Motion Correction for Free-Breathing Whole Heart T1 Mapping at 3 Tesla

Qian Tao[1], Pieternel van der Tol[1], Hildo J. Lamb[1], and Rob J. van der Geest[1]
[1]*Department of Radiology, Leiden University Medical Center, Leiden, Zuid Holland, Netherlands*

Purpose: Myocardial tissue characterization by MR T1 mapping has potentially important applications in diagnosis and treatment of a wide spectrum of cardiovascular disease. The modified Look-Locker inversion recovery (MOLLI) sequence[1] is an established technique for myocardial T1 mapping. However, MOLLI is typically acquired in a few slices, each requiring a breath hold of 17 heart beats. This results in limited heart coverage and contraindicates patients who cannot hold their breath. Free-breathing whole heart T1 mapping is desirable, but the quality of T1 mapping can be deteriorated by respiratory motion both within and through the image plane. The purpose of this work is to develop a dedicated motion correction workflow for non-navigated free-breathing whole heart T1 mapping sequences.

Methods: A free-breathing MOLLI (fbMOLLI) sequence[2] was implemented on a 3.0 Tesla Ingenia (Philips, Best, The Netherlands), covering the whole heart. The respiratory signal was recorded during the fbMOLLI scan by a respiratory belt, as shown in Figure 1 A. In 9 patients (5 male, age 47±21 years, normal N=2, infarct N =2, dilated cardiomyopathy N =5), single-slice breath-hold MOLLI and whole heart fbMOLLI were acquired, both prior to and after Gadolinium (DOTAREM, Guerbet) bolus injection.[3]

Motion correction for fbMOLLI included two parts: (1) Correction for through-plane motion by retrospective respiratory gating: Histogram analysis of the respiratory signal showed that during free-breathing, most slices were acquired at the end-expiration phase. For retrospective gating, the end-inspiration slices, identified as those with respiratory signal > 2000 (empirical threshold from histogram analysis), were excluded for T1 mapping. (2) Correction for in-plane motion by mutual information registration: Mutual information based registration is suitable for aligning MOLLI frames with varying signal intensity and contrast, but mis-registration frequently occurred due to the reduced contrast between blood and myocardium at certain inversion times and continuous drifting of heart position during free breathing. Robust registration requires enhancement of the blood-myocardium contrast and regulations of the registration scheme. The proposed algorithm was as follows: firstly, we enhanced the blood-myocardium contrast by histogram equalization; secondly, we incorporated the specific 5-5-5-5 order of the fbMOLLI into the registration scheme. Each group of 5 free-breathing slices, which were acquired during one experiment of T1 relaxation, was rigidly registered; then an average image was computed from each registered group to rigidly register the 4 groups together. The final registration matrix was applied to the original non-enhanced slices. The pixel-wise T1 map was computed from the motion-corrected fbMOLLI sequences.

Results: For 9 subjects, pre-contrast (native) and post-contrast whole heart T1 mapping were computed. The actual number of slices used for fitting after retrospective gating was 15±2. The T1 values estimated from fbMOLLI were compared to those from the breath-hold MOLLI. For native T1, the fbMOLLI resulted in higher T1 values than the breath-hold MOLLI (1243±23 vs. 1195±31 ms, P=0.003), for post-contrast T1, the values were not significantly different (611±50 vs. 608±29 ms, P=0.81). The T1 fitting error significantly decreased after applying the in-plane and through motion correction (Figure 1 B), with the root mean square (RMS) error reduced from 0.25±0.14 to 0.16±0.07 after in-plane correction (P=0.01), and 0.13±0.08 after both in and through-plane correction (P=0.008).

Conclusion: By parallel development of fbMOLLI and motion correction techniques, free-breathing whole heart T1 myocardial mapping is feasible both prior to and after contrast injection. Motion correction leads to significantly reduced T1 fitting errors, indicating higher precision[4] in T1 mapping. A trend of higher T1 estimation at large T1 values was demonstrated by the fbMOLLI compared to the breath-hold MOLLI.

References: 1. Messroghli et al. MRM 2004 52(1). 2. Tsai et al. Med. Phys. 2012. 39(12). 3. van der Tol et al. ISMRM 1347, 2014. 4. Kellman et al. JCMR 2013 15:56.

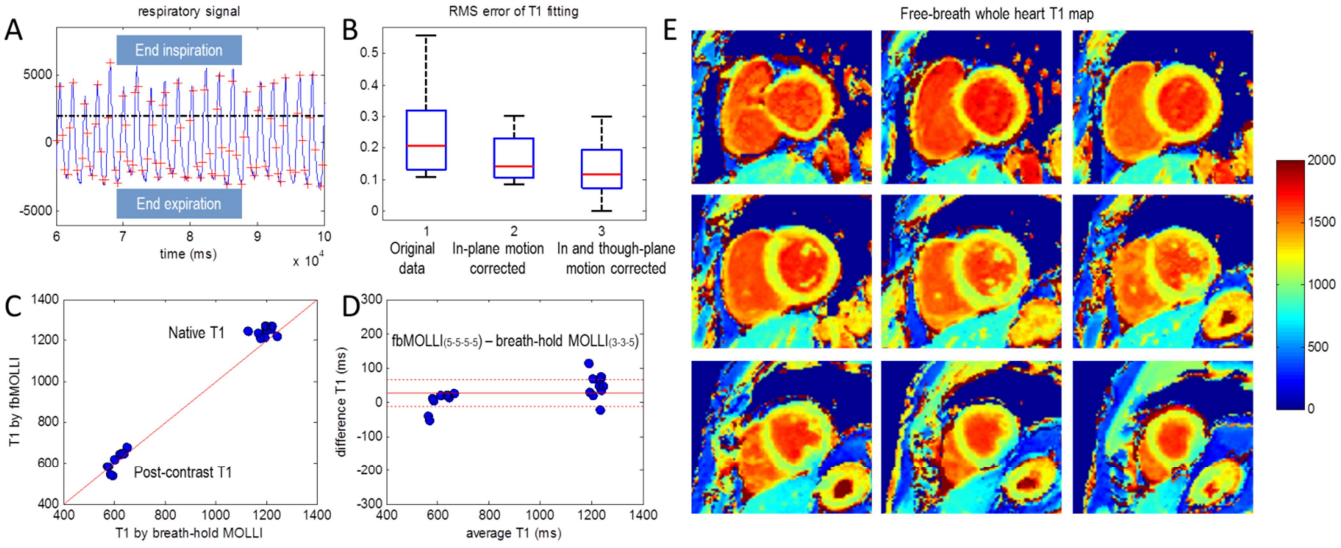

Figure 1. A. Respiratory signal with red crosses indicating timing of acquisition. B: Root mean square error of T1 fitting before and after motion correction. C and D. Bland-Altman plot of T1 values. D. An example of the motion-corrected whole heart native T1 mapping.