

MYOCARDIAL AND LV BLOOD T1 MEASUREMENT USING 3.0T MOLLI: IMPORTANCE OF HEART RATE CORRECTION

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Purpose

The modified look-locker inversion recovery (MOLLI) sequence is an accurate and reproducible technique for the measurement of myocardial and LV blood T1 relaxation time (T1). However, it has been recognized that MOLLI underestimates true myocardial and blood T1 as heart rate and T1 increase. Therefore, an empirical heart rate correction for MOLLI-derived T1 has been proposed for the more accurate myocardial T1 quantification [1,2]. Thus far, however, no specific algorithm for heart rate correction has been provided. The purposes of this study were (1) to determine the heart rate correction formula based on the phantom study and (2) to demonstrate the importance of the heart rate correction for the accurate measurement of myocardial and LV blood T1.

Methods

Fifteen healthy volunteers (11 male, 35 ± 6 years) were evaluated with a 3.0T MR system (Philips, Ingenia 3.0T Omega). Two 3-3-5 MOLLI (17 heart beats, 3 inversions blocks, 3 recovery beats, 11 images) images were acquired on consecutive slice locations in mid-ventricular short axis orientation using the following parameters: non-segmented steady state free precession readout, field of view: 300 x 330mm, matrix: 176 x 141mm, thickness 10mm, TE/TR/FA: 2.6ms/10.86ms/35°, SENSE factor 2. Healthy volunteers were divided into lower-heart rate group (7 subjects; heart rate <70bpm) and higher-heart rate group (8 subjects; 70bpm ≤ heart rate) based on the heart rate during MOLLI imaging. Phantoms containing dilute gadolinium contrast (10 tubes with T1 ranging from 300 to 2300ms) were scanned on the same 3.0T MR system. 3-3-5 MOLLI images were acquired with simulated heart rates from 60 to 100 bpm in increments of 10 heart beats. To determine the reference T1 of each phantom, single shot look-locker (SShLL) sequence with same FOV and matrix size were acquired at 24 different TIs with a TR/TE of 4.6ms/2.2ms and a fixed simulated heart rate of 10 bpm [3]. For both phantom and human studies, T1 maps were calculated by the dedicated software (Relaxation Maps Tool Ver.2.1.2). Each short-axis slice was divided into 6 segments in the volunteers.

Results

The measured myocardial and LV blood T1 in the higher heart rate groups were significantly smaller than those in the lower heart rate group (1224ms vs. 1239ms, p<0.001 and 1705ms vs. 1819ms, p<0.001, respectively) (figure 1). For the phantom study, 3-3-5 MOLLI sequence progressively underestimated T1 for values more than ≈700 ms compared with SShLL sequence as T1 and heart rate increased (Fig.2). From those results, the heart rate correction formula was determined using 6th order polynomial approximation as $T1_{corrected} = \{3 \times 10^{-20} (T1_{measured})^6 + 5 \times 10^{-18} (T1_{measured})^5 + 7 \times 10^{-13} (T1_{measured})^4 + 5 \times 10^{-9} (T1_{measured})^3 + 5 \times 10^{-5} (T1_{measured})^2 + 0.9847 (T1_{measured})\} + \{(\text{heart rate} - 60) \times \{2 \times 10^{-9} (T1_{measured})^3 - 2 \times 10^{-6} (T1_{measured})^2 + 6 \times 10^{-4} (T1_{measured}) - 0.2211\}\}$. Once measured T1 was corrected for myocardium and LV blood using this formula, myocardial and LV blood T1 were substantially augmented both in lower and higher heart rate groups, resulting in a smaller difference of T1 between the groups (1317ms vs. 1311ms, p=0.05, for myocardium and 2014ms vs. 1963ms, p=0.05, for LV blood, respectively) (figure 1). After the heart rate correction, intra- and inter-observer reproducibility of myocardial T1 measurement was good (ICC 0.82, CoV 1.6 and ICC 0.78, CoV 2.0, respectively). Bland-Altman plot showed acceptably small bias and limit of agreement for intra- and inter-observer measurements (mean difference: -4.7±27ms, 8.4±21ms, respectively).

Conclusion

The results of this study demonstrated that T1 measurement with heart rate correction by 3-3-5 MOLLI at 3.0T allows for the accurate measurement of non-contrast myocardial and LV blood T1 regardless of heart rate and inherent tissue T1 values with good intra- and inter-observer reproducibility.

References

- Messroghli DR, et al. Radiology 2006;238:1004, 2. Lee JJ, et al. JCMR 2011;13:75, 3. Deichmann et al. MRM 1999;42:206

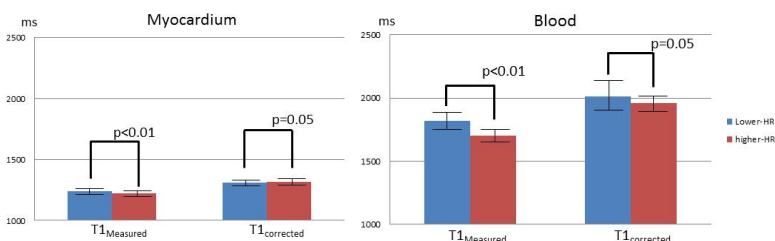


Figure 1 Myocardial and LV blood T1 before and after heart rate correction. Comparison between lower- and higher heart rate groups.

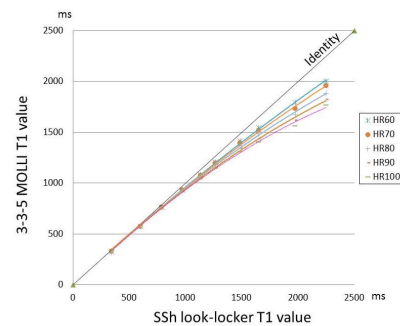


Figure 2 Relation between 3-3-5 MOLLI-T1 and SShLL-T1.