T_1-Weighted MRI Visualizes Functional Anatomy in the Marmoset Cortex

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Introduction: A major goal of neuroimaging is to develop independent anatomical MRI methods for visualizing specific functional regions of the cortex[1-3]. Typically in MR images, however, cortical gray matter is uniform in appearance and there is little contrast between different regions. Conversely, many major cortical areas can be visualized with *ex vivo* histological staining because of their high myelin content relative to surrounding gray matter[4]. We hypothesize that these differences in cortical myelination may be reflected in gray matter T_1 values and propose that the pattern of myelination over the entire cortex in a non-human primate can be visualized using a pulse sequence optimized for T_1 contrast within gray matter.

Methods: We imaged an anesthetized female common marmoset monkey on a Bruker 7 Tesla MRI with a four-element phased-array receive RF coil. We performed T_1 mapping in a single coronal slice in the occipital lobe using a 2D inversion-recovery EPI sequence with geometric inversion-time sampling (TE = 31 ms, TR = 12000 ms, FOV = 38.4 mm x 19.2 mm, Matrix = 98 x 48, In-plane resolution = 400 μm, Slice thickness = 1.5 mm, Number of inversion times = 16, First inversion time = 21 ms, Inversion time scale factor = 1.5, Number of averages = 2). We fitted this image data to a three parameter, single-exponential T_1 recovery function in Matlab to produce a T_1 map (not shown). We then measured T_1 in two regions of the cortex: the highly myelinated middle temporal region (MT) and a region of immediately adjacent cortical grey matter that has little myelin content[5]. The T_1 in MT was 1590 ms and in adjacent gray matter it was 1800 ms.

Based on these T_1s and using published equations[6,7], we then calculated the optimum parameters for a 3D magnetization-prepared rapidly acquired gradient echo (MP-RAGE) pulse sequence to maximize the T_1 contrast between regions of the cortex based on myelin content. We then imaged the marmoset with the sequence (TE = 4.5 ms, TR = 13 ms, Flip angle = 12 degrees, Inversion time = 1200 ms, FOV = 42.0 x 42.0 x 19.7 mm, Matrix = 256 x 256 x 120, Isotropic resolution = 164 μm, Number of segments = 4, Repetition time between segments = 6000 ms, Total imaging time = 48 minutes). To increase our signal-to-noise, we made six images over two imaging sessions. We corrected these individual images for B_1 inhomogeneity using a reference image method, spatially registered them in Amira, and created a sum-of-squares average image.

Results and Discussion: Figure 1 shows a horizontal slice from our final 3D MP-RAGE image of the marmoset brain. There is marked contrast between regions of the cortex with low (L) and high (H) myelin content, as identified from published maps based on histology[4]. To display the pattern of T_1-enhancement over the entire cortex, we volume rendered the 3D MRI data using the Voltex function in Amira (Figure 2). Bright regions in the MRI data correspond to major cortical areas (V1 = primary visual cortex, MT = middle temporal region, DM = dosomedial area, A1 = primary auditory cortex, S1 = primary somatosensory cortex, vis = vasomotor sector of frontal cortex). These data show that T_1-weighted imaging can be used to visualize and identify major functional areas in the non-human primate cortex.
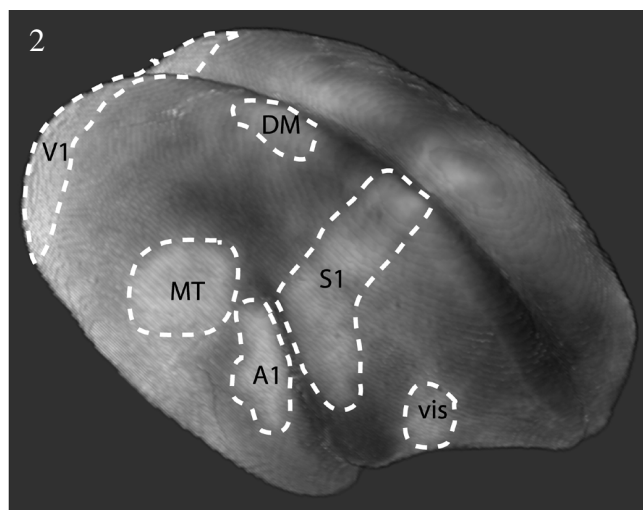
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