Improved Diffusion MR imaging of Premature Newborns Using an MR Compatible Incubator and a Specialized Neonate MR Coil

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Introduction

MR diffusion tensor imaging (DTI) is a powerful technique for assessing tissue microstructure. Although primarily used in adult studies, DTI may be especially valuable for the study of brain development and injury in premature newborns. Technical challenges for neonatal DTI include: the ability to perform MR exams on young, unstable premature babies; the small size of the neonatal head for which the adult head coil is suboptimal; and potential motion artifacts in unsedated neonates. These problems were addressed in this serial DTI study of premature brain development by using an MR compatible incubator incorporating a specialized neonatal head coil (1).

Materials & Methods

A total of 95 DTI-MR exams were acquired from 60 premature newborns with no, mild, and moderate evidence of white matter injury (WMI) on conventional MR imaging. The subjects were born at estimated gestational ages of 24-34 weeks and were imaged initially between 28-36 (median 33) weeks and were followed up between 35-43 (median 37) weeks using an MRI-compatible incubator with a specialized high-sensitivity neonate head coil (1). 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. ROI analyses were performed for the directionally-averaged apparent diffusion coefficient (Dav), each eigenvalue ($\lambda 1$, $\lambda 2$, $\lambda 3$), fractional anisotropy (FA) and relative anisotropy (RA) localized to: basal ganglia (BG), thalamus (Thal), corticospinal tracts (CST), optic radiations (OR), parietal white matter (PWM), frontal WM (FWM), and the posterior limb of the internal capsule (PLIC). Image SNR measurements were compared to prior serial DTI studies of preterm newborns acquired using a standard head coil (2).

Results

The MR compatible incubator improved the ease and safety for MR serial studies of young, unsedated preterm neonates with a 40-50% increase in SNR compared to a standard head coil. Significant ($p<0.05$) differences in diffusion parameters were noted between regions and with increasing age in neonates without white matter injury. No significant differences were found between right and left sides. In this normative group, Dav decreased significantly with age in all regions ($p<0.01$) except the frontal white matter and FA increased significantly in all white matter regions ($p<0.01$) except the frontal white matter regions (see figure). Similar but less pronounced changes were seen in newborns with white matter injury in all regions. Compared to the group with no white matter injury, newborns with white matter injury showed significant differences in the thalamus for Dav in (mild p=0.031, moderate p=0.025) and FA (moderate P=0.033). The PLIC demonstrated significant differences in the rate of change of Dav (p=0.044) between the mild and moderate white matter injury groups.

Conclusions

The MR-compatible incubator with its high sensitivity neonatal head coil improved MR exams of preterm infants by providing a warm, quiet, well-monitored environment and a substantial increase in SNR. Serial DTI studies of premature neonates demonstrated significant regional and maturational differences in diffusion parameters in subjects with normal imaging findings. The association of these DTI parameters with neurodevelopmental outcome will be determined as this cohort develops through childhood.

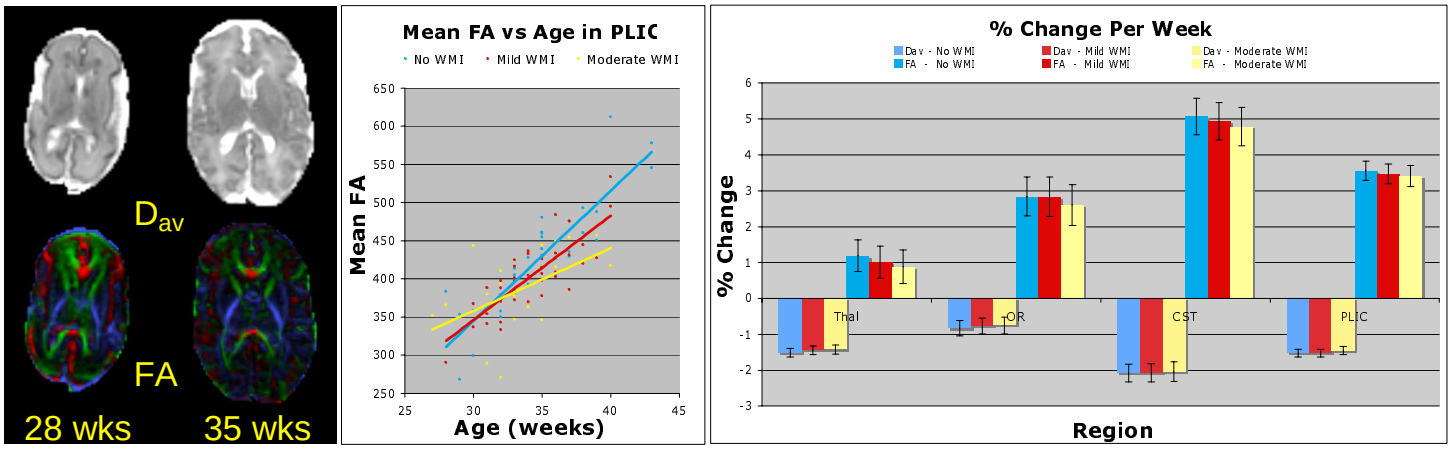

Figure: Left image shows Dav and color-coded FA image maps from subject scanned serially at 28 and 35 weeks. Middle graph shows spread of FA data points and trend lines from PLIC of newborns with no (blue), mild (red), and moderate (yellow) white matter injury. Right graph shows percent change per week of Dav and FA in regions Thal, OR, CST, and PLIC in newborns with no (blue), mild (red), and moderate (yellow) white matter injury.

References: 1. Dumoulin CL, et al. Concepts in Magnetic Resonance (Magn Reson Engineering) 2002; 15:117-128. 2. Miller SP et al. JMRI 16:621-632, 2002.

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