

Effects of Brain Tumor on Corticospinal Tract and Motor Function: Diffusion spectrum imaging tractography analysis of generalized fractional anisotropy

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Introduction

Recent studies in brain tumors using diffusion MRI found noticeable changes in the integrity of white matter microstructures as reflected by altered diffusion indices. [1-3]. Further analysis of microstructure integrity, as represented by generalized fractional anisotropy (GFA) along the corticospinal tract (CST) could provide more insight to the effects of brain tumors on CST and consequently on the motor function. Therefore, in this study, we aimed to study the effects of brain tumors on the GFA values of CST and how the GFA values related to the motor function of limbs and tumor properties.

Materials and Methods

Subjects Twelve right-handed patients with brain tumors were recruited in the study (7 males and 5 females; age range: 18-63 years; mean: 48.53 \pm 11.8 years). **Diffusion Spectrum Imaging** All images were acquired on a 3T MRI system (Trio, Siemens, Erlangen, Germany) with an eight-channel head coil. The DSI experiment was performed by applying 203 diffusion gradient vectors. DSI analysis entailed computation of probability density function (PDF) by the Fourier transform of diffusion echo signal sampled in the q-space, and computation of orientation distribution function (ODF) by the second moment of PDF in the real space [4]. The ODF at each voxel provided information about orientations of local fibers and allowed determination of generalized fractional anisotropy (GFA). **CST Tractography** Tractography was reconstructed based on a simple algorithm that was adapted for DSI data. All fiber orientations of the nearest voxels were used to decide the proceeding orientation for the next step. The algorithm started with placing the seed points in the whole white matter, and CST was obtained by selecting tracts that passed through the cerebral peduncles, pyramid and the motor cortex. **Mean Path** Having obtained CST, GFA values along CST tracts, specifically from the cerebral peduncle to motor cortex, were sampled. Plots of GFA along the path of CST were obtained by projecting the sampled GFA onto a single mean path of the CST tracts. **Definition of Parameters** Each CST was segmented in three different ways, namely, whole tract, three-level, and five-region segmentation (Fig. 1). The three levels were segmented with respect to the tumor location, namely above (level above tumor), tumor, and below (level below tumor). The five regions were segmented by the anatomical landmarks, namely top (internal capsule to motor cortex), IC (internal capsule), middle (internal capsule to midbrain), MB (midbrain), and bottom (pyramid to midbrain). Tumor properties, including tumor volume, center and the distance from CST to the closest tumor edge, were assessed on T2-weighted and Gd-enhanced T1-weighted structural images. Clinical motor presentation parameter was muscle power. The clinical presentation of muscle power, ranging from 0 (total weakness) to 5 (normal), was assessed and scored by physicians. **Statistic Analysis** In each way of segmentation, two-tailed paired t test was performed to compare GFA values of CST on the tumor side versus that on the healthy side. The difference was considered significant if $p < 0.05$. Correlation was investigated between GFA and the muscle power scores, and between GFA and tumor properties.

Results

The types of the tumors were as follows: five glioblastoma multiforme, two astrocytoma, two meningioma, one ependymoma, one gemistocytic astrocytoma, and one malignant melanoma with metastasis. Seven patients had normal muscle power and 5 patients had reduced muscle power. The GFA values tended to decrease on the tumor side with respect to the healthy side. In the whole tract segmentation, GFA was significantly decreased ($p=0.01$); in the three-level segmentation, GFA was significantly decreased at the tumor level ($p=0.012$); in the five-region segmentation, GFA was significantly decreased in the top ($p=0.016$), IC ($p=0.046$), middle ($p=0.004$), and MB regions ($p=0.012$). There was no correlation between GFA and the muscle power scores. There was no correlation between GFA and the tumor center. For the correlation between the tumor properties and GFA, we found that GFA of the top region had a significant positive correlation with the tumor edge distance ($r^2 = 0.42$; $p=0.042$) (Fig. 2), and GFA of the IC region had a significant positive correlation with the tumor volume ($r^2 = 0.38$; $p=0.033$, Fig. 3).

Conclusions

GFA was generally decreased in the CST on the tumor side. Specifically, it was decreased at the tumor level, and in all regions except the bottom part. The GFA values on the tumor side were not correlated with the muscle power scores. The GFA values changed counteractively by different aspects of tumor properties; it increased with the tumor volume and decreased with the tumor edge distance. Therefore, the GFA values of CST on the tumor side may not strongly relate to the muscle power impairment.

References

[1] Yvonne *et al.* Neurosurgery 2007. [2] Nelsson *et al.* Childs Nerv Syst 2008. [3] Helton *et al.* Neurosurgery 2008. [4] Wedeen *et al.* MRM 2005.

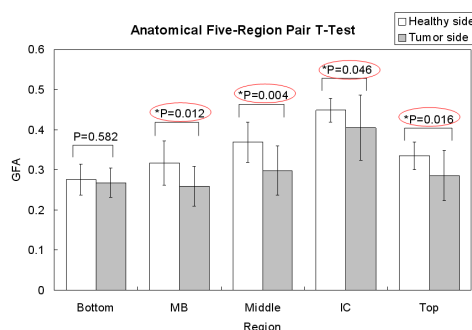


Figure 1 GFA values of CST are significantly decreased in MB ($p=0.012$), middle ($p=0.004$), IC ($p=0.046$), and top regions ($p=0.016$) on the tumor side.

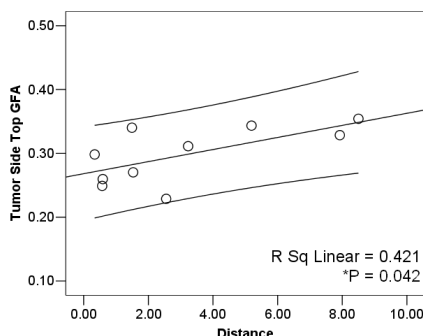


Figure 2 Tumor edge distance shows positive correlation with GFA of the top region on the tumor side.

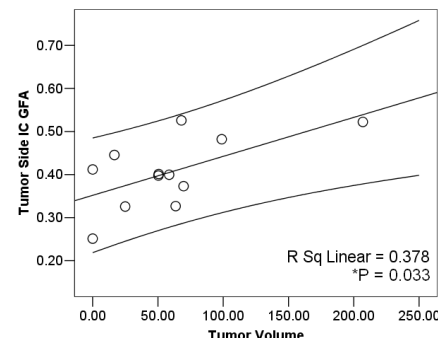


Figure 3 Tumor volume shows positive correlation with GFA of the IC region on the tumor side.