Real-time motion correction for T1rho mapping of human brain

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Target Audience: developers of pulse sequences for rotating frame relaxation imaging; neuro-radiologists and neuroscientists interested in imaging biomarkers for neurodegeneration, cancer or stroke.

Purpose. T1 relaxation in the rotating frame (T1rho) is sensitive to molecular dynamics of water molecules interacting with macromolecules and has been shown to be a valuable imaging biomarker in stroke, neurodegenerative diseases (Alzheimer's Disease, Parkinson Disease), cancer, liver cirrhosis and cartilage damage [1-6]. Mapping of T1rho relaxation constant requires the acquisition of a time series of images with increasing rotating frame relaxation weighting. Perfect alignment of the images in the time series is critical for the accurate fitting of the T1rho constant. Measurements of T1rho maps may involve long acquisition times due to SAR and the need to wait for relaxation recovery. Hence, subject motion is likely to affect the data quality and bias fitted T1rho values, especially in patients with neurological impairment. Because of large changes in the contrast among images acquired at different preparation (weighting) times, postprocessing motion correction algorithms have difficulties to accurately coregister serial volumes and may introduce false displacements. Here we show that real-time motion correction improves the quality of T1rho mapping when subjects move.

Methods. Pulse sequences were implemented on whole-body Magnetom Tim Trio 3T MR scanners (Siemens AG, Erlangen, Germany) running IDEA VB17A software. The body coil was used for transmit and the 32-channel head coil for receive. T1rho relaxation was achieved with a recently developed sequence [7] employing a train of low power adiabatic GOIA-W(16,4) pulses of 4 ms duration, 5 kHz bandwidth, 400 Hz B_1 amplitude. Images at five preparation times 0, 16, 32, 48, 64 ms were acquired. 3D turbo-FLASH (TFL) was used for image readout, FOV=256x256x170 mm, matrix size of 192x192x128 (1.33 mm isotropic), GRAPPA factor 2, TR/TE = 800/1.08 ms, total acquisition time 7:13 min:sec. A volume navigator EPI was inserted before the T1rho preparation and rigid prospective motion correction (PACE) was applied to correct for head pose [8]. The T1rho maps were obtained by fitting the signal decay according to a mono-exponential law S(t) = S(0)*exp(-t/T1rho). We tested our sequences in phantoms and volunteers. Human subjects were scanned with informed consent approved by IRB. T1rho maps were acquired under static and motion, with and without real-time correction. Motion was reproduced across trials.

Results. Results obtained in the human brain are shown in Figure 1. Because of the magnetization recovery by the end of TR the navigator images have more uniform intensity across the time series making prospective motion correction more robust than postprocessing methods on the T1rho weighted volumes with large signal changes. The T1rho map acquired during motion without correction shows overall blurring of the anatomical features and signal drop-out, especially in the frontal regions. The static and motion corrected T1rho preserve anatomical details and signal. The goodness of fit (R^2) decreases overall for the T1rho map without correction, and is improved by real-time correction. This is illustrated also by the fact that the signal decay curves are not anymore smooth exponentials in the time series without motion correction.

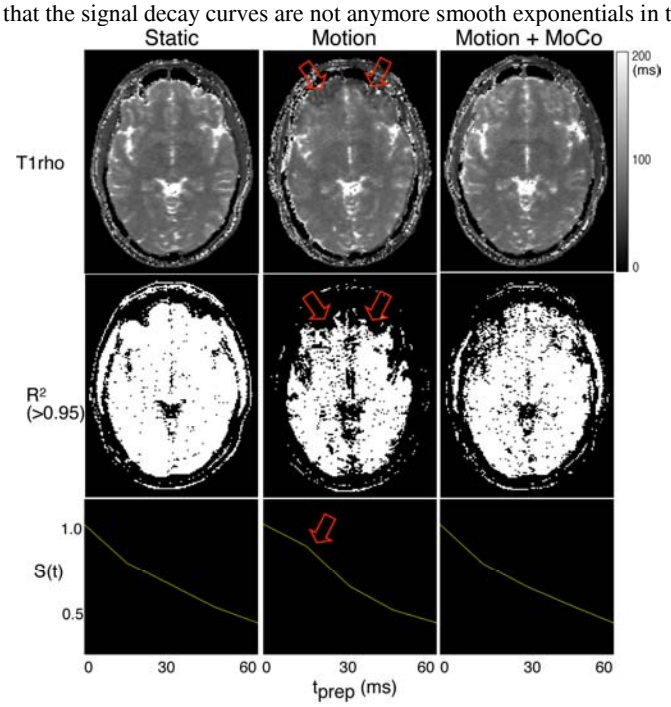

Figure 1. T1rho mapping with real-time motion correction (MoCo). Upper Row: motion degrades the T1rho maps with overall blurring and frontal signal drop-out (middle column); with real-time motion correction the quality of T1rho mapping is recovered (right column).
Middle Row: goodness of fit maps showing only the voxels with $R^2 > 0.95$. The number of voxels with $R^2 > 0.95$ decreases in the presence of motion, and is restored by real-time correction.
Lower Row: signal decays are not smooth exponential curves in the presence of motion, and are improved with real-time correction.

Red arrows in the middle column indicate the regions with the most severe motion artifacts.

Discussions/Conclusion. T1rho mapping benefits largely from the possibility of real-time motion correction. It is expected that the improvement in T1rho imaging and fitting quality will be important especially in clinical applications where it could have the largest impact, such as patients with Alzheimer's Disease, Parkinson Disease or stroke. Further improvement and validation of this methodology is underway.

References: [1] Michaeli S et al, Mov Disorders, 2007, 22, 334-340; [2] Haris M et al, J Neurol, 2011, 258:380-5; [3] Wang YX et al, Radiology, 2011, 259:712-9; [4] Jokivarsi KT, JCBFM 2009, 29: 206-216; [6] Kettunen MI, Radiology, 2007, 243, 796-803; [7] Andronesi OC et al, Proc ISMRM 2013, #2511; [8] Tisdall DM et al, MRM 2012, 68:389-99.