Correlation Time vs. Pulsed Field Gradient Diffusion MRI of the Brain: On the Effects of Magnetization Transfer and Myelination as a Function of Age

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Purpose: Correlation time diffusion MRI (1,2) can be used to generate maps of the diffusion coefficient (D_{CT}) with considerably less sensitivity to the artifacts (motion, eddy currents, and magnetic field inhomogeneities) that are typical of current pulsed field gradient techniques (D_{PFG}). The two approaches to diffusion coefficient mapping are however fundamentally different from each other; the former is based on T1 relaxometry and consequently probes molecular motions at a much shorter time scale (picoseconds) than typical PFG techniques (milliseconds). The purpose of this work is to study the quantitative differences as a function of age between D_{CT} and D_{PFG} in the human brain in the myelination age range from 0.5 to 25 years of age. Differences are studied at a global scale using whole brain histogram analysis.

Experimental Methods: This study protocol was approved by the institutional review board of our institution; all 27 subjects –age range 0.5-24 years-- were consented following HIPAA guidelines. All imaging was performed on a 1.5 Tesla clinical MRI scanner (Achieva and Intera, Philips Medical Systems of North America, Cleveland, OH, USA). Images were acquired using the mixed turbo spin-echo (mixed-TSE) pulse sequence and two different DW PFG pulse sequences: single-slice DW conventional spin-echo (DW-CSE) for the phantom experiments and multi-slice single-shot echoplanar imaging (DW-SE-sshEPI) for brain imaging. Key imaging parameters for the mixed-TSE sequence: voxel dimensions=0.94x1.25x3.00mm, 80 contiguous slices, TR=14.88s, $TE1/2_{eff}$=7.1/100ms, TI1/2=700ms/7.44s, acquisition time=9:00min. Key imaging parameters for the DW-SE-sshEPI sequence: voxel dimensions=2.2x3.2x5.00mm, 25 slices, TE=74, b-factors=0/1000, acquisition time=1:00min. Mixed-TSE is a fast four-time-points pulse sequence that combines in a single acquisition the principles of T_1-weighting by inversion recovery and of T_2-weighting by dual turbo spins echo sampling. This yields parametric maps of PD, T_1, and T_2 which are used as input to a series of equations incorporating the effects of molecular kinetics, paramagnetic and MT effects on T_1 relaxation time, ultimately yielding the rotational correlation time which is used to solve for the correlation time diffusion coefficient on a pixel by pixel basis.

Results: As shown in **Fig.** 1, the peak D_{CT} and D_{PFG} histogram values as functions of age can be fitted to power functions leading to medium (R^2= 0.47) and high (R^2= 0.92) degrees of correlation respectively. Furthermore, these peak values are linearly correlated (R^2 = 0.41) and the differences in peak values did not exceed 17% for the youngest subject (see **Fig.** 2).

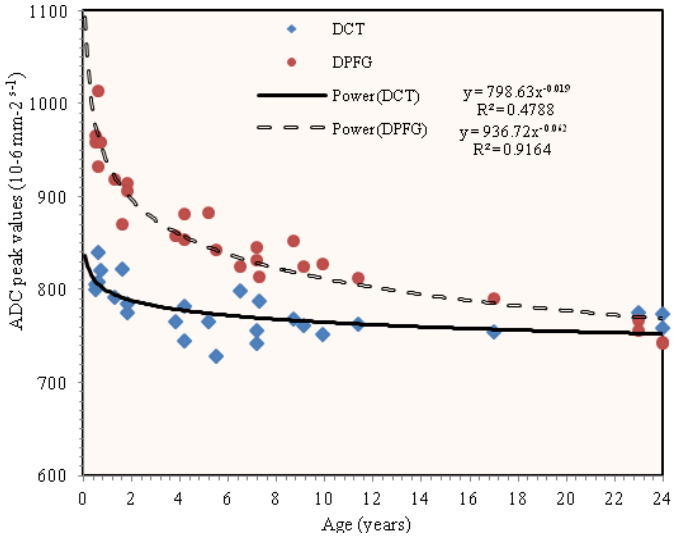

Figure 1: Global peak D_{CT} and D_{PFG} histogram values as functions of age.

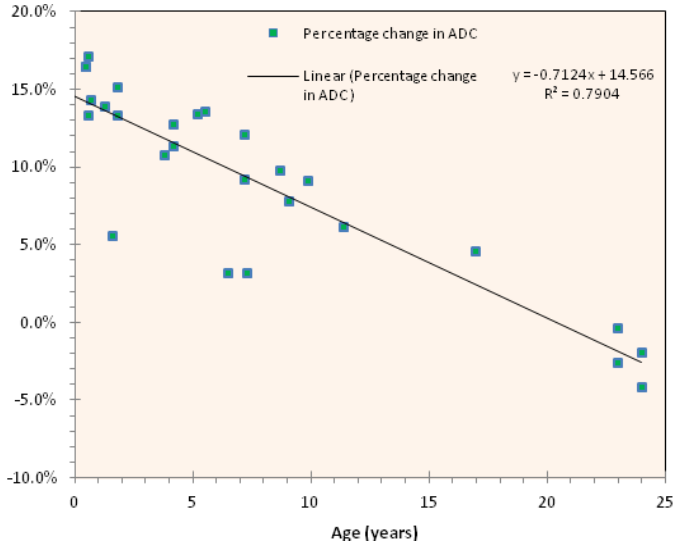

Figure 2: Percent differences in peak values as a function of age.

Conclusion: Global measures of diffusion generated with two techniques show general agreement for the studied age range (0.5-24years) with an age dependent difference, which correlates linearly with age and does exceed 17%. It is likely that the measured difference could arise from varying degrees of myelination and the resulting magnetization transfer effects, which affect primarily the D_{CT} technique but not the D_{PFG} technique.

References

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