JOINT MYOCARDIAL T1 AND T2 MAPPING USING A SATURATION-RECOVERY SEQUENCE

Mehmet Akçakaya[1], Sebastian Weingärtner[1,2], Tamer A. Basha[1], Sebastien Roujol[1], and Reza Nezafat[1]
[1]Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, United States, [2]Heidelberg University, Mannheim, Germany

TARGET AUDIENCE: Scientists and clinicians interested in myocardial tissue characterization.

INTRODUCTION: Quantitative myocardial T_1 mapping allows assessment of interstitial diffuse fibrosis in the myocardium [1], while quantitative T_2 mapping has been proposed to overcome challenges associated with T_2 weighted imaging [2]. These maps are traditionally acquired with different sequences, necessitating image registration to evaluate them jointly. A sequence that can jointly estimate T_1 and T_2 maps has been proposed [3], but it requires multiple relaxation cycles, which requires a lengthy free-breathing acquisition. In [4], an alternative joint estimation sequence was proposed based on the IR-bSSFP method. In this study, we sought to develop a saturation-recovery based sequence that exhibits no heart-rate dependence, that can be acquired in a single breath-hold and that allows for accurate simultaneous estimation of myocardial T_1 and T_2.

METHODS: SEQUENCE: The sequence diagram is depicted in **Figure 1**. At every heartbeat, a saturation pulse is applied to eliminate the magnetization history. The longitudinal magnetization then recovers for T_{sat} based on the T_1 value. Subsequently a T_2-prep pulse [5] with echo length TE_{prep} is applied to generate the additional T_2 weighting, after which a single shot bSSFP image is acquired. The mapping sequence acquires the first image with no preparation, followed by 12 heartbeats with various (T_{sat}^k, TE_{prep}^k) corresponding to heartbeat k, to sample different T_1-T_2 weighted images. The T_1 and T_2 maps are estimated jointly by voxel-wise least squares fitting to a 4-parameter signal model, $A\,(1- \exp(-T_{sat}^k/T_1))\,\exp(-TE_{prep}^k/T_2) + B$.

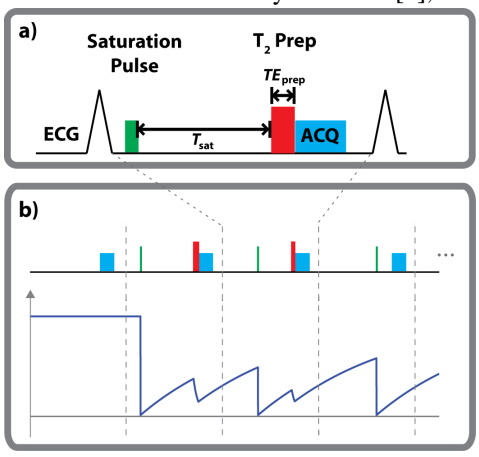

Figure 1: *a) The sequence diagram. A saturation pulse is applied in every R-R interval to eliminate the magnetization history. Following T_1-based recovery for a duration of T_{sat}, a T_2-prep with echo length TE_{prep} is applied to generate the additional T_2 weighting, after which a single shot bSSFP image is acquired. b) The mapping sequence acquires the first image with no magnetization preparation (corresponding to $T_{sat} = \infty$ and $TE_{prep} = 0$), followed by 12 images (3 are shown) acquired with different T_{sat} and TE_{prep} values. The major characteristics of the longitudinal magnetization signal curve are depicted under the pulse sequence diagram.*

IMAGING: Phantom Imaging: 14 vials with different T_1/T_2 values were imaged using the proposed sequence, and compared to inversion-recovery and CPMG spin-echo references, respectively. Imaging parameters for the proposed sequence were: FOV=280×280 mm^2, resolution=2×2 mm^2, slice thickness=8 mm, TR/TE/α= 2.8ms/1.4ms/70º, SENSE=2.5, partial Fourier=0.75, acquisition window=121 ms.

In-vivo Imaging: Imaging was performed on 6 healthy adult subjects (2 men, 28±12 years). A mid-ventricular short-axis slice was acquired using the proposed sequence. Comparison maps were acquired with SASHA T_1 mapping [6], and a breath-held T_2 mapping sequence with 4 T_2prep echo times [7], with the same acquisition duration. The same imaging parameters were used as in phantom imaging for all sequences. T_1 and T_2 measurements were performed with a region-of-interest in the septum, and were compared among the different sequences.

RESULTS: Phantom imaging resulted in T_1 and T_2 values not significantly different than the references (P = 0.481 and 0.479 respectively). Example in-vivo T_1 and T_2 maps are depicted in **Figure 2**, comparing the different techniques. For this subject, the T_1 and T_2 values were: 1217 ± 90 ms vs. 1210 ± 96 ms for SASHA and proposed T_1 respectively; 47.8 ± 7.0 ms and 45.6 ± 7.3 ms for conventional and breath-held T_2 respectively, showing good agreement. Across the 6 subjects, the estimated T_1 values were: 1196 ± 33.4 ms and 1181 ± 26.5 ms (P = 0.39) for SASHA and proposed T_1 mapping respectively. The estimated T_2 values were: 48.0 ± 2.9 ms and 46.7 ± 2.8 ms (P = 0.10) for breath-held and proposed T_2 mapping respectively. The precision, measured as the signal homogeneity in the septum, was: 120 ± 31.0 ms and 117 ± 26.2 ms (P = 0.60) for SASHA and proposed T_1 mapping respectively; and 7.1 ± 0.7 ms and 7.9 ± 1.6 ms (P = 0.19) for conventional and proposed breath-held T_2 mapping respectively.

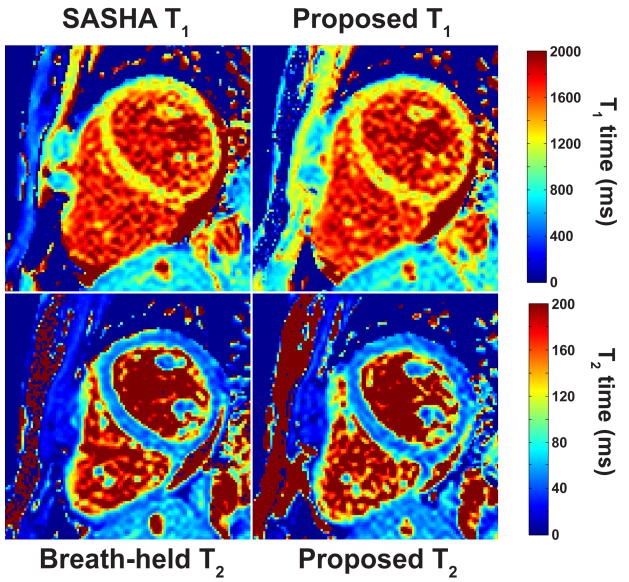

Figure 2: *T_1 (top row) and T_2 (bottom row) maps from a healthy subject, acquired using the proposed technique, as well as SASHA T_1 mapping, and conventional T_2 mapping using 4 T_2prep echo times. Both the T_1 and T_2 maps generated jointly with the proposed method are similar to the individual maps with similar magnetization preparations. The maps generated with the proposed method were acquired in the same time as each individual map, and are jointly registered by design.*

CONCLUSIONS: The proposed sequence allows for the simultaneous estimation of accurate and jointly registered quantitative T_1 and T_2 maps with similar accuracy and precision to saturation-based T_1 mapping and to T_2 mapping of same duration.

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