Visualization of Absolute T1 and T2 Along Specific White Matter Tracts

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INTRODUCTION: T_1- and T_2-weighted images are currently the most prevalent methods for diagnosing and characterizing disease. However, such data are influenced by many additional factors including proton density, field and coil inhomogeneities, which can obscure subtle changes. Quantitative T_1 and T_2 mapping eliminates these problems, but has not found wide favor on account of the limited resolution (needed to localize specific brain regions) and limited volume coverage of conventional methods. A recently introduced method[1], overcomes these obstacles, allowing whole brain high-resolution T_1 and T_2 mapping in a scan time comparable to conventional weighted imaging. This method provides absolute quantification of T_1 and T_2, providing excellent white / gray matter contrast. However, the white matter appears largely homogeneous despite being comprised of anatomically and functionally distinct networks. A more complete white matter characterization would localize the microstructural and biochemical information provided by relaxometry to *specific* white matter fasciculi. To this end, we have combined the DESPOT schema with DT-MRI tractography to obtain for the very first time, tract-specific T_1, T_2 and diffusion measurements.

METHODS: Acquisition: All data were acquired on a GE Signa 1.5T system with 40 mT/m gradients. *Relaxometry*: Both SPGR and SSFP data were acquired with a matrix = 200 x 200 x 140, FoV = 25 cm; Slice = 1.3mm; For SPGR, TE/TR = 2.9/8.6 ms, α = 4º & 15º; For SSFP, TE/TR = 2.3/4.5 ms, α = 15º & 70º. Total acquisition time = 11 minutes; *Diffusion MRI:* Whole brain diffusion-weighted (DW) data were acquired using a peripherally gated single-shot EPI sequence, with diffusion gradients applied in 64 isotropically-distributed directions, and 7 B =0 images, (voxel size = 2.5 mm isotropic). Total acquisition time = 20 minutes; Analysis: T_1 and T_2 maps using conventional DESPOT processing. After correcting the DW-data for motion and eddy currents, the diffusion tensor was estimated in each voxel. Coregistration: To account for differences in image distortion and subject motion, the T_1-weighted image was co-registered to the average B = 0 image, using an initial affine registration followed by a set of nonlinear transformations (7 x 8 x 7 basis functions), using normalized mutual information, and the transformations applied to both the T1 and T2 maps. Visual inspection revealed excellent alignment between all anatomical landmarks checked. Tractography: A continuous field was fit to the tensor data using a B-spline approach[3] and streamline tracking of association, commissural and projection fibers performed using the approach similar to that described elsewhere. At each step in the tract evolution (0.5 mm), the mean diffusivity and anisotropy were recorded. Further, by fitting a continuous B-spline field to the T_1 and T_2 data, it was also possible to extract absolute T1/T2 values at each (sub-voxel) step along the trajectory. Visualization: Using an approach similar to that reported elsewhere, trajectories were visualized using illuminated streamtubes – with each vertex colored according to the parameter of interest (T_1, T_2, Trace, Fractional Anisotropy) to allow inspection *in situ* of tract-specific values. Finally, mean values were extracted for each tract in both hemispheres.

RESULTS AND DISCUSSION: Space prevents us from showing all results. Instead, Figure 1 show a single result obtained in the left superior longitudinal fasciculus (SLF). The first thing to note is that the T_1 and T_2 values within the main body of the tract are consistent with previously reported values for white matter. Further, note the distinct gradient in both T1 and T2 along the medial lateral axis – as the fibers reach towards the cortex and the T_1 and T_2 values approach those published for gray matter[4]. This is particularly useful for identifying the cause of cessation of tracking in particular regions – i.e. with anisotropy-threshold-based termination criteria, tracking may cease in a region of low anisotropy which arise from powder averaging of fiber orientation within the voxel, As this often solely within white matter, no increase in T_1 or T_2 are seen. In contrast, if the anisotropy becomes low because the gray matter is encountered – then this becomes evident on the relaxometric maps. The visualizations were also helpful for more clearly identifying the sites of projections of fiber systems into cortex, which may prove helpful in future fMRI/DTI combined studies. Finally, we have previously shown how examining the trace along a trajectory can help identify CSF partial volume artifacts. Addition of relaxometric maps provides complementary information. Increased T1 or T2 along a tract may indicate partial volume of white matter with gray matter or CSF. The former would not lead to increased trace, in contrast to the latter.

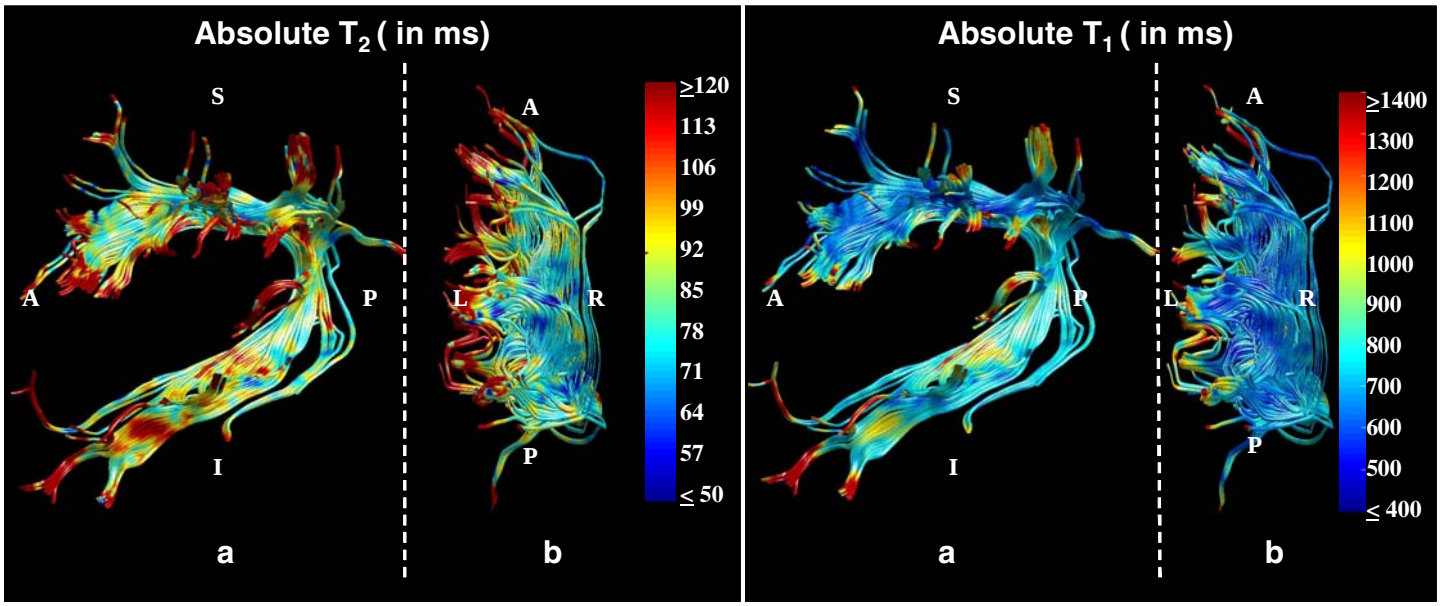

Figure 1. Visualization of absolute T_1 and T_2 along the course of the left superior longitudinal fasciculus. a. Lateral view; b. Superior view. (L = Left; R = Right; A = Anterior; P = Posterior; S = Superior; I = Inferior)

CONCLUSION: We have described, for the first time, the visualization of both T_1 and T_2 along specific anatomical pathways, from data collected in 31 minutes. As such, this approach has tremendous potential clinical and clinical research utility. For example, for monitoring specific development trajectories – as specific pathways are known to myelinate at different times, which are thought to be reflected by T_1 and T_2 changes. The method provides a more complete characterization of white matter fasciculi than previously possible. We are currently exploring a range of data reduction techniques including PCA and support vector machines from tract-specific relaxometry and diffusion data acquired in a range of neurological and psychiatric conditions to identify which tissue signature most powerful differentiates afftected tissue.

REFS: 1. Deoni et al. *MRM* 2003, 49; 515-; **2.** Jones et al. *J Mag Res*. 2005; 53; 1462-; 3. Basser et al. *MRM* 2000; 44: 625-. 4. Whittall K et al. *MRM* 1997; 37; 34-