Cortical FA Mapping of Developing Rat Brains

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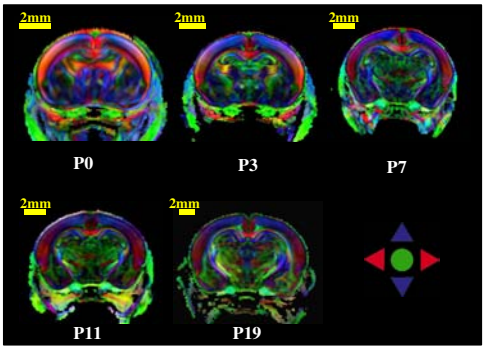
Introduction

Diffusion tensor imaging is sensitive to the microstructural changes in the cerebral cortex. It has been used to assess the fetal mouse brain development [1] and cortical development of human premature newborns (2,3). Fractional anisotropy (FA) is an index to describe how elongated a tensor is and thus be used to quantitatively characterize the microstructures. Both mouse and human studies have found that FA is decreasing during the period of fetal development (1-3). In this study, developmental normal rat brain after birth from P0 to P19 is delineated with DTI. FA mappings on the cortical plates quantitatively and three dimensionally demonstrate the pattern of the cortical development. The FA change orthogonal to the cortical surface is also measured at rostral and caudal cortical locations. These findings can reveal both microscopic and macroscopic cortical development of the rats. They can also be used as reference for the studies on transgenic and knockout rat models of cortical dysfunction.



Methods

Data acquisition: Bruker 9.4T and 4.7 T scanner were used for data acquisition, depending on the size of the specimens. Rat heads were fixed using 4% paraformaldehyde in phosphate-buffered saline (PBS) and stayed in fixation solution for over 1 month. Before imaging, we placed rat heads in PBS for more than 48 hours and transferred them into custom made MR–compatible tubes. The rat heads were bathed with fomblin during scanning. 3D DTI multiple spin echo sequence was used to acquire DTI data. Parameters for diffusion weighed images (DWI) were: FOV=10-18/10-18/10-18mm, 3D imaging matrix = 128×80×72 (zero-filled to 128×128×128), TE=34ms, TR=700ms, 6 independent diffusion weighted directions with b value = 1000 sec/mm^2, 2 additional images with minimal diffusion weighting (b= 50 sec/mm^2). The pixel size after zero filling for DTI images was 80-150/80-150/80-150μm. For each specimen, the DTI acquisition time was about 20 hours. ***Tensor fitting:*** Raw DWI images were registered with B0 images by AIR. The six independent elements of the 3×3 diffusion tensor were calculated using multivariate linear fitting. Fig. 1 shows the DTI colormaps of rat brains from P0 to P19. ***Cortical FA mapping:*** Averaged DWI images were used for cortical surface rendering. FA of cortical plate was mapping to the triangular nodes of the surface.

Fig 1: Coronal slice of DTI colormap at caudal corpus callosum (CC) level.

Results

Cortical FA mapping: FA is mapped to the outside cortical plate and shown in Fig. 2. Overall decrease of FA during the postnatal development is evident. Averaged FA on the cortical plate is reduced from 0.68 at P0 to 0.25 at P19. The major cortical FA change takes place from P0 to P11 and there is no significant change of cortical FA after P11. From P0 through P7, the cortical FA value is not uniform all over the whole cortical plate. Regular and symmetric patterns of FA can be observed. For P0, FA at the superior rostral part is lower than the rest of the cortical plate. For both P3 and P7, FA at the lateral caudal part is a little higher than other parts. ***FA along the axis orthogonal to the cortical plate:*** Figs. 3(a) and 3(b) show the FA change along the axis orthogonal to the outside cortical surface and penetrating the whole cortical plate. The FA at different time points is shown with the depth of cortical plate all normalized at a same length. Two locations, the rostral and caudal parts of the cortical plate, were chosen to display the FA change orthogonal to the cortical surface. Orthogonal FA changes at two locations display similar patterns. For P0 and P3, FA is sharply decreased. FAs at different time points converge to a similar value at the inner boundary of the cortical plates.

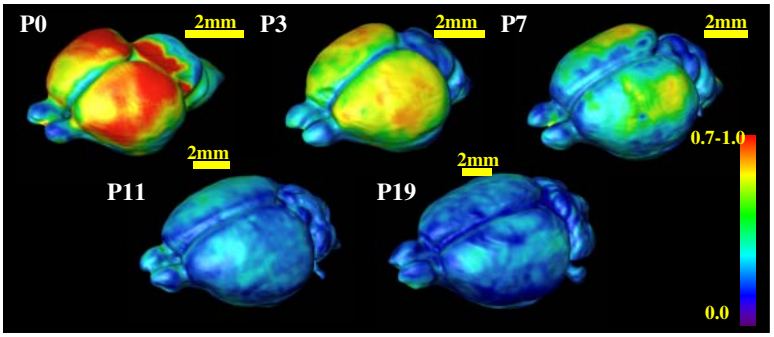


Fig 2: FA mapped to the outside cortical surface from P0 to P19. Color bar shows the FA value of mapped FA.

Discussion

This abstract shows some preliminary results of the cortical FA mapping of developing rat brains. The dynamic change of FA demonstrates a systematic and regular pattern across and orthogonal to the surface of cortical plate. Due to the relationship of FA with microstructures, this study reveals the microstructural development of cortical plate three dimensionally and quantitatively. It can also help to detect the abnormalities in the cortical plate for transgenic and knockout models of cortical dysfunction. In the future, more specimens at each time point will be added to reveal the statistical change of cortical FA during development.

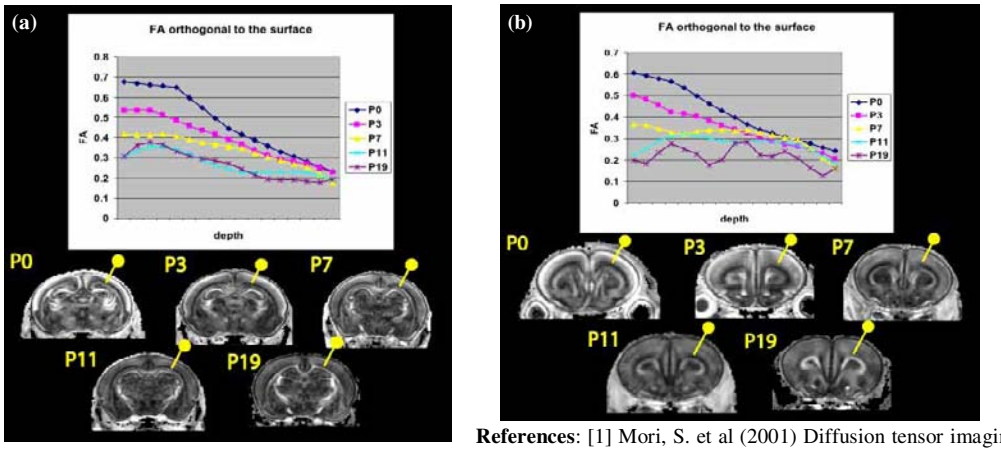


Fig 3: FA along the axis orthogonal to the cortical surface at caudal (a) and rostral (b) brain.

References: [1] Mori, S. et al (2001) Diffusion tensor imaging of the developing moue brain, MRM 46, 18. [2] McKinstry, RC. et al (2002) Radial organization of developing preterm human cerebral cortex revealed by non-invasive water diffusion anisotropy MRI. Cereb. Cortex 12, 1237. [3] deIpolyi, AR. et al (2005) Comparing microstructural and macrostructural development of the cerebral cortex in premature newborns: Diffusion tensor imaging versus cortical gyration. NeuroImage 27, 579. **Acknowledgement:** This study was sponsored by NIH grant R01 AG20012.