Cortical Mapping Inside Out: Mapping of Cortical Areas Associated with Specific White Matter Tracts Using Diffusion Tensor Imaging and Tractography

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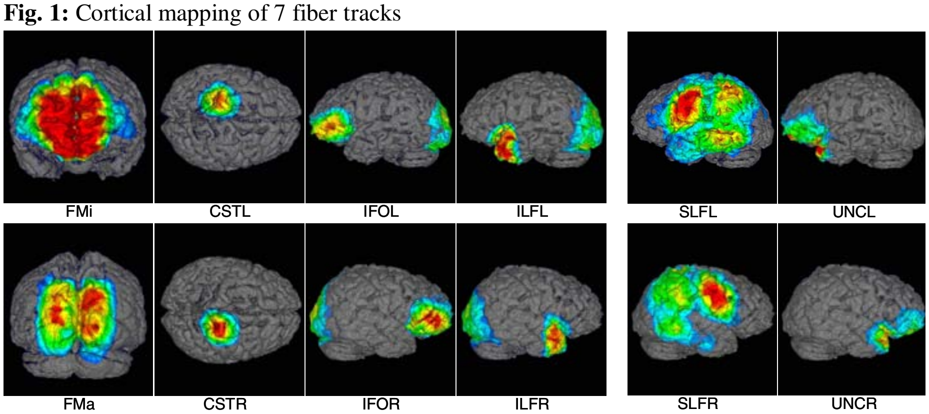
Introduction

Three-dimensional tract tracking based on DTI can reconstruct trajectories of major white matter tracts. This technique, called tractography, can faithfully reconstruct cores of prominent white matter tracts by using existing anatomical knowledge as anatomical constraints. This technique can be used to identify connected cortical regions. However, tractography is also known to contain errors due to noise, partial volume effects, and complex axonal structures within a voxel. Probabilistic approaches could be an effective way to address these issues because random errors are not expected to have significant contribution. In this study, the tracking results in each subject were first extrapolated to identify associated cortical regions. The labeled cortical regions were mapped to the Talairach space and created a probabilistic map from 28 normal subjects. Probabilistic maps of the corticospinal tract, corpus callosum, and 4 association fibers were created and compared with Brodmann's functional map in the Talairach coordinates.

Method

DTI data were acquired by using a single- shot echo-planner imaging sequences with sensitivity encoding (SENSE), parallel – imaging factor 2.5, on a Philips 1.5T scanner. Twenty-eight healthy adults (mean 26.1 +/- 5.48 years old, male 17, female 11) were involved in this study, all with no neurological history. The DTI datasets were processed using home made software DtiStudio. FACT method and multi-ROI approach was used to reconstruct following 7 fiber tracks; forceps major (FMa), forceps minor (FMi), corticospinal tract (CST), inferior fronto-occipital fasciculus (IFO), inferior longitudinal fasciculus (ILF), superior longitudinal fasciculus (SLF), and uncinate fasciculus (Unc). Using the anatomical image of each subject and the JHU-DTI template brain, a transformation matrix was determined based on 12-mode affine transformation. Tracking results in each subject were then registered into the template. To determine cortical areas associated with a specific fiber bundle, a 10mm diameter sphere was attached at the end of individual fibers. A new volume was then created from the union of all the spheres. The associated cortical regions were then identified from the intersections of the spheres and the cortical surface of the template brain. The cortical mapping of 7 tracts in the template brain was repeated for the 28 normal subjects and averaged for each standard coordinates.

Fig. 1: Cortical mapping of 7 fiber tracks



Results & Discussion

Fig. 1 shows results of cortical connectivity maps of 7 tracts. With these four major association tracts (IFO, ILF, SLF, Unc), all 4 brain lobes are connected each other; namely, fronto–parietal (SLF), fronto-occipital (IFO), fronto-temporal (Unc), parietal–occipital (SLF), parietal-temporal (SLF, ILF), and occipital-temporal (ILF). High degree of symmetry was observed for most fibers, but three well-clustered regions are apparent for the SLF only in the dominant hemisphere. Fig. 2 shows Talairach coordinates of these three cortical regions with high probability in the SLF mapping. These regions are identified as area Broadmann 21 (Wernicke's area), 44 (Broca's area), and 40 (supermarginal gyrus). Care must be taken because the results may contain false positive and negative depending on complexity of tract architecture. Nonetheless it is encouraging that our tractography-based cortical mapping of the SLF could identify major language areas[1, 2]. The proposed method could be an effective tool to estimate associate cortical regions and to characterize alteration of white matter anatomy for future clinical studies.

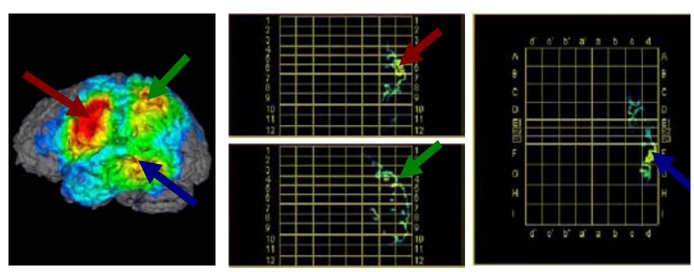


Fig. 2: Probability cortical mapping shows SLF connects to following three areas :
Broadmann 44 (Broca's area) Broadmann 40 (Supermarginal gyrus)
Broadmann 21(Wernicke's area)

References

1: Catani et al, Ann. Neurol. 2005, 57, 8-16

2: Parker et al, NeuroImage, 2005, 24, 656-666