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

Y-Y. Yeh1, S-C. Huang2, W-Y. Chiang3, F-C. Yeh1, J-C. Tsai1, H-M. Tseng1, and W-Y. I. Tseng1

1Center for Optoelectronic Biomedicine, National Taiwan University College of Medicine, Taipei, Taiwan, 2Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan, 3Department of Surgery, National Taiwan University Hospital, Taipei, Taiwan, 4Department of Medical Imaging, National Taiwan University Hospital, Taipei, Taiwan

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 ±11.8 years). 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).

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.

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

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