Impact of Magnetization Transfer on Relaxometry using Transient Steady-State Free Precession Imaging

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Introduction. Several methods proposed the use of the transient response of balanced steady-state free precession (bSSFP) for quantification of relaxation times and spin densities [1-3]. After inversion, the transition to steady state closely follows a mono-exponential signal behavior with an apparent relaxation rate T1* [1,4], which depends on the flip angle, T1 and T2. However, it has been shown that magnetization transfer (MT) affects the steady state of bSSFP and is dependent on pulse duration and repetition time [5]. Furthermore, it has been shown that MT effects can lead to an overestimation of T1 for spoiled gradient echo [6]. During transition to steady state also MT effects built up, thus it is likely that MT affects the estimation of relaxation parameters using inversion recovery bSSFP [1,2] and similar transient SSFP methods [3]. In this work, we will show exemplarily for inversion recovery bSSFP [1] that significant deviations arise from MT leading to deviations in calculated T1 and T2 by 30-60%.

Materials and Methods. A single slice of normal appearing brain was acquired using a segmented inversion recovery bSSFP sequence. The transient response of bSSFP after slice selective inversion recovery was sampled at 31 time points for 3100ms extended by a recovery period of ~6s. It was shown that bSSFP signal is modulated by MT with RF pulse prolongation. For the assessment of MT effects, the scan was thus repeated twice: first with a short MT-sensitizing RF pulse of 450µs duration (TR=97.2ms; 27 PE/segment) and second with a relatively long RF pulse of 2800µs duration (TR=97.6ms; 16 PE/segment) which should guarantee negligible MT effects [5]. Therefore, the second scan will be referred to as "MT-free". The experiment was performed on a 1.5 T clinical scanner (AVANTO, Siemens) with 1.3*1.3mm in plane resolution and 6.5mm slice thickness. The flip angle was set to 50°.
The transient response of bSSFP after inversion was fitted pixelwise as described in any detail in the work of Schmitt et al. [1] and results in parametric maps of T1, T2, and of the spin density. The results of the MT-weighted and MT-free transient response were compared in selected regions of interest (ROI) for gray (GM), white matter (WM) and cerebrospinal fluid (CSF).

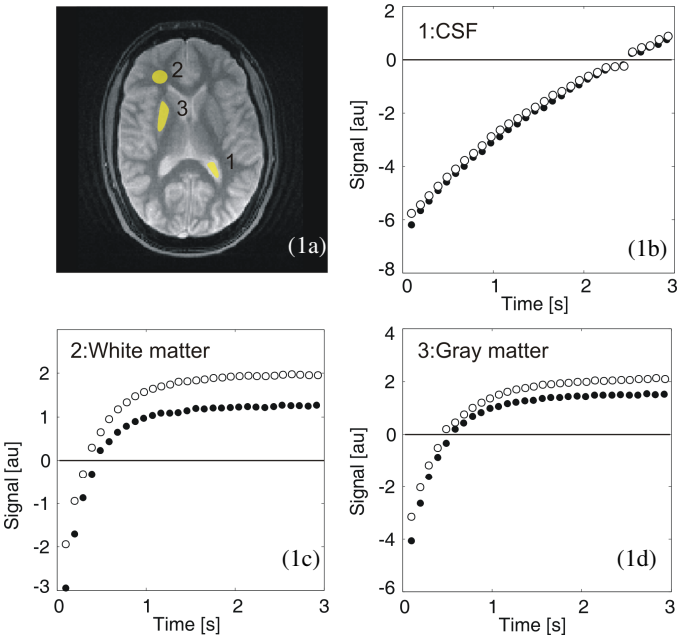

FIG. 1: (a) Selected ROIs for the transient response of CSF (b), frontal white matter (c) and caudate nucleus (d) for the MT-free inversion recovery bSSFP scan (open circles) and for the MT-weighted one (filled circles).

Results. The observed transient response (i.e. signal recovery to steady state) with respect to the short and long RF pulse is displayed in Fig. 1. Steady state is approached for white and gray matter, whereas for CSF transition to steady state is not completed even after 3.1s. It was already shown that MT can have a strong influence on the steady state signal amplitude [5]. This is reflected by the different steady state signal levels in Figs. 1b,c for gray and white matter with short and long RF pulse durations, respectively. In addition to the overall change in steady state signal intensity, the apparent transition rate is decreased in the presence of MT (i.e. the zero-crossing of the curve is shifted to longer recovery times). The deviations in the calculated T1 and T2 parameter maps between the MT-free and the MT weighted scan are shown in Fig. 2 (the values are given in percentile deviations according to $\Delta T_{1,2}= [T_{1,2}(\text{MT-free})-T_{1,2}(\text{MT})]/T_{1,2}(\text{MT-free})$).

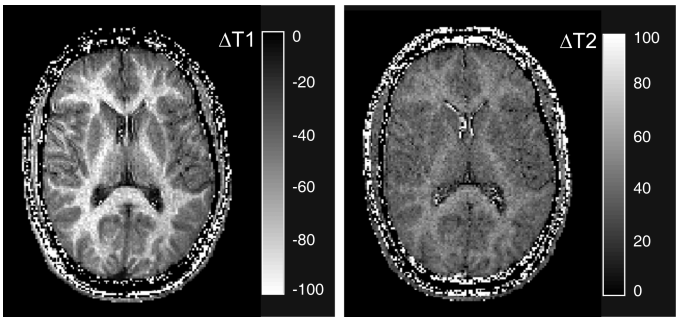

FIG. 2: Observed deviation in T1 and T2 from MT effects: ΔT1 map (left) and ΔT2 map (right) given in percentile units relative to values derived from the MT-free scan.

Discussion. In addition to the steady state, the transient response of bSSFP may be influenced by MT (see Fig. 1). As a result, quantitative parameter estimations based on inversion recovery bSSFP or other transient SSFP methods, may fail in the presence of MT and significant inaccuracies can occur. For inversion recovery bSSFP, MT has a considerably larger impact on T1 quantification as compared to T2 (see Fig. 2), and deviations are larger for white than for gray matter. This might be due to the fact that MT effects are more pronounced with bSSFP for white as compared to gray matter [5].

Conclusion. Care has to be taken on possible MT effects that arise with the use of short RF pulses and may hamper a reliable and accurate quantification of T1 and T2 using transient bSSFP methods.

References. (1) Schmitt P et al. MRM 51 (2004). (2) Scheffler & Hennig JMRI 45 (2001). (3) Hargreaves & Nishimura, Proc. ISMRM (2003) p.1100 (4) Scheffler K, MRM 49 (2003). (5) Bieri & Scheffler. MRM 58 (2007). (6) Ou & Gochberg. MRM 59 (2008).