Accurate T2-Mapping with CPMG Prepared Turbo-Flash Sequence

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TARGET AUDIENCE: This work is relevant to an accurate and reliable T2-mapping technique.

PURPOSE: Over decades, T1- and T2 quantification have been widely used in clinical routine diagnosis, e.g. evaluation of musculoskeletal cartilage, cardiac function and so forth [1-2]. Diagnosis relies objectively on absolute T1, T2 quantization rather than subjectively on qualitative gray-scale contrast. In practice, non-ideal RF pulse profiles might not affect reading gray-scale images but will have large impact on quantified mapped values, like T2-mapping. In particular, for multiple contrast spin-echo readouts, non-ideal RF pulse profiles decrease the first echo signal, while the 2nd and even echo signals are usually hyper-intensive due to the superimposed stimulated echo effect. Following previous works and based on other relevant works[3,4], this study proposes a truly CPMG [5] prepared T2-mapping technique, which largely removes non-ideal RF profile related errors, resulting in improved accuracy and reliable T2-mapping.

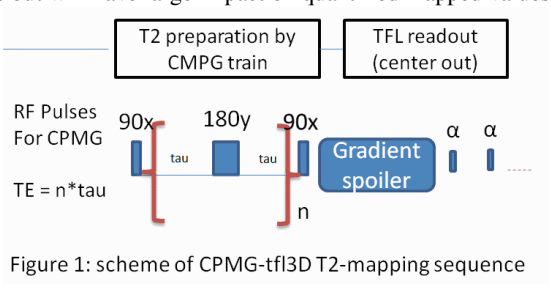

Figure 1: scheme of CPMG-tfl3D T2-mapping sequence

THEORY: Figure 1 illustrates the scheme of CPMG-tfl3D T2-mapping sequence. To avoid slice profile related errors, firstly the T2-preparation part is fixed for all echo signals. That means the signal path is the same for all T2W signals. Secondly, non-selective (block) RF pulses are used in T2-preparation, to minimize slice profile and stimulated echo effects. The acquisition is realized by using a 3D turbo-flash sequence with in-out partition phase encoding, the same scheme as used T1ρ techniques [6]. The number of 180 RF pulse in the T2-preparation part can be defined from 1 to N, making it possible to map subtle T2-compartment of tissues. Thus, slice profile will have an identical impact on all T2W signals, and stimulated echo related contamination is removed. Mapped T2 values then are more independent of protocol parameter changes, like RF pulse shape, duration and amplitude.

METHODS: Phantom studies were performed on several 3.0T MRI systems (Tim Trio, Verio and Skyra, Siemens Healthcare AG, Erlangen, Germany) with a 12- and 32-channel head coils, respectively. A multiple contrast phantom (calculated T2 ranges from 27 to 100 [ms]) was used. For calibration, single 2D spin-echo (SE) acquisitions were performed repeatedly with different TE times, ranging 12 to 84 [ms]. Conventional 2D multiple contrast spin-echo (se_mc) sequences were also used as references. Two types of slice-selective 180 RF pulses with lower and normal RF amplitudes, were employed in both single SE and se_mc acquisitions. In the condition of the same voxel size, CMPG-prepared tfl3D acquisitions were performed. To check T2-value changes due to temperature fluctuation in different environments, SE was used each time for the sake of calibration. Imaging time were 7 x 5:05. for SE, and 5:05 for se_mc acquisitions, and 5:30 for CPMG-tfl3D acquisition with factor of 2 parallel acquisitions. Linear fitting was used online for all acquisitions.

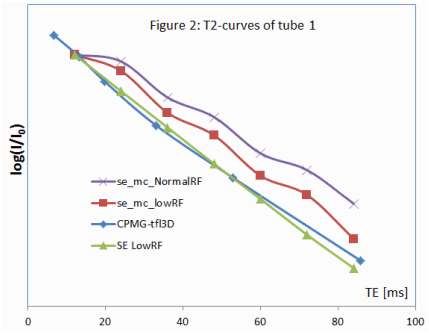

Table 1: Calibration, refererence and CPMG-tfl3D data from 3.0T MRI systems

	Multiple contrast phantom		Tube 1	Tube 2	Tube 3	Tube 4
	Calculated T1 [ms]		775	909	426	571
	Calculated T2 [ms]		27.0	28.0	39.0	100.0
1	Skyra (D13-SP2)	se_mc_3000_7x12_NormalRF	36.0	40.8	50.5	154.0
2		se_mc_3000_7x12_LowRF	29.5	34.8	42.5	127.0
3		SE_3000_7x12_NormalRF	23.5	26.6	34.3	92.7
4		SE_3000_7x12_LowRF	23.7	26.9	34.6	93.8
5	Tim Trio (B17)	SE_3000_7x12_NormalRF	22.2	25.3	32.9	87.1
6		CPMG_tfl3D, 7 echoes, TR=1000	22.7	25.7	34.6	88.8
7	Verio (B17)	SE_3000_7x12_NormalRF	22.8	26.3	33.2	91.0
8		CPMG-tfl3D, 7 echoes, TR=1000	24.6	25.8	35.9	89.6

RESULTS & DISCUSSION: Table 1 presents calibration (SE), reference (se_mc) and CPMG-tfl3D mapped T2-values, acquired on several 3.0T MRI systems. Using se-mc, the mapped T2-values change obviously with RF pulses of low and normal amplitude. This is because the signal paths are strongly dependent on RF pulse profiles in se_mc sequence. SE acquisition shows rather consistent results, nearly independent of RF pulse type. In fact, the impact of non-ideal RF profile on SE echo signals still exists, but it is identical to all echo signals. The mapped T2-values with se_mc are clearly offset from the SE calibration data with errors ≥ 25.1% (row 2 vs. row 4). It is noted that the calibration data with SE sequence are slightly different on different systems (Skyra vs. Tim Trio & Verio), mainly due to temperature differences. As shown in table 1, the measured T2-values with CPMG-tfl3D are very consistent with SE calibration data (error ≤ 7.8%, the worst case in row 7 vs. 8). Figure 2 gives a comparison of T2-curves of Tube 1.

CONCLUSION: This study demonstrates a feasible and simple method to improve the accuracy and reliability of T2-mapping. Using CPMG T2W preparation with all non-selective block RF pulses can greatly minimize non-ideal RF pulse profile introduced errors, yielding more accurate mapped T2-values. In addition, the 3D acquisition provides seamless volume coverage in comparison with conventional 2D acquisitions, which significantly improves clinical diagnosis, for instance high resolution isotropic cartilage T2-mapping. Further works will be focused on applying available fast imaging techniques on tfl3D acquisition part, to shorten imaging time. Secondly, protocols can be further optimized. With ideal exponential decay, the number of sampled T2W echo signals can be reduced as pointed in previous work [7], to further reduce total imaging time.

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