

Quantitative T1 mapping at 7 Tesla identifies primary functional areas in the living human brain

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Introduction: Ultra high field MRI enables the extraction of microstructural, myeloarchitectonic features as a basis for cortex parcellation [1]. The obvious relationship between the presence of myelin and the longitudinal relaxation time T1 suggests that quantitative T1 mapping (qT1) might be the technique of choice [2]. We present T1 maps that reveal several architectonic areas known from histology in the living human brain. Such data can be acquired in a single scan session, making this approach far less time consuming than ex-vivo histology. T1 maps are well suited for automatic cortical parcellation, and should enable the creation of in vivo histological maps of the human cerebral cortex and their direct correlation with functional imaging in the same subjects.

Materials & Methods: We used the novel MP2RAGE sequence [3] to acquire whole-brain scans with an isotropic resolution of 600 μm (flip angles=7°/5°, TI=1000ms/3500ms, TE=3.16ms, TR=5000, BW=240Hz/px) at a Siemens MAGNETOM 7T scanner (Erlangen, Germany). This sequence, which uses two read-outs at different inversion times, provides a purely T1-weighted image with uniform bias field along with a quantitative T1 map. A standard FSL BET brain extraction based on the two inversion contrasts was followed by a probabilistic tissue classification using a modified SPM unified segmentation. Based on the segmentation we reconstructed the gray matter (GM) - white matter (WM) boundary and calculated appropriately curved transcortical profiles [4]. Along these profiles we sampled the quantitative T1 map and calculated an average value across the cortex that may represent the overall cortical myelin content. These values were mapped back to the cortical surface and rendered in 3D. The cortical surface was also inflated to better reveal borders hidden in deep sulci.

Results: Figure 1a shows a coronal view of the quantitative T1 map at the level of the central sulcus. The arrows mark the transition zone between primary motor cortex M1 and somatosensory cortex. This decrease in T1 visible on the precentral gyrus (PrG) reflects the increased myelin content in M1 due to a large number of myelinated axons penetrating deep into the cortex. Figure 1b, in a sagittal view, additionally shows the same effect for the primary auditory area A1, located on Heschl's gyri [5]. An overall decrease in T1 is also noticeable in the region of the calcarine sulcus, corresponding to the primary visual area V1, which contains the heavily myelinated stria of Gennari. Figure 2a shows reconstructed cortical surfaces of the GM/WM boundary with sulcal depth (left) and average intracortical qT1 values (right) mapped onto it. The bottom row shows the inflated versions of the surfaces. Arrows indicate the regions mentioned above. The crowns of the gyri are coloured in green to identify landmarks in the inflated version. Figure 2b shows a zoomed view onto the inflated cortical surface, where the border between primary motor and somatosensory cortex is indicated slightly anterior to the fundus of the central sulcus.

Discussion: We showed that mapping T1 at 7T with the MP2RAGE sequence provides data of a quality suitable for identification of some major primary functional areas on the basis of their structure in-vivo. Our surface and profile based approach can extract this information across the cortical surface. This automatic and observer independent analysis promises individual in-vivo maps of myeloarchitectonic areas, forming the basis for direct correlations between microstructure and function in living human brains.

References:

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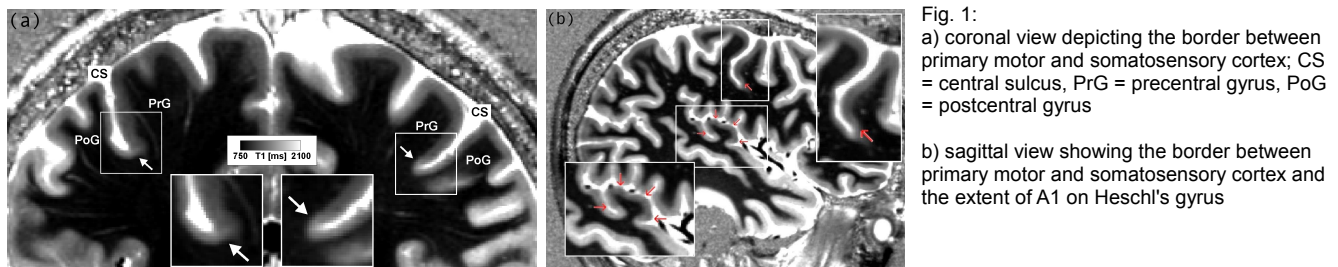


Fig. 1:
a) coronal view depicting the border between primary motor and somatosensory cortex; CS = central sulcus, PrG = precentral gyrus, PoG = postcentral gyrus
b) sagittal view showing the border between primary motor and somatosensory cortex and the extent of A1 on Heschl's gyrus

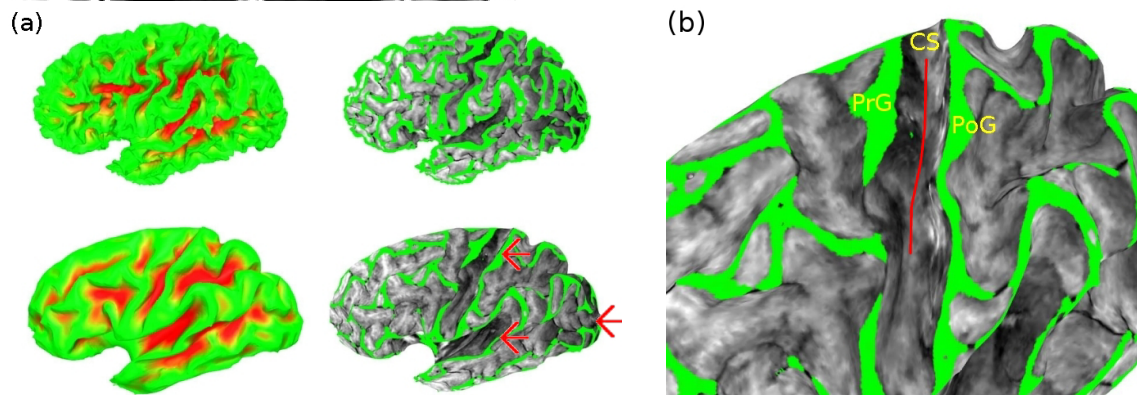


Fig. 2:
a) polygonal surface of the GM/WM boundary with sulcal depth (left) and average intracortical qT1 values (right) mapped onto it. The bottom row shows the partly inflated versions of the surfaces. The green areas on the T1 maps indicate the gyral crowns.
b) zoomed view of the inflated version of 2a) showing the region of the central sulcus. The red line suggests the border between primary motor and somatosensory cortex. CS = central sulcus, PrG = precentral gyrus, PoG = postcentral gyrus