EKG-Triggered, Navigator-Gated SSFP Saturation Recovery For Quantitative T1 Mapping With High Resolution During Free Breathing

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Introduction

Multipoint T1 mapping techniques, as described first by Look and Locker [1], sample the relaxation curve multiple times after an initial inversion pulse. However, these approaches require a sufficiently long relaxation delay before each inversion pulse. Saturation recovery sequences [2,3] may overcome this limitation. However, current approaches [3,4] do not cope with cardiac arrhythmia or respiratory motion. Thus, the acquisition is limited to the duration of a breath-hold, which limits spatial resolution and coverage. We propose an enhanced saturation recovery sequence with respiratory navigator gating and arrhythmia rejection, which allows acquiring T1 maps of the heart with high spatial resolution during free breathing. Patient comfort is improved substantially, and motion-induced artifacts are eliminated. First results are shown in phantoms and *in vivo*.

Methods

Experiments were performed on a 1.5T clinical MR scanner (Achieva, Philips Medical Systems) equipped with a cardiac coil array. Navigator gating and EKG-triggering with arrhythmia rejection was employed. Saturation prepulse and image acquisition were always performed in the same RR interval (cf. Fig. 1), and invalid data that were acquired during cardiac arrhythmia or respiratory motion were re-acquired in the next RR-interval. To sample the T1 relaxation curve, the offset T_S between presaturation (S) and image acquisition (AQ) was varied by shifting the saturation pulse towards the onset of the cardiac cycle [3], and 10 relaxation phases were measured. Since the preceding saturation pulse may spoil the respiratory navigator signal, a 2D-selective restore beam (N*, α = -90°) was performed prior to the 90° saturation pulse, where a minimal delay between the magnetic center of both pulses was retained to mitigate off-resonance effects. A 2D SSFP sequence (α = 60°, TR/TE=4.2/2.1 ms, 32 readouts per cardiac cycle, resolution measured/reconstructed 0.89×1.25×8mm/ 0.59×0.59×8mm) with a centric phase encoding order was employed [5]. T1* was obtained using a two-parameter fit to the measured data (y) according to $y = A \cdot (1 - \exp(-T_s/T1^*))$. Phantom experiments were performed and compared with the results obtained with a conventional sequence [1] as a reference. Furthermore, T1 maps were acquired *in vivo* in 7 healthy volunteers in short axis orientation. The scan time was approximately 2 minutes during free breathing.

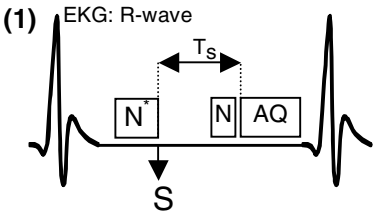
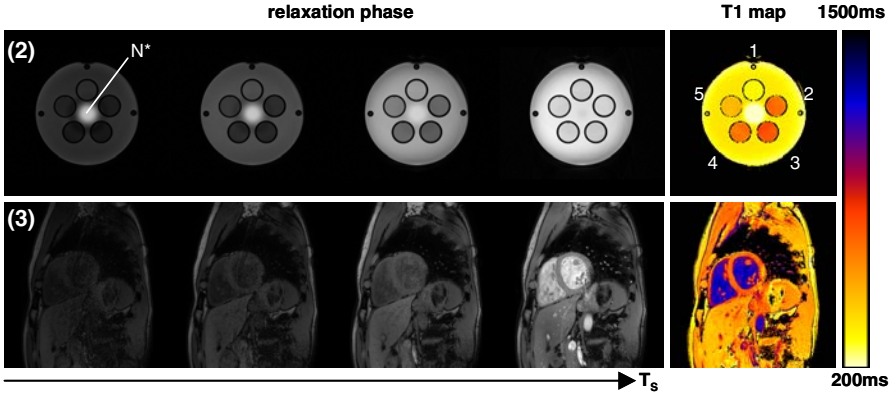


Fig. 1 EKG-triggered, navigator gated saturation recovery sequence

Results

All *in vivo* experiments were completed successfully, and results of the phantom and volunteer study are shown in Figs. 2 and 3, respectively. The measured T1 values (mean ± standard deviation) are summarized in Tables 1 and 2.



Figs. 2 and 3 Left: Phantom- and in vivo images acquired at different T_S. Right: T1 maps generated using a two parameter fit to the measured data

Table 1 Measured T1 values (phantom)

phantom section	T1 (Ref.) [ms]	T1* [ms]	deviation (mean)
1	314 ± 6	300 ± 3	-4%
2	713 ± 11	635 ± 9	-11%
3	824 ± 12	749 ± 10	-9%
4	713 ± 12	663 ± 8	-7%
5	508 ± 11	477 ± 4	-6%

Table 2 Measured T1 values (in vivo)

tissue	T1 [ms] (Literature)	T1* [ms]	deviation (mean)
myocard	870	550 ± 38	-37%
liver	500	401 ± 53	-20%
fat	250	241 ± 9	-4%
blood	1200	1227 ± 45	2%
muscle	870	537 ± 21	-38%

Discussion and conclusion

Using the EKG-triggered, navigator-gated saturation recovery sequence, quantitative T1 maps of the myocardium could be acquired with high spatial resolution during free breathing. A clear depiction was achieved, and no motion artifacts were observed. However, a systematic underestimation of the absolute T1 value was observed predominantly for species with long T1, which requires further investigation and appropriate correction algorithms. The performance of this sequence in contrast-enhanced imaging of myocardial infarction, myocarditis or plaque, e.g. in late enhancement, should be addressed by further studies.

References
[1] Look DC et al, Rev Sci Instr 1970; 41: 250-251
[2] Fischer SE et al, Der Radiologe 1997; 37:366-371
[3] Higgins DM et al, Med Phys 2005; 32: 1738-45
[4] Messroghli DR et al, MRM 2004; 52:141-46
[5] Scheffler K et al, MRM 2001; 45:720-23