Brain White Matter and Cortex Maturation Monitored by Combined DTI and T2 Measurements

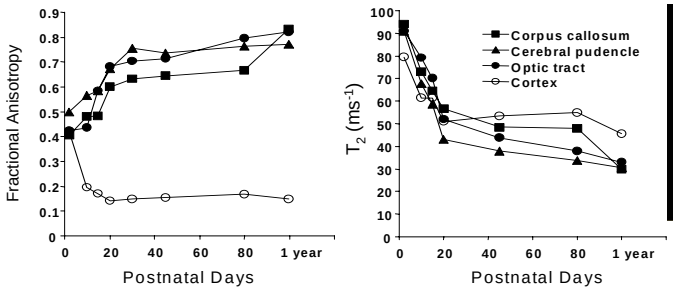
S. Wakana[1,2], J. Zhang[1], L. Nagae-Poetscher[1,2], H. Jiang[1,2], P. van Zijl[1,2], S. Mori[1,2]

[1]Radiology, Johns Hopkins University, Baltimore, MD, United States, [2]F.M.Kirby research center, Kennedy Krieger Institute, Baltimore, MD, United States

Different brain regions have different maturation rates during development. T_2 relaxation is known to be sensitive to the maturation, but, contrary to DTI provides poor anatomical information in neonates. We acquired DTI and T_2 maps of pediatric brains and used DTI as anatomical guidance to quantify T_2 and FA of individual white matter tracts. The approach was first applied to mouse neonate postmortem samples and then healthy human volunteers. Results indicate characteristic maturation patterns for cortex and white matter tracts. Using this approach, we are establishing a normal database to quantitatively characterize the brain maturation process.

Introduction; There is a large literatures indicating that T_2 is sensitive to myelination (e.g. see (1)). DTI (diffusion tensor imaging)-based parameters, such as ADC and FA, have been also reported to be sensitive to the brain development process (see e.g. (2,3)). DTI reflects both axonal and myelin properties and can thus be used to identify white matter in neonates as well as changes in myelination. From histology-based studies, it has been known that different white matter tracts have different myelination rates. Detailed T_2-based myelination assessment is difficult because of lack of white matter contrast in neonatal and pediatric MRI. In this study, we used DTI for anatomical guidance to identify white matter tracts of interest and quantified T_2, and FA of developing brains. The technique was first applied to neonatal mouse brains. Then it was applied to human neonates and pediatric volunteers.

Methods; ***Mouse ex vivo study*****;** Male C57BL/6J mice at age P0,3,7,10,15,20,30,45 and adult (N>2) were perfused and fixed using 4% paraformaldehyde.. Images protocols are **(a)** DWI (multiple SE with twin navigator echoes, 0.09-0.12mm/pixel resolution, TE37,TR 900ms, b value;1200s/mm^2). **(b)**T2 weighted images (TE37,60,90,120ms,TR900ms) using 9.4T GE Omega. Diffusion tensor and T_2 map were fitted from diffusion and T_2-weighted images. ***Human in vivo neonatal study*** : Informed consent was obtained from all subject or guardian. Seven pediatric (6-13yo, aver 8.5, M5,F2,) and 4 newborn (2-3days-old,F4) volunteers participated our study. Imaging protocols are **(a)** DWI (single-shot EPI,TE80ms, TR>6s, matrix80-96x80-96, reconstructed 256x256, FOV150-240mm, slice thickness 1.88-2.5mm, no gap, SENSE (r2.5),30 independent axes, b-value 700s/mm^2), **(b)** T_2 weighted images (TE 100/40, same resolution as DWI) using 1.5 T Philips Gyroscan NT. The six elements of diffusion tensor were calculated at each pixel using multivariate linear fitting.



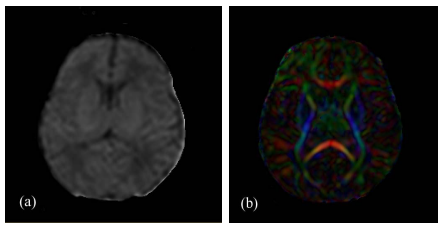


Fig.1 : FA and T_2 values of representative fiber tracts during the postnatal development period of mouse brains.

Fig. 2: Color map (a) and R2 map (b) of 0year old showing color map is needed to identify white matter tracts.

Results&Discussion.: Fig. 1 shows results from mouse neonates. During the first 20 days of the neonatal period, FA of white matter increases by 60 – 80 % , while that of the cortex decreases to 1/3 . In both the white and gray matter T_2 decrease during development but with different rates. In human studies (Fig. 2). the color map indicates that major white matter tracts are already formed at this age but the T_2 provides poor anatomical information about locations of individual tracts. We used the color map to identify various anatomical landmarks, draw ROIs, and quantify T_2, and FA (Fig.3). Many white matter tracts had higher FA than cortex at birth, indicating human brain is more matured than mouse brain at birth. Limbic fibers (cingulum and fornix) tend to have slower FA evolution, which was not clearly observed in T_2. In this study, we combined that anatomical information with quantitative MRI to study brain maturation in tract-specific manner. Accumulation of this type of data is expected to provide quantitative description of brain maturation process and abnormalities.

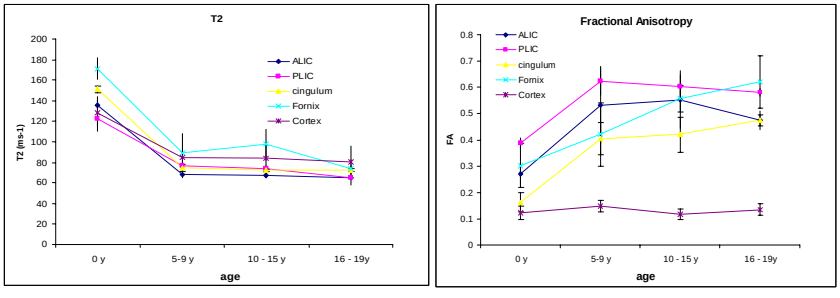


Fig.3: FA and T_2 values of human neonates and pediatric volunteers. ALIC: Anterior limb of internal capsule, PLIC: Posterior limb of internal capsule, Cortex: Motor cortex.

References (1) A. J. Barkovich,et.al, Radiology 1988;166, 173-80, **(2)** J. Neil, Radiology 1998; 209, 57-66, **(3)** C. Baratti et al, Radiology 1999; 210, 133-142.