Characterization of White Matter Maturation in Cats: Diffusion Spectrum Imaging Tractography

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Introduction

Standard diffusion tractography (based on diffusion tensor imaging, or DTI) tends to terminate in brain areas with low water diffusivity, indexed by low diffusion fractional anisotropy (FA), which can be caused by crossing fibers as well as fibers with less myelin. For this reason, DTI tractography is not effective for delineating the structural changes that occur in the developing brain, where the process of myelination is incomplete. We have shown that at postnatal day (P) 35 kittens, the degrees of myelination varied in white matters in different brain areas (Takahashi et al., 2009). Our purpose of current study was to quantify the FA and ADC values on different fiber tracts in this specific developmental phase of juvenile kitten to characterize regional difference in degrees of maturation, and to compare these values between P35 (pediatric). Using high-resolution diffusion spectrum imaging (DSI) tractography, we successfully imaged the 3-dimensional structure of the cortical and subcortical pathways in P35 cats.

Methods

We performed scans on the brains of five kittens (P35). After the cats were euthanized, their brains were perfused with phosphate buffer saline (PBS) solution followed by 4% paraformaldehyde, removed from the cranium and fixed in 4% paraformaldehyde containing 1 mM gadolinium (Gd-DTPA) MRI contrast agent for 1 week to reduce the T1 relaxation time while ensuring that enough T2 -weighted signal remained. For MR image acquisition, the brains were placed in the Fomblin solution (Fomblin Profludropolyether; Ausimont, Thorofare, NJ). We used 4.7T Bruker Biospec MR systems. The pulse sequence used for image acquisition was a 3D diffusion-weighted spin-echo echo-planar imaging (EPI) sequence, TR/TE = 1000/40 ms, with an imaging matrix of 96 x 112 x 128 pixels for P35 brains. Spatial resolution was 420 x 420 x 420 μm for the P35 cats. We performed diffusion spectrum encoding as previously described (Wedeen et al., 2005). Briefly, we acquired 515 diffusion-weighted measurements, corresponding to a cubic lattice in Q-space contained within the interior of a ball of maximum radius b_{max} = 40k, with small delta = 12.0 ms, large delta = 24.2 ms. The total acquisition time was 18.5 hours for each experiment. Diffusion Toolkit and TrackVis (http://trackvis.org) were used for reconstructing and visualizing tractography pathways.

Figure 1

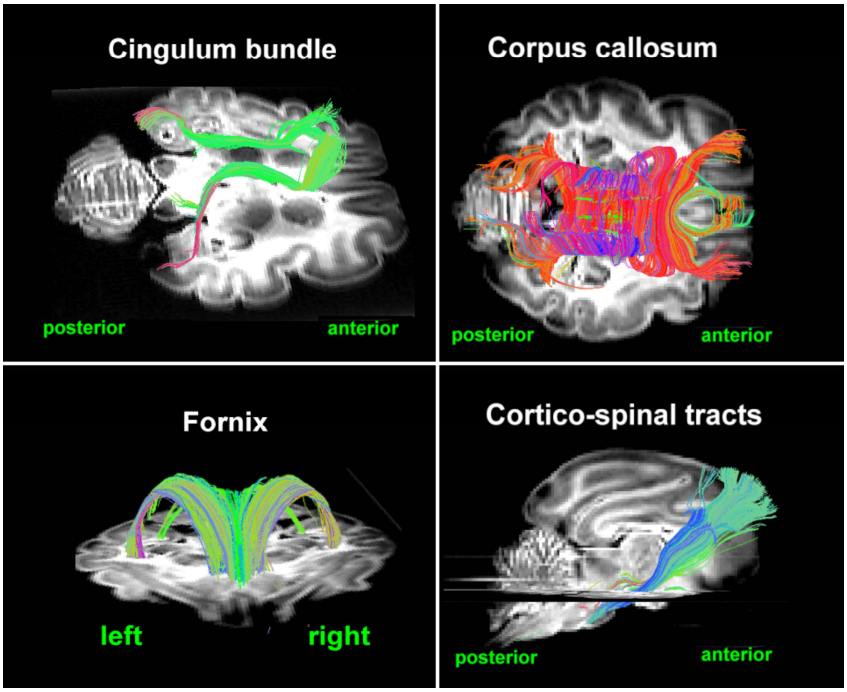
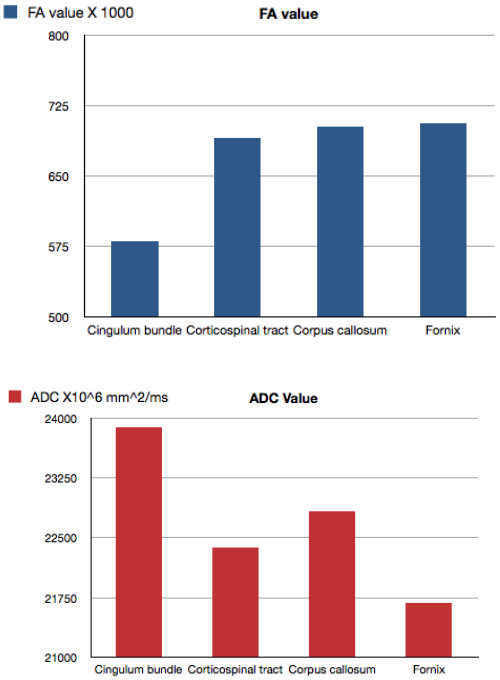


Figure 2



Results & Conclusions:

We successfully identified main fiber tracts of the P35 kitten brains, including the cingulum bundle, fornix, cortico-spinal tract and corpus callosum as shown in Figure 1. The detailed FA and ADC values were showed in Figure 2. Cingulum bundle showed low FA values compared to other fiber bundles. On the other hand, ADC values were higher on the cingulum bundle, intermediate on the cortico-spinal and corpus callosum, and low on the fornix. These results demonstrate that DSI tractography successfully depicted regional variations of white matter tracts during development when myelination is incomplete. Specific low FA and high ADC values on the cingulum bundle suggest that the cingulum bundle is less mature than the others at this developmental stage.

References:

Wedeen et al., MRM 2005
Takahashi et al., Neuroimage 2009