Detection of cortical layers via Magnetization Transfer imaging at 7T

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Introduction

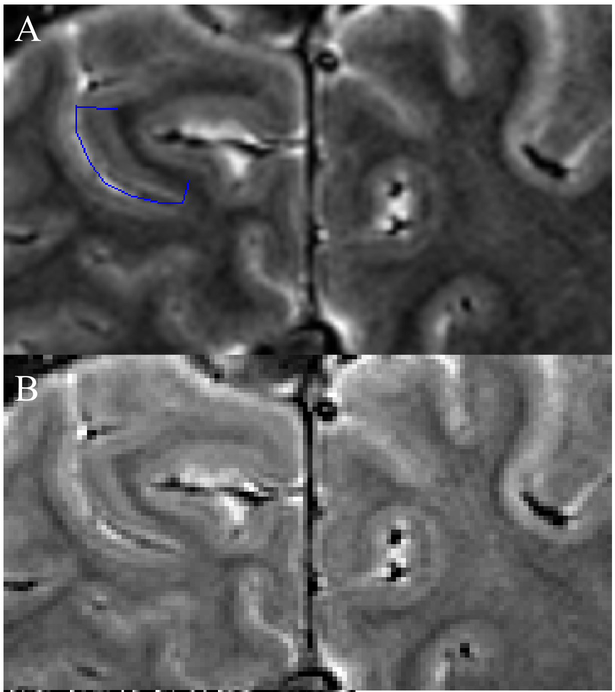
Myelination is known to vary across the thickness of the cortex, for instance the calcarine sulcus can be distinguished by the presence of the stria of Gennari, a dense band of myelination within the cortical grey matter of ~0.3 mm thickness. Detection of contrast in the grey matter has previously been achieved using high resolution MRI (1) for instance using MPRAGE (2) and Turbo Spin Echo (3) optimized for grey /white matter contrast. Magnetization Transfer Imaging is generally used to study variations in myelination in the white matter (WM) but provides a method for potentially quantifying variations in myelination across the cortex. However to provide adequate sensitivity in high spatial resolution MT imaging, the data must be acquired at ultrahigh field (eg 7T). Here, we use pulsed train magnetization transfer in conjunction with Turbo Field Echo (4) at 7T to quantify changes in MTR across the cortical layer in vivo in humans.

Methods

Scanning was carried out using Philips Achieva scanner at 7T. High resolution MT data were required using an MT-TFE sequence (1) to acquire two images. The first (MT_{sat}) applied a train of 20 off-resonance pulses (13.5 µT Gaussian-windowed, sinc pulses with a bandwidth of 200 Hz and off-resonance by 1.05 kHz (3.5ppm), with 50 ms between each pulse), followed by a Turbo-Field echo (TFE) readout (TR/TE=22/13ms, flip angle= 8°, $0.4x0.4x1mm^3$, FOV of 180x160x30mm, centre-out sampling, total imaging time of 7min 20s) with a shot to shot interval (SSi) of 10 s. The second (MT_{noSat}) reference image acquired the TFE sequence, with no off-resonance saturation pulses applied. High resolution MTR maps were calculated from $(MT_{noSat}-MT_{Sat})/MT_{noSat}$ on a pixel by pixel basis after registration of the two volumes of interest. Five healthy volunteers were scanned with this sequence with local ethics committee approval. One subject was also scanned at 0.4 mm isotropic resolution. Noise propagation from the in the raw images (both MT_{noSat} and MT_{sat}) propagates to the MTR maps, was assessed using the propagation of errors [5]. The SNR in the raw images were 65 (±8), giving a SNR in the MTR image of 3.0 (±0.6) for the WM, and 2.0 (±0.8) for the GM. This predicted a CNR in the MTR maps 0.19 (±0.07) for GM/WM and 0.11 (±0.05) for GM/stria. Therefore for quantitative analysis the data were averaged along the stria. Curves of ~1.5cm were drawn parallel to the cortex surface on the MT_{noSat} images and applied to the MT_{Sat} images, averaged and then used to calculate an MTR for the curve. This was repeated with the curve moved progressively from the pial surface to the WM surface to give a spatially averaged profile across the cortex. As the width of the cortex within and between subjects varies, the profiles were spatially normalized before averaging across subjects (0 being the CSF and 1 the WM surface). Four regions of the cortex were investigated per subject on 5 subjects, one being where no stria was visible.

Results

A band within the cortical grey matter indicating the stria of Gennari was clearly visible in the visual cortex in slices aligned perpendicular to the calcarine sulcus for all four subjects on MT_{Sat} and MT_{NoSat} (hypointense) and MTR (hyperintense) images. Similar structure was observed in laminar GM in other regions of the brain, including the pre/-post central sulcus and parietal sulcus (fig. 1A-C). High resolution maps also showed intracortical contrast (fig. 2A). Quantitative analysis of the MTR across the cortex showed a general increase MTR from CSF to WM. However in areas where stria were present there was a trend for a peak and dip in this curve as indicated in figure 1D. The dip was present on all individual data sets (the error bars indicate variation between subjects and different regions of grey matter).



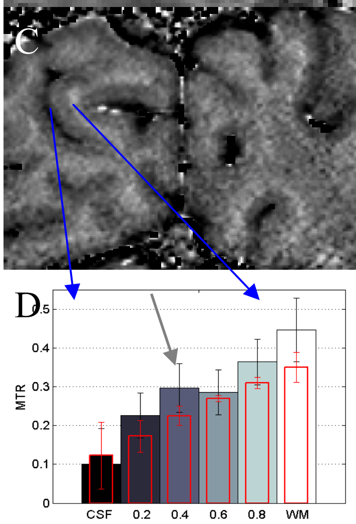


Fig. 1: Sat. image (A) and noSat image (B) acquired in 7min20s using MT-RAGE with a resolution of $0.4x0.4x1mm^3$ at 7T. MTR image (C) with the line and arrows showing an example of where profiles were drawn parallel to the cortex on A and B. The measured lines were spatially normalized and averaged across subjects to give an overall profile of the cortex (D), both with (black contour) and without (red contour) visible stria. A peak and dip in the profile can be seen corresponding to the stria (grey arrow), not visible in the red bars.

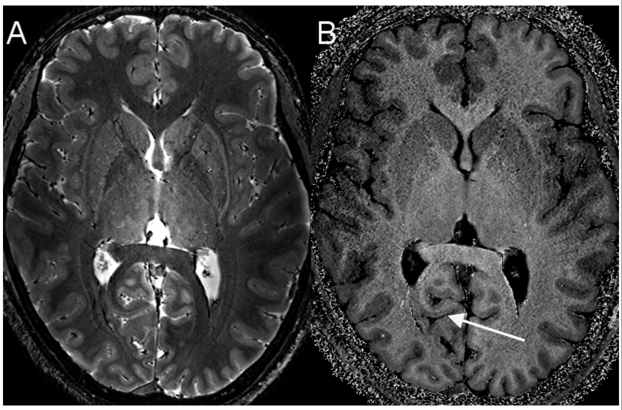


Fig. 2: MTsat (A) and MTR (B) images at 7T acquired using MT-RAGE at resolution of $0.4x0.4x0.4mm^3$ (7T) with 3 averages (33min).

Discussion

Variations in MTR in GM can be detected and probably correspond to intracortical variations in myelination. Furthermore MTR maps can be used to detect the known increased myelination in the Stria of Genari. Software is being developed to produce profiles automatically across the cortex, which will be important for systematic studies of cortical myelination. The detection of changes in intracortical myelination using MTR will be important in studies of brain function, development and neurodegeneration and for the early detection of multiple sclerosis lesions in GM.

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