Toward Full Visualization of the Pyramidal Tract in Brain Tumor Patients: Tractography Based on Directional Diffusion Function

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Introduction

Diffusion tensor tractography is an emerging MR technique to visualize the white matter tract in the brain based on the diffusion tensor imaging (DTI) data. Most importantly, tractography has been used to visualize the pyramidal tract for pre- and intra-operative guidance in brain tumor surgery. In most conventional tractograhy techniques, the primary eigenvector is used to track the fiber tracts. It has been claimed that these conventional techniques are unable to track the fiber tract beyond the areas of fiber crossing and branching. As a result, the conventional methods fail to visualize the pyramidal tract to its full extent. This issue is critical because invisible part of the tract may be accidentally damaged during the surgery. Toward full visualization of the pyramidal tract, we have developed a new tractography method that allows for crossing and branching of the fiber tracts. In the present study, we applied this new tractography method to brain tumor patients to test the validity and feasibility in the clinical settings.

Materials and Methods

DTI data of seven patients with a primary brain tumor (17-60 years old, 5 in right hemisphere and 2 in left hemisphere) were retrospectively analyzed. The DTI data were obtained using a 1.5 T MRI scanner and a DTI pulse sequence with 6-directional diffusion-weighting. For each voxel, diffusion tensor was calculated, and a directional diffusion function (DDF) was defined based on a three-dimensional Gaussian function of the diffusion tensor. The connectivity between neighboring voxels was defined based on the overlaps of the DDFs in the two voxels. A path connectivity was defined by averaging the connectivity along the path between the user-defined "seed" and "target" regions. The white matter tract was estimated by selecting the path with the maximum path connectivity between a certain set of voxels. For each patient, the pyramidal tracts were visualized both in the hemisphere affected by the tumor and unaffected hemipshere. Two neuroradiologists visually evaluated the validity of the estimated pyramidal tracts comparing with the anatomical knowledge. Degree of visualization was classified into 4 grades based on the extent of path arrival in the precentral gyrus: grade 1 (only most medial part) to grade 4 (full visualization). The number of estimated paths and mean path connectivity were compared between the affected and unaffected hemispheres.

Results

The estimated pyramidal tract was consistent with the anatomical knowledge both in affected and unaffected hemispheres in all patients. Full visualization (grade 4) of the pyramidal tract was achieved in 4 cases (57%) and 2 cases (29%) in the affected and unaffected hemisphere, respectively (Fig. 1). No significant difference was found in the number and path connectivity between the affected and unaffected sides. Figure 2 shows tractgrams of the pyramidal tracts of a brain tumor patient.

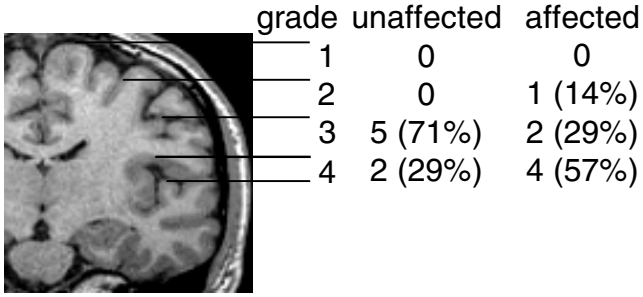

Fig. 1: Extent of visualization of the pyramidal tract.

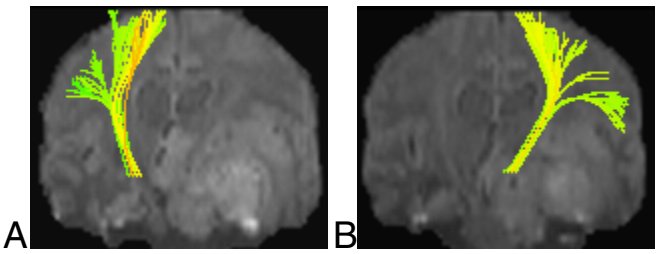

Fig. 2: Tractograms of the pyramidal tracts in the unaffected (A) and affected (B) hemispheres of a glioblastoma patient.

Discussion

Our preliminary results supported the validity and feasibility of DDF tractography. Lack of significant difference in the number and connectivity of the paths between the affected and unaffected hemispheres suggested that the pyramidal tract is trackable in most cases despite the displacement and/or involvement by the tumor. Overall, full visualization of the pyramidal tract was achieved in 6 hemispheres (43%), demonstrating improved visualization in comparison with the conventional methods.