Correction for heart rate bias of post-contrast myocardial T1 values derived using MOLLI sequence

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Introduction: The T1 mapping technique in cardiovascular magnetic resonance (CMR) allows detection of diffuse myocardial fibrosis in a wide range of conditions including cardiomyopathy, hypertrophic cardiomyopathy and amyloidosis. To measure the T1 time, a gadolinium contrast agent is typically administered, followed by measurement of T1 time by CMR at one or more time intervals. The MOLLI scheme is currently one of the favored techniques for CMR T1 mapping (1).

Post contrast myocardial T1 values (as well as derived values such as partition coefficient and ECV) can show variation due to the acquisition scheme. In particular, variation due to heart rate (HR) results in biased values for T1. We show that under certain circumstances this bias can exhibit a systematic relationship with heart rate. An *ex post facto* solution is proposed which would allow for comparison of T1 values between subjects with varying heart rates. Results of a phantom study are presented to illustrate our correction method.

Materials and Methods: MRI experiments: A phantom consisting of a tube with DTPA $NiCl_2$-agar solution mimicking post contrast myocardium was imaged on a Philips 3T Achieva scanner using a 5-3 MOLLI sequence with following relevant scan parameters: $TI_{min}/TI_{max} \approx 145/400$ms, $TR_{BSSFP}/TE = 2.3/0.9$ms, ramp up preparation, 10 dummy acquisitions, $\alpha = 35°$, *linear encoding* of k-space, SENSE factor=2. T1 was estimated by curve fitting and the three parameter model correction was applied ($T1_{est}$). In a clinical setting, the aforementioned scan parameters can be held constant. The FOV or resolution is typically expected to change to accommodate different subjects. Either of these would imply a change in the shot duration (T_{shot}). Consequently, the turbo shot duration was changed and for each T_{shot}, the HR was varied from 50 bpm to 100 bpm. The fit for $T1_{est}$ (uncorrected for HR) to TR = $(60/HR)\times10^3$ ms has the form $(A - B.\exp(-C.TR))$ for each T_{shot}, where A, B and C are constants. The first step in the correction involves normalization of $T1_{est}$ to the value A (to give $T1_p$). Once normalized, a plot of $T1_p$ vs T_{shot} shows a linear relationship and a second correction can be effected to get the final HR corrected T1. IR-SE sequence was used as the gold standard to determine true T1 of the post-contrast myocardium.

Results: Figure 1 shows the change in T1 values with HR and corresponding model fits for four T_{shot} values. Figure 2 shows the linear relationship between A and T_{shot}. The two step correction results in a near constant T1 value across T_{shot} and TR (or HR) as seen in Figure 3. Comparing the accuracy with the IR-SE derived T1 (506ms) gave a mean error of 19.7% and 5.5% before and after HR correction, respectively. Precision of the values can be defined by the coefficient of variation (COV=mean/std). The COV improved from 0.035 before HR correction to 0.0034 after HR correction.

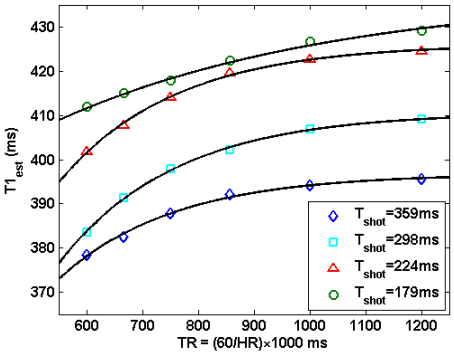

Figure 1: $T1_{est}$ vs HR for different T_{shot}.

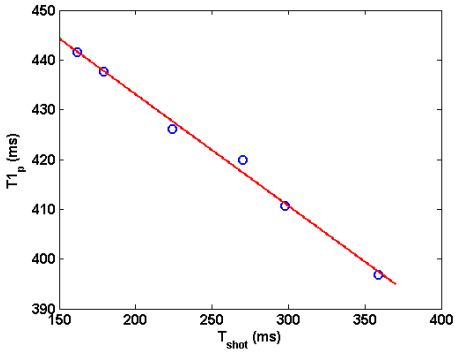

Figure 2: $T1_p$ (partially corrected) vs T_{shot}.

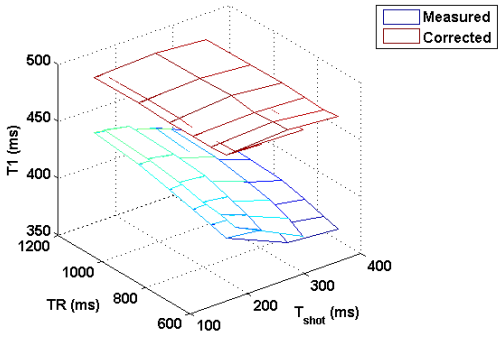

Figure 3: Measured and corrected T1 vs (T_{shot} and HR)

Discussion: Post-contrast myocardium T1 values have the potential to be more sensitive to disease than other derived values such as ECV. However, bias due to heart rate variation needs to be dealt with effectively to realize this potential. Current methods deal with heart rate correction in an ad-hoc manner and typically use a linear model. Such a correction would be ineffective when T_{shot} is different across different subjects in a clinical setting. Assuming *linear* k-space acquisition (which is preferred due to reduced artifacts), we have shown that a monotonic relationship exists between T1, HR and T_{shot}. Therefore, a lookup table can be created to effectively correct T1 given the HR and shot duration. This correction scheme is valid for T1 values in the range of post-contrast myocardium (200ms-600ms) and for all contrast agents since the dependence is only on the uncorrected (for HR) T1 value, HR and T_{shot}. Some deviation from the ideal values can be expected due to B0 and B1 inhomogeneity. However, the impact on corrected values is minor for typical variations. A dependency on T2 value can also be expected. This is again a non-factor since T2 value of post-contrast myocardium is constant (~50ms) except in certain diseases related to iron overload. When cardiac arrhythmia is present, the correction may be not be accurate.

References: [1] Messroghli DR, et al. *MRM*, 2004;52(1):141-146.