Anatomical Connectivity of the Internal Capsule

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Introduction: White matter tracts in the internal capsule (IC) are of great interest as potential targets for deep brain stimulation (DBS) treatment of psychiatric disorders such as severe depression (1). Clarifying the connectivity of IC to subcortical nuclei may prove invaluable for improving outcomes of such treatment. High angular resolution diffusion imaging (HARDI) based tractography permits noninvasive segmentation of a brain structure (2). We apply this segmentation approach for the first time to the IC. We also show that a statistical correction that accounts for distance-related bias in tractography (3) is important for generating consistent results across subjects.

Methods: Six rhesus macaques were scanned under a Cleveland Clinic ethics board-approved protocol on a 3 tesla TIM Trio (Siemens Medical Systems, Erlangen, Germany) with a high spatial resolution, HARDI acquisition (1.5 mm isotropic voxels, 71 non-collinear diffusion weighting gradients with $b=1000s/mm^2$, eight b=0). We assessed connectivity between the IC and 3 surrounding subcortical structures: caudate, lentiform nucleus (LN), and thalamus. The structures were selected by ROIs drawn by hand on fractional anisotropy images. Probabilistic tractography was run from each voxel in the IC to the entire brain using fiber orientation distributions (FOD) calculated by spherical deconvolution (4). Tractography was repeated using an isotropic distribution to generate a null distribution map for statistical elimination of connections due to chance. Each voxel in the IC was classified according to which of the three target structures had the highest number of tracks between that IC voxel and the target. The track count was normalized by the number of voxels in each target connected to the IC.

Results: The statistical correction has a large impact on segmentation results. Among the 6 subjects, 23±6% of voxels in the IC changed classification because of the statistical correction. Figure 1 shows the effect for one slice. Many voxels classified as LN (purple) change classification to thalamus (blue) and caudate (green) after applying the statistical correction. The connection patterns are similar across all 6 studies, more so with the statistical correction than without. A pattern emerges in which the anterior head of the IC is classified as most connected to caudate. The remainder of the IC divides into medial and lateral regions corresponding to thalamus and LN, respectively.

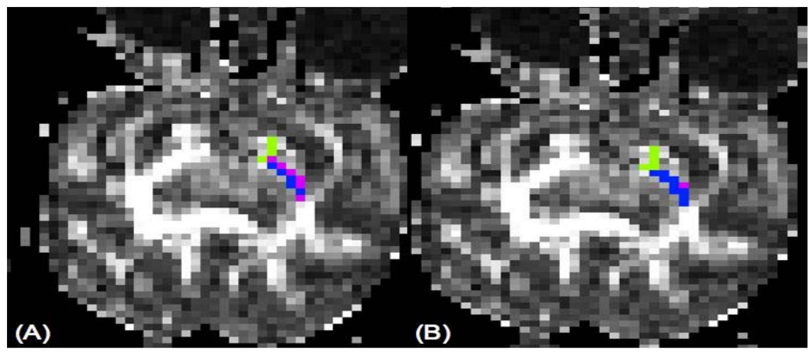

Figure 1: Effect of statistical correction on IC segmentation. Axial view of segmentation before (A) and after (B) application of the statistical correction. Green indicates that the IC voxel is most connected to caudate, purple to LN, and blue to thalamus.

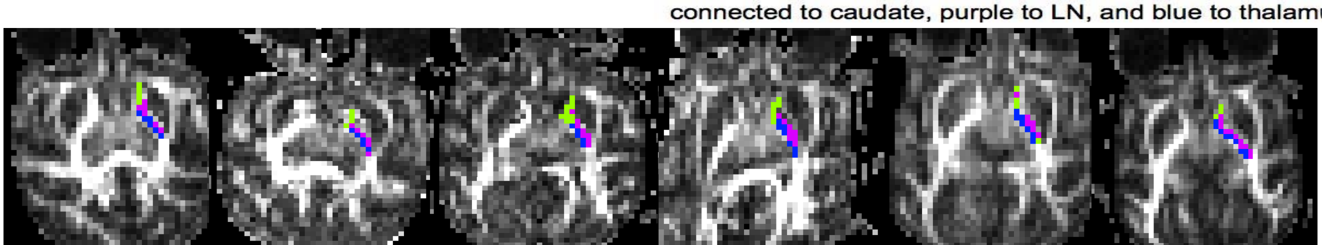
Figure 2: IC Segmentation results for the same axial slice across all six studies. Green corresponds to caudate, purple to LN, and blue to thalamus.

Conclusion: We find similar connectivity patterns across the 6 subjects suggesting that segmentation of white matter tracts using DTI is robust. Application of statistical normalization in probabilistic tractography may be essential given the large change in segmentation results observed in the IC and known distance-related biases in tractography. Future work will examine the potential of these methods to determine which white matter tracts correlate with optimal outcomes in DBS for psychiatric disorders and for optimizing electrode placement.

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References:
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