

High-resolution Quantitative T1-based Cortical Thickness Estimates at 7 Tesla

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Introduction: Cortical thickness estimates from magnetic resonance images (MRI) are widely used to investigate neuroanatomical correlates of brain development, aging, learning, and neurological disease. Such measurements typically derive from T1-weighted images at 1 mm isotropic resolution acquired at 1.5 or 3 Tesla (T), but have recently been challenged by Lüsebrink et al. [1] who estimated cortical thickness from higher resolution T1-weighted images at 7 T. In order to estimate cortical thickness more accurately, we have developed new tools that can make use of high-resolution quantitative T1 maps. Here we present cortical thickness measurements from 0.5 mm isotropic T1 maps acquired at 7 T, and we compare the results to lower resolutions.

Methods: 12 human subjects were scanned on a 7 T MR system with a 24-channel receive-only head coil. The T1 maps were acquired using the MP2RAGE sequence (T1/TI2 = 900/2750 ms, TR = 5 s, TE = 2.45 ms, $\alpha_1/\alpha_2 = 5^\circ/3^\circ$, bandwidth = 250 Hz/Px, echo spacing = 6.8 ms, partial Fourier = 6/8). 6 subjects were scanned at 0.9 and 0.7 mm isotropic, and the other 6 subjects at 0.7 and 0.5 mm isotropic. The 0.9 and 0.7 mm scans were accelerated using GRAPPA by a factor of 2. The 0.5 mm scan was acquired as two sagittal slabs, which were co-registered into MNI space at an isotropic resolution of 0.4 mm and fused to generate a whole brain image. The T1 maps were segmented and the cortical surfaces reconstructed in native space for the 0.9 and 0.7 mm data, and in MNI space for the 0.5 mm data [2]. Cortical profiles and thickness estimates for the left hemisphere were obtained with a distance-preserving layering model [3]. The cortical thickness measurements were transformed into MNI space for comparison. We explored the effect of image resolution by performing pairwise comparisons between 0.9 and 0.7 mm and between 0.7 and 0.5 mm resolutions.

Results: With the help of the increased SNR at 7 T, high quality 0.5 mm isotropic T1 maps were acquired using the MP2RAGE sequence. Such a map with corresponding cortical boundaries is shown in Fig. 1, along side cortical thickness estimates at each resolution mapped onto an inflated surface. The consistency across resolutions is striking. The maps show a decrease in thickness in the primary somatosensory cortex, and an increase in thickness at gyral crowns, particularly in the frontal cortex. Both of these observations are in agreement with previous in-vivo MR [4] and histological [5] measurements. Mean cortical thickness estimates at different resolutions are shown in Fig. 2, for several cortical regions. We found that the mean cortical thickness estimated from T1 maps using our method is robust to changes in image resolution, within the range 0.5 - 0.9 mm. The differences in cortical thickness between resolutions are not statistically significant, with the exception of the temporal cortex for 0.5 - 0.7 mm. The high values in the temporal lobe at 0.5 mm appear to be artifactual. B1 inhomogeneity and poor RF coil coverage cause a decrease in local CNR and consequent tissue segmentation errors. The standard deviation of the mean cortical thickness is much smaller at 0.5 mm resolution than at 0.7 mm. The latter may be due to improved precision in areas penalized by partial volume effects.

Discussion: In contrast to [1], we show that cortical thickness estimates derived from quantitative T1 maps in native space using our tools are robust to changes in image resolution. The level-set surface-based approach estimates thickness at sub-voxel resolution. Since image segmentation is performed on quantitative and bias-field-free T1 maps instead of T1-weighted images, the tissue model parameters are stable and require no adjustment for individual subjects or image resolution.

References:

- [1] Lüsebrink et al. ESMRMB 2012 #646
- [2] Bazin et al. OHBM 2012 #883
- [3] Wahnert et al. OHBM 2012 # 898
- [4] Fischl & Dale PNAS 2000
- [5] von Economo & Koskinas 1925

Fig. 1: T1map at 0.5 mm labeled with cortical boundaries and cortical thickness estimates mapped onto an inflated central surface of 1 subject.

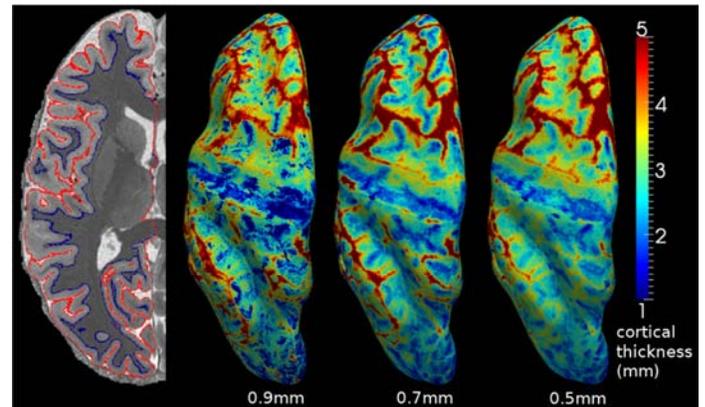


Fig. 2: Quantitative T1-based cortical thickness estimates at different resolutions.

