# Effects of Brain Tumor on Corticospinal Tract and Motor Function: Analysis of tract stretch using diffusion spectrum imaging tractography

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## Introduction

Diffusion tractography studies on corticospinal tract (CST) have revealed various microstructural alterations adjacent to the lesion, presenting either decrease [1] or increase [2,3] of generalized fractional anisotropy (GFA). This could attribute in part to weak correlation of GFA with the manifested muscle power impairment. In this study a new parameter, tract stretch, was proposed and its relations with the clinical presentation of motor function and with the tumor properties were investigated.

## 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 ±11.8years). _Diffusion Spectrum Imaging_ All images were acquired on a 3T MRI scanner (Trio, Siemens, Erlangen, Germany) with an eight-channel head coil. The DSI experiment was performed by applying 203 diffusion gradient vectors. DSI analysis entailed reconstruction of the probability density function (PDF) at each voxel by the Fourier transform of the diffusion echo signal 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. _CST Tractography_ Tractography was performed 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 the tracts that passed through the cerebral peduncles, pyramid and the motor cortex. _Mean Path Algorithm_ Having obtained CST tractography, the mean path algorithm was used to calculate the mean direction of neighboring fibers via averaging the directions of the local fibers sliced by recursively tilting planes [5]. A disc on a tract bundle was defined as the one perpendicular to the fibers passing through the disc. The local orientation of the mean path was determined by the disc normal, and the position of the mean path was determined by the geometric center of the fibers on the disc. The same procedure repeated for the next step till the whole fiber tract was covered. The total steps of the mean path along CST, from the cerebral peduncle to motor cortex, were calculated. _Definition of Parameters_ The tract stretch was defined as: [(steps of the mean path on the tumor side) – (steps of mean path on the healthy side)] / (steps of the mean path on the healthy side). 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 structure images. Parameter of motor function, muscle power, was assessed by neurosurgeons. The muscle power scores ranged from 0 (total weakness) to 5 (normal). _Statistic Analysis_ In each way of segmentation, correlations between tract stretch and tumor properties and between tract stretch and parameters of motor function were investigated.

## 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 presented normal muscle power and five patients presented abnormal muscle power. The tract stretch in the IC region revealed significant negative correlation with the muscle power ($r^2$= 0.47; p=0.015, Fig. 2). The tract stretch in the MB region showed significant negative correlation with the tumor volume ($r^2$= 0.58; p=0.010). No correlation was found when the stretch of the whole tract or at the three levels of CST was analyzed.

## Conclusions

The morphological change of CST, as quantified by tract stretch, at the internal capsule was found to be correlated with the muscle power impairment. Our results suggest that the tumor stretch of the CST at the internal capsule may impose significant impact on the motor function.

## References

[1]Yvonne *et al*. Neurosurgery 2007.
[2]Assaf *et al*. Isr J Chemistry 2003.
[3]Schonberg *et al.* NeuroImage 2006
[4]Wedeen *et al.* MRM 2005.
[5]Chiang *et al.* ISMAR 2007.

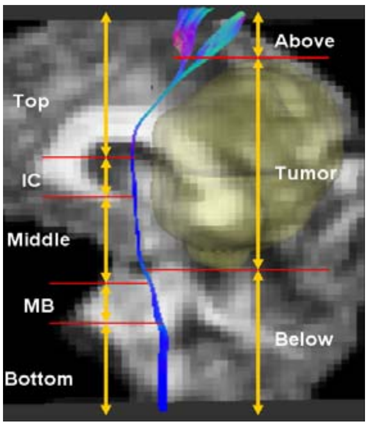


**Figure 1** Tractography of CST on the tumor side. The yellow mass shows the tumor. The yellow arrows and the red lines defined the range of three levels and five regions of CST. The three levels indicated the level above the tumor, at the tumor level, and below the tumor. The five regions were defined as top, IC, middle, MB, and bottom.

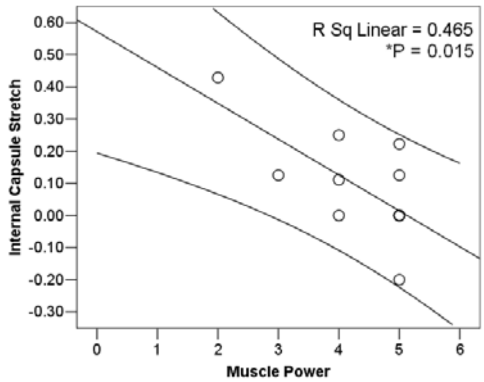


**Figure 2** Tract stretch in the IC region has negative correlation with muscle power.