Apparent Fiber Density Alterations in the Brain during Aging

M. S. Pinto*, A. C. Santos**, C. E. G. Salmon*

*Lab. InBrain, Depto de Física, FFCLRP, Universidade de São Paulo, Ribeirão Preto, Brasil.
**Depto de Clínica Médica, FMRP, Universidade de São Paulo, Ribeirão Preto, Brasil.
e-mail: mairaspinto@gmail.com

Introduction: The human brain undergoes continuous and non-linear changes over the life span. Magnetic Resonance Imaging (MRI) enables the study of the brain structure in the aging process. Diffusion MRI (dMRI) uses the information of the water diffusion in the brain tissues to quantify different parameters that describe its integrity. Apparent Fiber Density (AFD) [1] is a parameter related to the "intra-axonal restricted compartment", and would be of great interest to be studied in the aging process for the understanding of how the integrity of the fiber bundles are altering within the voxel. The aim of this work is to compare this integrity parameter between groups of different ages to evaluate which areas of the white matter are affected in its fiber composition, and to evaluate if it happens in a global or specific manner.

Methods: The data was retrospectively collected from Ribeirão Preto University Hospital. Image data consists of Diffusion and T1-weighted images, from 158 healthy individuals, acquired in a 3T Philips Achieva MR scanner. Subjects were divided into three groups, based on age: Young Adults (G1): 78 subjects (43 men) aged between 18 and 40 y.o., Middle Adults (G2): 34 subjects (19 men) aged between 41 and 60 y.o. and Old Adults (G3): 46 subjects (15 men) aged between 61 and 83 y.o. dMRI image processing was performed using MRtrix package (J-D Tournier, Brain Research Institute, Melbourne, Australia, https://github.com/MRtrix3/mrtrix3). The images were corrected and normalized, the fiber orientation distributions (FOD) were estimated using Constrained Spherical Deconvolution (CSD) modelling. Fixel (fibre bundle within a specific voxel) analysis was performed, AFD was estimated and whole-brain fiber tractography was performed. Statistical two-tailed test was performed using connectivity-based fixel enhancement, comparing the groups two by two.

Results: The whole-brain group analysis demonstrated a significant ($p<0.05$) decrease in the AFD parameter with age. Figure 1 shows the regions in the white matter where this parameter is more affected.

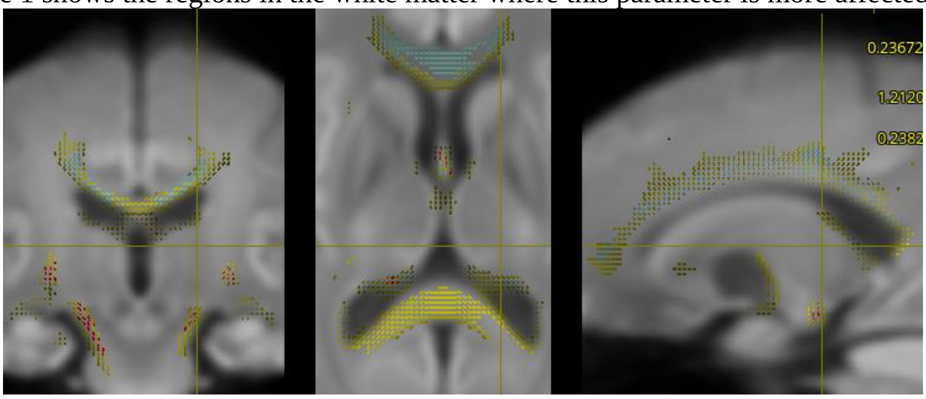

Figure 1. Significant ($p<0.05$) differences in AFD parameter in the group comparisons. Coronal, axial and sagittal views of the brain. AFD differences: Red: G1 vs G2, Blue: G2 vs G3 and Yellow: G1 vs G3.

It is possible to verify in figure 1 that comparing between the younger groups there are very few regions with significant alterations of AFD, those being the following tracts: fornix, cerebellar peduncle and base of the cortico-spinal tract (CST). When comparing the elderly group there is a broader pattern of degeneration of the white matter tracts. The analysis between G2 and G3 demonstrated alterations in the corpus callosum, fonix, inferior lateral fasciculus, inferior fronto-occipital fasciculus and anterior thalamic radiation, and between G1 and G3 all of those were affected but also the CST and cerebellar peduncle. Showing that from the 60th decade of age the brain integrity changes occurs more abruptly.

Discussion and Conclusion: With this results, it is understood that the white matter degeneration, considering the fiber density parameter, occurs in the tract specific way, and some tracts are more affected in different age ranges, the fornix being one of the first tracts to be affected in this natural degeneration process. This results agree with the literature shown for other white matter integrity parameters, as the fractional anisotropy and mean diffusivity [2]. In this way, AFD seems to show complementary information for understanding the white matter integrity alterations throughout the lifespan.

References: [1] Raffelt D, et al. NeuroImage 59 (2012) 3976–3994. [2] Kochunov P, et al. NeuroImage 35 (2007) 478-487.