Characterising an Inversion-Recovery prepared Steady-State Free-Precession sequence for measuring myocardial T1 relaxation times pre- and post-contrast administration.

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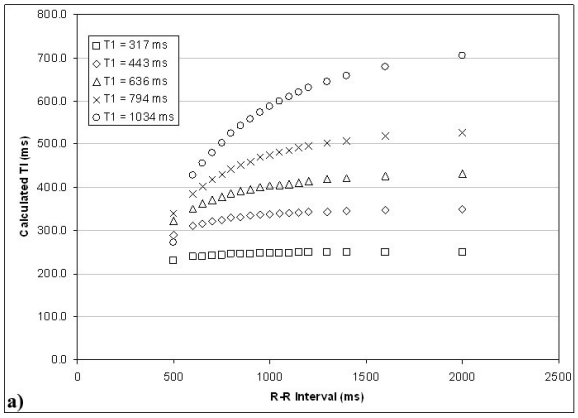
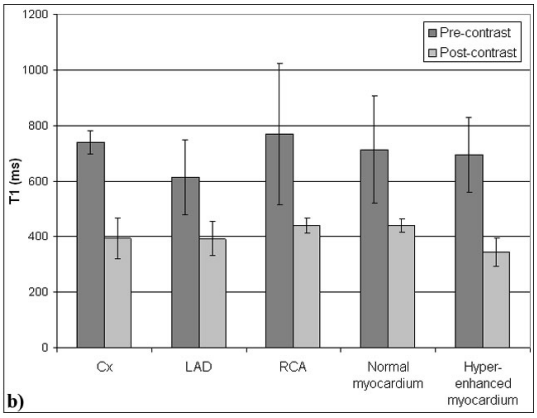
Introduction: Delayed-enhancement of myocardial fibrosis is a well established technique in cardiac MRI. There is interest in quantifying the degree of enhancement by measuring T_1 relaxation times in cases of known ischaemia, as well as in cases of suspected cardiomyopathies[1] where diffuse enhancement can be a valuable prognostic indicator. A modified Look-Locker technique is often used, where an inversion recovery (IR) preparation is applied and then a segmented cine gradient-echo or Steady-state Free-precession (SSFP) sequence is used to sample the recovery curve during the cardiac cycle. The Inversion Time (TI) is easier to calculate and can act as a substitute for T_1. For the case of the SSFP readout, the signal follows an exponential recovery to the steady state magnetisation with a time constant T_1^* that depends on T_1, T_2 and the flip angle[2]. The heart rate can also affect the results, as data is acquired on every second or third heart beat; therefore, there may be incomplete recovery of magnetisation between IR pulses if the patient has a rapid heart rate. The aim of this pilot work was to characterise heart rate variability in phantoms and see if it can be accounted for in measurements on a small cohort of clinical patients with known cardiac disease.

Methods: Twelve agarose gel phantoms (Eurospin test objects, Diagnostic Sonar, Livingstone UK) with calibrated relaxation times ranging from 210—1040 ms (T_1) and 50—380 ms (T_2) were used for the phantom work. These were validated using standard IR and multi-echo spin echo sequences. The scans were performed on a 1.5T Magnetom Avanto (Siemens Healthcare, Erlangen, Germany) using an IR-SSFP sequence with the following parameters: TR/TE = 3.35/1.44 ms, flip angle 50°, Slice thickness = 8 mm, FOV = 250×250 mm, matrix = 192×192, number of segments = 9. A simulated ECG trace was set to run with R-R intervals ranging from 2000 ms to 500 ms and the scan acquired data every second R-R interval. Data were analysed using MATLAB (MathWorks, Natick, US). A small cohort of five male patients, referred for delayed enhancement cardiac MRI, were scanned with a mid ventricular short-axis IR-SSFP sequence before and ten minutes after administration of contrast. Regions of interest (ROIs) were placed in areas of myocardium corresponding to the three main coronary territories (Circumflex-Cx, Left Anterior Descending-LAD and Right Coronary-RCA). TIs were calculated and then this was converted into a T_1 values corrected for variable R-R intervals using look-up tables developed from the phantom work.

Results: The variation in TI with R-R interval is demonstrated in figure a). Only five gels are shown for clarity. Variability ranged from 4.1% for the short T_1 gel to 49.2% for the long T_1 gel. The patients' R-R intervals varied from 1010—720 ms. Hyper-enhancement was observed in the LAD territory in two patients and in the Cx territory for the other three. When grouped by territory (figure b)), the pre-contrast scans showed the greatest variability in T_1 values, even after correcting for variable R-R intervals. When grouping by normal/hyper-enhanced myocardium, no significant difference was seen between the two groups pre-contrast, whereas a significant difference was seen post-contrast ($p<0.05$). Variability was still greater on pre-contrast results.





Discussion: The phantom work demonstrates that there is marked variability in TI measurements with R-R interval, especially for longer T_1 gels. In a small cohort of patients, there is still a large degree of variability even when R-R interval corrections are applied. This is more noticeable in the pre-contrast data. This may have implications for studies where pre- and post-contrast T_1 measurements are used to quantify the amount of contrast uptake, in particular in cases of diffuse enhancement. Further work with a larger group of patients is necessary to verify these preliminary findings.

[1] Han Y *et al.* (2009) *J Magn Reson Imaging,* 30 (5): 967—972.

[2] Schmitt P *et al.* (2004) *Magn Reson Med*, 51 (4): 661—667