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Case Report: Practicability of functionally based tractography of the optic radiation during presurgical epilepsy work up

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HIGHLIGHTS

- Damage of the optical radiation is reported after resective epilepsy surgery.
- Postchiasmal pathway and visual cortex vary anatomically in between individuals.
- Therefore, anatomically based tractography might be inferior to a functional approach.
- Regions of interest for tractography were identified with fMRI-based retinotopy.
- Functionally based tractography proves feasible during presurgical epilepsy work up.

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ABSTRACT

Pre-operative tractography of the optic radiation (OR) has been advised to assess the risk for postoperative visual field deficit (VFD) in certain candidates for resective epilepsy surgery. Diffusion tensor imaging (DTI) tractography relies on a precise anatomical determination of start and target regions of interest (ROIs), such as the lateral geniculate nucleus (LGN) and the primary visual cortex (V1). The postchiasmal visual pathway and V1 show considerable inter-individual variability, and in epilepsy patients parenchymatous lesions might further complicate this matter. A functionally based tractography (FBT) seems beneficial for precise OR identification. We assessed practicability of FBT for OR identification in a patient with occipital lobe epilepsy due to a temporo-occipital maldevelopmental tumor. The MRI protocol at 3 T included a T1-weighted sagittal 3D scan, a T2-weighted axial 2D scan and a DTI scan using an echo planar spin echo sequence. ROIs for fiber tracking of OR (LGN & V1) were determined with T2*-weighted fMRI-based retinotopic assessment. After DTI pre-processing and fiber tracking, paths with similar properties were combined in clusters for visual presentation and OR localization. Retinotopic phase maps allowed for the identification of V1 and LGN for a precise DTI-based reconstruction of OR, which was distant to the patient's tumor. Location and structure of ORs were comparable in each hemisphere. FBT could thus influence the human research of the extrastriate visual pathway and the risk management of post-operative VFD in epilepsy surgery.

1. Introduction

Partial visual field defects (VFD) are a well-known risk after anterior temporal lobe resection (aTLR) [10], and potentially curative surgery is sometimes avoided in occipital lobe epilepsy, because the risk for a subsequent impairing VFD is considered too high. Even small amounts of brain movement during aTLR can

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affect the surgeon's judgment of the correct localization of the OR. Recently a new workflow for optimizing this procedure-specific complication has been introduced [4]. In this context, pre-operative diffusion tensor imaging (DTI) tractography of the optical radiation (OR) has been advised in order to minimize the risk for VFD after resective epilepsy surgery [30,31]. In the light of new MRI-guided ablative surgery techniques [3], which are not hampered by perioperative brain movements, surgically relevant information may be obtained through the precise pre-operative visualization of functionally important anatomical structures.

Considerable inter-individual variability of the OR has been demonstrated in post mortem [9] and in vivo studies [7], but also non-invasively using MRI tractography [21]. MRI tractography traditionally relies on the precise anatomical determination of start and target regions of interest (ROIs), namely the lateral geniculate nucleus (LGN) and the primary visual cortex (V1). The post-processing method chosen can also greatly influence the tractography results [31]. We thus set out to minimize these inherent methodological difficulties through functionally based ROI determination. We report on a patient with pharmacoresistant occipital lobe epilepsy evaluated for resective epilepsy surgery and assessed for the practicability of a functionally based tractography (FBT) of the OR. The LGN and V1 were separately identified by fMRI-based retinotopic mapping [11,17] and subsequently used as ROIs for MRI tractography.

2. Materials and methods

2.1. Case presentation

A 27-year-old, otherwise healthy female reported visual-autonomic auras with a feeling of discomfort, hyperventilation, tachycardia, and simple and unformed visual phenomena. Seizure frequency varied between 0.5 and 4 seizures per month. The first seizure, at the age of 23, was a bilateral tonic–clonic seizure, preceded by a habitual visual-autonomic aura. MRI investigation revealed a cystic, partially contrast-enhanced lesion in the caudal part of the right medial and lateral occipito-temporal gyri, compatible with a maldevelopmental tumor (ganglioma or dysembryoplastic neuroepithelial tumor; see Fig. 1). The patient took six sufficiently dosed antiepileptic drugs (AEDs) without achieving seizure freedom.

A presurgical evaluation was initiated, because she felt considerably distressed by her visual auras and their reoccurrence substantially limited the pursuit of her daily activities. During the video-EEG-monitoring a habitual aura with a rhythmical theta seizure pattern starting from the right temporo-occipital region was recorded (Fig. 1). Her maldevelopmental changes near the OR could be associated with anatomical variations, as already shown in patients with focal cortical dysplasia [6]. Therefore a functionally based tractography (FBT) of the geniculo-striate tract was performed. Visual acuity and visual fields as tested with automated static perimetry (Octopus 101 Perimeter; Haag-Streit, Koeniz, Switzerland) were normal.

2.2. MR-data acquisition

Data were acquired using a 3 T Siemens MAGNETOM Trio scanner (Siemens, Erlangen, Germany) with an 8-channel phased-array head coil for signal reception and Syngo VA35 software. The MR protocol included a T1-weighted sagittal 3D scan (MPRAGE sequence, 192 slices, slice thickness: 1.0 mm, TE: 4.77 ms, TR: 2500 ms, TI: 1100 ms, flip angle: 7 degree, bandwidth: 140 Hz/pixel, scan time: 9:20 min), a T2-weighted axial 2D scan (TSE sequence, 72 slices, slice thickness: 2 mm, TE: 78 ms, TR: 3300 ms, acquisition matrix: 256 × 192, voxel size: 1.0 mm × 1.0 mm × 2.0 mm, scan time: 4:24 min) and a DTI-scan with a TRSE-EPI sequence [23]. The parameters of the DTI-scan were 68 axial slices with the same center position of the image block as in the T2-weighted scan, TR: 8200 ms, TE: 89 ms, PAT-modus: GRAPPA (acceleration factor 3, 25% phase oversampling), slice thickness: 2.0 mm, acquisition matrix: 128 × 128, voxel size: 2.0 mm × 2.0 mm × 2.0 mm, 4 runs each with 2 averages and frequency adjustment for each run, total scan time: 4 × 4:39 min, each run with one non-diffusion-weighted volume and 12 diffusion-weighted volumes (non-collinear diffusion gradient directions from Siemens MDDW mode), *b*-values of 1000 s/mm^2. Furthermore a fMRI scan for retinotopic mapping with the following parameters: 38 slices parallel to the calcarine sulcus, acquisition matrix: 64 × 64, TE 30 ms, TR 2.4 s, 3.5 mm isotropic resolution, field of view 224 mm × 224 mm, a total of 5 runs with 112 volumes each, as specified below, was acquired.

2.3. DTI-data pre-processing and fiber tracking

The DTI images were co-registered based on the non-diffusion-weighted images of the first run using SPM5. Diffusion tensors were calculated for each voxel and further decomposed into eigenvalues and eigenvectors using the SPM diffusion toolbox [15]. On this basis,

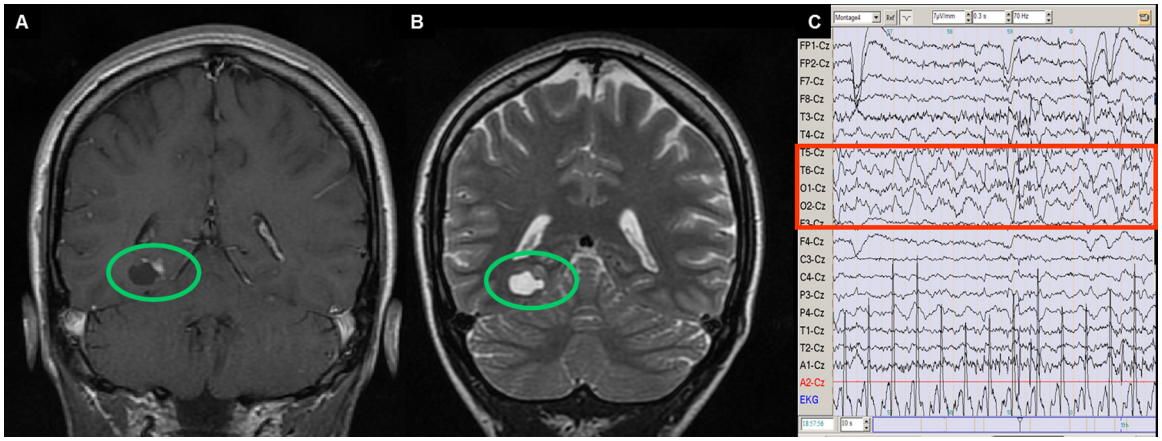

Fig. 1. Structural MRI and patient EEG. (A) T1-weighted MRI with contrast enhancement. (B) Corresponding T2-weighted MRI-images. The green circles indicate the epileptogenic lesion with characteristic features of a dysembryoplastic neuroepithelial tumor. (C) Ictal EEG with rhythmic theta/delta-activity seizure pattern (red rectangle, with maximum at electrodes T6 and O_2) during a habitual visual-autonomic aura (note the tachycardia). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)