Improving contrast in 3D structural brain imaging at 3T by incorporating magnetisation transfer pulses into MDEFT (MT-MDEFT)

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Introduction

3D MDEFT is an established imaging technique for whole brain T_1-weighted imaging, particularly at high field strength [1-3]. Typically, high resolution (1mm^3) images are acquired with good contrast between grey matter (GM), white matter (WM) and cerebrospinal fluid (CSF). In order to differentiate between tissue types and perform segmentation effectively, it is important for the contrast-to-noise ratio (CNR) of the images to be as high as possible. In this work, we describe a modification to the MDEFT sequence which increases the CNR of GM, WM and CSF in the brain. We achieve this by adding magnetisation transfer (MT) pulses to the first part of the MDEFT preparation period. The contrast introduced by these MT pulses combines constructively with the inherent T_1 contrast to produce images with higher CNR than standard MDEFT.

Methods

The modified MDEFT (MT-MDEFT) sequence is shown in Figure 1. The standard MDEFT pulse sequence is shown in black (saturation, τa delay, inversion, τb delay, spoiled TurboFLASH acquisition) and the extra MT pulses are shown in red. The MT pulses preferentially attenuate the recovery of tissues which contain a high proportion of 'bound' protons (e.g. WM in the brain) while having negligible effect on tissue which consists mainly of 'free' protons (e.g. CSF). As a result, the magnitude of the longitudinal magnetisation of WM at time τa is reduced when the MT pulses are applied. Following inversion, the starting point for WM signal recovery is closer to the null point and hence WM M_z will be greater at the end of the τb period when MT pulses have been applied. Since WM M_z is inherently high in T_1-weighted images, the effect of the MT pulses during τa should serve to reinforce the T_1 contrast and therefore improve the overall image CNR.

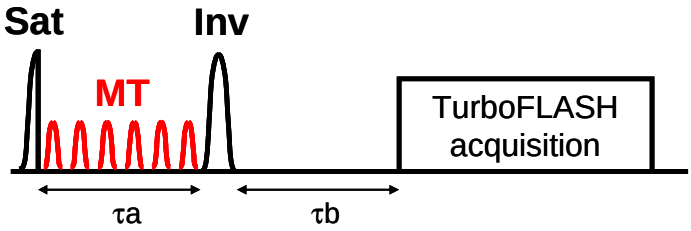

Figure 1 MT-MDEFT: MDEFT sequence with additional MT pulses during the preparation period (shown in red). Recovery of WM M_z is attenuated during τa, resulting in higher M_z at the end of τb and consequently higher CNR.

Sequence details: Numerical simulations were performed in Matlab to determine the optimum MDEFT pulse sequence parameters (τa, τb and excitation pulse flip angle (α)) with and without MT pulses during τa. For both versions of the sequence, 3D data sets were acquired using a 2-segment, centre-out phase-encoding approach, as described previously [2]. Images were acquired on three healthy subjects using a 3T Siemens Tim Trio MRI system. The same preparation period (τa+τb) of 910ms was used for both versions of the sequence; for the standard MDEFT, τa=446ms, τb=464ms, α=16°; for the MT-MDEFT sequence, τa=455ms, τb=455ms, α=14°, and a train of 20ms Gaussian MT pulses with 2000Hz frequency offset, amplitude ~12μT and 15ms separation was applied during τa.

Results

Simulations predicted an increase in CNR for all tissue types with the MT-MDEFT compared to the standard MDEFT sequence. Figure 2 shows a comparison of the images acquired using the two approaches. Despite requiring a lower excitation pulse flip angle, signal intensity in WM and GM is higher in MT-MDEFT due to the suppressed recovery during τa. This results in a higher WM-GM CNR (mean CNR increase of 5%, measured over a range of ROIs in all 3 subjects). Due to the lack of MT effect in CSF and lower α, the CSF signal in MT-MDEFT is lower than in standard MDEFT, resulting in an even greater degree of CNR improvement between CSF and WM/GM (mean GM-CSF CNR increase of 24% over 3 subjects).

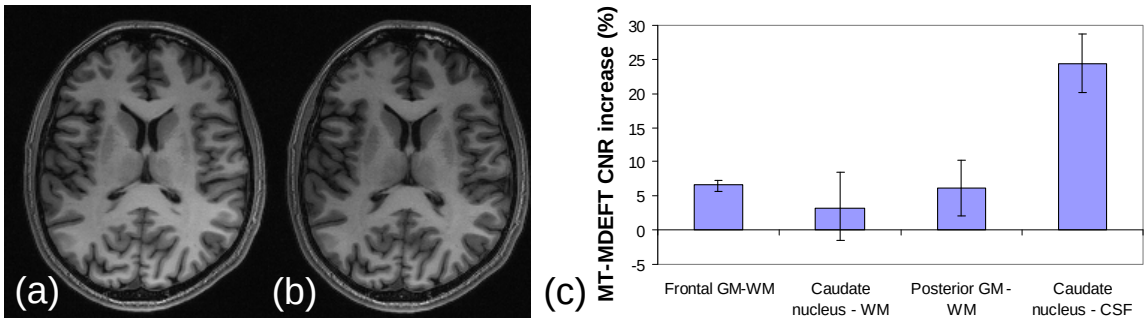

Figure 2 Comparison of images acquired on one subject using (a) MT-MDEFT and (b) standard MDEFT. Higher SNR in the MT-MDEFT image is apparent (c) Mean CNR increase of the MT-MDEFT sequence for several ROIs for all subjects (error bars show minimum and maximum CNR differences of all 3 subjects). Mean CNR increases: WM/GM = 5%; GM/CSF = 24%

Conclusions

We have introduced a modification to the MDEFT sequence which increases CNR in structural brain imaging at 3T. By incorporating MT pulses in the MDEFT preparation period, we have combined T_1 and MT weighting to increase the SNR of WM and GM and improve the suppression of CSF signal. This will facilitate tissue segmentation and may improve the sequence's sensitivity to pathology.

References [1] Lee MRM 34:308 (1995); [2] Deichmann NeuroImage 21:757 (2004); [3] Thomas MRM 53:1452 (2005)