Influence of T1 contrast and resolution on myelinated cortical thickness at 7 Tesla

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Target audience: Neuroscientists and clinicians interested in cortical mapping using high-field anatomical MRI.

Purpose: Myelinated axons in the human cerebral cortex are regionally organized in relation to neuronal function, with a distribution that evolves over the lifespan or as a result of disease. MRI now visualizes these myelin patterns in-vivo, with new applications to study changes in the myelin content of the cortex and the organization of its regions. Current myelin mapping techniques have measured mean signal (T1- or T2*-weighted, quantitative T1) through the cortical thickness or at a specific depth. A recently proposed alternative approach demonstrated at 3T and 1 mm resolution defines an intracortical anatomical boundary driven by myelin content and derives its thickness.[1] We present here a new algorithm to estimate this myelinated thickness and study its behavior across resolutions and variants of T1 contrast at 7T.

Methods: Nine human subjects were scanned on a 7-T Siemens MR system with a 24-channel head coil. T1-weighted images and T1 maps were acquired using the MP2RAGE sequence (TI1/TI2 = 900/2750 ms, TR = 5 s, TE = 2.45 ms, $\alpha_1/\alpha_2 = 5°/3°$, bandwidth = 250 Hz/Px, echo spacing = 6.8 ms, partial Fourier = 6/8) at 0.9, 0.7 and 0.5 mm isotropic resolution. The 0.5 mm scan was acquired as two sagittal slabs, which were co-registered into MNI space at 0.4 mm and fused to generate a whole brain image. All images were segmented and the cortical surfaces reconstructed in MNI space at 0.9, 0.7 and 0.4 mm respectively.[2] Myelinated cortical thickness was estimated using a fuzzy clustering [3] of intensities inside the WM and cortical GM into three classes, followed by a level set surface evolution adapted from [4] to find the boundaries between WM, myelinated GM (GMm) and unmyelinated GM. Measures of myelinated cortical thickness and thickness ratio of myelinated to total cortical thickness were extracted and mapped onto the subjects' 0.7 mm images. Cortical gyral labels were obtained with multi-atlas parcellation to provide regions of interest for the comparison of thickness and ratios estimated from the T1-weighted (T1W) or quantitative T1 (QT1) contrast at the multiple resolutions.

Results: Myelinated thickness and ratios obtained for a test subject are displayed in Fig. 1. Estimates from T1W and QT1 contrasts are highly correlated (ratio: 0.976 +/- 0.020, thickness: 0.941 +/- 0.043 across resolutions, Fig. 2, top). Lower correlations are observed when comparing resolutions (ratio: 0.864 +/- 0.069, thickness: 0.562 +/- 0.292, Fig. 2, bottom), in particular for the thickness measurement. These lower values appear however largely due to segmentation errors on the temporal pole, enthorinal gyrus and parahippocampal gyrus of the 0.5 mm data, resulting in outliers. The ratio of inter- to intra- gyrus variation (Fig. 3), an indication of the power of a given contrast/resolution to discriminate between cortical regions, is higher for the myelinated ratio and for finer resolutions.

Discussion: Measures of myelinated thickness were demonstrated to be feasible at 7T over a range of resolutions and T1 contrasts. Although the corresponding values were different, T1W and QT1 contrast showed the same spatial pattern over the cortex for both metrics. These patterns were relatively preserved across all resolutions, especially for the myelinated ratio, which confirms the validity of the first maps made at 3T/ 1 mm resolution. This myelinated thickness and thickness ratio measurement provides a new measure of intra-cortical contrast, which may change differentially from myelin-related signal and total cortical thickness measurements as myelin is gained or lost, so that myelinated cortical thickness may be used to track changes in intracortical myelin in studies of plasticity or disease.

References

1. Hashim et al., *Myelinated cortical thickness measurements for in vivo morphological study of the human motor cortex*, poster 3811, OHBM 2014. **2.** Bazin et al., *A computational framework for ultra-high resolution cortical segmentation at 7 Tesla*, NeuroImage, 2014, 93, 201-9. **3.** Pham, *Spatial Models for Fuzzy Clustering*, CVIU, 2001, 84, 285-297. **4.** Han et al., *CRUISE: Cortical Reconstruction Using Implicit Surface Evolution*, NeuroImage, 2004, 23, 997-1012.

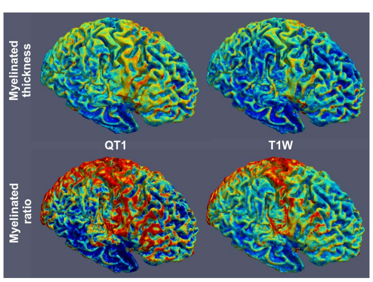

Fig. 1: Example of myelinated thickness and thickness ratio on one subject at 0.7 mm (color scales: [0-4 mm] for thickness, [0.25-1] for ratio).

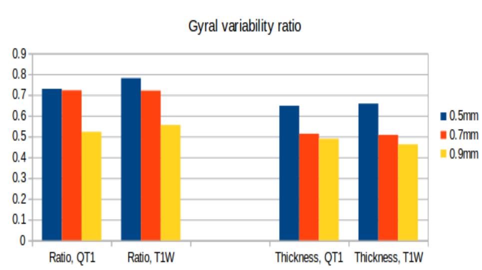

Fig.3: Ratio of variation of the myelinated thickness measures across gyri over the average intra-gyrus variation.

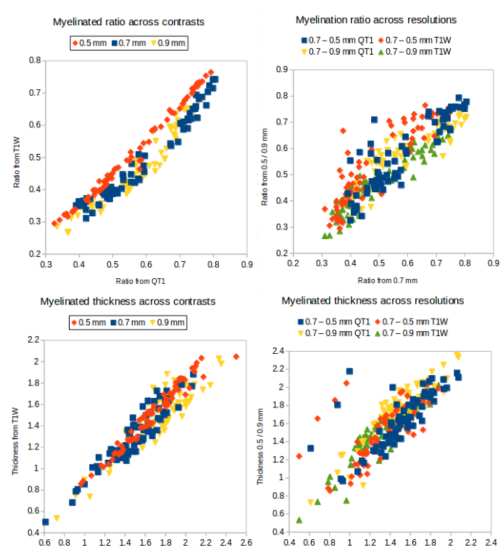

Fig. 2: Correlation of average myelinated thickness and thickness ratio for all subjects and gyri across contrasts and resolutions.