Simultaneous Quantification of Myocardial Deformation and T1-Relaxation

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Introduction: Myocardial scar detection plays an important role in the clinical diagnosis of various heart diseases. Quantitative T_1-maps acquired late after contrast agent injection can be used to identify regions with myocardial scar [1]. Additionally, quantification of cardiac deformation using CSPAMM [2] or N-SPAMM [3] tagging can give valuable insight into the resulting functional changes of the heart. A new method is introduced that allows obtaining T_1-maps of the myocardium as well as deformation parameters in a single scan. The approach exploits the inherent properties of the tagging preparation sequence which partly inverts / saturates the magnetization prior to the acquisition.

Methods: The signal intensity I_{Tk} for the k^{th} (k=1...n) heart-phase image of a CSPAMM or N-SPAMM acquisition can be described as [2]: $I_{Tk} \propto \exp(-t_k / T_1^*)\prod_{j=1}^{k-1}\cos(a_j)\sin(a_k)$; with t_k denoting the time after tagging preparation and $a_1...a_k$: variable flip angles. By using an optimized flip angle train, a constant tagging signal throughout the cardiac cycle can be obtained for one tissue type with known T_1 [2,4]. However, for tissues with a different T_1 value, a change in signal amplitude is still observed over the cardiac cycle (Fig.1).

After dividing I_{Tk} by $\prod_{j=1}^{k-1}\cos(a_j)\sin(a_k)$, the T_1*-value of any imaged tissue can be calculated using a two-parameter fit according to: $I=A\exp(-t_k/T_1^*)$. In order to use signal intensities from the same (moving) tissue points, HARP-tracking [5] needs to be applied prior to T_1*-calculation.

To obtain sufficient spatial resolution of the T_1-maps, a TFEPI-sequence as described in [6] was used and phase-cycling of the first tagging RF-pulse was incorporated to separate the harmonic peaks ('3-SPAMM', [3]). Furthermore, RF phase cycling was implemented in the acquisition to suppress coherent transversal signal across heart phases. Slice-following tagging images with a tag-line distance of 8mm were acquired in two navigator controlled breath-holds on a 1.5T Scanner (Philips Medical Systems, Best, NL): FOV:320x272mm^2, matrix:160x84 (recon. 320x320), EPI-factor:7, TFE-factor:2, flip angle train adjusted for T_1=870ms, flip angle for last heart phase:20°, cardiac phases:20, temporal resolution:30ms, total scan time:38s.

Experimental data were acquired in a phantom containing a range of Gd concentrations (Figure 1) and the obtained T_1*-values were compared with the results from an interleaved spin-echo and inversion recovery sequence as reference.

To test in-vivo feasibility a healthy volunteer was scanned and a T1-map as well as the circumferential shortening of a mid-wall contour was calculated from the same data set.

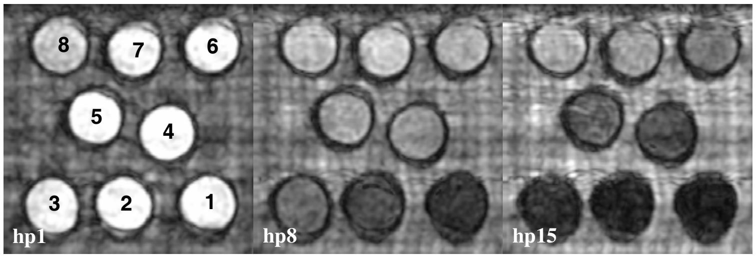

Figure 1: *3-SPAMM magnitude images for different heart phases acquired in a phantom with different Gd concentrations. The flip angle train was optimized for T_1=870ms.*

Phantom	T1* [ms]	
	Ref. Scan	Tagging
1	141	161
2	176	199
3	232	251
4	304	305
5	352	356
6	422	406
7	502	522
8	752	741

Table 1: *T_1*-values in the phantom using the reference (=Ref. Scan) and the tagging based approach.*

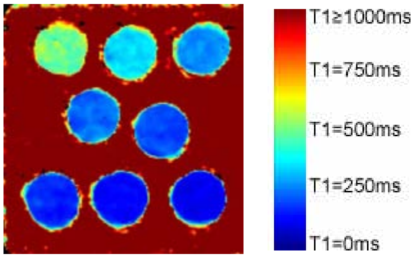

Figure 2: *T_1*-maps calculated from tagging data acquired in the phantom.*

Results: The obtained T_1*-map from the phantom experiment is shown in Figure 2. The measured T_1*-values corresponded well with the reference values (Table 1). For the in-vivo data circumferential shortening of the tracked mid-wall contour is plotted for six different sectors in Figure 3 and the T1*-map calculated from the same data set is shown in Figure 4.

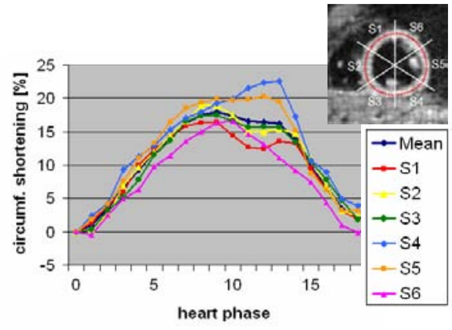

Figure 3: *Circumferential shortening of six sectors over the cardiac cycle.*

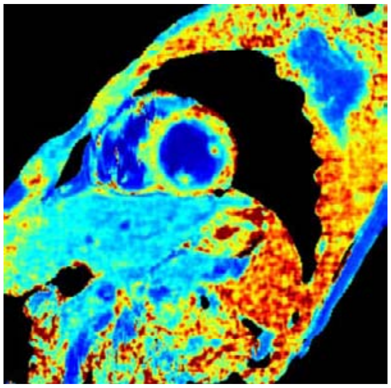

Figure 4: *In vivo T_1*-map (with the same color encoding as used in Figure 2) calculated from 3-SPAMM tagging data.*

Discussion: T_1*-values obtained from the phantom measurements showed good agreement with the reference values. Initial in-vivo results demonstrated the feasibility to quantify both cardiac deformation and T1-relaxation in a single scan. Deviations in T_1*-values along the circumference of the myocardial wall can partly be attributed to motion induced B_0 field variations. Further to this, work is required to evaluate the method in a larger cohort of subjects in particular under post-contrast conditions to correlate T_1*-values with functional manifestations.

References: [1] Messroghli DR, et al., 2004, MRM 52: 141-6. [2] Fischer SE, et al., 1993, MRM 30: 191-200. [3] Tsao J, et al., 2005, Proc. ISMRM: 273. [4] Stuber M, et al., 1999, MRM 9: 85-91. [5] Osman N, et al., 1999, MRM 42: 1048-60. [6] Ryf S, et al., 2005, JCMR 7:693-703.