Preliminary investigation of the use of parallel RF Transmission in MTR measurement in the human cervical cord

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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. Transmit non-uniformity has been shown to be the largest source of variation in multi-centre brain MTR histogram studies [2], and the relationship between MTR and B_1 is also complex [3], [4] and potentially tissue dependent.

Multi-transmit technology has the potential to mitigate this problem, by using data acquired in a calibration scan to generate an independent spatially tailored excitation (where RF pulses differ in their complete time course for individual transmit channels) and thereby compensate for flip angle inhomogeneities [5]. It has previously been shown that brain B_1 and MTR histogram peak locations are altered with the use of dual transmission, but that inter-subject variation is not significantly reduced, which could possibly be explained by local MTR changes [6]. The use of subject adaptive RF shimming also may enable reduced local Specific Absorption Rate (SAR) and/or shorter acquisition times since RF pulses may be shortened by using multiple transmit coils each with their own time-dependent waveforms and spatial sensitivities.

The spinal cord is commonly involved in neurological disorders such as multiple sclerosis (MS), and post mortem MRI and histology studies have demonstrated the presence of focal and diffuse abnormalities in the cord and correlations of quantitative MRI parameters with myelin and axonal density [7,8].

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

Methods - Acquisition: Three subjects (2 males, 1 female, aged 30.2±1.2 years) were scanned on a 3.0T Philips Achieva Tx scanner (Philips Healthcare, Best) and a 16-channel neurovascular receive coil. A 3D slab selective spoiled gradient echo (FFE) sequence (TR=11.0ms, TE=5.7ms, flip angle α =8°) was performed with and without Sinc-Gaussian shaped MT saturating pulses of nominal α=300°, offset frequency 1kHz, duration 18ms. 40 3mm slices were acquired in an axial orientation, with field-of-view (FOV)=160x220mm^2 and acquisition matrix 160x224, sinc interpolated in image space to 320x448. The total acquisition time for both the MT-on and MT-off sequences was approximately 8 minutes.

The spatial distribution of the B_1 transmit field was also measured via the actual flip angle imaging (AFI) method [9], with two excitation pulses of α =60° followed by delays of 22ms and 72ms and a 3D gradient echo readout at TE=6.2ms. 20 6mm slices were acquired with acquisition matrix 80 x 112 to give isotropic 2x2x6mm^{3}voxels in approximately 3minutes 30s. Both the MTR and B_1 mapping sequences were performed twice, with and without dTx (which can be turned on/off simply with a parameter selection in the protocol setup), which was implemented using data acquired from a single slice transverse B_1 calibration scan at the C2/C3 level of the cord.

Methods – Image Analysis: Semi-automatic cord segmentation was performed on non-MT-weighted images using Jim 6.0 [10] (www.xinapse.com). The cervical cord masks (from levels C1 to C7) were then applied to the MTR maps and fully normalised MTR histograms were generated for each volunteer. The same masks were applied to the B_1 maps and fully normalised B_1 histograms were also produced.

Results: Figure 1 consists of an example whole cord MTR (a) and corresponding B_1 histogram (b) for a single subject, showing data acquired both with and without dTx. MTR histogram dispersion is not significantly reduced with the use of dTx, however MTR peak locations are altered in all subjects. Tables 1 and 2 give the MTR and B_1 histogram metrics respectively for the three subjects studied here. From the tables it can be seen that the inter-subject variation in MTR histogram peak location was rather large for the three subjects when analyzing data acquired without dTx and that the variation in peak location and height between subjects was significantly reduced with the use of dTx. The coefficients of variance (CoV) between subjects are comparable to those observed in MTR histogram studies performed at 1.5T [11,12]. B_1 histogram peak location inter-subject variation was also reduced, however the peak location appeared to converge on a value of approximately 89% in the cervical cord for the three subjects studied here. Neither MTR nor B_1 peak widths were significantly reduced with dTx, suggesting that intra-subject variation in the cervical cord was not significantly altered by the use of dTx.

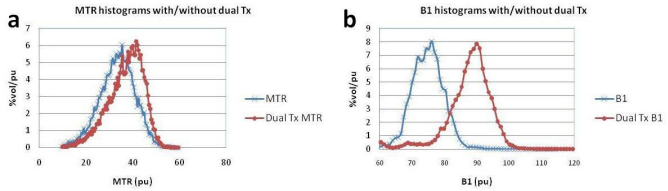

Figure 1: Set of whole cord MTR (a) and B_1 (b) histograms

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

The dTx adjustment for this study was made using software optimized for use in the body and 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 in the cervical cord, and could also benefit other quantitative MRI techniques in the cord. The reduction in the inter-subject variation of the mean MTR measurement could have important implications for sample size calculations and 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.

Whole cord MTR histogram peak widths were not significantly reduced when MTR data were acquired with dTx, which can be explained by local changes in MTR, although this will need to be confirmed with larger studies. The spinal cord has a rather small surface area with respect to the whole body volume B_1 optimisation performed by the dTx algorithm. As such, the shifts in the MTR (and B_1) histogram peaks observed in this study can be interpreted as a real measurement of improvement in global B_1 homogeneity across the body, with a limited effect on the small surface area of the spine.

A much larger group of healthy subjects is required in order to confirm the results of this preliminary study, which investigates only whole cord B_1 and MTR changes. Further research will also consider local reproducibility, which may provide additional evidence of the usefulness of the technique in this context.

Table 1: MTR peak locations and heights with and without dTx

Subject/ Measure	MTR Peak Location (pu)	MTR peak height (%vol/pu)	Tx MTR Peak Location (pu)	Tx MTR peak height (%vol/pu))
1	35.6	5.90	41.5	6.60
2	41.5	6.59	37.5	7.17
3	36.5	9.54	38.0	7.45
Mean	**37.9**	**7.34**	**39.0**	**7.07**
SD	**3.18**	**1.93**	**2.18**	**0.43**
CoV (%)	**8.39**	**26.3**	**5.69**	**6.12**

Table 2: B_1 peak locations and heights with and without dTx

Subject/ Measure	B_1 Peak Location (pu)	B_1 peak height (%vol/pu)	Tx B_1 Peak Location (pu)	Tx B_1 peak height (%vol/pu))
1	76.0	8.04	89.0	7.85
2	80.5	7.03	88.7	10.12
3	97.0	8.37	89.9	6.91
Mean	**84.5**	**8.01**	**89.2**	**8.41**
SD	**11.1**	**0.86**	**0.62**	**1.60**
CoV (%)	**13.1**	**35.7**	**0.70**	**19.8**

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