

The sources of white matter lateralization explored by conjunction of quantitative MRI methods

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Background: White matter axons with similar cortical endpoints are frequently bundled together, forming fascicles or tracts. While a single axon is below the resolution of MRI, fascicles or tracts are millimeters or even centimeters in diameter, making it possible to obtain accurate measurements of their properties. Most current tools to assess fascicles are based on diffusion-weighted MRI (DWI). The diffusivity along white matter fascicles is estimated as a means to assess white matter integrity, an unsatisfying term, and to differentiate between different groups of subjects and patients, as well as different brain functional organization such as brain laterality. The diffusivity variation along the fascicles can be explained by more specific causes than 'integrity'. We explore the different sources of tissue variation by combining quantitative MRI methods with diffusion imaging and tractography.

Methods: T1 and proton density (PD) maps were measured on 20 healthy human volunteers at 3T. SPGR images were acquired with different flip angles¹ ($\alpha = 4, 10, 20, 30$, TR = 20 ms, TE = 2 ms) at a 1mm³ resolution. Both transmit and receive coil inhomogeneities correction was applied. In addition, DWI was measured using a diffusion-weighted spin-echo EPI sequence with 2x2x2 mm resolution. We measured 96 diffusion directions with a b-value of 2.0 ms/ μ m² and eight non-diffusion weighted volumes. We used 2.5X ASSET acceleration to reduce EPI distortions. The data were also analyzed using a constrained spherical harmonic deconvolution (CSD)². We calculated a fiber-crossing index (CI) from the ratio of the different fiber orientation in each voxel. In addition, we generated streamline fiber tracts³ from the DWI data. Measures of tractography-based fiber count (FC), fraction anisotropy (FA), mean diffusivity (MD), PD and T1 along each streamline allowed us to calculate the mean and variance of each streamline.

Results: The mean FA and FC values of the cortico-spinal, the arcuate and the superior longitudinal fasciculus tracts show significant differences between the right and left hemispheres. The FA along each white matter tract may vary by up to 50 percent. Seeking an explanation for this variation we compared the CI along the tracts. We found that CI can explain much of the variations in the FA, suggesting that a big part of the FA variation within and between tracts can be attributed to differences in the amount of crossing fibers that have a greater effect on DTI. We found that PD values are almost constant along those tracts, suggesting that there are no differences in tissue density. T1 varied along part of those tracts, suggesting that physico-chemical environment is also different in these regions. Figure 1 shows an example of mean lateralization Z-score along the arcuate fasciculus.

Conclusions: The major white-matter tracts may vary in their fiber density, volume and the amount of axons branching along them. A combination of DWI and quantitative MRI analyses distinguish possible sources of anatomical variation. A major source of tissue differences between right and left white matter can be attributed to physico-chemical environment and to the amount of perpendicular connection and branching out of axons along the lateralized fiber bundles.

References:

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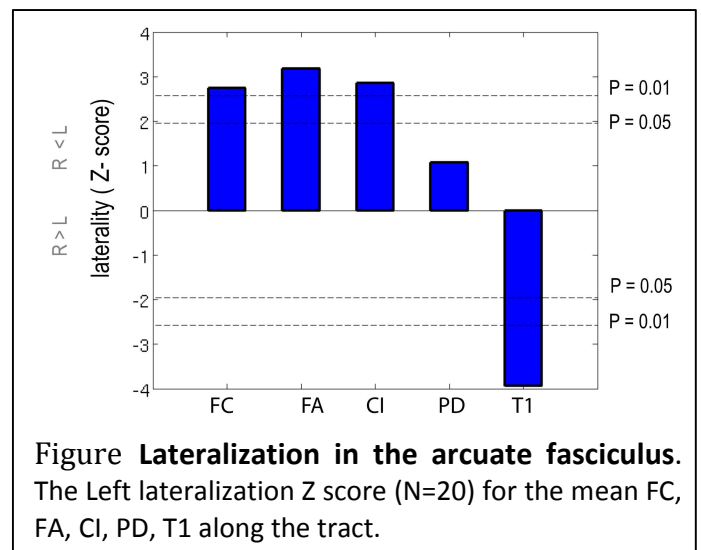


Figure 1. **Lateralization in the arcuate fasciculus.** The Left lateralization Z score (N=20) for the mean FC, FA, CI, PD, T1 along the tract.