Diffusion Tensor Imaging of the Developing Visual Cortex and Visual White Matter Pathways in Premature Newborns

R. T. Held[1], P. Mukherjee[2], S. Veeraraghavan[2], A. J. Barkovich[2], D. B. Vigneron[1,2]

[1]Joint Graduate Group in Bioengineering, UCSF/UCB, San Francisco, CA, United States, [2]Department of Radiology, University of California, San Francisco, CA, United States

Introduction: MR diffusion tensor imaging (DTI) stands as a viable method to assess white and gray matter maturation in neonates (1). In particular, fractional anisotropy (FA) and eigenvalue maps may be used to monitor the formation of white matter tracts as the diffusion of water becomes constricted in directions orthogonal to the length of the tracts. Previous studies also observed FA in the premature gray matter, which decreases rapidly with estimated gestational age (EGA) (1,2). The high FA in the developing preterm cortex was attributed to radial glial cells, while the drop in FA was associated with dendritic arborization. The current study used MR-DTI data obtained from premature newborns to investigate development of the optic radiations and primary visual cortex during the weeks following premature birth. Changes in DTI parameters were analyzed with respect to time, as well as hemisphere and patient gender.

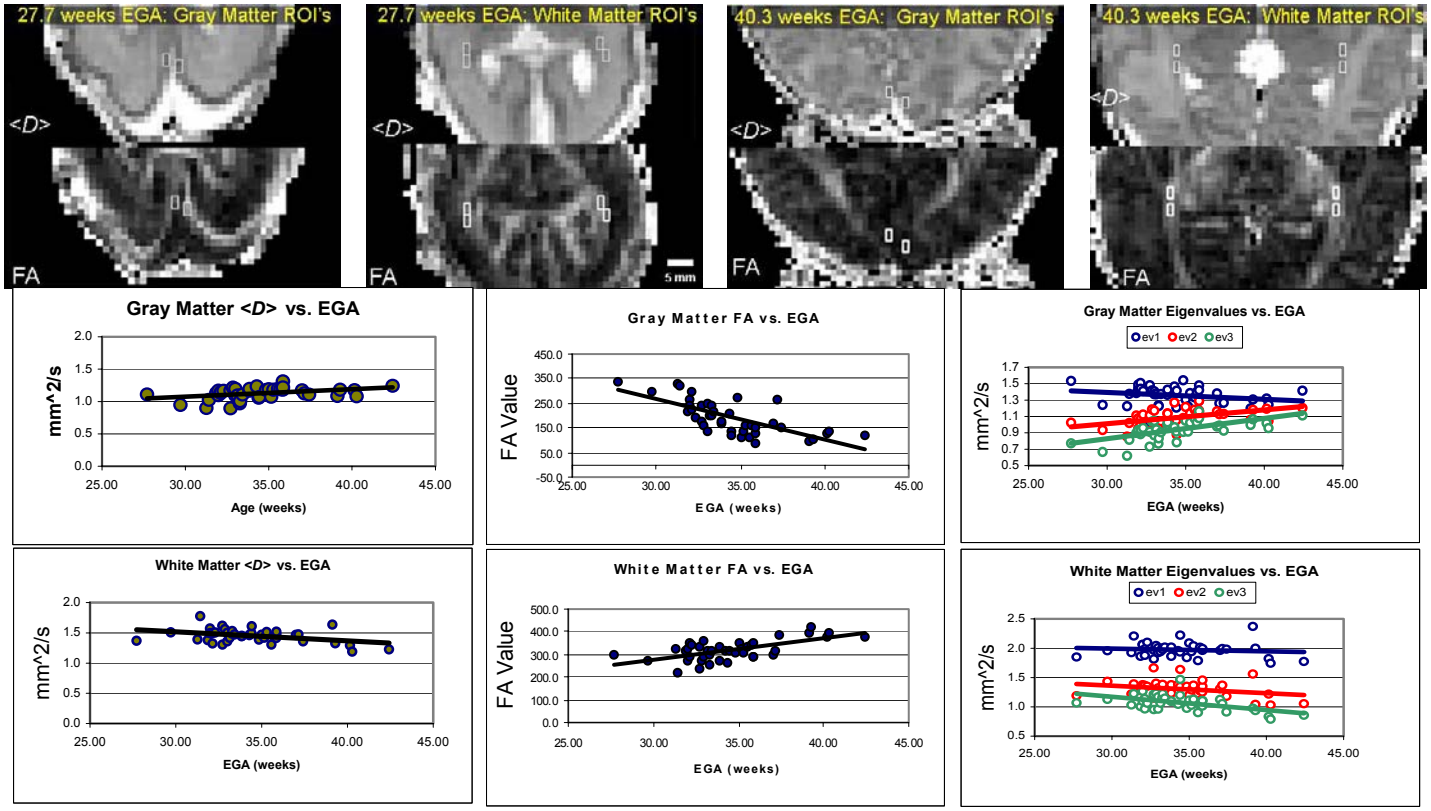
Materials & Methods: Forty-one DTI-MR exams were acquired from 29 premature newborns with normal neurodevelopmental outcome at one year. The exams were performed at estimated EGA's ranging from 27.7 to 42.4 weeks, using an MRI-compatible incubator with a specialized high-sensitivity neonate head coil (3). The whole-brain axial interleaved DTI images were acquired in 4.8 minutes at a 1.4 x 1.4 x 3.0 mm spatial resolution using a single-shot EPI sequence with 6 gradient directions, b=0 and 600s/mm2, TE=99.5ms, TR=7s, and 3 repetitions. Region of interest (ROI) analyses were performed for the directionally-averaged apparent diffusion coefficient (<*D*>), each eigenvalue ($\lambda1$, $\lambda2$, $\lambda3$) and fractional anisotropy (FA). ROI's were placed on either hemisphere in the gray matter of the primary visual cortex and on the white matter of the optic radiations (see figures). Analyses were performed to compare ADC, FA and eigenvalues with respect to age, gender and hemisphere.

Results and Conclusions: No significant differences were found between the right and left hemispheres or between males and females.

Gray Matter: While the gray matter in the primary visual cortex did not show a large change in <*D*>, the FA values dropped significantly from 28 to 42 weeks EGA. This may be attributed to the total diffusivity remaining constant while the directional diffusivities changed. The figure below shows that the primary, secondary and tertiary eigenvalues approach the same value as EGA increases. Importantly, the primary eigenvalue can be seen decreasing with EGA as the minor eigenvalues increase. Therefore, it appears that diffusivity decreased with maturity as the presence of radial glial fibers declined. Basal dendrite arborization apparently reduces the anisotropy caused by radial glial cells during early development (1,2,4,5).

White Matter: In the white matter, the <*D*> of the optic radiations decreased slightly with age. However, the FA increased significantly. This was due to a decrease in the minor eigenvalues with age while the primary eigenvalue remained steady. Thus, diffusivity orthogonal to the length of the optic radiations decreased with EGA, which agrees with previous findings (6).

The MR-DTI scans, which were permitted by an MR-compatible incubator with a high sensitivity neonatal head coil, provided data on the changes in diffusivity of gray and white matter in premature neonates. In particular, the study demonstrated the feasibility and normative values for DTI studies of the developing visual cortex and visual tracts in the premature neonatal brain.



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