Along-tract Characterization of Developing Rabbit Brain Using Diffusion Tensor Tractography

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Introduction

Characterizing complex anatomy at different stages of brain development not only aids in understanding this highly ordered process but also provides clues to detecting abnormalities caused by genetic or environmental factors. Diffusion tensor tractography allows for the in vivo delineation of white matter tracts in the brain in a manner that is individualized to the particular neuroanatomy of each subject. Diffusion anisotropy and diffusivity change in some brain regions with demyelinating disease and also with neural development [1-3]. However few studies identify these changes along the white matter tracts. Therefore the goal of this study was to characterize the changes of quantitative diffusion indices along white matter tracts in the developing rabbit brains. Along-tract method analyzes the quantitative diffusion indices associated with these virtual dissections in a way that is parameterized along the curving axes of the tract spines, instead of the more typical method of averaging this variation into a single mean estimate for each tract. In this study, DTI data of in vivo rabbit brains (4 weeks to 40 weeks) were acquired and analyzed. Fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD) in the regions of interest (ROIs) and along tracts were generated and compared across the ages. In our results, DTI tractography of the important white matter tracts, such as hippocampus, corpus callosum, and olfactory tract, showed refinement in regional tract architecture with maturation. Both regional and along-tract diffusion indices revealed these white matter tracts change during mature period.

Materials and Methods

Whole brain images were acquired from five healthy New Zealand rabbits with ages from 4 to 40 weeks using 1.5T MRI scanner (Siemens SONATA, Germany). During MRI experiments, each rabbit was anesthetized with 2-3 % isoflurance mixed with 300 ml/min air, and animal temperature was maintained at ~35.5°C using heat pad. Rabbits were immobilized and double loop array coils were used. Whole brain T2W images were acquired using turbo spin echo (TSE) sequence with the following parameters: in plane resolution= 0.39 × 0.78 mm^2, thickness= 1.5 mm, slice number= 30, repetition time/ echo time (TR/TE)= 3790 ms/ 114 ms, number of excitation (NEX)= 20, and the scan time was about 7 min. For DTI acquisition, whole brain was obtained with two slab scans. For each slab, diffusion weighted images (DWI) were acquired using 2D echo planar imaging (EPI) sequence with the following parameters: in plane resolution= 0.78 × 0.78 mm^2, thickness= 2 mm, slice number= 12, TR/TE= 2900 ms/ 133 ms, NEX= 9. The diffusion-encoding scheme constituted 12 diffusion-encoding directions with multiple q sampling. Diffusion attenuated images were obtained with diffusion sensitivity (b values) changing from 0 to 2,000 s/mm^2, and scan time was about 42 min for each slab.

DTI tractography, regional and along-tract diffusion indices were analyzed using DSI studio (National Taiwan University, Taiwan). For tractography, three tracts, hippocampus, corpus callosum, and olfactory tract, were selected for further analysis. Fractional anisotropy (FA), mean diffusivity (MD), axial diffusivity (AD), and radial diffusivity (RD) in the ROIs and along tracts were then calculated. The changes of these diffusion indices across the ages were also compared and discussed.

Results and Discussions

In our results (Fig. 1), DTI tractography of the important white matter tracts, such as hippocampus, corpus callosum, and olfactory tract, showed refinement in regional tract architecture with maturation. There was some minor interanimal tract variability, but there was remarkable similarity between the tracts in all animals. In Fig. 2, the regional white matter anisotropy increased with age, and all diffusion diffusivities decreased with age. The changes of diffusion indices implied the more restrictive diffusion during mature period. In Fig. 3, along-tract diffusion anisotropy revealed spatial localized change of these white matter tracts during mature period.

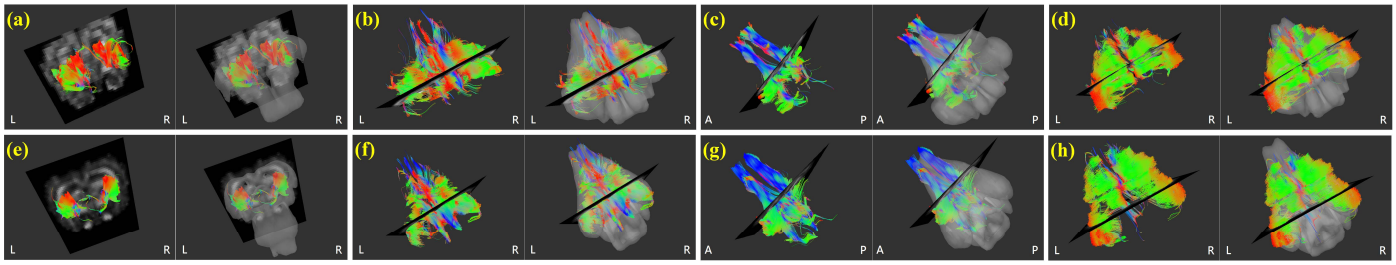

Fig. 1 DTI tractography of (a) hippocampus, (b) corpus callosum, (c) olfactory tract, and (d) cortex of 4 week-old rabbit. (e-h) The same tracts of 40 week-old rabbit.

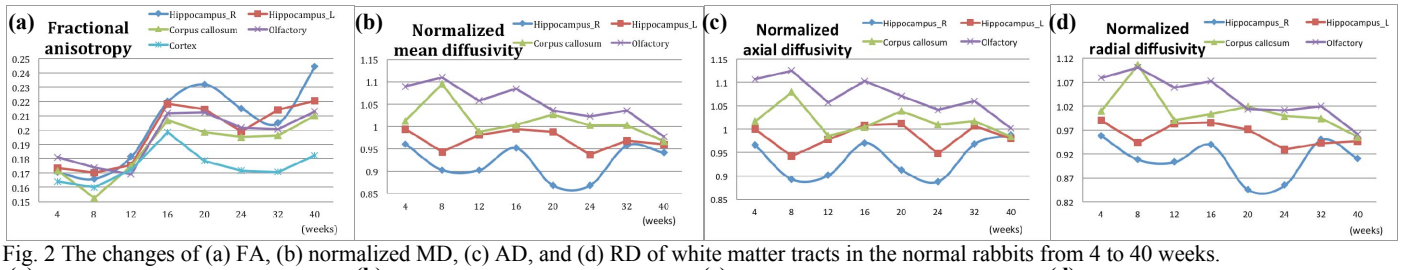

Fig. 2 The changes of (a) FA, (b) normalized MD, (c) AD, and (d) RD of white matter tracts in the normal rabbits from 4 to 40 weeks.

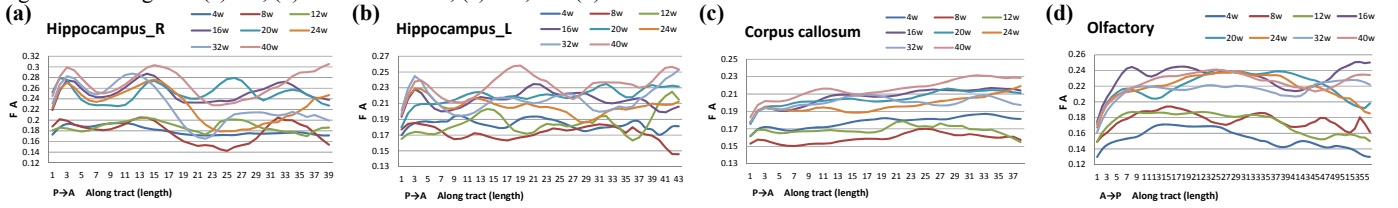

Fig. 3 Along-tract changes of FA in the (a) right hippocampus, (b) left hippocampus, (c) corpus callosum, and (d) olfactory tract in the normal rabbits from 4 to 40 weeks.

Conclusions

Our results showed that both regional and along-tract diffusion indices revealed the important white matter tracts change during mature period. In vivo DTI tractography is a potential tool for neuroscience investigations and can reveal effects, such as fiber tract pruning during development, which may be important targets for in vivo human studies.

References

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