Preliminary investigation of the use of parallel RF transmission in MTR measurement at 3.0T

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Introduction: RF B_1 transmit field non-uniformity, caused primarily by skin depth and dielectric resonance effects, is a large source of error in quantitative MR measurements, such as the Magnetisation Transfer Ratio (MTR), and this effect increases with field strength [1], and can be highly variable between subjects. The relationship between MTR and B_1 is also complex [2], and potentially dependent upon tissue type. Transmit non-uniformity has been shown to be the largest source of variation in multi-centre MTR histogram studies [3].

Multi-transmit technology has the potential to mitigate this problem, by using data acquired in a calibration scan to generate a spatially tailored excitation and thereby compensate for flip angle inhomogeneity [4].

This preliminary study compares MTR histograms in three subjects generated using MTR data acquired with and without the use of dual transmission at 3.0T and also examines B_1 histograms to investigate the effect of global changes in the transmitted field on global MTR data.

Methods: Two subjects (1 male, 2 female, aged 31.0±8.1 years) were scanned on a 3.0T Philips Achieva Tx scanner (Philips Healthcare, Best) and a 16-channel neurovascular receive coil. A slab selective spoiled gradient echo sequence (TR=5.7ms, TE=2.7ms, flip angle α =5°) was performed with and without Sinc-Gaussian shaped MT saturating pulses of nominal α=276°, offset frequency 1kHz, duration 18ms. 56 2.5mm slices were acquired in a sagittal orientation, with field-of-view (FOV)=220x220 mm^2 and acquisition matrix 88 x 88 (i.e. providing isotropic 2.5x2.5x2.5mm^3 voxels). The total acquisition time for both the MT-on and MT-off sequences was approximately 3 minutes.

The spatial distribution of the B_1 transmit field was also measured via the actual flip angle imaging (AFI) method [5], with two excitation pulses of α =60° followed by delays of 15 and 65ms and a gradient echo readout at TE=5.1ms. 28 5mm slices were acquired with acquisition matrix 44 x 44 to give isotropic 5x5x5mm^3 voxels in approximately 1min 40s. Both the MTR sequence and B_1 mapping sequence were performed twice, with and without dual transmission.

Following MTR map calculation, brain extraction (using FSL) and segmentation (using SPM8) was performed on the non-MT-weighted images in order to generate whole brain, white (WM) and grey matter (GM) masks for each subject. These masks were applied to the MTR maps and fully normalised whole brain, WM and GM histograms were generated for each of the volunteers.

The same masks were also applied to the (co-registered) B_1 maps and fully normalised B_1 histograms were also produced.

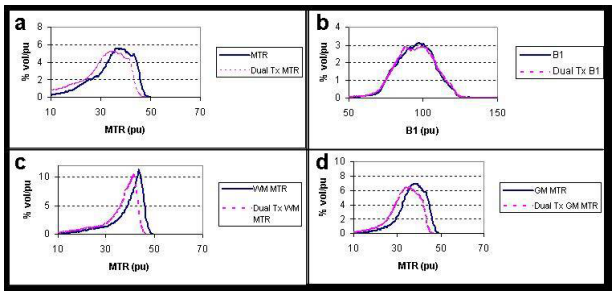

Figure 1: Set of whole brain MTR (a), whole brain B_1 (b) & WM (c) and GM (d) MTR histograms for a single subject

Results: Figure 1 consists of a whole brain MTR (a) and corresponding whole brain B_1 histogram (b) and WM (c) and GM (d) MTR histograms for a single subject, showing data acquired with and without dual transmission. MTR histogram dispersion is not reduced with the use of dual transmission (Tx), however MTR peak locations are altered in all subjects.

Table 1 gives the mean MTR histogram peak location and peak height for the three subjects studied here. From the table it can be seen that the variation in MTR histogram peak location was rather large for the three subjects and that the variation in peak location and height was significantly reduced with the use of dual transmission.

Figure 2 is a map of $\Delta MTR=MTR_{Tx}-MTR$ (left) and $\Delta B_1=B_{1Tx}-B_1$ for the same single subject, where MTR_{Tx} and B_{1Tx} are the MTR and B_1 maps acquired with dual transmission respectively. The apparent co-localisation of changes in these two difference maps can be observed, indicating that the changes in MTR observed due to the use of dual transmit technology relate to the intended alteration in local spatial B_1 variation with this method.

Discussion and Conclusions: The large variation in MTR peak location between the three subjects studied here demonstrates that B_1 is a significant problem in MTR measurement at 3.0T. The differences between B_1 histograms in these three subjects illustrates the potentially high inter-subject variation in B_1 at 3.0T, and highlights the necessity to take B_1 errors into account when making quantitative measurements at 3.0T.

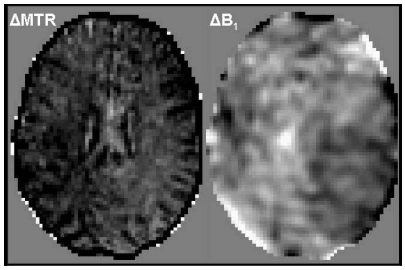

Figure 2: Difference maps of ΔMTR and ΔB_1 for the same subject

The dual-transmit adjustment for this study was made using preliminary non-head optimized software, based on a dedicated transverse B_1 measurement protocol. However, these preliminary results demonstrate that the technique has the potential to reduce between-subject variation in MTR measurement with standard deviations reducing to less than half the original values, and could be applied to other quantitative MRI techniques in the brain. The reduction of the inter-subject variation of the mean MTR measurement could have important implications for longitudinal clinical studies involving quantitative measurements made at 3.0T, where the B_1 variation is known to be larger than that observed at 1.5T.

Histogram peak widths were not reduced in MTR maps acquired with dual transmission, which could possibly be explained by local changes in MTR, therefore this will need further investigation.

A much larger group of healthy subjects is required in order to confirm the results of this preliminary study. This study only examines global changes in B_1 and MTR, whereas further research should also consider local reproducibility, which may provide further evidence of the usefulness of the technique in this context.

Table 1: Mean MTR histogram peak locations and heights with and without dual transmission

	Mean Peak Location (pu)	SD (pu)	Mean Peak Height (% vol/pu)	SD (pu)
Whole brain	39.34	3.33	5.70	0.28
Whole brain + dual Tx	37.51	1.50	5.25	0.12
White Matter	42.68	4.80	10.20	1.09
White Matter + dual Tx	40.84	1.15	9.47	0.84
Grey Matter	39.18	4.01	7.18	0.71
Grey Matter + dual Tx	37.18	1.53	6.54	0.30

References: [1] Berry I *et al.* JMRI 1999; 9: 441-446, [2] Samson RS *et al* MRI 24(3): 255-263, 2006, [3] Tofts PS *et al* Magn Reson Mater Phy 19: 209-222 (2006), [4] Katscher U & Bornert P NMR in Biomedicine 2006 19: 393-400, [5] Yarnykh V *et al* MRM 57 (1): 192-200 (2000)
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