Cortex mapping based on white matter connectivity using diffusion tensor imaging

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Introduction

It has been a common practice to parcellate human cortex based on surface features using MRI. While this approach has been proven useful for many application studies, complexity and large variation of gyrus patterns make it a challenging task to identify specific cortical areas. Although the gold standard of cortical parcellation is based on cytoarchitecture, this approach is not compatible with in vivo studies. In this paper, we established a framework for "inside-out" cortical parcellation based on underlying white matter anatomy. The technique is based on DTI and tract reconstruction method. We first established a protocol to reconstruct tracts of interest and identified several white matter tracts that can be reproducibly reconstructed. The trajectories were extrapolated to identify cortical areas that were likely to be associated with the tracts. After intra- and inter-rater reproducibility measurements, normal distribution of associated cortical areas were identified for each white matter by warping the results to a standard coordinate.

Methods

DTI data were obtained from our normal DTI database (2.5 mm isotropic resolution). The mapping technique presented in this paper starts with a triangle mesh representation of the human cortex that was generated from a 256x256x50 volume matrix with the native voxel size of 0.9375mmx0.9375mmx2.5mm. The 3D tract was reconstructed using the FACT (fiber assignment by means of continuous tracking) method with FA threshold of 0.2 [1]. Four fiber bundles, CST (corticospinal track), ILF (inferior longitudinal fasciculus), IFO (inferior frontooccipital fasciculus), UNC (uncinate fasciculus) were studied. The first step in determining a cortex areas associated with the fiber bundles was to attach a 20mm diameter sphere at the end of each individual fiber. A new volume was then created from the union of all the fiber spheres. The surface area defined by the intersection of the volume with the cortex triangle mesh was regarded as the associated cortex area. Intra-rater and inter-rater validation of this technique was conducted by three operators repeating the measurements three times. Inter-subject variability study was conducted by co-registering data from five subjects into one template using LDDMM [2].

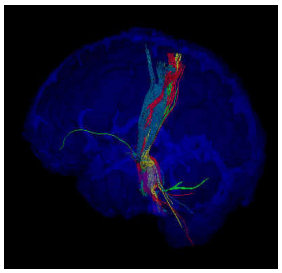

Fig.1: CST (left) from five subjects after LDDMM

Results

Fig. 1 shows results of co-registration of the corticospinal tracts from 5 subjects using LDDMM. Fig.2 shows representative results of the study. For these selected tract families, intra- and inter-rater reproducibility is excellent. The cross-subject statistical map shows that the associated cortical areas are well clustered. The CST identified medial regions of the motor cortex. The IFO connects frontal/orbital cortices to the occipital lobe, while the ILF connects the temporal pole to the occipital lobe.

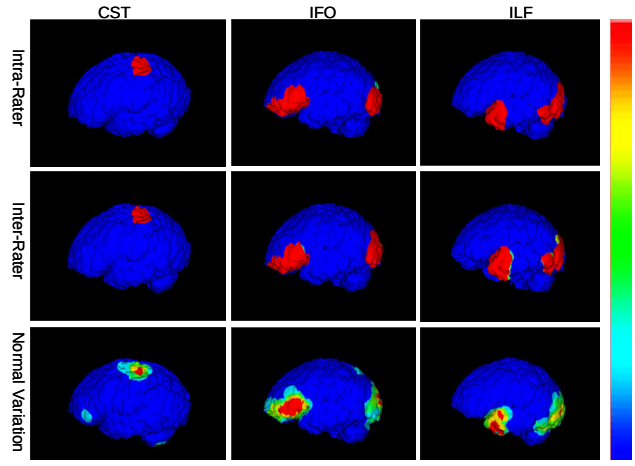

Fig. 2: Results of intra- and inter-rater reproducibility and normal variation studies. The color scale represents identified cortical areas with the degree of reproducibility (red 100 % - blue 0%).

Discussion

Previously, pixel-by-pixel connectivity map of the entire cortex has been postulated by Tuch et al [3] and Johansen-Berg et al [4]. In this study, we adopted an alternative approach in which cortical areas were associated with a specific white matter tract of interest using DIT-based tractography. The results suggest excellent reproducibility for intra- and inter-rater tests. The cross-subject data identify well-isolated cortical target areas for each tract. It would be interesting to apply this technique to see how the target distribution changes under pathological condition. The limitations of this approach should also be aware of. As exemplified by the fact that lateral regions of the motor cortex are not labeled by the CST, the tractography contains false positive and negative results. The tracking usually doesn't reach the cortex where anisotropy is low and we have to extrapolate the trajectory using a sphere of an arbitrary size. The connectivity information revealed by this approach can't be validated. These shortcomings could be ameliorate by using a group analysis and find a robust difference between populations. The interpretation of the results, however, require caution and multi-modality studies such as combination of fMRI, EEG, and TEMS may be needed to further elucidate the mechanism of the results.

Acknowledgements

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