Quantitative Magnetization Transfer and Diffusion Tensor Imaging Provide Complementary White Matter Information

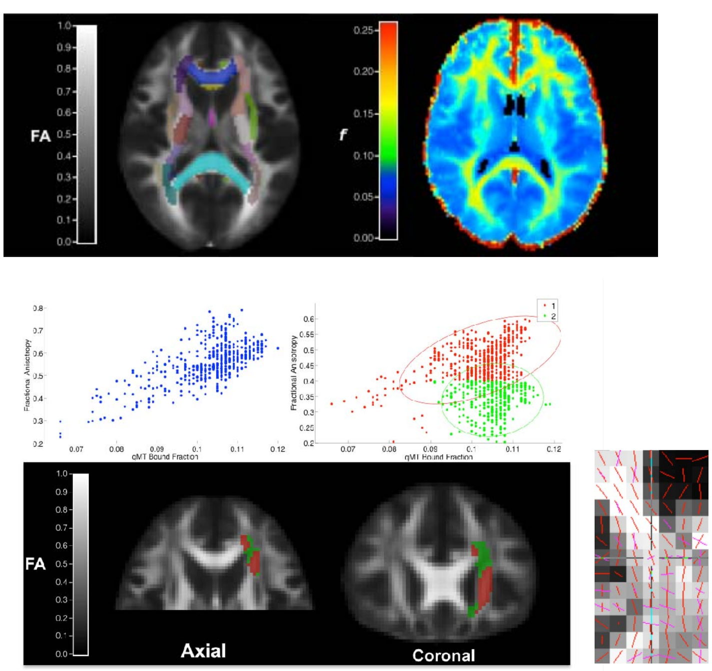
Gerard Thompson[1], Sha Zhao[1], and Alan Jackson[1]
[1]*University of Manchester, Manchester, United Kingdom*

Introduction: Diffusion tensor imaging (DTI) and magnetization transfer (MT) imaging have been used to study white matter (WM) in health and disease [1,2]. DTI-derived fractional anisotropy (FA) correlates with fiber orientation, density, and caliber. Voxels with coherent fiber directions and greater density exhibit higher FA. The bound fraction (f) from quantitative MT imaging (qMT) relates to the macromolecular content of the voxel. In the brain, this has been shown to relate to myelination, although other macromolecules make this relationship more complex. The relationship between these parameters may provide further insights into WM in development and disease. We aimed to compare qMT *f* and FA values to assess the relationship between these two distinct WM parameters. A secondary objective was to determine whether whole brain qMT *f* could be derived without the need for B1 field correction, even at higher field strengths.

Materials and Methods: Whole brain 2 mm isotropic qMT *f* and FA maps were generated for 26 healthy volunteers at 3 T using an in-house optimized version of the method of Cercignani *et al.* and 15 direction DTI (b=1000) [3,4]. High-resolution (1 mm isotropic) T1-weighted images were acquired and non-linearly registered to MNI152 space. The resulting warps were applied to the *f* and FA maps to produce respective templates in MNI space. The JHU white matter atlas was used to extract the values of FA and *f* in 6 midline and 21 paired WM structures [5]. Crossing fibers were identified using BedpostX [6].

Results: An axial slice from the *f* template is shown (top right,) with the corresponding FA template and white matter atlas (top left.) In 35/48 of tracts examined, FA was significantly directly correlated to *f* such as in the posterior thalamic radiation (middle left, blue.) In the coronae radiatae, however (6/48,) voxels were found with high *f* but low FA (middle right, green) in contrast to the direct relationship (middle right, red.) No significant relationships were observed for grey matter. The subcortical white matter exhibited low FA but intermediate *f*. Clustering of regions which did not exhibit direct FA/*f* correlation (middle right, green) revealed a pattern consistent with crossing fibers with comparatively low FA and high angular divergence (bottom right.) It was also confirmed that for *f*, even at 3 T, there is no need for B1 correction.

Conclusion: Within major white matter tracts, qMT *f* is directly correlated with FA (middle row, blue and red,) except in areas where lower FA is likely related to fiber crossing and directional heterogeneity within tracts (middle row, green.) This pattern is also seen in the subcortical region, where U-fibers exhibit myelination and intermediate *f*, but intravoxel directional change and low FA. The combination of *f* and FA has potential to characterize different aspects of WM structure, and could provide complementary information to assess and quantify the structural changes occurring during development and disease. This combination would, for example, allow interrogation of regions of fibre crossing and subcortical regions not normally assessable using FA alone. Finally, *f* can be measured at 3 T without the need for B1 homogeneity correction.



References:
[1] O'Donnell LJ, Westin CF. An introduction to diffusion tensor image analysis. Neurosurg Clin N Am. 2011 Apr;22(2):185-96.
[2] Ropele S, Fazekas F. Magnetization transfer MR imaging in multiple sclerosis. Neuroimaging Clin N Am. 2009 Feb;19(1):27-36.
[3] Cercignani M, Symms MR, Schmierer K et al. Three-dimensional quantitative magnetisation transfer imaging of the human brain. Neuroimage 2005 15;27(2):436-41.
[4] Smith SM, Jenkinson M, Johansen-Berg H, et al. Tract-based spatial statistics: Voxelwise analysis of multi-subject diffusion data. Neuroimage 2006;1:1487-1505
[5] Mori S, Oishi K, Jiang H, et al. Stereotaxic white matter atlas based on diffusion tensor imaging in an ICBM template. Neuroimage 2008 1;40(2):570-82.
[6] Behrens TEJ, Berg HJ, Jbabdi S et al. Probabilistic diffusion tractography with multiple fibre orientations: What can we gain? Neuroimage, 2007;34(1):144-55.