Quantitative Fiber Tracking Analysis of the Optic Radiations in Premature Newborns

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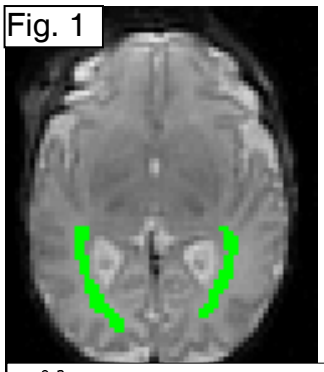
Introduction: The optic radiation or geniculocalcarine tract connects the lateral geniculate nucleus of the thalamus to the primary visual cortex and is among the earliest white matter tracts to mature and myelinate in the preterm human infant brain. Diffusion tensor imaging (DTI) of premature infants provides an opportunity to study the microstructure and physical maturation of this white matter structure. DTI fiber tracking enables the 3D segmentation of axonal bundles, even in unmyelinated white matter that is not visible on conventional MRI. Prior studies have used DTI fiber tracking to study the corticospinal tract in premature infants. In this study, a high-sensitivity neonatal head coil [1] was used to perform DTI of the premature infant brain to assess the feasibility of quantifying microstructural changes in the optic radiations during development. Measurements from 3D ROIs generated from DTI fiber tracks were correlated with a clinical visual gaze examination.

Methods: Twenty-seven premature infants were imaged between 31 and 41 weeks gestational age (GA) at 1.5T using an MR-compatible incubator with a custom designed neonatal head coil [1]. Eight of the infants were serially scanned at two time points for a total of 35 scans. DTI was acquired with a 4.8 minute single-shot, multirepetition echoplanar sequence and TR/TE = 7s/100ms, 3 NEX, 256 x 128 matrix, 360x180 mm FOV, and 3 mm slice thickness with no gap. Diffusion gradients were applied in 6 non-collinear directions with b=600 s/mm^2 in addition to a b=0 s/mm^2 image. SNR of the diffusion weighted images was approximately 35.

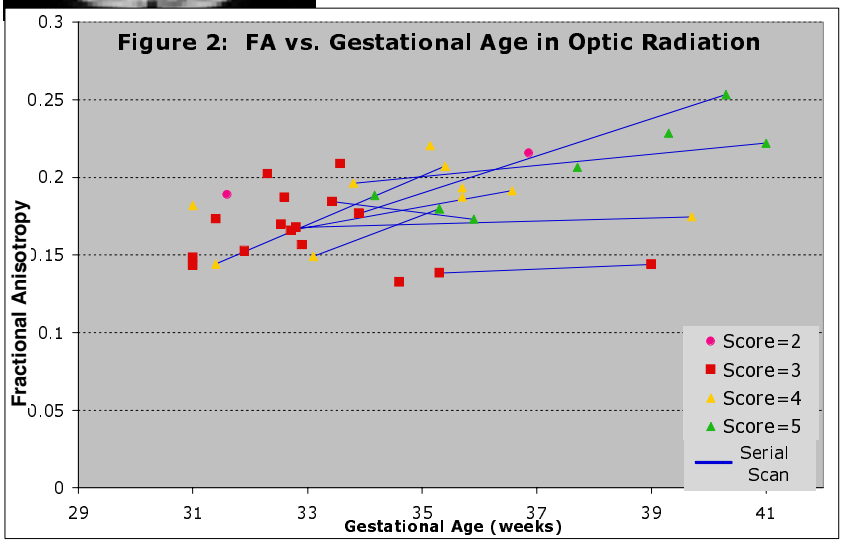
Fiber tracks were constructed using software based on the FACT [2] algorithm, which follows the primary eigenvector in 3D continuous space from voxel to voxel. Fiber trajectories were launched from a region of interest drawn in the white matter adjacent to the lateral geniculate nucleus. To retain fiber tracks within the optic radiations, target regions were drawn in white matter regions adjacent to the primary visual cortex. Fractional anisotropy (FA), directionally averaged diffusion coefficient (D_{av}), and the three eigenvalues (λ_1, λ_2, λ_3) were measured within the 3D regions defined by the fiber tracks. Mean values were weighted by the number of fiber tracks passing through each voxel. Left and right optic radiation measurements were averaged.

Infants were examined by a neurologist within 24 hours of MR and assigned two clinical gaze scores based on the predicted development of eye movements in premature newborns. The visual fixation and conjugate scores are ordinal scales from 0 to 5, with 5 being best, or most mature.



Results:

DTI fiber tracks (figure 1, green) delineated white matter adjacent to the posterior horn of the lateral ventricle, matching the known anatomical placement of the optic radiations. The FA increased with age, as seen in figure 2 (P<0.01, Spearman Rank). Transverse diffusivities, λ_2 and λ_3, decreased with age (P<0.05, Spearman Rank). In figure 2, infants scanned twice are indicated with blue lines connecting the serial scans and visual fixation scores are indicated by symbol color. Two older infants (GA > 39 weeks) with visual fixation scores less than 5 had FA measurements below the 95th confidence limits as defined by the infants with a normal score of 5.



Discussion/Conclusion:

This study demonstrates the feasibility of DTI fiber tracking to delineate the optic tract for quantitation in preterm infants during the early stages of maturation. Myelination, decreasing water content, and increasing density of axons may cause the observed changes in DTI parameters with age. This study suggests that infants with poor visual fixation scores for their age exhibit a corresponding delay in maturation of the optic radiations.

References:

1) Dumoulin et al. Magn Reson Engineering 2002; 15:117-128.

2) Mori S. et al. Ann Neurol. 45:265,1999.