS	70	70	80	90	70	70	70	70	70	70	70	80	60
3 m Postop KPS	90	80	80	90	70	90	70	70	80	90	80	100	70
CST													
Diff FA	0.04	0	0.03	0.01	0	-0.01	-0.02	0.03	-0.04	0.02	-0.03	0.01	0.04
AI	3.82	-0.16	3.04	0.79	-5.31	-1.32	2.23	7.68	4.56	-4.28	-2.95	5.14	4.82
%Asym	-6.93	0.33	-5.61	-1.56	10.63	2.63	-4.84	-14.79	-9.84	8.81	5.59	N/A	-8.65
SLF													
Diff FA	0.02	0.01	0.03	0.03	-0.04	0.01	0.02	0.07	-0.03	0	0.03	0.02	0.06
AI	3.76	1.98	4.02	2.98	-6.7	1.17	1.98	10.19	5.8	-1.05	5.13	6.83	10.45
%Asym	-6.59	-3.78	-6,15	-5.53	12.71	-2.22	-3.88	-13.66	-14.63	2.17	-8.43	-13.24	-19.19
ILF													
Diff FA	0.04	-0.01	0.03	0.02	-0.02	-0.01	-0.02	-0.01	-0.03	0.05	0.02	-0.01	0
AI	5.22	-5.97	2.97	5.59	1.85	1.75	3.47	9.17	4.76	-9.9	3.47	0.93	-0.84
%Asym	-9.42	24.21	-5.68	-10.92	-3.8	-4.64	-7.71	-18.81	-10.51	32.04	-5.38	-1.9	1.67
UF													
Diff FA	0	0.03	-0.01	0.01	0	0.06	0.07	-0.03	-0.01	0	0.01	-0.01	0.01
AI	-0.25	4.94	5.91	2.93	0.28	-13.66	-13.09	5.86	-1.6	-0.01	-9.6	-1.35	-2.18
%Asym	0.52	-9.35	-12	-4.69	-0.54	37.41	36.78	-12.67	2.85	0.04	19.47	2.51	4.43
AF													
Diff FA	-0.03	N/A	0.04	0.03	-0.01	0.01	0.01	0.07	0.03	-0.03	0	0	0.03
AI	-2.99	N/A	4.25	3.93	-1.99	1.47	-1.49	7.18	-6.1	5.65	-0.64	12.18	9.45
%Asym	4.13	N/A	-6.36	-7.34	3.7	-2.86	3.24	-9.6	15.29	-16.95	1.01	-24.69	-18.18
IFOF													
Diff FA	0.03	0.01	0.02	0.06	0	0.01	0.02	0.02	-0.08	-0.02	0.12	0	0.03
AI	3.78	-3.88	6.46	6.52	-0.61	-0.7	-2.72	2.74	10.01	2.32	15.02	0.21	-3.58
%Asym	-6.59	9.96	-12.62	-12.25	1.16	1.58	7.01	-5.4	-22.6	-6.66	-22.68	-0.44	7.62

* Data are presented as median unless indicated otherwise. N/A = Not available, CST = Corticospinal tract, FA = Fractional anisotropy, Diff FA = Average FA Difference, AI = Asymmetry Index, %Asym = Percentage of Asymmetry, SLF = Superior Longitudinal Fasciculus, ILF = Inferior Longitudinal Fasciculus, UF = Uncinate Fasciculus, AF = Arcuate Fasciculus, IFOF = Inferior Fronto - Occipital Fasciculus.

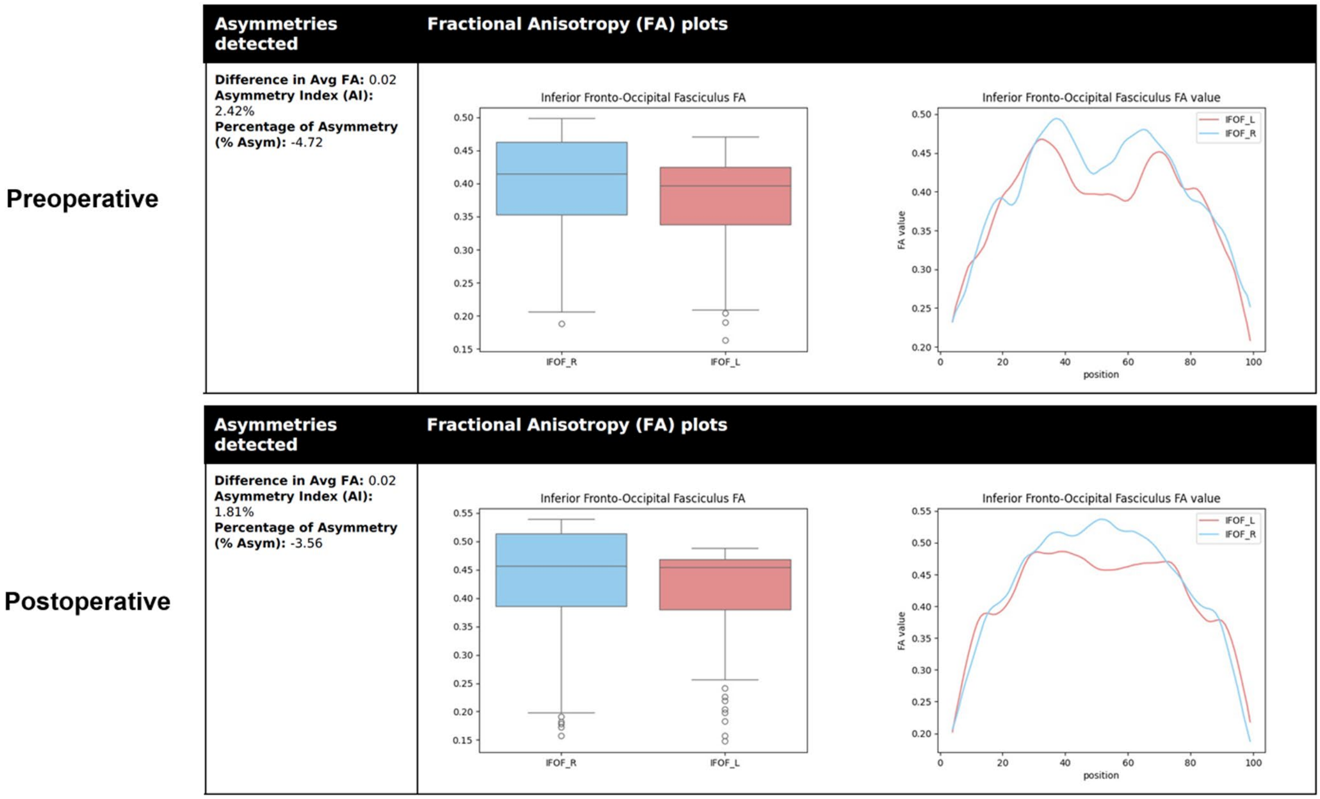

Fig. 2 Tractometry report comparing preoperative and postoperative FA indices for the IFOF in a representative patient. Postoperative data demonstrate normalization of the FA value along the tract and a reduction in hemispheric asymmetry, indicating improved interhemispheric balance following tumor resection

role in distributed motor and frontoparietal control networks [38]. In our cohort, the nominal rightward shift in SLF AI may reflect tract-level microstructural alteration relevant to motor network reorganization. However, without standardized timing or neurocognitive correlation, functional inference is premature.

Limitations

This study has several important limitations. First, it is descriptive and retrospective, without a counterfactual cohort; we did not quantify whether connectomics altered surgical strategy or outcomes. Second, tractometry was limited to an opportunistic subgroup ($n = 13$), constrained by scan site and protocol roll-out. Third, postoperative imaging intervals varied by clinical need, and timing is a major confounder for diffusion metrics. Fourth, FA is an indirect and nonspecific marker susceptible to edema, gliosis, and fiber-crossing effects. Fifth, our patient series lack formal cognitive assessment, using KPS as a surrogate. Finally, paired tests were uncorrected for multiple comparisons, and nominal p-values and effect sizes observed in the small tractometry subgroup should be interpreted cautiously.

Future directions

A prospective protocol is warranted with (i) harmonized acquisition and predefined postoperative timepoints, (ii) advanced diffusion modeling (e.g., fixel-based analysis) to address crossing fibers, (iii) pre-registered multiplicity control (e.g., false discovery rate), and (iv) standardized neuropsychological batteries to link tract-level asymmetry dynamics with cognitive outcomes. Parallel health-economic analysis and case-controlled outcome studies—now underway—will be essential to define clinical utility, cost, and generalizability.

Conclusions

Artificial intelligence–guided connectomic imaging can be successfully integrated into routine neurosurgical workflows, providing a feasible and clinically useful approach to individualized surgical planning and postoperative evaluation. Tract-based asymmetry analysis offers a sensitive, quantitative method to detect subtle improvements in white matter integrity following tumor resection, particularly within key language and semantic networks such as the UF

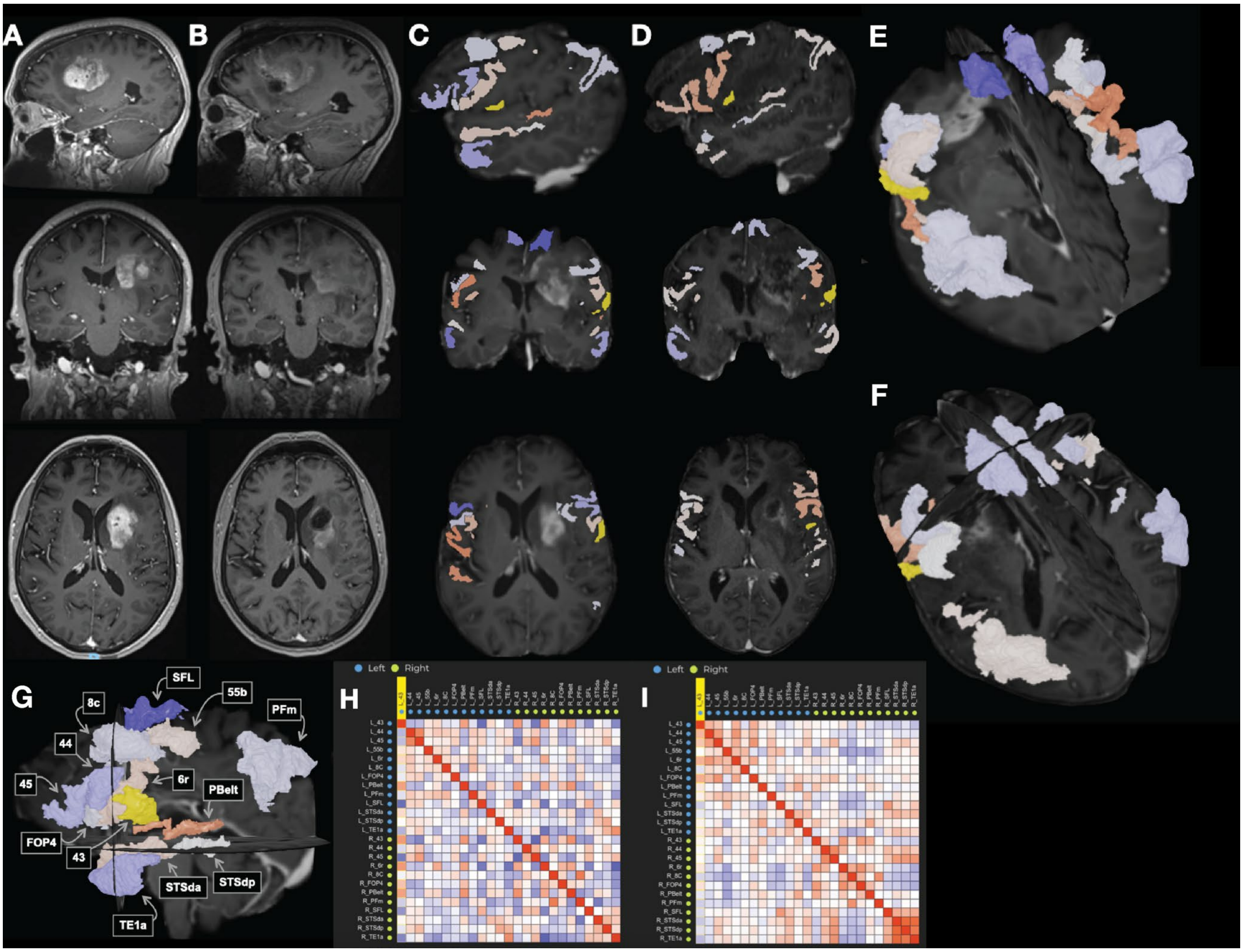

Fig. 3 **A**: Multi-planar reconstructions of a thin cut T1 post MRI sequence 11 days prior to resection in a 64 year-old female. **B**: Same sequence from a 7-month post-op MRI. Pathology was consistent with Glioblastoma WHO Grade IV. **C-D**: Functional associations were plotted on the preoperative (**C**) and postoperative (**D**) MRIs, using Blood Oxygenation Level-Dependent (BOLD) resting-state functional MRI (fMRI). Dark red indicates a -1 association while dark blue indicates a + 1 association, white indicates no association whatsoever. All associations are anchored relative to left-sided parcel 43 of each scan. **E**: labels each parcellation on the 3D models of all included language parcels. **F**: Preoperative 3D model and **G**: postoperative 3D model of the indicated parcellations. **H-I**: Association matrix of all associations between all different parcellations in preoperative (**H**) and postoperative (**I**) MRI scans

and IFOF, and motor-recovery supporting tracts as the SLF. Relative tract-based FA metrics that measure hemispheric asymmetry appear to provide greater insight into postoperative structural changes than absolute FA values alone. These findings highlight the potential to preserve, and possibly enhance, global brain network integrity through tailored surgical interventions. Ultimately, incorporating connectomics into surgical practice may refine surgical decision-making by emphasizing the broader network-level architecture of the brain, facilitating a personalized, systems-level approach to neurosurgical oncology.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11060-025-05383-5.

Author contributions ILS and RSD conceptualized the study. ILS wrote the initial draft of the manuscript. JC, ILS, LM, NS, SS and AB contributed to data extraction and analysis. RSD provided critical review and initial edits of the manuscript. SS, HS, JD, DGE, and MS provided additional review and edits. All authors reviewed and approved the final version of the manuscript.

Funding The authors would like to acknowledge funding support from the Northwell Health Cancer Institute Pilot Award for Mentoring in Cancer Research.

Data availability The authors confirm that the data supporting the findings of this study are available within the article.

Declarations

Ethical approval The study was approved by the Institutional Review Board (IRB) of Northwell Health (21 − 0008). All procedures followed were in accordance with the ethical standards of the responsible committee and with the 1964 Helsinki declaration and its later amendments. The IRB determined that informed consent was not required for this retrospective analysis.

Competing interests The authors declare no competing interests.

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