Effect of the Number of Echoes and Reconstruction model on the Precision and Reproducibility of T_2 Measurments in Myocardial T_2 Mapping

Tamer Basha[1], Mehmet Akçakaya[1], Sébastien Roujol[1], and Reza Nezafat[1]

[1] *Department of Medicine, Beth Israel Deaconess Medical Center & Harvard Medical School, Boston, Massachusetts, United States*

Target Audience Scientists and clinicians who are interested in myocardial T_2 mapping.

Introduction Quantitative myocardial T_2 mapping allows non-invasive assessment of myocardial inflammation/edema (1). Recent implementations use T_2-prepared (T_2prep) SSFP sequences to acquire multiple T_2 weighted images at different echo times, then generate the T_2 maps based on a 2-parameter fitting (2P-fit) model of T_2 decay (2,3). Recently, a 3-parameter fitting (3P-fit) model was found superior to the conventional 2P-fit model, as it compensates for T_1 relaxation effect, and results in more accurate T_2 measurements (4). In this work, we sought to characterize the 3P-fit approach in terms of precision and reproducibility and to evaluate the influence of the number of employed T_2prep echo times on these two metrics.

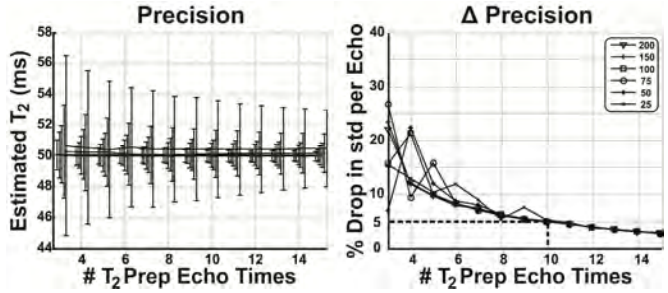

Figure 1. Numerical simulation results for the effect of number of echo images on the precision of the quantifications for different signal-to-noise ratios. As the number of echoes increases, the precision gets better till it nearly saturates for number of echoes ≥ 10.

Methods Numerical Simulations: Monte-Carlo simulations (N=1000) were performed to study the effect of increasing the number of T_2prep images. Block equation was used to simulate the signal intensities of a presumed tissue of T_2 = 50ms at different T_2prep echo times and different SNR levels. T_2 was then estimated using both 2P-fit and 3P-fit models, and the precision was quantified for each model.

In-vivo Pilot Study: Ten healthy subjects (27±10 y/o, 5m) were imaged using a 1.5 T Phillips scanner with a free-breathing ECG-triggered single shot T_2prep bSSFP sequence (FOV = 320×320 mm^2, in-plane resolution = 2.5×2.5 mm^2, slice thickness = 8mm, TR/TE = 2.2/1.1ms, FA = 40°, SENSE rate = 2, acquisition window = 140 ms, 14 T_2prep echo times = 0,25,35,…135,145 ms). To compensate for through-plane motion that might occur due to breathing, a prospective slice tracking was performed using a pencil-beam respiratory navigator positioned on the right-hemi-diaphragm and acquired immediately before each T2prep pulse. A 4s rest period after each image to allow for full spin relaxation. Data were reconstructed using the 3P-fit model. For comparison, a conventional T_2 mapping sequence was acquired (breath hold, 3 T_2prep = 20,50,75ms, and 2P-fit model). For each subject, both sequences were repeated 5 times. Precision and reproducibility were compared using different subset of T_2prep echo times.

In-vivo Experiments: Based on the pilot study results, an optimized T_2 mapping sequence using 10 T_2prep echoes and a 3P-fit model is proposed and evaluated in-vivo in 10 healthy subjects (29±17 y/o, 4m). This sequence is compared to the conventional T_2 mapping sequence (i.e. 3 T_2prep echoes and a 2P-fit model) in term of precision and reproducibility.

Data Analysis: All images were transferred to a separate workstation for analysis. Images were registered using non-rigid registration to compensate for residual in-plane motion, and T_2 values were calculated. Then, a myocardial segment based analysis was performed following the AHA segment model.

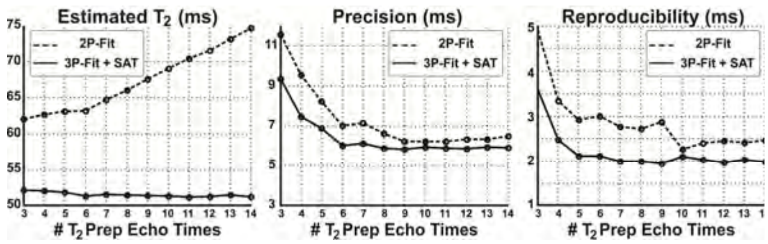

Figure 2. Accuracy, precision and reproducibility of T_2 mapping when using different number of echo images. With increasing the number of echoes, estimated T_2 values changes significantly when using 2P-fit, while it shows consistency when using the 3P-fit regardless of the number of echoes used for the estimation. Both precision and reproducibility increases when using more echo images for the T_2 estimation. However, and similar to what numerical simulations predicts, the effect nearly saturates for number of echoes ≥ 10.

Results Numerical Simulations: Fig. 1 shows the numerical simulations results. Increasing the number of T_2prep echoes improves the precision of the T_2 measurements. This effect decreases with increasing the number of T_2prep echo times till it nearly saturates for number of echoes ≥ 10.

In-vivo Experiments: Figure 2 shows the T_2 measurements in one example subject from the pilot study. T_2 measurements using a 2P-fit model are dependent on the number of T_2prep echo times while the 3P-fit model provides consistent T_2 measurements independent of the number T_2prep echo times. Increasing the number of T_2prep echoes leads to better precision and reproducibility of the measurements. However, and as numerical simulations predicts, this effect becomes minimal for large number of T_2prep echo times (≥ 10).

Figure 3 shows Improved in-vivo precision and reproducibility was achieved using the proposed sequence when compared to the conventional sequence (7ms vs. 11ms $p<0.05$ and 1.2ms vs. 2.4ms $p<0.05$, respectively).

Conclusion The proposed sequence using 10 T_2prep echoes times and a 3P-fit model provides T_2 measurements that are independent from the number of T_2prep echo times, and results in better in-vivo precision and reproducibility compared with the conventional T_2 mapping sequence.

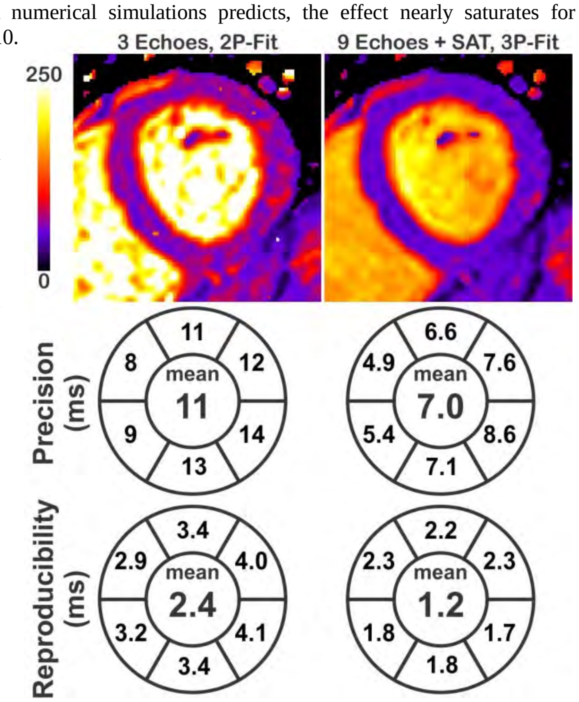

Figure 3. An example for the T_2 maps of one healthy subject. The bullseyes shows the overall segment-based precision and reproducibility over all 10 subjects, when using the 3 echoes with 2P-fit, and 10 echoes with 3P-fit. The values in each bullseye center represent the measurement value over the whole myocardium not the average of the segments values.

References

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