MRI texture spectral similarity detects white matter microstructure as compared with diffusion tensor imaging

Yunyan Zhang[1], Lenora Brown[1], and Luanne M Metz[1]
[1]*University of Calgary, Calgary, AB, Canada*

TARGET AUDIENCE: Imaging scientists and clinicians who are interested in the white matter structure of the nervous system.

BACKGROUND and PURPOSE: Diffusion tensor imaging (DTI) serves as an important in vivo tool for probing the microstructure of white matter. Within a voxel, the anisotropic feature of diffusion along major directions is used to infer the organization of white matter architecture. However, image voxels often have coherency, and unique inter-voxel relationships known as image texture may form and associate with the specific biophysical properties of the imaged tissue. Indeed, based on a multi-scale local spatial frequency-based technique, namely, polar Stockwell transform (PST), texture analysis of standard MRI predicts myelin and axonal density in postmortem multiple sclerosis (MS) brain[1] and detects subtle activity changes in MS lesions.[2] The objective of this study was to investigate the architecture and regional variance of brain white matter using PST MRI texture analysis in comparison with DTI.

METHODS: Five healthy volunteers aged 25 - 58 years were imaged at a 3T scanner in an ongoing study of the structure and function of corpus callosum. T2-weighted MRI was acquired using a spin echo sequence (TR/TE = 3000/80 ms), and whole brain DTI was obtained by an echo-planar sequence (TR/TE = 10000/78 ms, b = 1000, 31 directions); both used the same FOV (24 cm^2), matrix size (256x256), and slice thickness (3 mm), and followed the same anatomical landmarks for positioning. Diffusion-weighted images were lined up with the b = 0 MRI, which were then co-registered with the T2-weighted MRI to ensure consistency of regions of interest (ROIs). Fractional anisotropy (FA) and radial and axial diffusivity were calculated from DTI using FSL (FMRIB, Oxford). At each voxel, PST spectrum was computed using the T2-weighted MRI showing the largest area of genu and splenium of corpus callosum; within the image, the ROIs of forceps minor (FM) were also chosen, and the T2 MRI 2 slices above the roof of lateral ventricles to assess superior corona radiata (SCR). Texture angular similarity was calculated between each spectrum of the image and the mean spectrum of white matter that was used as a reference. Non-parametric ANOVA and Spearman correlation was used for statistical analysis ($p \leq 0.05$ was set as significance).

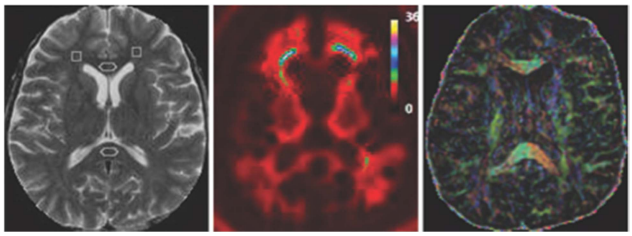

Fig.1: T2-weighted MRI (left) with ROIs in the forceps minor (squares) and genu & splenium of corpus callosum (ovals), scaled texture similarity map (middle), and fractional anisotropy map (right) from the same subject.

RESULTS: Distinct white matter organization was seen in both FA and texture maps (Fig. 1). While DTI and texture measures differ slightly from voxel to voxel within a ROI, the largest difference was found between structures ($p = 0.02$ for radial diffusivity; $p < 0.01$ for others). Opposite to the pattern observed in radial diffusivity, the genu and splenium of the corpus callosum demonstrated greater FA, axial diffusivity, and texture irregularity than the FM and SCR (Fig. 2). No difference was detected between genu and splenium of corpus callosum, FM and SCR, or bi-hemispheric ROIs within structure, and no correlation was observed between DTI and texture outcomes in any structure.

DISCUSSION: PST analysis determines scale-specific spectra that dictate the local organizing patterns of a voxel relevant to its neighborhood. At a sub-millimeter level, the angular similarity of these multi-scale spectra calculates the microscopic geometry of white matter biophysically translated in MRI. While both measures distinguished the architecture of corpus callosum, the degree of distinction appears greater in texture than in FA. Similar to axial anisotropy in whiter matter, FA is found relating mostly to axonal property rather than myelin quantity.[3,4] Thus, our data suggest that PST texture analysis be sensitive to the regularity of microstructure from entire white matter inclusions.

CONCLUSION: Based on conventional MRI, PST texture analysis can be embedded into routine clinical practice. With confirmation, texture spectral similarity may become an alternative measure of white matter microstructure in normal and pathological conditions.

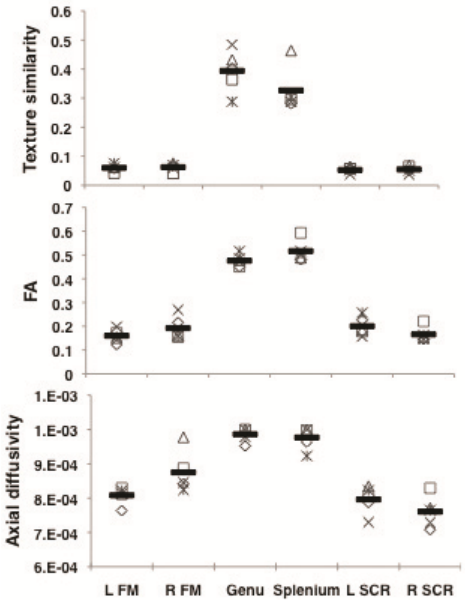

Fig. 2: Texture and DTI outcomes in the left (L) & right (R) hemispheric FM & SCR, and genu & splenium of corpus callosum of 5 subjects labeled differently. Horizontal bars represent group means.

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