

Cardiac Motion-Corrected Inversion Prepared Real-Time (“TIRT”) Cine TrueFISP Imaging for Rapid Myocardial T1 Estimation

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Introduction: T1 mapping is a promising means for quantifying the extent of myocardial cell integrity. Existing methods suffer from relatively long breathhold times [1] and show susceptibility to respiratory motion and heart rate variability. We propose a new method to rapidly map T1 in the heart based on an IR-prepared real-time Cine TrueFISP sequence in combination with an elaborate motion correction algorithm based on non-rigid registration of the IR prepared images with synthetic image estimation [2]. The new method is intrinsically robust against changes in heart rate and respiratory motion and allows extremely short breathhold times.

Subjects & Methods: An acquisition sequence employing a single inversion recovery pulse followed by a train of single-shot TrueFISP readouts was implemented on a clinical 3T MRI scanner (MAGNETOM Verio and Avanto, Siemens AG, Erlangen, Germany) to sample the T1 relaxation curve. Imaging parameters included TE/TR 1.0/2.3 ms, typical in-plane spatial resolution 1.8x2.1mm², 8 mm slice thickness, shot time per image 150 ms, total acquisition time 5000 ms, 30 deg flip angle (Fig. 1). Data were acquired at 3T pre contrast and 10 min post Gd-DTPA contrast administration in healthy subjects (n=10, 39.6±8.4y, 5f). Inline motion correction was applied to register the individual images before inline T1 fitting was performed using a mono-exponential 3-parameter fit. MOLLI [3] datasets were acquired for comparison. Flip angle and heart rate dependence were investigated in scans on volunteers and phantom studies using a calibrated T1/T2 phantom. TIRT and MOLLI were applied at 1.5T in a patient (84 y, m) suffering from myocardial infarction (MI). For comparison late Gadolinium enhancement was performed.

Results: The motion correction performed well even in the TIRT multi-phase IR prepared data which exhibit strong changes in image contrast throughout a set of CINE images. The T1 maps based on the TIRT acquisition approach showed very good agreement with the data resulting from MOLLI acquisitions (Fig. 2). Only for rather small T1 value T1 was underestimated with TIRT. For the high T1 values, TIRT proved to underestimate T1 less as compared to MOLLI. In-vivo studies (Fig. 3) revealed that TIRT overestimated T1 in the myocardium (TIRT 1391±47 ms vs. MOLLI 1164±31 ms pre contrast, TIRT 502±55 ms vs. MOLLI 441±28 ms post contrast). In the patient post contrast MOLLI and TIRT T1 maps showed very comparable results (MOLLI T1 scar 308±30 ms, remote 464±47 ms; TIRT T1 scar 318±38 ms, remote 464±50 ms) (Fig. 4). The flip angle dependence was found to be irrelevant for T1-quantification when using flip angles between 5 to 30 deg (978 ms to 1108 ms), though the signal-to-noise ratio was significantly reduced for flip angles below 15 deg.

Discussion: TIRT allows an instant pixel-based T1 estimate in a 5 second acquisition. The method could be used as an automated T1 optimization method for late enhancement and also could be an alternate approach for rapid T1 quantification. No compromise has to be taken in nominal spatial resolution compared to other single shot based methods such as MOLLI but caution needs to be taken since our preliminary results indicate that the direct exponential fit values as resulting from TIRT showed to overestimate T1 in vivo. This effect may be further enhanced by applying a correction as proposed in [4]. The low standard deviations indicate that the bias is probably not attributed to motion or spatial resolution effects. Nevertheless, due to the multi-phase data acquisition, the performance of the motion correction may not always be perfect. Therefore, the imaging module may be shifted towards onset of diastole so that short T1 contrast images are acquired in diastole. Also, it might be beneficial for T1 quantification to completely remove some images acquired in systole from the pixel based fitting to reduce if not eliminate motion induced effects on TIRT based T1 mapping.

References: [1] Messroghli DR et al, Magn Reson Med 2004;52:141-6. [2] Xue H. et al., Magn Reson Med doi: 10.1002/mrm.23153 [3] Messroghli DR et al, J Magn Reson Imaging. 2007 Oct;26(4):1081-6. [4] Schmitt P et al, Magn Reson Med 51:661–667 (2004).

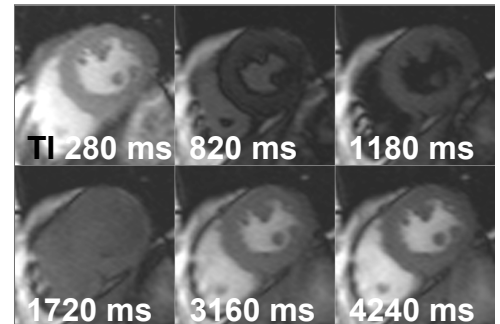


Figure 1: Single images resulting from a TIRT acquisition (frames 2, 5, 7, 10, 18, 24 of 30).

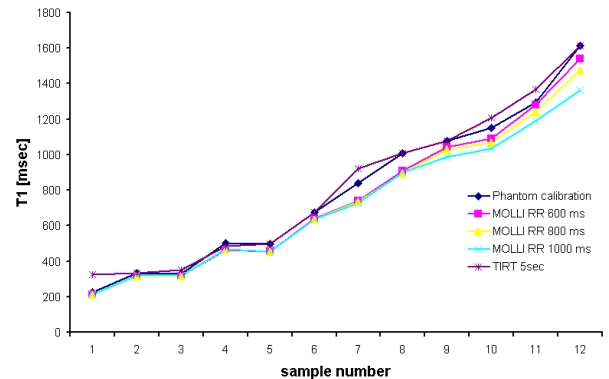


Figure 2: Overview of T1 values from MOLLI and TIRT vs. known reference T1 values in calibrated phantom.

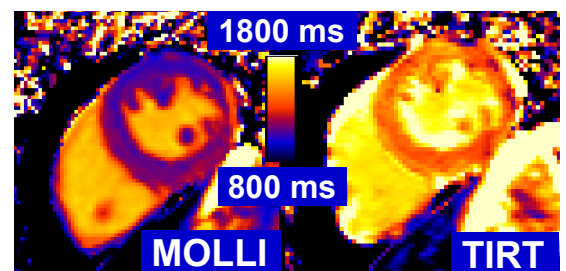


Figure 3: Comparison of T1 maps based on MOLLI and TIRT acquisitions acquired pre contrast.

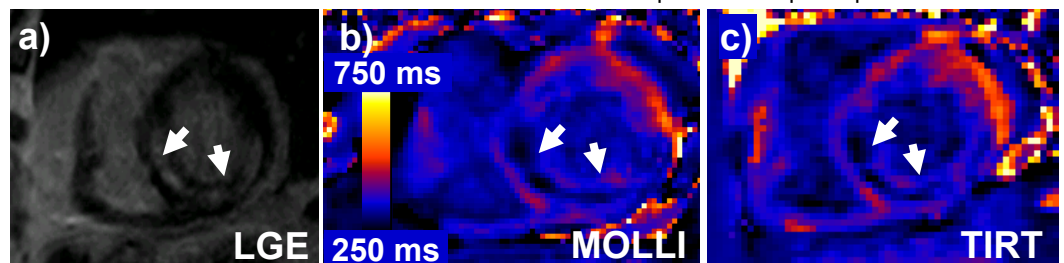


Figure 4: a) short axis LGE image and T1 maps based on b) MOLLI acquisition, c) TIRT post contrast in 84y MI patient. Arrows point to area of enhancement (a) and shortened T1 (b,c).