Fiber Tractography in Patients with Gliomas: Assessment of the extent of tumor cell infiltration in brain fiber tracts

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Introduction:

Delineation and characterization of fiber bundles is important for the understanding of normal brain functions as well as changes due to pathologic processes [1]. Knowledge about the involvement of white matter structures in the surrounding and border zone of gliomas is essential for the planning of neurosurgical therapy strategies [2]. A significant problem in the presurgical course is the ability to identify the extent of malignant cell infiltration of white matter tracts. However, conventional magnetic resonance (MR) imaging methods are not able to answer these questions in a sufficient manner [3]. Fiber tracking using MR diffusion tensor (DT) imaging allows studying the structure of neuronal fibers noninvasive by characterization the properties of water diffusion.

Methods:

We retrospectively correlated fiber tracking using MR DT imaging and histopathological data of 25 patients (18−63 y) with biopsy-proved diagnosis of a supratentorial WHO grade II (nine patients) or III (16 patients) glioma. DTI data were obtained using an EPI diffusion sequence (TR/TE 9200/86 ms) with six diffusion directions (b=1000 s/mm^2), an isotropic voxel size of 1.9 mm^3 and 5 averages. Fractional anisotropy (FA) was calculated from DTI data. Co-registration with a 3D MPRAGE data set, which was used for stereotactic brain biopsies, allowed correlation of FA values with histopathologic findings expressed as tumor cell number and % tumorinfiltration [4]. Fiber Tractography using DTI-Studio and the Fiber Assignment by Continuous Tracking (FACT) [5] method was performed to investigate the integrity of with matter tracts in the surrounding/border zone of the lesions. Anatomically segmented regions of interest (ROIs) for seed areas were placed for tracking of callosal, projection and/or association fibers, depending on the location of the lesion. The tracing procedure were stopped for FA thresholds=0.1, 0.15, 0.2, 0.25, and 0.3 or tract turning-angle>60°.

Results:

Tractography using the 5 different FA thresholds resulted in the following ranges of FA values for brain fiber tracts located nearest to the lesions: FA threshold of 0.3: FA=0.35 - 0.43, FA threshold of 0.25: FA=0.28 - 0.38, FA threshold of 0.2: 0.23 - 0.29, FA threshold of 0.15: 0.17 - 0.21, and FA threshold of 0.1: 0.13 - 0.17 (Fig. 1A). The histopathologic findings of 92 MR image-guided stereotactic biopsies from all 25 patients were correlated with the corresponding FA values at the biopsy locus. For FA we found a negative logarithmic correlation (r=-0.828, p<0.001) with the number of tumor cells (Fig. 1B). In 9 patients we retrospectively reconstructed intact brain fiber tracts at biopsy loci (2-32% tumor infiltration) using a FA threshold of 0.15 and 0.2, but not for a threshold of 0.25 or 0.3 (Fig. 2).

Discussion:

A FA threshold of 0.25 and 0.3 leads to an underestimation of potential tumor infiltrated fiber tracts. A threshold of 0.1 delivers reconstructed fibers that run well into the maximum pathology of the MR signal changes and may not represent functional intact neuronal pathways. Therefore a FA threshold of 0.15 to 0.2 seems to be best suitable to gain realistic fiber tract reconstruction around an infiltrating intrinsic brain tumor. Additionally we showed potentially tumor cell infiltration of intact brain fiber tracts.

References:

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Figure 1

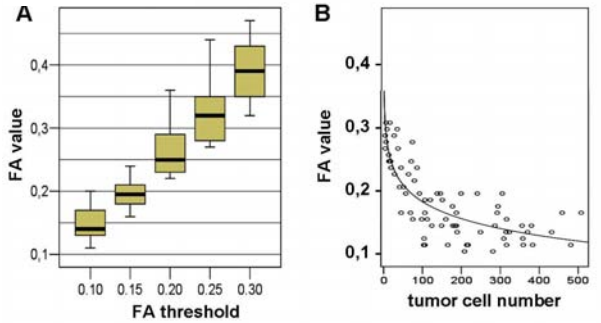

Figure 2