Age Dependence of the Fractional Anisotropy of Genu and Splenium of Human Corpus Callosum Using Optimized DT-MRI

K. M. Hasan[1], B. P. Kanabar[2], R. M. Santos[3], L. Ewing-Cobbs[4], P. A. Narayana[5]

[1]Radiology, University of Texas, Houston, TX, United States, [2]Biomedical Enginerring, UH, Houston, TX, United States, [3]UT, Houston, TX, United States, [4]Pediatrics, UT, Houston, TX, United States, [5]Radiology, UT, Houston, TX, United States

Introduction

The corpus callosum (CC) in the human brain constitutes the largest inter-hemispheric commissural fiber network and is involved in integrating the corticocortical communication. It has been implicated in a number of neurological, neuropsychological, and developmental disorders. Diffusion tensor imaging (DTI)-based anisotropic fractional measure, FA, is increasingly used to probe the callosal fiber integrity. Corpus callosal fibers are quite heterogeneous across the functionally distinct regions within CC and exhibit different age-dependences **[1].** However, relatively little is known about the FA values across CC and their age dependence. Such information is critical for a proper interpretation of the FA values in various neurological disorders. In this abstract we report the age-related changes of FA in seven functionally distinct regions of the CC **[2]** using an optimized icosahedral DT-MRI acquisition scheme with whole brain coverage and supervised ROI analysis.

Methods

Subjects A total of 65 whole brain DT-MRI data sets were acquired on 7 children (all males, average age at scan ±SD: 13±2, range 9-15 yrs), 15 normal adults (11 males, 4 females, 34±13, range:20, 60 years) and 43 subjects diagnosed with multiple sclerosis (34 females, 9 males, age 39±14, range 19-69 yrs) who had normal FA in the splenium and genu as confirmed by the FLAIR MRI exam and analyzed further.

DT-MRI Data Acquisition. DT-MRI data were collected on a 1.5 T GE scanner using a dual spin echo prepared single shot echo planar MRI sequence with ramp sampling. The encoding scheme used is the uniformly distributed multi-faceted balanced Icosa21b with b=1000 s mm^{-2} **[3]** with the following acquisition parameters: slice thickness = 3 mm with no gap, total number of slices = 42, FOV = 240 mm X 240 mm, acquisition matrix (80 *ky*, ramp sampling), image matrix =256 x 256, TR ~ 7 seconds and TE= 85 ms, NEX = 4. The total DT-MRI acquisition time of 10 minutes was especially helpful in imaging children.

Data Processing: Distortion correction and analysis were performed using an in house DT and multidimensional MRI toolbox. This software package has a sophisticated ROI tool that displays and fuses multi-plane DT-MRI maps with multi-modal MR images or DT-MRI derived maps (**Figure** 1). The ROI tool also includes a user-guided semi-automated implementation of the Witelson subdivision of the CC **[2]** based on the midsagittal section identified on the interpolated and FA modulated principal vector overlaid on the ADC or T2w images (**Figure** 1). The CC is divided into 7 segments (**Figure** 1):CC1-rostrum, CC2-genu, CC3-rostral midbody, CC4-anterior midbody, CC5-posterior midbody, CC6-isthmus and CC7-splenium. To facilitate the comparison with other white matter and gray matter structures, we have also included the R-L putamen, head of caudate nucleus, and the posterior limb of the internal capsule (**Figure** 1). The 13 ROI selections on all subject data was supervised and validated by an experienced neurosurgeon blinded to the details about the subjects.

Results and Discussion

Figure 2 shows the FA results on the 13 selected subregions used in this study from the 15 normal adult controls. Notice the regional variability in FA, with low values in gray matter structures and variability across callosal subregions. The mean FA was lower in the genu than in the splenium, reflecting regional differences in CC microstructure **[4]. Figure** 3 shows the FA values of the genu and splenium as a function of age (9-69 years). Note that this is the first full brain DT-MRI report on this broad age range and shows that the splenium FA was relatively age-independent, whereas the genu FA increased till adulthood and decreased thereafter. The Genu FA vs age data was fit with quadratic polynomial least squares with a predicted peak at age ~ 28 years, whereas a smoother cubic fit predicted a peak at age ~ 21 years. The use of high SNR, optimal high angular icosahedral DT-MRI encoding schemes, and careful ROI placement are critical for robust results. These findings are consistent with the late maturation of frontal lobe structures which may extend to the third decade [5] and vulnerability of the genu to age-related decline **[6].** The splenium FA is relatively stable with age, possibly due to the earlier functional maturation of posterior cortical regions than anterior regions **[5-8].** Our findings are consistent with separately published reports **[6-8]** and known functional and histological studies **[1,2].** The findings reported here are preliminary and clearly more data samples and stratification are required.

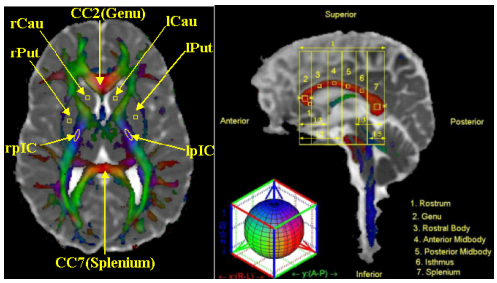

Figure 1. Illustration of the DT-MRI Guided Witelson CC subdivision method and the ROIs selected on an axial and midsagittal sections.

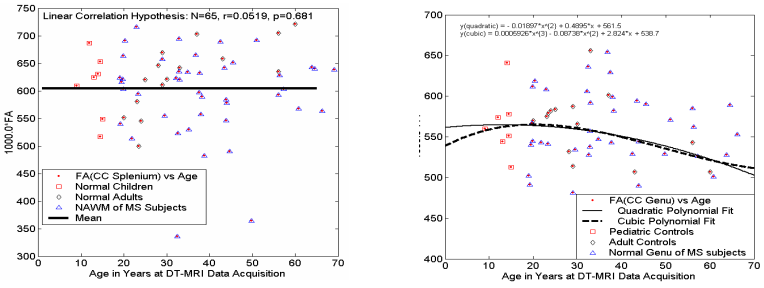

Figure 3. FA vs. Age dependence in the splenium and genu of the CC. The genu FA(Age) was fit with curvilinear polynomials (quadratic and cubic), whereas the FA of the splenium showed a rather age-independence.

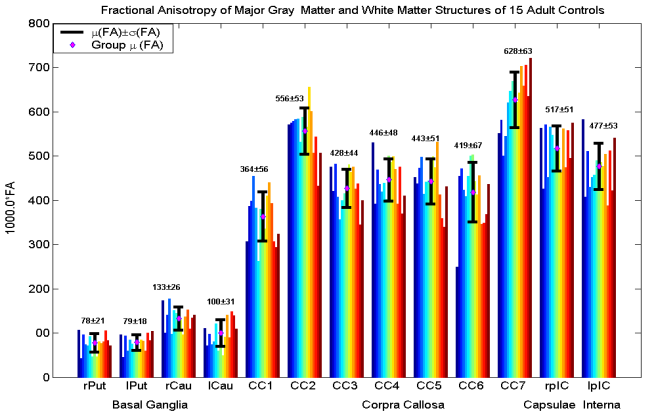

Figure 2. The FA values mean ± SD for GM and WM different regions including the CC seven subdivisions **(see Fig 1)** on 15 normal adult controls.

References

[1] Aboitiz et al. Neuroreport. 1996; 7(11):1761-4.
[2] Witelson SF et al. Brain 1989; 112: 799–835.
[3] Hasan KM, Narayana PA. Magn Reson Med 2003;50(3):589-98.
[4] Chepuri et al. AJNR Am J Neuroradiol 2002;23(5):803-8
[5] Sowell ER et al. Nat Neurosci 1999;2(10):859-61.
[6] Sullivan EV et al. Neuroreport 2001 22;12(1):99-104.
[7] Schmithorst VJ et al. Radiology 2002;222(1):212-8.
[8] Neil J et al. NMR Biomed 2002;15(7-8):543-52.