Improved high-resolution diffusion spectrum imaging in young and normal aging monkeys

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Introduction

The complex fiber architecture of the brain entails noninvasive depiction of small structures in the brain using advanced diffusion MRI techniques. Given the limited signal-to-noise of diffusion-based images and severe susceptibility artifacts of the monkey brains on conventional clinical scanners, we utilized an enhanced gradient insert system with parallelized RF coils to implement high-resolution Q-ball imaging in anesthetized monkeys. Using diffusion spectrum imaging (DSI) that has the ability to map complicated fiber architecture at the scale of single MRI voxels [1], we aimed to make a quantitative comparison of the fiber tractography in young and old monkeys and combined neuroanatomical histological method to cross-validate early degenerated axonal fibers.

Methods

Seven (aged at 4-8 years) and sixteen monkeys (aged at 20-25 years) were scanned on a 3T MRI system (Siemens Healthcare) using a head gradient (AC88 system, 80mT/m, slew rate = 800T/m/s), with a custom-made single channel transmit and 8ch receive coil. DSI data were acquired using a twice-refocused spin-echo EPI sequence with a HARDI scheme (DSI Q4 Half). The parameters were TR=6300ms, FOV=96mm×96mm, matrix=64×64, slice thickness=1.5mm, b-value=2500s/mm^2. The TE/echo spacing were 76ms/0.47ms on the AC88 system. Each acquisition was sampled at 30 directions with five b=0 directions interspersed. In order to acquire high quality images, we collected the DSI data twice with the opposite phase-encode directions (anterior-posterior and posterior-anterior). The entire DSI raw images were corrected for subject motion, field inhomogeneity and eddy current artifacts, and then imported into DSI Studio software to track the white matter fibers. Multiple regions of interest (ROI) were chosen to reconstruct the tracts of interest in monkey brains.

Results

We tracked six main objectives pathways in the monkey brains (Figure1, A–F). The corpus callosum was the largest fiber bundle of the monkey brain and connected left, right cerebral hemispheres. The cingulum was a medial associative bundle that ran within the cingulate gyrus all around the corpus callosum. The internal capsule and corona radiation contained the ascending fiber tracts from the thalamus to the cerebral cortex and the descending fiber tracts from the fronto-parietal cortex to subcortical nuclei and spinal cord. The uncinate fasciculus was a ventral associative bundle that connected the anterior temporal lobe with the medial and lateral orbitofrontal cortices. The fronto-occipital fasciculus connected the frontal lobe and the orbitofrontal cortex. The inferior longitudinal fasciculus was a ventral associative bundle with long and short fibers connecting the occipital and temporal lobes.

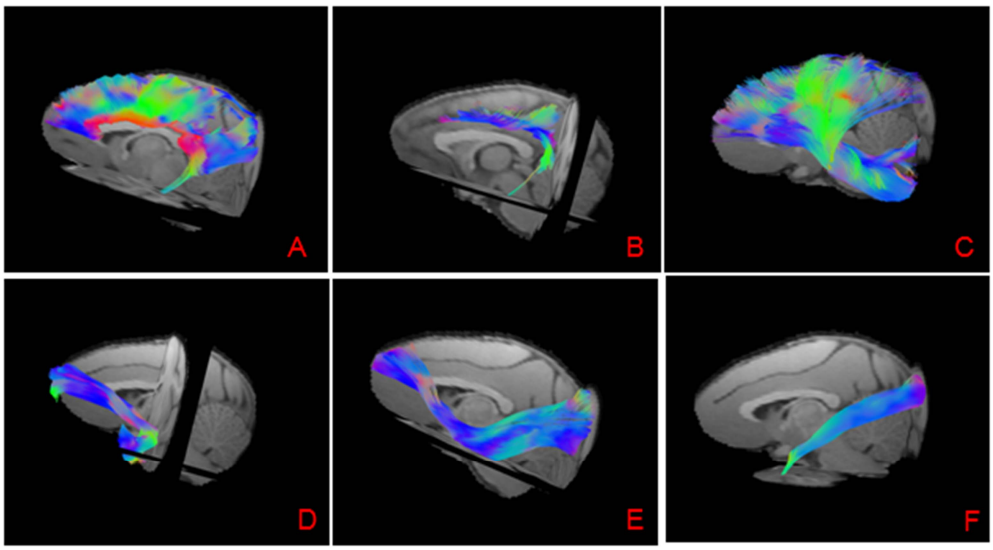

Figure1, Example 3D visualization of six major association fiber pathways from one young monkey, viewed from left lateral side.
(A) Corpus callosum.
(B) Cingulum.
(C) Uncinate fasciculus.
(D) Internal capsule.
(E) Fronto-occipital fasciculus.
(F) Inferior longitudinal fasciculus.

Discussion

Our preliminary results showed in vivo high-resolution tractography of white matter fiber tracts in anesthetized monkeys using an enhanced gradient system. The fiber tracts observed in the monkey brain were also identified in the human brain, with analogous structural organization and topology [2, 3]. It suggests that the comparative study between young and normal aging monkeys could serve as an animal model to investigate structural network organization of the human brain under normal and diseased states.

References

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