Characterization of displaced white matter tracts using DTI and fMRI

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Introduction

Diffusion tensor imaging (DTI) can be used for 3D visualization of specific fiber bundles, and to indicate the involvement of white matter in vicinity to brain lesions. DTI based fiber tractography necessitates definition of a seed region of interest (ROI) that is located at the path of the investigated fiber network system. Selecting seed ROIs based on known anatomical landmarks has identified a large number of fiber bundle systems in healthy subjects. Brain lesions, especially space occupying lesions (SOL) often involve the white matter and alter the known anatomical path in which the fibers pass. Nonetheless in many of these cases only partial or no functional deficit is observed leading to the assumption that the fibers are still partially functionally intact even if they are deviated. In such cases, white matter mapping using seed ROI based on known normal anatomical locations might be misleading. In this work we used fMRI driven seed ROI choosing procedure in patients with SOLs where probable deviation of white matter tracts was observed. We used analysis of the principal diffusivities to characterize the displaced white matter.

Methods

Nine patients with SOL's affecting either the pyramidal or the superior longitudinal fasciculus (SLF, arcuate fasciculus) were scanned on a 1.5T scanner (GE, Milwaukee, USA). Imaging protocol included both fMRI and DTI. Functional MRI included mapping of motor activity of hand related areas (using a finger tapping task) and language related activated areas (using auditory verb generation task). Functional MRI was done using a gradient-echo echo-planar-imaging (GE-EPI) with the following parameter: TR/TE=3000/55ms, FOV=24cm and 17 slices of 5mm thickness with 1 mm gap. DTI protocol was done using a pulsed gradient spin echo echo-planar-imaging pulse sequence (PGSE-EPI) with the following parameters: TR/TE=6000/98ms, Δ/δ=31/25ms, b=1000 s/mm^2, FOV=24cm, 48 slices of 3mm thickness with no gap acquired in 6 non-collinear gradient directions. Functional MRI was analyzed using BrainVoyager © and was multi-registered with DTI and high resolution T1-wieghted 3D MRI. Functional MRI activations were used as landmarks to choose seed regions of interest for fiber tracking. Fiber tracking was used to mark areas of displaced white matter and on which DTI measures were extracted.

Results

Figure 1 demonstrates DTI based fiber tracking of the SLF for a healthy subject (top) tracked using conventional anatomical seed ROI and a patient (bottom) with left temporal lesion (M/26y) displacing the SLF. The SLF of the patient in figure 1 was tracked using the fMRI landmarks as the seed ROI (light blue). Figure 2 demonstrates DTI based fiber tracking of the pyramidal tract for a healthy subject (top) tracked using conventional anatomical seed ROI, and a patient with a lesion below the central sulcus (M/23y) displacing the pyramidal tract anteriorly. It should be noted that for the two patients, fiber tracking without a-priori knowledge of the fMRI activation area (i.e. using conventional anatomical landmarks as seed ROI's), resulted in non meaningful tracts. DTI measures of the displaced fiber tracts revealed several significant changes compared to the opposite healthy hemisphere within each patients. The radial diffusivity was significantly reduced by approximately 50% (compared to the healthy side), while the parallel diffusivity increased by ~20%, as a result the fractional anisotropy (FA) increased by 30%. The opposite change in the diffusivities caused the ADC to remain at similar values to the opposite non-lesioned hemisphere.

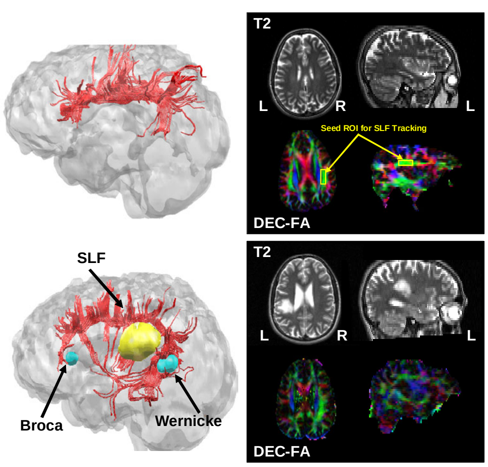

Figure 1

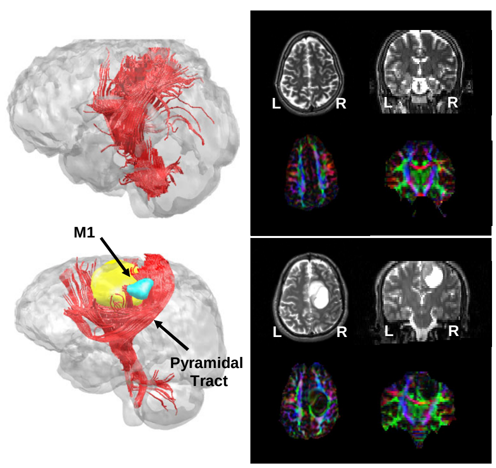

Figure 2

Discussion

The arcuate fasciculus and pyramidal tract are large bundles of white matter which connect critical areas of language and motor functions, respectively. Knowledge of the path of the fibers, as well as the functional locations of the language or motor activation areas are essential data for pre-surgical mapping of patients with space occupying lesions. Tracking displaced white matter, using conventional anatomical locations is not a trivial task and thus in this work we showed the utility of combining fMRI and DTI for achieving this goal. With this suggested procedure, fiber-tracking can be used more reliably to provide better and more accurate maps for clinical use. Detailed analysis of the DTI measures showed that the displaced fibers are characterized by increased FA, deceased radial diffusivity and increased parallel diffusivity.