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Inferior fronto-occipital fascicle displacement in temporoinsular gliomas using diffusion tensor imaging

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Abstract

Background and Purpose: Brain tumors can result in displacement or destruction of important white matter tracts such as the inferior fronto-occipital fascicle (IFOF). Diffusion tensor imaging (DTI) can assess the extent of this effect and potentially provide neurosurgeons with an accurate map to guide tumor resection; analyze IFOF displacement patterns in temporoinsular gliomas based on tumor grading and topography in the temporal lobe; and assess whether these patterns follow a predictable pattern, to assist in maximal tumor resection while preserving IFOF function.

Methods: Thirty-four patients with temporal gliomas and available presurgical MRI were recruited. Twenty-two had insula infiltration. DTI deterministic region of interest (ROI)-based tractography was performed using commercial software. Tumor topographic imaging characteristics analyzed were as follows: location in the temporal lobe and extent of extratemporal involvement. Qualitative tractographic data obtained from directional DTI color maps included type of involvement (displaced/edematous-infiltrated/destroyed) and displacement direction. Quantitative tractographic data of ipsi- and contralateral IFOF included whole tract volume, fractional anisotropy, and fractional anisotropy of a 2-dimensional coronal ROI on the tract at the point of maximum tumor involvement.

Results: The most common tract involvement pattern was edematous/infiltrative displacement. Displacement patterns depended on main tumor location in the temporal lobe and presence of insular involvement. All tumors showed superior displacement pattern. In lateral tumors, displacement tendency was medial. In medial tumors, displacement tendency was lateral. When we add insular involvement, the tendency was more medial displacement. A qualitative and quantitative assessment supported these results.

Conclusions: IFOF displacement patterns are reproducible and suitable for temporoinsular gliomas presurgical planning.

KEYWORDS
diffusion tensor imaging, glioma, inferior fronto-occipital fasciculus, surgical navigation systems, temporal lobe

INTRODUCTION

The inferior fronto-occipital fasciculus (IFOF) is the longest associative white matter bundle, and bridges frontal, parietal, and occipital lobes via the inferior external capsule and posterior temporal lobe. It is the main component of the ventral associative stream or "what" pathway.[1] Among its functions, the IFOF plays a crucial role in semantic lexical and orthographic processing of language.[2,3] Accordingly, damage or electrical stimulation of this tract anywhere along its anatomy reproducibly induces semantic paraphasias.[4] To avoid surgical damage and consequent postsurgical neurological deficits, functional brain mapping techniques aim to offer the maximum possible safe resection, optimizing patient survival while avoiding damage to essential eloquent cortical and subcortical structures, such as the IFOF. Precise mapping of brain structures is currently done by combining direct-electrical stimulation and neuromonitorization techniques during awake and asleep interventions with the guidance of presurgical MRI mapping techniques such as functional MRI and diffusion tensor imaging (DTI) tractography, which can be integrated into the operating room.[5-7]

The anatomical components of this fasciculus have been studied extensively by ex vivo, surgical dissection, and in vivo neuroimaging MRI techniques such as DTI-tractography.[8-11] However, in the context of tumor surgery, little has been said about the precise patterns of involvement of the IFOF. Specifically, along the tract's long transit through the temporal stem, external capsule, and temporal lobe, the compacted fibers of the tract are promptly exposed to temporal and temporoinsular tumors. Knowledge of the exact location of this fascicle and its relationship with the tumor can be of help to guide neurosurgical interventions and minimize surgical damage in patients with gliomas that involve the temporal lobe.

Intraoperative subcortical brain mapping studies have shown that DTI-tractography data are reliable and accurate in describing the trajectories of the tracts and their modifications caused by the lesions, providing information about its usual course, displacement, infiltration or edema, or destruction.[12-17]

Four major patterns have been described in affected white matter tracts in the directionally encoded color maps (DEC map) focusing on the color intensity modulation provided for visual inspection and fractional anisotropy (FA) values.[18,19]

> **Pattern 1**: Displacement pattern, consisting of preserved or only slightly decreased FA with abnormal location and/or direction resulting from bulk mass displacement.
> **Pattern 2**: Edematous pattern, with substantially decreased FA with unchanged location and direction (preserved hues on DEC map).
> **Pattern 3**: Tumor infiltration pattern, with substantially decreased FA with abnormal hues on DEC map
> **Pattern 4**: Destruction pattern, consisting of isotropic (or near-isotropic) diffusion such that the tract cannot be identified on DEC map.

It should be noted that combinations of the above patterns may occur. Very few other studies have performed a qualitative and clinically orientated analysis of the different particular patterns of tract involvement.[15,20-22] Furthermore, tractographic patterns of involvement have not been thoroughly studied.

The aim of this study was to analyze whether the preoperative study of the IFOF involvement caused by temporal and temporoinsular gliomas would follow predetermined patterns based on the tumor's topography.

METHODS

This study has been revised by our center's research ethics committee. Patient data were anonymized before analysis. Patient confidential information was protected in accordance with National and European norms. A nonspecific general informed consent to participate in research projects was obtained from all patients. Waiver of a specific informed consent was provided by the ethics committee due to the retrospective nature of this study.

Participants were consecutively recruited through a review of our center's presurgical MRI brain-mapping registry for studies performed between January 2011 and July 2019. This registry includes patients with lesions near to eloquent brain areas, who are candidates for surgical tumor resection with awake brain mapping. MRI mapping with functional MRI and DTI-tractography is performed in our center to help guide surgery.

Inclusion criteria were (1) MRI protocol included at least T1-weighted image (WI), fluid-attenuated inversion recovery, T1WI post-contrast, and DTI; (2) MRI-suggested brain tumor with pathological confirmation; (3) at least a part of the lesion involved the temporal lobe on MRI; (4) no previous surgical or oncospecific treatment. Image quality was evaluated by two neuroradiologists subspecialized in neuro-oncological imaging (AC and PNB). Low-image-quality studies due to movement or other artifacts were excluded.

Studies were performed on a 1.5T Philips Healthcare Intera or Achieva magnet (Best, The Netherlands). DTI data were obtained using a single-shot echo planar imaging sequence. Diffusion gradients were applied along 16 or 32 directions using b-values of 0 and 800 or 1000 seconds/mm^2. DTI sequences were acquired in the axial plane with 60 contiguous sections, a 2-mm section thickness (voxel size $2 \times 2 \times 2$ mm^3), no intersection gap, repetition time 15,600 ms, echo time 79 ms, field of view 170×234 mm^2, and matrix 84×117.

Postprocessing of DTI and tractography was performed with the DTI Tractography module of Philips Intellispace Portal version 10 (Best, The Netherlands). A manual deterministic tracking algorithm was used for fiber tracking, with a minimum FA value of 0.15, minimum fiber length of 100 mm, and maximum angle of 27°. Maximum angle was raised to a maximum of 45° for tracts, which were extremely displaced and distorted. The final generated tracts were thoroughly revised on T1WI and DEC map to confirm their veracity. The whole
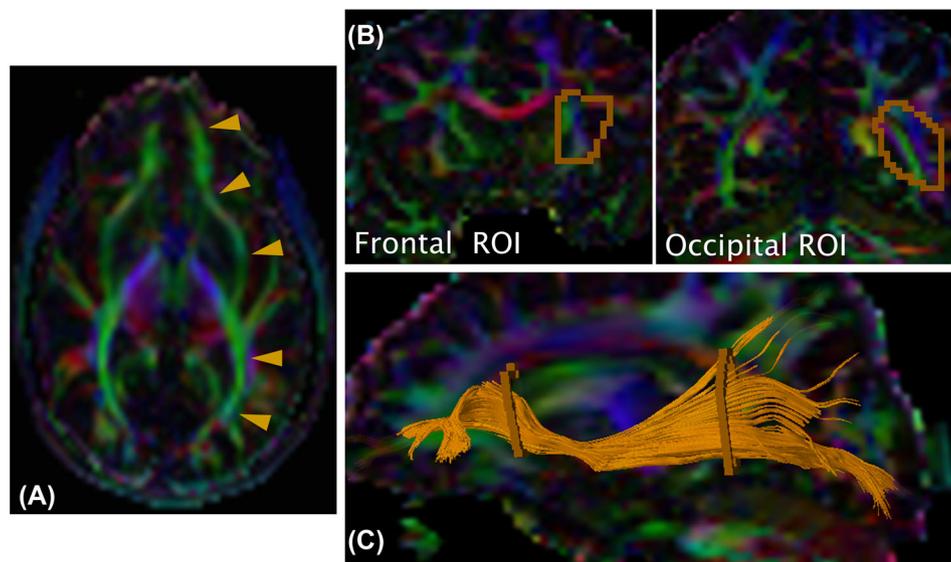
FIGURE 1 (A) The inferior fronto-occipital fascicle (IFOF) is represented in green on the color maps and is shown in the axial plane at the level of the subinsular region (orange triangles). (B) Tracking of the IFOF is performed with two regions of interest (ROIs) drawn on coronal slices perpendicular to the IFOF trajectory. In general, the seed ROI is placed in the deep white matter of the occipital lobe and the target ROI at the anterior edge of the genu of corpus callosum. (C) After connecting the two ROIs, the tractogram is inspected for a priori anatomical consistency. The exact location of the ROI may vary depending on the displacement of the tract, which may be inspected on the fractional anisotropy color map

preprocess, manual region-of-interest placement, and verification process were performed by consensus by two board-certified neuroradiologists with specific subspecialized experience in presurgical DTI-tractography mapping (AC and PNB) (Figure 1).

The primary outcomes evaluated were the involvement of the IFOF measured by (1) direction of displacement and (2) pattern of FA abnormality. Direction of displacement was defined as a circular discrete continuous variable established as the vector resulting from the difference between the expected and actual location of the IFOF. The expected location was defined by determining the mirror image of the contralateral IFOF on the coronal plane relative to a vertical line drawn on the midline. Resulting vectors were discretized to of one of eight 45° cardinal coronal plane directions (superior, superior-lateral, lateral, inferior-lateral, inferior, inferior-medial, medial, and superior-medial). Pattern of FA tract abnormality was established as zero (intact nondisplaced tract), or into one of three categories of involvement: Type 1, displaced (preserved or elevated FA); Type 2, infiltrated/edematous (low FA preserving directional data with or without displacement); and Type 3, destroyed (extremely low FA with loss of congruent directional data), represented in Figure 2.

Secondary results evaluated included volume and mean FA value of the whole tract and mean FA of the tract in a coronal 2-dimensional region of interest (ROI) at the level of maximum tract involvement by tumor. All three of these parameters were compared relative to contralateral IFOF and between different types of involvement.

The main predictors evaluated were tumor type, World Health Organization (WHO) grade, and tumor location in the temporal lobe.[23]

Tumor location was established as temporal with or without insular involvement. Intratemporal location was further categorized by drawing a line that divided the temporal lobe into two equal parts and then categorized the tumors by one of three locations: (1) predominantly medial location, (2) predominantly lateral location, and (3) those that affected both medial and lateral (latero-medial).

Statistical analyses were performed with R software (version 4.0.0; http://www.r-project.org/). Quantitative comparisons between two groups were performed with Wilcoxon rank-sum test. Comparisons of categorical data were performed with Fisher's exact test. Comparisons of circular ordinal 8 polar direction between tumor location groups was performed with a two-sample circular Watson test for two-way comparisons (insular and noninsular involvement) and with Watson-Williams test for three-way comparison (medial, lateral, and latero-medial lesions), both tests available in the "circular" package available in the comprehensive R archive network repository. Multivariate analyses of quantitative measures were performed with Kruskal-Wallis test.

RESULTS

A total of 34 patients were included with primary brain tumors involving the temporal lobe with full functional and DTI-MRI brain mapping. Mean age was 48 years (standard deviation 13.2). Sixteen (47%) were women and 33 (97%) were left-sided lesions. Histologically, 14 were WHO grade IV gliomas, 14 were grade III gliomas, 5 were grade II diffuse astrocytomas, and 1 was a grade I ganglioglioma. Individual patient characteristics are shown in Table 1.

Regarding the intratemporal extension of the lesions, 14 (41%) involved mainly the medial aspect of the temporal lobe, 14 (41%)
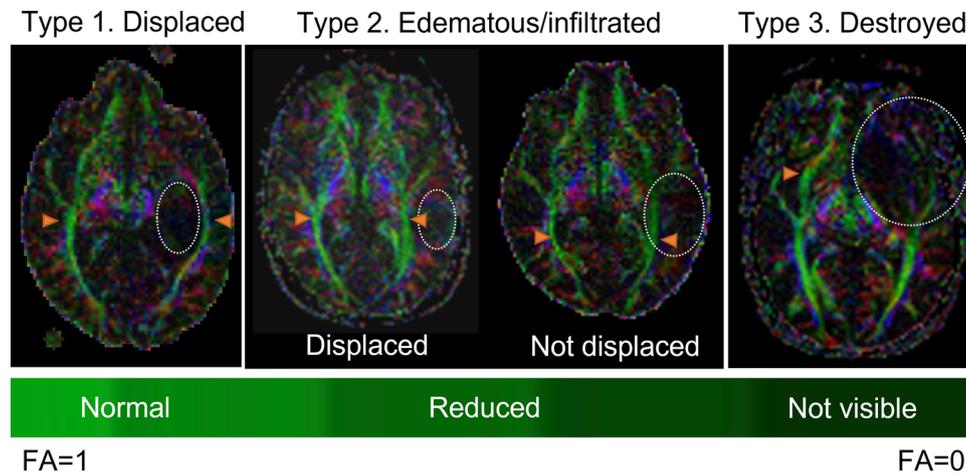
FIGURE 2 Proposed patterns of tract involvement. Type 1: Displacement pattern with preserved or increased fractional anisotropy (FA) and tonality. Type 2: Infiltration-edema pattern with reduced FA and tonality both with and without displacement. Type 3: Destruction pattern when tonality cannot be detected (orange triangles: inferior fronto-occipital fascicle; circle: tumor)

involved mainly the lateral aspect, and 6 (18%) involved medial and lateral aspects. Twenty-two (65%) of these lesions involved the insula, and 12 (35%) did not.

According to tumor grade, the most common pattern of tract involvement in all tumor-grades was type 2 (infiltrated/edematous). Type 3 (destroyed) involvement was observed more frequently in grade IV lesions, less frequently in grade III lesions, and not at all in low-grade lesions.

Tract displacement was observed in 32 out of 34 lesions. One case had no tumor or edema near the tract. The other of these two cases without displacement had type 2 infiltration/edema pattern but no mass effect and unchanged trajectory of IFOF. This implies that 20 out of 21 lesions with a type 2 pattern were visibly displaced. Results of the statistical analysis are presented in Table 2.

The predominant direction of tract displacement changed according to the location of the epicenter of the lesion in the temporal lobe. Three-way Watson-Williams test comparing the count vectors of displacement for lesions with medial, lateral, or lateral medial location was marginally significant ($p = .044$). The plots representing count vectors of displacement are presented in Figure 3D-F, which show that medially located tumors seem to have a more variable pattern of displacement than the other locations. Medially located tumors are then further subdivided among those with and those without insular involvement in Figure 4. In this subgroup, medial tumors without insular involvement tend to displace the IFOF in a superior-lateral direction, while those with insular involvement tend to displace the IFOF in a superior-medial direction. These results were contrasted using with Watson's two-sample test, which yielded significant differences with a p-value between .01 and .05. Furthermore, when the same test of insular versus no insular involvement was applied to lateral located subgroup of tumors, no significant differences were identified ($p > .1$).

Quantitative analysis of the reconstructed tracts included mean FA of the whole tract, volume of the whole tract, and mean FA of a coronal 2-dimensional ROI on the tract at the slice of closest relationship with the tumor.

Comparison between the type 1 tract involvement (not-infiltrated) versus type 2 (infiltrated or edematous) for the IFOF ipsilateral to the tumor is shown in Table 3 and graphic examples in Figure 2. FA of the whole tract was significantly lower in infiltrated/edematous tracts than in noninfiltrated tracts. Volume of the whole tract was not statistically different between type 1 and type 2.

When comparing the tract ipsilateral to the tumor versus the tract contralateral to the tumor for noninfiltrated type 1 involvement, no significant differences were observed for whole-tract FA, whole tract volume, or 2-dimensional coronal ROI. However, for type 2 infiltrated/edematous tracts, whole tract FA and 2-dimensional coronal ROI FA were significantly lower in the ipsilateral tract than the contralateral tract, while volume did not significantly change (Table 4).

Tracts with type 3 involvement (destruction of tract) by definition could not be generated, and thus, neither whole-tract FA or volume could be obtained. Coronal 2-dimensional ROIs were obtained following the assumed trajectory of the tract on the directionally encoded color (DEC) FA map.

DISCUSSION

This study demonstrates that involvement of the IFOF in patients with temporal and temporoinsular gliomas tends to follow predetermined patterns based on the tumor's topography and grade. As far as we are aware, this is the first study that aims to describe and predict the pattern of involvement and displacement of the IFOF by preoperative DTI. Knowledge of the structural involvement and exact course of the tracts in oncological patients would provide useful information to guide tumor resection and minimize surgical morbidity.[4-6,12,24]
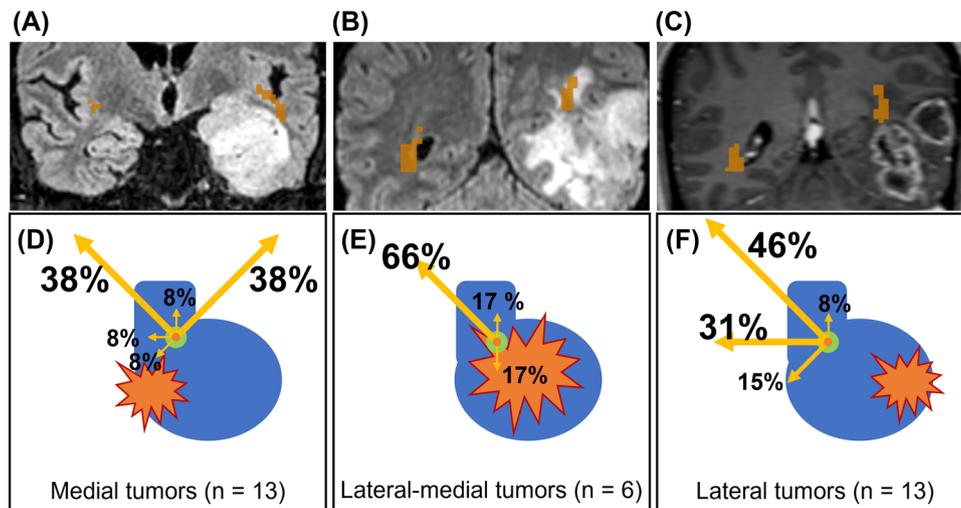
FIGURE 3 Patterns of tract displacement depending on main location of the tumor in the temporal lobe. Above (A-C) examples of medial location (A), lateral-medial location lesion (B), and lateral location lesions (C); 2-dimensional bilateral inferior frontal occipital fascicle trajectory on this slice is marked in orange. Below (D-F), circular plots representing the main vector of displacement for tumors each group. In blue, a representation of coronal view of insula and temporal lobe. In orange spikes, a representation of the lesion location. Arrows represent count vectors of cases that presented this direction of displacement among all the tumors in this location. Note that one medial and one lateral tumors were excluded from this graph as there was no displacement. Three-way comparison between the groups with Watson-Williams test yielded $p = .044$. n, number of subjects
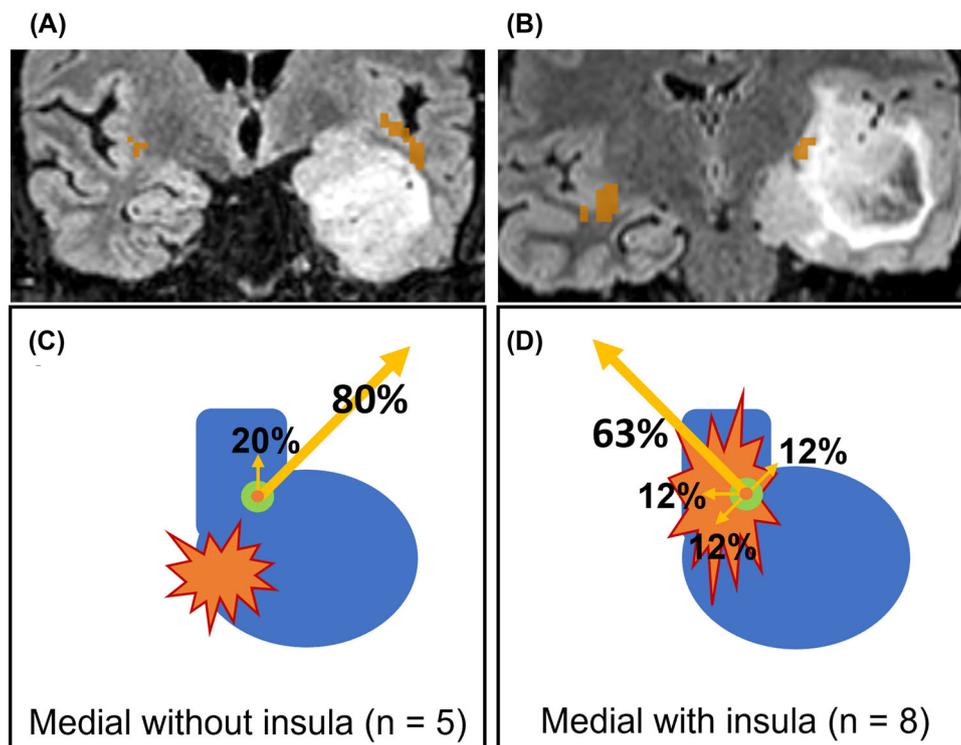

FIGURE 4 Patterns of tract displacement for subgroups of medial located tumors depending on if they had insular involvement or not. Above (A and B) examples of medial tumors without insular involvement (A) and medial tumors with insular involvement (B); 2-dimensional bilateral inferior frontal occipital fascicle trajectory on this slice is marked in orange. Below (C and D), circular plots representing the main vector of displacement for tumors in each subgroup. Comparison between the two groups with Watson's two sample test yielded p between .01 and .05. n, number of subjects

TABLE 1 Patients included in the study

	Sex	Age (years)	Histology	Grade	Location	Insular involvement	Tract pattern	Displacement direction
1	M	22	GG	1	L	Yes	1	Med
2	F	49	PXA	2	L	No	0	None
3	F	63	DA	2	M	Yes	2	None
4	M	33	DA	2	M	Yes	1	Med-Inf
5	M	25	DA	2	M	Yes	2	Med-Sup
6	M	31	DA	2	LM	Yes	2	Med-Sup
7	F	45	AA	3	L	No	2	Med
8	M	52	AA	3	LM	Yes	1	Sup
9	M	41	AA	3	M	Yes	3	Med
10	F	42	AA	3	M	Yes	2	Med-Sup
11	M	32	AO	3	M	No	2	Lat-Sup
12	F	55	AA	3	LM	Yes	2	Inf
13	M	46	AA	3	L	Yes	2	Med-Sup
14	M	58	AA	3	L	No	2	Med-Sup
15	F	41	AA	3	M	No	2	Lat-Sup
16	F	46	OA	3	M	Yes	2	Lat-Sup
17	F	39	OA	3	LM	Yes	2	Med-Sup
18	M	36	OA	3	M	Yes	3	Med-Sup
19	M	38	OA	3	LM	Yes	2	Med-Sup
20	F	34	AA	3	M	Yes	3	Med-Sup
21	M	71	GBM	4	M	No	1	Sup
22	F	64	GBM	4	L	No	1	Med
23	F	41	GBM	4	M	Yes	3	Med-Sup
24	M	58	GSM	4	L	No	2	Med
25	M	59	GBM	4	L	Yes	2	Med-Sup
26	F	69	GBM	4	L	Yes	2	Med-Sup
27	F	49	GBM	4	L	No	3	Med-Sup
28	M	64	GBM	4	M	No	2	Lat-Sup
29	F	66	GBM	4	L	Yes	3	Med-Inf
30	F	62	GSM	4	L	Yes	2	Med-Inf
31	F	56	GBM	4	M	No	2	Lat-Sup
32	F	57	GBM	4	L	No	2	Med-Sup
33	M	62	GBM	4	L	Yes	2	Sup
34	F	39	GBM	4	LM	Yes	3	Med-Sup

Abbreviations: AA, anaplastic astrocytoma; DA, diffuse astrocytoma; F, female; G, ganglioglioma; GBM, glioblastoma; GSM, gliosarcoma; Inf, inferior; L, lateral; Lat, lateral; LM, lateromedial; M, male; Med, medial; OA, anaplastic oligodendroglioma; PXA, pleomorphic xanthoastrocytoma; Sup, superior.
Tract pattern: 1 = Displaced, 2 = Edematous/infiltrated, 3 = Destroyed.

The IFOF cannot be identified using conventional MRI, but reconstructions can be visualized in vivo using the DEC maps and tractograms generated by DTI.[8,9,25] Tractography provides insight into the organization of the fibers of the IFOF inside or around the tumor[13,26–29] and permits delineating it from adjacent tracts.[25,30] However, most tractography studies refer mostly to nontumor or healthy subjects.[8,9,25] In the case of presurgical planning for brain tumors, the tracts are often distorted and displaced by the mass, and the tractography workflow is prone to erroneous reconstructions.[31] Often, the anatomic references for placing classic ROIs for tract reconstruction are not valid in these situations and will render false tracts or no tract at all. This can be overcome in part with precise knowledge of the subcortical anatomy on DEC map by applying hands-on modifications on multiple ROIs and reconstruction parameters. However, this

TABLE 2 Pattern of tract involvement by tumor grade, intratemporal location, and presence of insular involvement

	n	None (*n* = 1)	Type 1 (Displaced) (*n* = 5)	Type 2 (Edema/infiltration) (*n* = 21)	Type 3 (Destroyed) (*n* = 7)	*p*
By tumor grade						
Grade 1 (*n* = 1)	1	–	1 (100%)	–	–	.23
Grade 2 (*n* = 5)	5	1 (20%)	1 (20%)	3 (60%)	–	
Grade 3 (*n* = 14)	14	–	1 (7%)	10 (71%)	3 (21%)	
Grade 4 (*n* = 14)	14	–	2 (14%)	8 (57%)	4 (29%)	
By intratemporal location						
Medial	14	–	2 (14 %)	8 (57%)	4 (29%)	.77
Lateral	14	1 (7%)	2 (14 %)	9 (64%)	2 (14 %)	
Lateromedial	5	–	1 (20%)	4 (60%)	1 (20%)	
By insular involvement						
With insula	22		3 (14%)	13 (59%)	6 (27%)	.38
No insula	12	1 (8%)	2 (17%)	8 (67%)	1 (8%)	

Note: Significance statistics are generated using Fisher's Exact Test.
Abbreviation: *n*, number of subjects.

TABLE 3 Quantitative tract characteristics between tract-involvement types ipsilateral to lesion

	Type 1	Type 2	Type 3	*p*
N	5	21	5	
Whole tract volume (mm^2)	6310 ± 3528	5308 ± 4447	–	.408
Whole tract mean FA	0.46 ± 0.03	0.39 ± 0.06	–	<.01
ROI mean FA	0.42 ± 0.06	0.32 ± 0.07	0.29 ± 0.09	.035

Note: Values presented as mean ± standard deviation. Whole tract values are not obtainable for type 3 involvement, because the tract cannot be reconstructed. Whole tract volume and whole tract mean FA between types 1 and 2 were compared by Wilcoxon rank-sum test. ROI mean FA between the three groups was compared using Kruskal-Wallis test. Comparison for ROI mean FA between types 1 and 2 with Wilcoxon rank-sum test yields $p = .017$ and between types 2 and 3 yields $p = .629$.
Abbreviations: FA, fractional anisotropy; *n*, number of subjects; ROI, region of interest.

TABLE 4 Comparison of quantitative tract characteristics between lesional and contralateral sides for each tract involvement type

	Ipsilateral	Contralateral	*p*
Type 1 (*n*)	5	5	
Whole tract volume (mm^2)	6310 ± 3528	6669 ± 5327	1
Whole tract mean FA	0.46 ± 0.03	0.47 ± 0.03	.813
ROI mean FA	0.42 ± 0.06	0.39 ± 0.08	.625
Type 2 (*n*)	21	21	
Whole tract volume (mm^2)	5308 ± 4447	9084 ± 5938	.004
Whole tract mean FA	0.39 ± 0.06	0.48 ± 0.04	<.001
ROI mean FA	0.32 ± 0.07	0.41 ± 0.06	<.001
Type 3 (*n*)	5	5	
ROI mean FA	0.29 ± 0.09	0.4 ± 0.06	.063

Note: Values presented as mean ± standard deviation. Whole tract values are not obtainable for type 3 involvement, because by definition the tract cannot be reconstructed. Variables were compared by Wilcoxon rank-sum test.
Abbreviations: FA, fractional anisotropy; *n*, number of subjects; ROI, region of interest.

must be done with close visual supervision to guarantee congruency of the results with the trajectory of the tract observed on the DEC map and to avoid reconstructing false tracts.

Previous studies have found that the altered states of white matter resulting from brain tumors influence the measurement of diffusion tensor anisotropy and orientation in various ways. This results in several possible patterns of involvement. The tracts can be displaced, infiltrated, edematous, or destroyed.[18,32]

One of the main contributions of our study is to propose a practical classification focused on DEC maps using Field and Jellison classifications[18,19] as an initial starting point from which to build on. In a recent study by Leroy et al,[20] the authors demonstrated good pre-diction of fiber tract disruption by visual inspection of DEC maps compared to histological analysis. This DTI/histology correlation could help predict postoperative outcomes and the WHO tumor grade. The four-category model by Jellison and colleagues of compressed/displaced, edematous, infiltrated, and destroyed fibers has the drawback that DTI imaging is limited for differentiation of edematous versus infiltrated fibers because there is significant overlap.[20,33]

Therefore, we propose some modifications and establish three basic patterns depending on the location and tonality of the tract by visual inspection: (1) displacement pattern with preserved or increased FA

and tonality, (2) infiltration-edema pattern with reduced FA and tonality both with and without displacement, (3) and destroyed pattern when tonality cannot be detected.

In our study, as in previous studies,[12,20,34–36] we have noted that destruction pattern is most frequent in grade IV gliomas than in grade III gliomas (29% vs. 21%). Besides in the present study, a destruction pattern was not observed in low-grades I and II gliomas. Furthermore, we reported that overall, in high- and low-grade tumors, the most common pattern is edema-infiltration with displacement, followed by destruction in high-grade gliomas.

Comparison of quantitative FA and volume parameters between ROIs demonstrated significant differences between affected and contralateral IFOF for patterns 2 and 3, and no differences for pattern 1, supporting our visual classification. In fact, whole-tract and ROI FA comparisons of the affected side between patterns 1 and 2 and patterns 1 and 3 were also different, not so for comparison between patterns 2 and 3, suggesting that differentiation of edema/infiltration from destruction by FA measurement alone is not straightforward. However, in our experience and according to Leroy et al,[20] differentiation by visual inspection is feasible and relatively straightforward for an experienced neuroradiologist.

Other findings of this study are the identification of different tractographic patterns of the displacement of the IFOF depending on the compartment of tumor origin within the temporal lobe and considering insular involvement. Note that gliomas are characterized by a diffuse and infiltrative pattern of growth along white matter fiber tracts. Temporal gliomas often extend to the adjacent lobes, and pure-temporal tumors are less frequent.[27,37]

The most predominant displacement patterns were as follows: (1) medial tumors superior and lateral; (2) latero-medial tumors superomedial; and (3) lateral tumors superomedial. These results also indicated the tendency of the superior displacement of the IFOF regardless of location. When considering the presence of insular involvement, the predominant displacement of medial tumors changed from superolateral in patients without to medial displacement in patients with insular involvement. In a previous study, Martino et al found that the insular tumors displace and compress medially this eloquent bundle.[4] In all other tumor locations, lateral and latero-medial, the displacement pattern was unaffected by insular involvement, reinforcing the hypothesis that the direction of the displacement of the tract is narrowly predetermined by the anatomical location and congruent with the origin of tumor growth.

Thus, using our proposed classification system in three basic locations of the tumor (in the temporal lobe as lateral, medial, and lateromedial) and assessing if there was involvement of the insula, we have shown distinct patterns of displacement. This suggests that the fibers of the IFOF are flexible even when they are partially infiltrated or edematous, being these observations in convergence to what has been reported in the presurgical study of the optic radiations.[24]

Finally, we would like to emphasize that the joint evaluation of the DEC map and the tractographic reconstructions are necessary to guarantee a proper overall assessment of tract involvement.

Limitations

Reconstruction and interpretation of DTI tractography data have drawbacks related to the differentiation between the decrease of FA value because of a real neoplastic infiltration or to the peritumoral edema. Some of these problems can potentially be overcome by using other diffusion techniques such as high-angular resolution sequences, advanced reconstruction techniques, or probabilistic approach. These analytical techniques are harder to implement in the clinical routine of presurgical planning because of time limitations and technical demands.[26,38,39] Moreover, tractography is operator dependent and requires careful monitoring of tract reconstruction, which might limit the success of more automatic tracking methods. Besides, this is even more problematic in the case of brain tumor patients, which have distorted tracts, and which are prone to aberrant fiber generation. We believe this is partially overcome using reconstruction analysis carried out by neuroradiologists with specific subspecialization and ample experience in presurgical mapping.

We found that the IFOF follows different patterns of displacement depending on tumor location in the temporal lobe and if the insula is involved. Knowledge of the tract displacement patterns and exact tract location will be of help to guide neurosurgical interventions and minimize surgical damage in patients with gliomas that involve the temporal lobe.

CONFLICT OF INTEREST
None.

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