Motion Correction of Free Breathing Quantitative Myocardial T2 Mapping: Impact on Reproducibility and Spatial Variability

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Target Audience

Scientists and clinicians who are interested in myocardial tissue characterization.

Purpose/Introduction

Quantitative myocardial T_2 mapping is a promising technique for the detection of inflammation and edema[1]. Conventional sequences generally use a breath-hold electrocardiogram (ECG)-triggered T_2-prepared (T_2prep) steady-state free precession (SSFP) acquisition[1]. Due to limitations of breath-hold duration, these sequences are typically restricted to the acquisition of four T_2-weighted images. Free breathing myocardial T_2 mapping sequences remove this time constraint and enable the acquisition of more samples along the T_2 decay curve, which may result in improved precision and reproducibility of T_2 estimates. However, this approach requires more advanced respiratory motion correction techniques[2]. We recently developed a technique for Adaptive Registration of varying Contrast-weighted images for improved TIssue Characterization (ARCTIC) which we have evaluated for myocardial T_1 mapping[3]. In the current study, we sought to investigate the performance of ARCTIC for free breathing T_2 mapping and its impact on in-vivo reproducibility and spatial variability of myocardial T_2 estimates.

Materials and Methods

T_2 mapping sequence: A free breathing respiratory gated ECG-triggered T_2prep SSFP acquisition was used with different T_2prep echo times (TE_{T2P})[4]. A 6 second rest cycle was inserted between the acquisitions of two successive T_2-weighted images to ensure full re-growth of longitudinal magnetization. Image acquisition immediately after a saturation pulse was used to simulate an infinitely long T_2prep echo time ($TE_{T2P} = \infty$). No T_2prep or imaging pulses were applied if the navigator signal was outside the gating window.

In-plane motion correction: The ARCTIC approach was used to compensate for in-plane motion between T_2-weighted images. In this approach, all images are registered individually to a common reference image, chosen as the first image of the series ($TE_{T2P} = 0$). Affine motion descriptors are first estimated over a region of interest surrounding the heart. This global transformation is then used as initialization of a local non-rigid motion estimation step which simultaneous estimates motion field and intensity variations on a per-pixel basis with an additional regularization term based on automatic feature tracking. A GPU implementation of ARCTIC was used to accelerate the process.

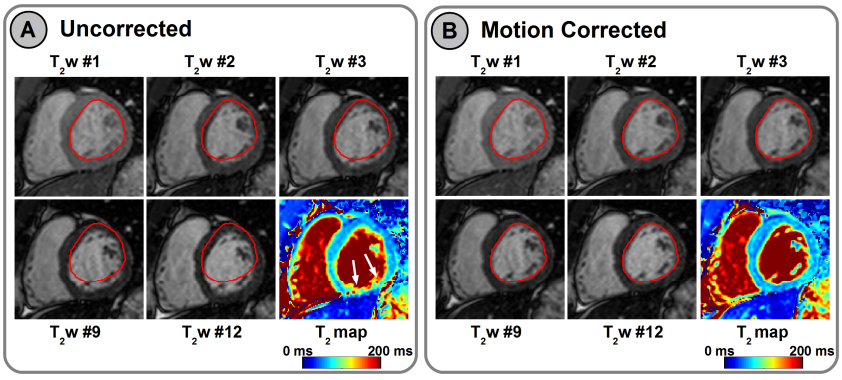

Figure 1. *Uncorrected (a) and ARCTIC motion corrected (b) T_2-weighted images and T_2 maps. The ARCTIC technique improves the alignment of T_2-weighted images and the T_2 map quality.*

Experimental evaluation: All data were acquired on a 1.5 T Phillips scanner. Seven healthy adult subjects (30±17 years, 3 male) were imaged 5 times using the described T_2 mapping sequence (1 slice, field of view = 240×240 mm^2, in-plane resolution = 2.5×2.5 mm^2, slice thickness = 8 mm, TR/TE = 2.7 ms/1.35 ms, flip angle = 85°, 10 linear ramp-up pulses, SENSE rate = 2, acquisition window = 138 ms, phase encoding lines = 51, linear k-space ordering, 20 T_2prep echo times (0, 25, 30, 35, …, 95, 100, ∞, ∞, ∞). T_2 maps were reconstructed using a 3-point fit model[4].

Data Analysis: In-vivo spatial variability and reproducibility of T_2 mapping were measured in uncorrected and motion corrected T_2 maps using a 6 myocardial-segment based analysis. Spatial variability was defined as the average (over the 5 scans) of the standard deviation of T_2 estimates over a given segment. Reproducibility was defined as the standard deviation (over the 5 scans) of the spatial average T_2 values in one given segment. To investigate the motion influence in T_2 mapping sequences using a conventional number of T_2prep echo times, this analysis was performed using all 20 T_2prep echo times (20TEs) and using only a subset of the T_2-weighted images (4 T_2prep echo times (4TEs) of 0, 25, 50, ∞). Statistical significant differences between continuous variables were assessed by means of Student's t-Tests.

Results

Figure 1 shows an example of uncorrected and motion corrected data where The use of ARCTIC substantially improved the alignment of all images and resulted in improved T_2 map quality. Reduced spatial variability was observed over all subjects and myocardial segments in T_2 maps reconstructed from 4 T_2prep echo times (13.7±4.3 vs. 11.1±3.6 ms, p<0.001) and 20 T_2prep echo times (10.6±5.3 vs. 7.9±1.8 ms, p=0.001) (Figure 2a). Improved reproducibility was observed over all subjects and myocardial segments in T_2 maps reconstructed from 4 T_2prep echo times (5.9±3.1 vs. 5.0±2.3 ms, p=0.011) and 20 T_2prep echo times (4.3±3.9 vs. 2.4±1.0 ms, p=0.002) (Figure 2b). T_2 maps reconstructed with 20 T_2prep echo times had higher reproducibility and lower spatial variability than motion corrected T_2 maps with 4 T_2prep echo times (p<0.001).

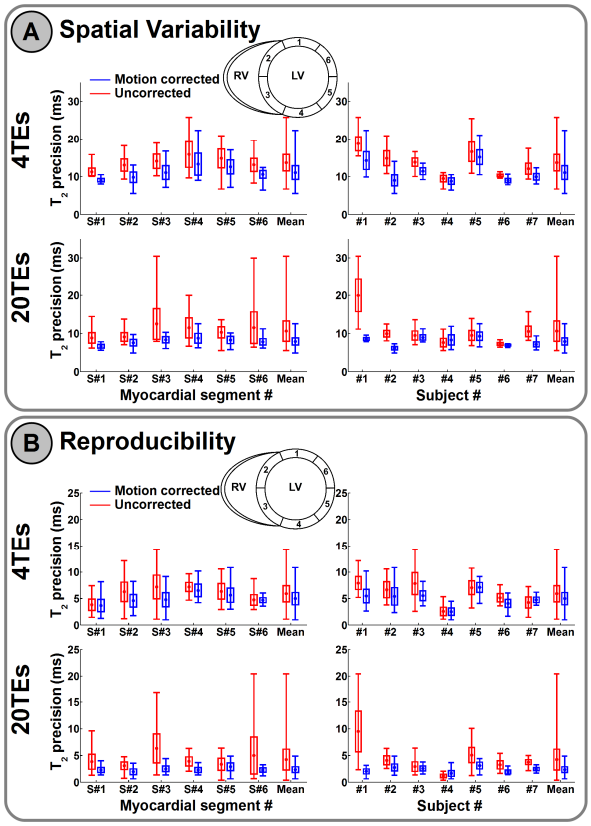

Figure 2. *In-vivo spatial variability (a) and reproducibility (b) of T_2 mapping. ARCTIC motion correction improved both spatial variability and reproducibility of T_2 estimates.*

Conclusions

The ARCTIC technique improves the reproducibility and spatial variability of in-vivo free breathing myocardial T_2 mapping.

Acknowledgements

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References

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