MR Morphometry of Myeloarchitecture for In-vivo Cortical Mapping

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Target audience: Neuroscientists interested in cortical mapping and cortical plasticity using high-resolution anatomical MRI.

Purpose: Recent MRI studies of the cerebral cortex have shown intra-cortical contrast that reflects its myeloarchitecture. There is a growing interest in using these T1, T2* or T1w/T2w myelin maps to create subject-specific parcellations. This would allow us to study how the structure of a cortical area relates to its function, and vice-versa. At ultra-high field, it is possible to acquire whole brain images at 0.5mm isotropic resolution to analyze the layer structure of the cortex. Recently, a new MR-based anatomical boundary between the deeper myelinated cortical layers and the more superficial unmyelinated ones was defined[1]. From this new boundary, we can define more specific anatomical ROIs and derive anatomical features such as the myelinated cortical thickness (mCT) and the myelinated thickness ratio (mCTR). Here, we present an in vivo MR-based delineation of this intra-cortical boundary on a group of subjects, and discuss its relevance to brain mapping and plasticity studies.

Methods: Nine healthy volunteers were scanned on a 7-T Siemens MR system with a 24-channel head coil. 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 0.5 mm isotropic resolution. Two sagittal slabs were acquired, co-registered into MNI space at (0.4 mm)[3], and fused to generate a whole brain image. The images were segmented and the cortical surfaces reconstructed[2]. The intra-cortical boundary was estimated from the T1 maps using a fuzzy clustering[3] of intensities inside the WM and cortical GM into three classes, followed by a level set surface evolution[4] to find the boundaries between three tissue compartments: WM, myelinated GM (mGM) and unmyelinated GM. These surface boundaries are illustrated in Fig. 1. Measures of total cortical thickness (CT), mCT, mCTR and T1 at the central surface were extracted. The cortical surfaces of the right hemisphere were aligned[4] to create a group average.

Results: The group average T1 times of the three tissue compartments are displayed in Fig. 2. The group average T1, CT, mCT and mCTR are shown on the inflated surface in Fig. 3. The new MR-based anatomical features, mCT and mCTR, provide complementary contrast to T1 and CT, which can help parcellate the cortex. In the central sulcus area for instance, the primary motor cortex M1 (precentral gyrus) is characterized by a low T1 (due to strong myelination), and thick cortex, whereas a higher T1 and thinner cortex characterizes the primary somatosensory cortex S1. We also show that M1 is uniquely characterized by a very high mCTR and S1 by a very low mCT. The extrastriate visual areas, which have a lower T1, are also characterized by a high mCTR. It is also clear in Fig. 3 that the contrast between sulci and gyri is stronger for mCT and mCTR in comparison to the CT and T1. This agrees with the observations by Bok[5] that the deeper layers are thinner in the sulci than in the gyri.

Discussion: We illustrate a new intra-cortical boundary estimated from high-resolution MR images where layer contrast is visible. The resulting intra-cortical segmentation and morphometry measures (mCT and mCTR) could improve sensitivity to differences between cortical areas and thus facilitate brain mapping. Furthermore, recent research shows that we may have underestimated the role of intra-cortical myelin in brain plasticity[6]. This new MR-based anatomical boundary can be used to define an intra-cortical ROI or a quantitative myeloarchitectonic measure that is more sensitive to lifespan or learning-induced plasticity.

References: 1. Hashim et al (2014) *Myelinated cortical thickness measurements for in vivo morphological study of the human motor cortex.* OHBM #3811. 2. Bazin et al (2014) *A computational framework for ultra-high resolution cortical segmentation at 7 Tesla*. NeuroImage 93: 201-9. 3. Pham (2001) *Spatial Models for Fuzzy Clustering*. CVIU 84: 285-297. 4. Han et al (2004) *CRUISE: Cortical Reconstruction Using Implicit Surface Evolution*. NeuroImage, 23: 997-1012. 5. Bok (1959) *Histonomy of the cerebral cortex.* Elsevier, Amsterdam. 6. Haroutunian et al (2014) *Myelination, oligodendrocites, and serious mental illness.* Glia 62: 1856-77.

Fig. 1: WM (yellow), mGM (green) and pial (red) surface boundary.

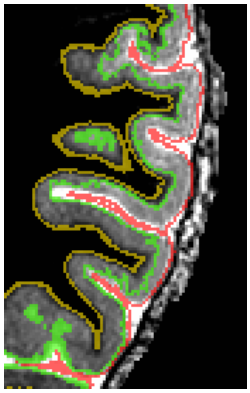

Fig. 2: Group T1 statistics.

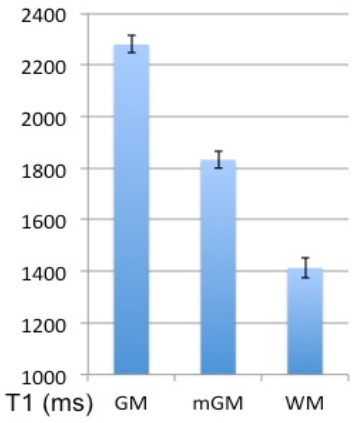

Fig. 3: Group average cortical surface.