

T1rho and T2rho mapping with gradient offset independent adiabatic pulse trains

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Introduction. T1 and T2 relaxation in the rotating frame (T1rho, T2rho) are sensitive to slow molecular dynamics on the ms time scale, relevant for interaction of water with important biological systems such as proteins, glycosaminoglycans and cell membranes. In many studies T1rho and T2rho have been used to investigate pathology of stroke, Alzheimer's Disease, Parkinson Disease, liver cirrhosis and cartilage damage [1-3]. However, because T1rho and T2rho contrasts are created by the application of a long spin lock RF field, or by a train of adiabatic inversion pulses this results in sequences that have high specific absorption rate (SAR). An additional complication may arise from the fact that T1rho and T2rho are created with spatially non-selective pulses. As a result, long TR need to be used leading to long scanning times, limited spatial resolution, reduced brain coverage, which often is limited to single or few slices. Here we propose a pulse sequence based on low power gradient offset independent adiabatic modulated pulses modulated with wurst functions (GOIA-W(n,m)) for decreasing SAR and performing slice selective T1rho and T2rho mapping.

Methods. Pulses sequences were implemented on whole-body 3T MR scanners (Tim Trio, Siemens, Germany) running IDEA VB17A software. The body coil was used for transmit and the 32-channel head coil for receive. We tested our sequences in an agar phantom and five volunteers. GOIA pulses were used to construct T1rho and T2rho modules according to MLEV-4 scheme [4]. In particular we tested GOIA-W(16,4) of 4 ms duration, 5 kHz bandwidth, 300 Hz maximum B1 field, and GOIA-W(16,3) of 2 ms, 10 kHz bandwidth and 800 Hz maximum B1 field. We compared our T1rho sequence with T1rho obtained using conventional adiabatic pulses (HS8) [5] or continuous wave (CW) [6]. For image acquisition we used 2D spin-echo EPI (se-EPI) or 3D turbo FLASH (TFL) readout. In particular for 3D TFL we used a matrix size of 192x192x128 with GRAPPA factor 2 and 6/8 partial phase encoding resulting in 7:13 min:sec acquisition for whole head T1rho mapping at 1.3 mm isotropic resolution (TR = 0.8s and 6 T1rho times: 0ms, 16ms, 32ms, 48ms, 64ms, 80ms). For 2D se-EPI we acquired 20 slices at 128x128 matrix (3x1.7x1.7 mm³) resulting in 1:30 min:sec acquisition time (TR = 0.5s per slice, the same 6 T1rho times as in 3D TFL). The T1rho or T2rho maps were obtained by fitting the equation for longitudinal relaxation in the rotating frame $I(t_{sl}) = I(0) \cdot \exp(-t_{sl}/T_{1,2\rho})$. Human subjects were scanned with informed consent approved by IRB.

Results. We investigate in phantom (Figure 2) the performance of adiabatic T1rho in the presence of B0 or B1 inhomogeneity, and compared it with performance of CW T1rho. For CW T1rho we used the schemes designed to compensate for B1 and B0 inhomogeneity [6]. However, in the presence of 1-2 ppm (125-250 Hz) offsets the adiabatic T1rho is superior and shows no bending artifacts. Further, we did not notice any artifacts for ±1 kHz offsets when operating at 800Hz maximum B1 field. Results obtained in vivo with GOIA based T1rho and T2rho mapping are shown in Figure 3 in the case of human brain imaging on healthy volunteers.

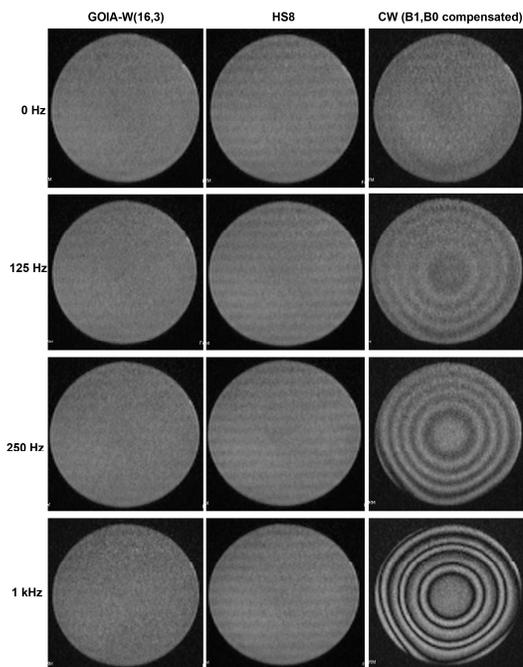


Figure 2. Offset dependence of T1rho weighted images with GOIA-W(16,4), HS8 and CW irradiation. B1max was matched to 800Hz and duration to 48ms for all T1rho schemes. Image readout has been done with spin echo EPI.

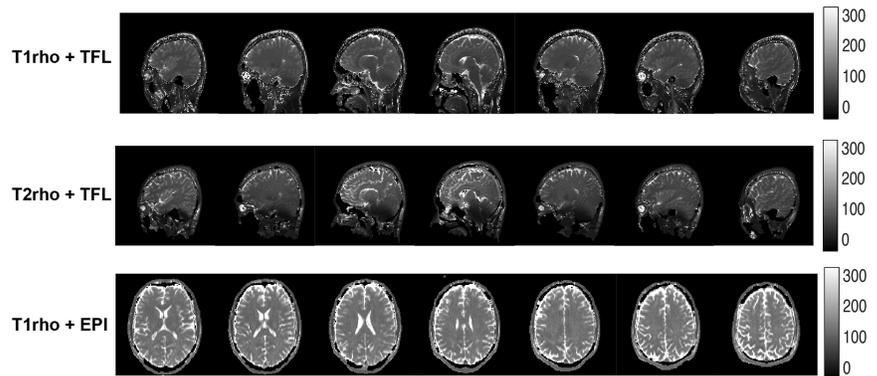


Figure 3. T1rho and T2rho obtained in human brain with GOIA-W(16,4) adiabatic pulses trains (4ms, 5 kHz BW, 300 Hz B1max). The pulse train was composed according to MLEV-4. Image readout has been done with turbo FLASH (TFL) or spin echo EPI. The bars show T1rho and T2rho values in ms.

Conclusions. T1rho and T2rho with GOIA-W pulses enables reduction of SAR compared to adiabatic pulses for the same inversion bandwidth and for the same B1max of CW irradiation. In addition GOIA pulse can be shorter than adiabatic pulse allowing a more flexible choice of T1rho encoding time. Slice selective and reduction of SAR allow scans of the whole head at 1.3 mm isotropic resolution in 7 min. Phantom results show no bending artifacts up to 1 kHz offsets. Further development, validation and applications are mandatory for clinical use.

References: [1] Haris M et al, J Neurol, 2011, 258:380-5; [2] Wang YX et al, Radiology, 2011, 259:712-9; [3] Borthakur A et al, Spine, 2011, 36:2190-6; [4] Andronesi OC et al, Magn Reson Med, 2010, 64:1542-56; [5] Michaeli S et al, Current Analytical Chemistry, 2008, 4, 8-25; [6] Witschey WRT et al, JMR 2007, 186:75-85.