Fast Cardiac T1 Quantification with an ECG-Triggered Radial Single-Shot Inversion Recovery Sequence (TRASSI)

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Introduction: Several recent studies have shown that cardiac T_1 measurements can be used to acquire diverse morphological and functional information. Potential capabilities include distinguishing between healthy and diseased cardiac tissue, quantification of regional fluids and/or blood volume, and perfusion measurements. Hence, cardiac T_1 mapping is becoming an increasingly important imaging technique, which establishes new non-invasive diagnostic possibilities. A common method for myocardial T_1 mapping is an inversion recovery (IR) Look-Locker cine technique [1]. Here, multiple heart phases are acquired after an inversion pulse using a continuous acquisition of data. Another established approach for cardiac T_1 mapping is the modified Look-Locker IR (MOLLI) pulse sequence [2]. However, these currently available techniques for acquisition of T_1 maps are accompanied by several drawbacks. The major limitations are that they are highly heart rate dependent [1,2] and the T_1 values are underestimated [1,2]. In addition, these methods are quite slow, requiring breath holds up to 18s and more [1,2]. Therefore, this work aims at developing a fast cardiac T_1 quantification technique that can generate very accurate T_1 maps in very short time. This was realized by using an electrocardiogram (ECG) triggered radial single-shot IR sequence (TRASSI) with a special fitting algorithm [3], which simulates the pulse sequence with the known timings. Accurate, high-resolution T_1 maps without motion artifacts and without any heart rate dependency can hereby be acquired.

Methods: All measurements were performed on a 1.5 T whole-body imaging system. The pulse sequence scheme is illustrated in Figure 1a. The TRASSI sequence consists of multiple radial imaging blocks, starting with a certain trigger delay after the corresponding R-waves. Before the first imaging block, a non-selective adiabatic 180° inversion pulse is given. Due to the alternation of pulse blocks and interruptions during the heart contractions, the signal evolution exhibits a saw-tooth-like course of magnetization (black lines). The grey curve shows the normal Look-Locker exponential decay which would be reached over time with continuous pulsing, and the dashed lines indicate free exponential decays during the pulse interruptions. The radial imaging blocks are acquired with a golden-ratio-based [4] trajectory profile. Images were reconstructed using a modified KWIC-filter [5] to generate 42 images with different inversion times (TIs). For data analysis a special fitting algorithm was implemented that simulates the pulse sequence with the known timings and thus allows the calculation of the correct T_1 relaxation times [3].
Seven volunteers (6 men, 28 - 41 years, 52 - 103 kg, heart rate 50 - 88 bpm) with no history of cardiac disease were investigated with the implemented TRASSI pulse sequence. The data acquisition was performed in end-expiration breath holds each acquisition with duration of less than 6s. The duration of the radial imaging blocks was chosen dependent on the heart rate of the subject under investigation, ranging from 238 to 493 ms. Sequence parameters were: FOV = 300 x 300 mm², TR = 4.23 ms, TE = 1.99 ms, FA = 7°, slice thickness = 8 mm. The images were reconstructed and zero-filled from 128 readout points to 256 x 256 matrix size, which resulted in an in-plane imaging resolution of 1.17 mm.

Results: In all seven volunteers T_1 mapping was successfully realized using the TRASSI sequence. Cardiac morphology was clearly depicted in the resultant maps with sharp edges and no motion artifacts (Figure 1b). Short-axis and 4-chamber views equally show very good image quality. Mean left ventricle T_1 was determined to be 1013 ± 20 ms over all volunteers, which is in the range of the expected values from former publications [6]. The value is approximately 5 - 10 % above the value obtained with MOLLI sequences as expected, since MOLLI is known to underestimate T_1 [2].

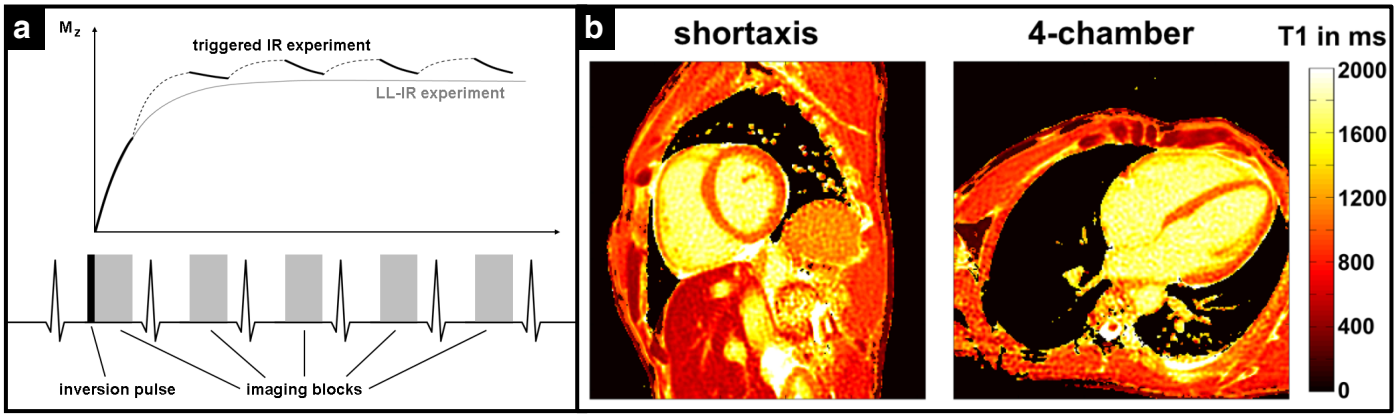

Fig. 1a) *Pulse sequence scheme. A non-selective adiabatic inversion pulse is applied after the first R-wave followed by multiple radial imaging blocks starting after a certain trigger delay. Because of the alternation of pulse blocks and interruptions during the heart contractions, the signal evolution exhibits a saw-tooth-like course of magnetization (black lines).* ***b)*** *Short-axis and 4-chamber views of a healthy volunteer. The cardiac structures can be identified with sharp edges without motion artifacts.*

Discussion and Conclusion: The current study introduces a fast and accurate cardiac T_1 mapping technique which makes myocardial T_1 mapping within a single-shot IR experiment possible. This allows rapid measurement of the myocardial T_1 with high spatial resolution. The presented method enables the generation of very accurate T_1 maps with an acquisition time of less than 6s, requiring breath holds shorter than 7s. In comparison to commonly used MOLLI sequences, the T_1 values proved to be more exact and were acquired in up to 70% less time (depending on the heart rate). With TRASSI, cardiac structures could be identified with sharp edges in all examinations without any motion artifacts. This good image quality could be achieved independent of the heart rate, imaging plane, and volunteer size. Hence, TRASSI has the potential to replace the currently used techniques as the new gold standard in clinical routine, because it allows for very fast and at the same time very robust cardiac T_1 mapping.

References:

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