Non-Linear Modeling of T1, T2 and MWF Developmental Trajectories

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Introduction: Magnetic resonance imaging (MRI) affords a unique opportunity to investigate the rapid neurodevelopmental changes that take place during the first few years of life[1,2]. As this period is typically viewed as a time of vulnerability to developmental disorders, characterization of normal brain maturation is key to having the ability of detecting atypical changes. One possible way of obtaining such an anatomical model would be through acquiring quantitative parameter maps of healthy infants and toddlers and fitting this data to a characteristic growth model. Such a model could prove informative in describing typical brain maturation, in particular for investigating the maturation of myelinated white matter.

Objective: In this work, we sought to model regional and whole-brain development of T_1, T_2, and myelin water fraction (MWF) maps of healthy children under 5 years of age.

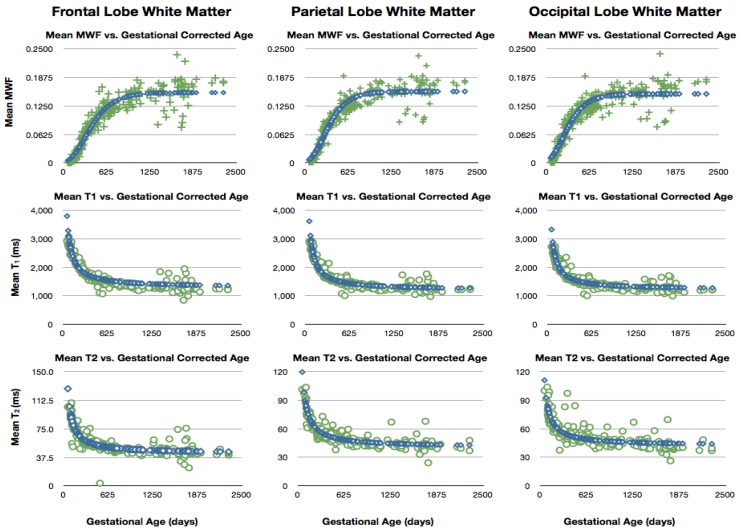

Fig. 1: Mean regional trajectories of MWF (1st row), T_1 (2nd row), T_2 (3rd row) for frontal, parietal and occipital lobe white matter. Green points represent measured values while model values are shown in blue.

Materials/Methods: *MRI Acquisition:* Whole brain mcDESPOT data was successfully acquired from 258 healthy children between the ages of 3 months and 5 years of age on a Siemens Tim Trio scanner using a 12 channel head RF array. *Data Analysis:* T_1, T_2, and MWF parameter maps were calculated[3,4] and aligned to a common study template[5]. Mean parameter values from each region was then calculated and plotted against gestational corrected age. Nonlinear regression of the trajectories was performed using a robust Nelder-Meade simplex. T_1 and T_2 trajectories were fit to an inverse hyperbolic cosecant ($csch^{-1}$) model, while MWF trajectories were fit using a Gompertz growth model. Whole-brain fits were done in a similar fashion, fitting voxel-wise data.

Results: Representative mean trajectories and corresponding fits of the frontal, parietal, and occipital lobes are shown in Figure 1. Average MWF maps were reconstructed at 90, 360, 720, 540, and 720 days (Fig. 2).

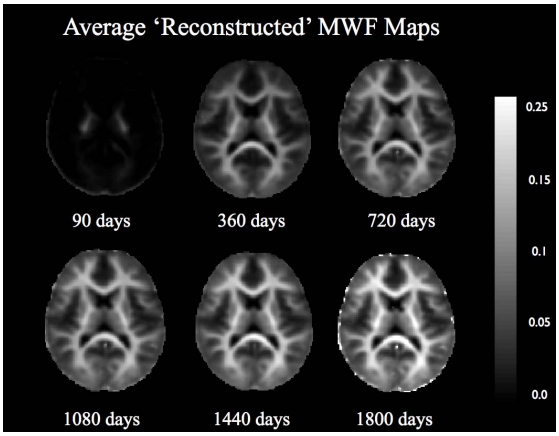

Fig 1: Representative axial slices of average reconstructed MWF maps at 90, 360, 720, 1080, 1440, and 1800 days (corrected for gestation).

Discussion: We observe a monotonically decreasing function with respect to age for both T_1 and T_2, while the MWF data appears to be logistical in shape. Although the observed changes reflect the development of myelinated white matter, changes in T_1 and T_2 are also influenced by decreasing water content during this early time[6]. We find good agreement of the non-linear models to the regional relaxometry and MWF data. Reconstructed MWF maps illustrate a similar developmental pattern observed in the measured MWF maps, giving confidence that the models accurately represent the observed changes.

Conclusions: In this work we have sought to characterize observed T_1, T_2, and MWF changes with respect to age in children under 5 years old. Modeling acquired from healthy, typically developing children a normative, 'group-averaged' atlas can be derived and serve as a baseline to investigate neurodevelopmental disorders (such as autism) believed to manifest during during this early period. Uncertainty in the fitting parameters, critical for being able to make normative comparisons, can be obtained via bootstrap resampling of the residuals[7] and is currently being worked on.

References: [1]Johnson MH et al. Trends in Cognitive Sciences. 2005;9:152 [2]Fornari E et al. Neuroimage. 2007;38:511 [3]Deoni SCL et. al. MRM. 2008;60:1372. [4]Deoni SCL, et al., MRM. 2012 [5]Avants et al. Med. Image Anal;12:26 [6]Deoni SCL, et al., Neuroimage. 2012;63:1038 [7]Dean DC et al. Journal of Neuroscience. 2012; *Under Review*