Postnatal Neural Development of the Brain: In vivo Diffusion Tensor Imaging

K. H. Bockhorst[1], M. Kamel[2], P. Ahobila[1], J. Ramu[1], J. Wosik[2], R. Perez-Polo[3], and P. A. Narayana[1]

[1]DII, UTH Medical School, Houston, Texas, United States, [2]Texas Center for Superconductivity and Electrical and Engineering Department, University of Houston, Houston, Texas, United States, [3]Department of Human Biological Chemistry and Genetics, University of Texas Medical Branch, Galveston, Texas, United States

Introduction:

Diffusion tensor imaging allows us to noninvasively follow the effect of neurologic injury on neuronal development. Rodents are commonly used as animal models to understand the effect of injury on normal brain development. However, most of the developmental studies in rodents, based on DTI, have so far been performed on excised brains. The diffusion properties of ex vivo brain samples may be affected by fixation and tissue temperature. In these studies we report the in vivo DTI results in normal rats from day 0 to 28 after birth.
These results should serve as 'normal' reference for to understand the effect of insult on brain development.

Methods:

23 Wistar rats were scanned on days 0,2,4,6,8,14,21, and 28 after birth under isofluorane anesthesia (2 % in an 7:3 mixture of air and oxygen). Their heads were fixed in a custom built holder and their body temperature was maintained by blowing temperature controlled warm air. Their respiratory rate and body temperature were monitored continuously throughout the scan. All MRI scans were performed on a 7T/30cm bore Bruker scanner. A 72 mm id volume coil was used for RF transmission and a home built 22 mm circular surface coil was used for signal reception. In order to minimize stray electric fields that can lead to additional dielectric loss in the sample, a double-sided structure was chosen to introduce distributed capacitance in the coil design. The coil consisted of two split rings placed on two sides of the substrate, and each split-ring was rotated 180° from each other. High resolution dual echo RARE images (TE: 21, 56 ms, TR 5 s, up to 35 slices, 256*256 matrix, 0.5 mm slice thickness, RARE factor 4) were recorded for anatomical reference. Diffusion weighted images were acquired using a four-shot EPI sequence with the diffusion encoding gradients applied along 42 (21 alternating polarity) directions) with a b = 800 s mm^{-2}. The DTI scan parameters were: slice thickness 0.5 mm, number of slices 35, TE/TR=38/4000 ms, FOV = 35 mm, acquisition matrix 128x128, number of averages was 4 with diffusion gradients turned on and 9 without diffusion gradients. The FA maps were generated using the in-house written software. ROI analysis of the FA maps was performed in the superior cortex at the bregma and in adjacent slices up to ± 2 mm.

Results:

The color coded FA maps around the bregma from day 0 to 28 after birth are shown in Fig. 1. In vivo DTI confirmed a high anisotropy (FA > 0.25, Fig. 2) in the cortex immediately after birth. The FA value decreased during the following days. At day 6 they were no longer significantly different from the value found in adult rats (FA ~ 0.17, day 28). The differences between left and right hemispheres were not significant. Also, values measured posterior or anterior to the bregma were not significantly different. The contrast between the superior cortex and the adjacent corpus callosum clearly decreased during the observation period (Fig. 2).

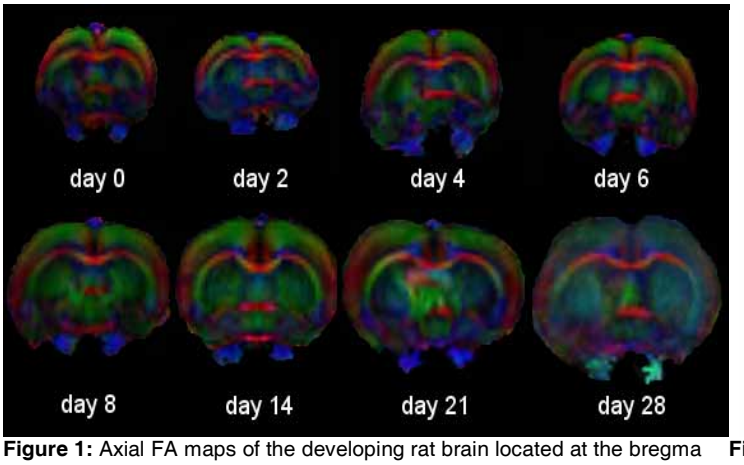

Figure 1: Axial FA maps of the developing rat brain located at the bregma between day 0 and day 28 after birth.

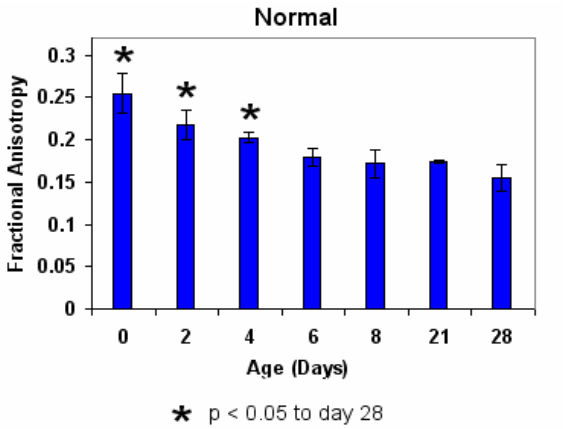

Figure 2: Bars present FA values by age (day 0 to 28) measured in the superior cortex at bregma and adjacent slices.

Discussion:

We believe that these are the first in vivo DTI studies of rats from birth to day 28. Our results are consistent with those reported by Zhang et al. on excised mouse brain. Based on the reported developmental studies, the decreased FA value with age perhaps reflects the neuronal migration along the specialized glia fibers (2). The decreased anisotropy from day 6 indicates maturation of neocortex. The temporal profile of FA appears to reflect brain development that could help understand how brain injury affects normal brain development.

References:

(1) Zhang et al., Magn Reson Med 55, 439-449 (2006)
(2) Gupta et al., J Neurosci Res 81, 172-178 (2005)