Intra- and Inter-Scanner Variability of Magnetization Transfer Ratio Using Balanced SSFP

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Introduction. Magnetization transfer ratio (MTR) has become an important tool to study various tissue abnormalities, such as demyelination in brain white matter (1). Recently, a new technique for measuring MTR has been proposed based on balanced steady-state free precession (bSSFP) with modified radiofrequency pulses (2). In this study, the reproducibility and variability of MTR-bSSFP was analyzed on six healthy volunteers using two different 1.5 T clinical systems. Intra-scanner MTR measurements were well reproducible (< ±0.3 pu) and inter-scanner variation is below 0.4 pu for optimal flip angle settings ([pu]: percentage units).

Methods. All experiments were performed in 3D with sagittal orientation based on a 144×192×192 matrix yielding 1.3 mm isotropic resolution. Non-selective RF pulses were used with T_{RF} = 150 µs (TR = 2.80 ms) and with T_{RF} = 2100 µs (TR = 4.75 ms) for the MT-weighted and non-MT weighted bSSFP sequence, respectively. Using parallel imaging (acceleration factor of 2) and partial Fourier (6/8), a whole brain MTR scan was finished within 1:17 min. Flip angles α were varied from 35° to 55° in order to estimate B_1 sensitivity. Reproducibility of MTR was assessed with four consecutive acquisitions on the same healthy volunteer on two systems (system A: Siemens Avanto, system B: Siemens Espree). Before each scan, the subject was taken out of the scanner, repositioned (however, no care was taken to ensure that the position of the head was consistent), and a manual shim was performed. MTR variability between two scanners was assessed on six normal subjects. Values in four different regions of interest (ROIs: Fig. 1, left) were analyzed.

Results & Discussion. Reproducibility (intra-scanner variability) is characterized by standard deviations (SD) in the four consecutive MTR scans for several gray and white matter ROIs (exemplary curves in Fig. 1 a,b, and all results in Table 1). MTR values were highly reproducible (SD < 0.3 pu for α = 35°, SD < 0.4 pu for α = 40° to 50°, and SD < 0.8 pu for α = 55°) for all regions of interest and on both systems. Variability in MTR between scans of the same subject on system A and B are calculated for each volunteer separately (exemplary curves in Fig. 1 c,d) and averaged values are listed in Table 2. Mean differences amounted to less than 0.4 pu for 35°, less than 1 pu for 40°, and less than 2.5 pu overall. As a result, flip angles near 35° to 40° are proposed to achieve highest intra-scanner stability and lowest inter-scanner variability. In addition, MTR-bSSFP is less sensitive to B_1 variations (less than 5% change in MTR for a 20% change in B_1) than standard methods using MT-prepared spoiled gradient echo (MT-SPGR: about 17% change in MTR for a 20% change in B_1) (3). In summary, our first results indicate low intra- and inter-scanner variability which might be a direct result of the simplified normalization procedure (no MT pre-pulses). Standardization of bSSFP for MTR scans using systems of different manufacturers and at different sites will be analyzed.

Conclusion. MTR scans with bSSFP can be optimized to yield low intra- and inter-scanner variability which might turn out to be superior to the one achieved with common MT-SPGR methods. Flip angles near 35° are proposed to achieve highest stability and lowest variability. MTR-bSSFP benefits further from relatively low B_1 sensitivity, high signal-to-noise ratios, and short overall acquisition times.

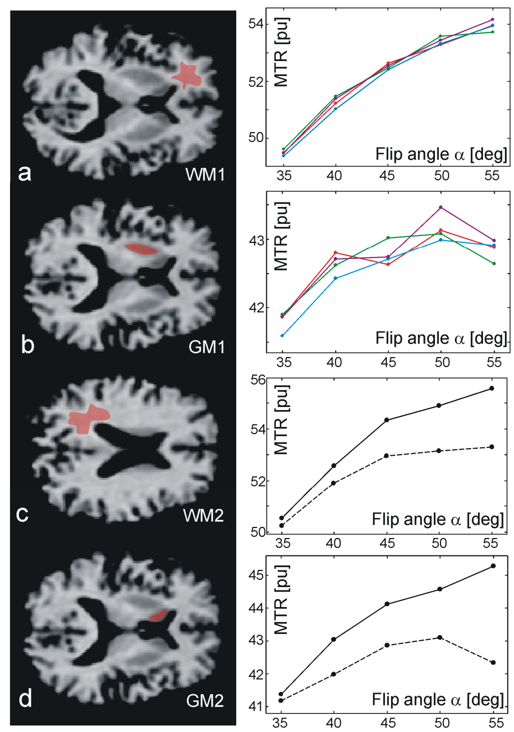

Fig. 1: Inter- and intra-scanner variability in MTR using bSSFP as a function of flip angle. Reproducibility was assessed with four consecutive acquisitions on the same healthy volunteer: (a) for frontal white matter (WM1) with scanner A (Siemens Avanto) and (b) for putamen (GM1) with scanner B (Siemens Espree). Scanner specific differences are shown for one volunteer (solid line: scanner A, dashed line: scanner B) (c) for occipital white matter (WM2) and (d) for caudate nucleus (GM2).

References. 1. Dousset et al., *Radiology* **182** (1992) 2. Bieri et al., *MRM* **58** (2007) 3. Ropele et al., *MRM* **53** (2005)

	SD(MTR)[1] [pu]		SD(MTR)[2] [pu]		SD(MTR)[3] [pu]		SD(MTR)[4] [pu]	
α [deg]	A	B	A	B	A	B	A	B
35	0.10	0.30	0.24	0.21	0.19	0.15	0.14	0.20
40	0.19	0.10	0.33	0.13	0.22	0.16	0.32	0.22
45	0.09	0.29	0.30	0.16	0.17	0.17	0.36	0.10
50	0.13	0.10	0.14	0.28	0.17	0.20	0.34	0.37
55	0.19	0.07	0.19	0.33	0.45	0.15	0.76	0.32

Table 1 (Intra-scanner variability): Standard deviations of four consecutive MTR scans on the same healthy volunteer with respect to flip angles α, white (1,2: Fig. 1a,c) and gray (3,4: Fig. 1b,d) matter ROIs and scanners (A: Siemens Avanto, B: Siemens Espree).

α [deg]	ΔMTR[1] [pu]	ΔMTR[2] [pu]	ΔMTR[3] [pu]	ΔMTR[4] [pu]
35	0.30 ± 0.19	0.34 ± 0.17	0.25 ± 0.21	0.29 ± 0.22
40	0.44 ± 0.29	0.53 ± 0.20	0.92 ± 0.29	0.84 ± 0.14
45	0.77 ± 0.32	1.17 ± 0.25	1.54 ± 0.27	1.16 ± 0.66
50	1.34 ± 0.31	1.97 ± 0.45	2.28 ± 0.52	2.00 ± 0.54
55	1.63 ± 0.82	1.95 ± 0.47	2.45 ± 0.83	2.07 ± 1.26

Table 2 (Inter-scanner variability): MTR variability (ΔMTR) of scans between scanner A (Siemens Avanto) and scanner B (Siemens Espree) for flip angles α = 35° – 55°. Mean values and standard deviations from six healthy volunteers are calculated in two white (1,2: Fig. 1a,c) and two gray (3,4: Fig. 1b,d) matter ROIs.