HEART-RATE INDEPENDENT NON-CONTRAST MYOCARDIAL T1 MAPPING

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INTRODUCTION: Recent studies indicate that myocardial T_1 mapping may potentially identify scar/fibrosis without the use of a contrast-agent (1). A Modified Look-Locker Inversion Recovery (MOLLI) sequence (2) is widely used for 2D cardiac T_1-mapping. In MOLLI, multiple (3 or 5) inversion recovery images are acquired after a single magnetization preparation. The imaging pulses induce a disturbance of the magnetization relaxation curve. Since the sequence is ECG-triggered, this disturbance of the relaxation curve is heart-rate dependent, which causes strong a correlation between T_1 times determined using MOLLI and the heart rate. In this study, we sought to develop a novel heart-rate independent T_1 mapping sequence.

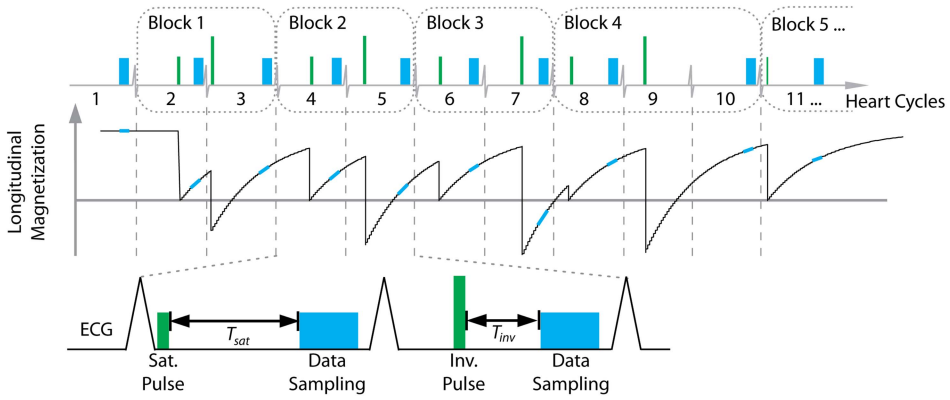

Fig. 1: *Sequence diagram depicting the proposed acquisition of multiple blocks with interleaved saturation and inversion recovery preparation pulses. The middle part shows a characteristic longitudinal magnetization recovery curve and the sampling points on this curve throughout the sequence. The lower part shows the pulses and timings within one block.*

METHODS: ***Sequence:*** Figure 1 shows the schematic of the proposed sequence, where multiple single-shot images with different T1-weighted contrasts are acquired within seven sequence blocks. Each sequence block contains a saturation pulse and the acquisition of two single-shot images. An additional inversion pulse is applied in selected blocks to enhance the T_1-weighted contrast. The blocks have a duration of two or three heart-cycles depending on which part of the longitudinal relaxation curve is being sampled.

The heart-rate invariance is due to two properties of the sequence blocks: 1) The saturation pulse in the first heart-cycle of the block nullifies the magnetization history, ensuring that the sampling of the T_1 relaxation curve in each block starts from the same point; 2) T_{sat}, the time between the saturation pulse and the first acquisition window, is pre-specified by the operator, and is not dependent on the subject's heart rate. Thus, the imaging pulses in the first acquisition window will cause the same disturbance to the relaxation curve, independent of the heart rate of the subject. In other words, the second acquisition window will see the same disturbance of the relaxation curve due to the imaging pulses, irrespective of the heart-rate of the subject. We hypothesize these two properties enable heart-rate independent T_1 measurements.

In addition to the sequence blocks, an image without magnetization preparation is acquired before the first block to capture the fully-recovered portion of the T_1 relaxation curve. A model for the longitudinal magnetization recovery for the combination of the saturation and the inversion pulses was derived from the Bloch-equations. A voxel-wise fit of the image intensities to this signal model yielded the T_1 maps.

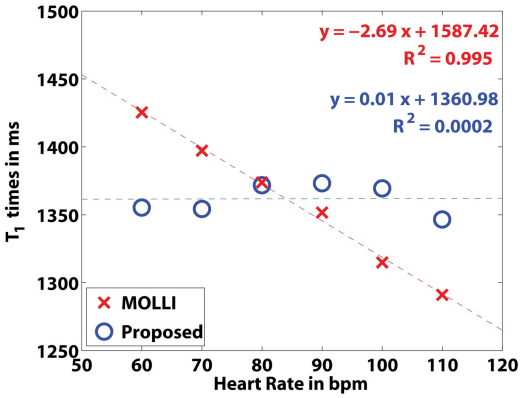

Fig. 2: *T_1 measurements in a phantom using the proposed technique and MOLLI. MOLLI measurements show strong correlation with heart rate. No significant correlation with the heart-rate was observed using the proposed technique.*

Imaging: Phantom measurements were performed to test whether the T_1 values determined using the proposed sequence were heart-rate dependent, and to compare T_1 values to the T_1 estimation using MOLLI. A bottle phantom was scanned with various simulated ECGs of heart-rates between 60 and 110 bpm. Non-contrast T_1 maps of five healthy volunteers and one patient (30 ± 14 years) were acquired with the proposed technique and MOLLI. The T_1 times in the myocardium, the left and right ventricles (RV) were quantitatively analyzed.

RESULTS: Figure 2 shows the T_1 times determined in the phantom measurements. The proposed method and MOLLI are in good agreement for a heart-rate of 80 bpm (Relative difference: <1%). No significant correlation with the heart rate was found for the proposed method ($R^2 < 0.0003$), while MOLLI is highly correlated ($R^2 > 0.995$).

Figure 3 shows representative T_1-maps of two subjects. For the in-vivo data the proposed method showed reduced correlation to the heart-rate compared to MOLLI (R^2 = 0.06 proposed, R^2 = 0.21 MOLLI). No significant difference was observed in the T_1 values determined using the two methods ($P > 0.15$), since the heart-rate dependence in MOLLI caused both, overestimation and underestimation, with respect to the proposed method. Also no significant difference was found in the homogeneity of the myocardium or the right ventricle ($P > 0.4$), indicating comparable quality between the two sequences. The breath-hold duration was the same for both sequences (10-18 s).

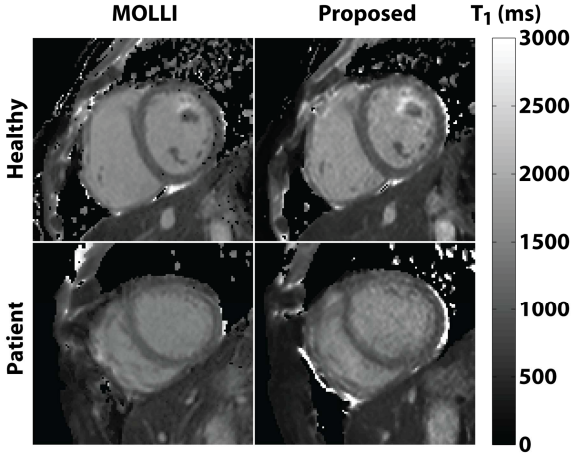

Fig. 3: *Non contrast T_1 maps acquired in two subjects using the proposed sequence and MOLLI.*

CONCLUSIONS: The proposed T_1-mapping method enables heart-rate independent pre-contrast myocardial T_1-mapping for evaluation of diffused fibrosis.

REFERENCES: 1. Bull, S. JCMR, 2012; 2. Messrohgli, D.R. MRM, 2004;