Improvement of Quantitative MRI using Radial GRAPPA in Conjunction with IR-TrueFISP

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Introduction: In quantitative MRI, T1, T2 and proton density (M0) values are assessed and employed for image visualization. Several different acquisition schemes have recently been proposed for rapid quantitation of these parameters. Specifically, the use of radially sampled IR-TrueFISP imaging for continuous sampling of magnetization recovery after spin inversion was proposed several years ago, and the capability of this acquisition technique to accurately quantify T1, T2 and M0 has been demonstrated [1-3]. However, rapid signal decay of species with short T1 and T2 values can lead to problems in quantifying these parameters. This is due to the use of the KWIC filter [4], which requires a significant number of projections in order to create the first image. If too many projections are required, the initial relaxation of these short T1/T2 species can be missed, leading to parameter quantification errors. This work explores the possibility of using a recently proposed formulation of radial GRAPPA, the so-called through-time radial GRAPPA [5], to reconstruct images with very few projections, thereby capturing the early relaxation and generating an improved parameter fit. Phantom experiments are demonstrated using this new reconstruction scheme with radially sampled IR-TrueFISP data.

Methods: A phantom with T1/T2 values which varied between 51ms/34ms and 1177ms/890ms was created by diluting Gadolinium solutions (0 to 5 mM).. Experiments were performed on a 1.5-T whole body clinical scanner Magnetom ESPREE (Siemens, Erlangen, Germany) equipped with a standard 12 channel head coil. After nonselective adiabatic refocusing spin inversion, a short delay for gradient spoiling of residual transverse magnetization and the application of a single preparation pulse, data were acquired using the previously reported radial TrueFISP acquisition with the following parameters: TR=3.04 ms for 128 readout points at a bandwidth of 1220 Hz/pix, flip angle 45°, slice thickness = 5 mm, FoV of 230 mm². Total image acquisition time was approximately 5 seconds. The TrueFISP module for KWIC reconstruction consists of a golden ratio projection angle increment [6] and a total of 2200 projections. Because the through-time radial GRAPPA method requires several fully-sampled radial datasets, the reference data acquisition was comprised of 40 fully-sampled radial datasets with 128 projections each, lasting over 6 seconds total acquisition time. The accelerated data used for the radial GRAPPA reconstruction and parameter fit was made up of 16 projections per frame and a total of 150 averages in order to capture the entire relaxation curve. For the standard golden-angle radial IR-TrueFISP reconstruction with KWIC, the filter was designed to use only 13 adjacent projections with all 128 readout points and fill the outer portions of k-space according to the Nyquist criterion with the outer readout points from view-shared projections (total number of projections contributing to each image along the relaxation curve was 233). With a sliding window of 13 projections, the total number of images in the time series was 163 to cover the entire magnetization evolution curve. For radial GRAPPA, all 40 references images were used to generate the GRAPPA weights for segments of size 2 x 4 (in the projection and read directions, respectively), as described in [5]. After through-time radial GRAPPA reconstruction or application of the KWIC filter, images were generated using a the NUFFT gridding algorithm [7]. A pixel-wise 3 parameter monoexponential fit described by the formula in [2] was used to determine the underlying T1, T2 and M0 parameter maps. As a gold-standard, spin echo and turbo spin echo based quantification experiments were performed.on the same phantom.

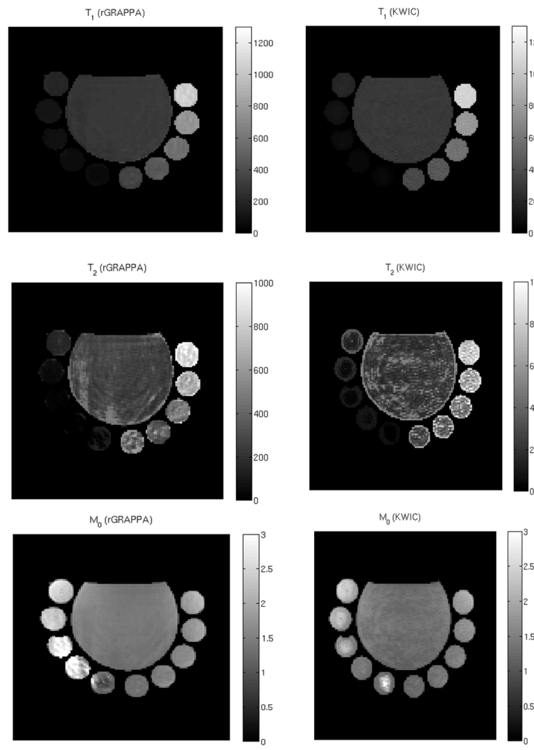

Figure 1: T1, T2, and M0 maps calculated using the radial GRAPPA IR-TrueFISP method (left) and the standard method using KWIC.

Results: The images in Figure 1 shows the results of T1, T2 and M0 maps in the phantom for KWIC and radial GRAPPA reconstructions. Both methods yield results similar to those obtained using the gold-standard spin echo experiment. The results from radial GRAPPA are more homogeneous than those from the standard IR-TrueFISP with KWIC.

Conclusions: In this work we have demonstrated that the through-time radial GRAPPA reconstruction has significant potential to quantify the relaxation parameters of species with low T1 and T2 values, which can be difficult to quantify using the standard golden-angle radial IR-TrueFISP method with a KWIC filter. Further work must be performed in order to assess the feasibility of using this method for in vivo quantification of these parameters, which could be useful to determine changes between images acquired before and after the injection of a Gadolinium-based contrast agent, and particularly in pathological conditions such as tumors, where very short T1 and T2 values can be encountered.

Bottle	T1 [ms]			T2 [ms]			M0 [a.U.]		
	SE	rGRAPPA	KWIC	SE	rGRAPPA	KWIC	SE	rGRAPPA	KWIC
1	1177	1054	1071	890	867	790	2,52	1,97	1,87
2	752	760	779	649	677	674	2,18	1,78	1,67
3	569	570	579	482	486	526	1,8	1,61	1,49
4	474	452	450	378	379	425	1,78	1,52	1,38
5	352	359	382	317	419	310	1,84	1,34	1,25
6	51	58	55	34	48	10	1,84	1,05	2,37
7	65	73	52	43	15	68	1,85	2,52	1,42
8	81	88	75	54	18	33	1,86	2,84	2,03
9	115	111	108	85	47	78	1,94	2,37	2,13
10	226	200	205	167	161	170	2,21	2,39	2,29
11	311	294	297	268	275	277	1,74	1,44	1,32

Table 1: T1 and T2 parameters calculated using the Spin Echo method, radial GRAPPA, and the standard IR-TrueFISP with KWIC.

References: [1] Griswold et al, *ISMRM*, 2661 (2004) [2] Schmitt et al, *Magnetic Resonance in Medicine*,51:661—667 (2004) [3] Gulani et al, *Investigate Radiology*, 39:767—774 (2004) [4] Song, H.K. and Doughery, L., *Magnetic Resonance in Medicine*,44:825—832 (2000) [5] Seiberlich N, et al. Proc. 3rd Annual International Parallel Imaging Workshop, 2009 [6] Winkelmann et al, *IEEE transactions on Medical Imaging*, 26(1):68—76 (2007) [7] http://www.eecs.umich.edu/~fessler/code/