Reproducibility of myocardial T1 estimation with modified CINE-IR in rat myocardium at 7T

Henk Smit[1], A. Ruggiero[1], G.N. Doeswijk[1], M. Milanesi[2,3], G.C. Houston[4], M.R. Bernsen[1], G.P. Krestin[1], S. Klein[1], and G. Kotek[1]
[1]*Erasmus MC, Rotterdam, Zuid Holland, Netherlands,* [2]*Agilent Technologies UK Ltd.,* [3]*MRI Lab, Fondazione G. Monasterio-CNR, Pisa, Italy,* [4]*GE Healthcare, Netherlands*

Introduction This work addresses the feasibility, accuracy and the sensitivity of a novel T1 mapping method [1] in rat myocardium at 7.0 T. Cine Inversion Recovery has been shown to be a reliable method for T1 mapping [2]. In a conventional Cine-IR sequence an inversion pulse is played at the beginning of each cardiac phase, followed by a segmented (CINE) acquisition. As a result each cardiac phase experiences a different TI depending on the distance to the IR pulse. This approach faces many limitations when the heart rate is getting high, as in small animals (~350bpm), because the longitudinal magnetization recovery can be insufficient to produce a reliable T1 estimation, even when an extra R-R interval is left for recovery [3]. In the modified Cine Inversion Recovery (mCINE-IR) [1], the effective TR can be adjusted to allow much more longitudinal recovery between two subsequent inversions pulses. Furthermore, the magnetization recovery is monitored by the CINE loop acquisition during the entire number of R-R intervals within the chosen TR. The capability of mCINE-IR to produce sensitive T1 maps at 7T was assessed by injecting Gd-liposome labeled stem cells in the myocardium of a rat whereas its reproducibility was evaluated on a healthy animal.

Materials and Method Rat mesenchymal stem cells (rMSCs) were labeled with 125µM Gd-liposomes (4h), as previously reported [4]. $1.5 \cdot 10^6$ cells were injected in the heart of a Wistar rat during open heart surgery, and the rat was scanned with the proposed mCINE-IR sequence to assess the feasibility of stem cell tracking. A healthy rat was scanned four times with mCINE-IR to study the reproducibility. For data acquisition a 7T pre-clinical scanner (Discovery MR901^{TM}, Agilent Technologies – GE Healthcare) was used along with a 72mm volume coil as RF transmitter and a 4 channel phased-array surface coil as signal receiver. The TI range was determined by an effective TR of 15 R-R intervals. Because it is a CINE sequence the entire heart cycle could be used to produce inversion recovery curves, but having as much as 15 R-R intervals at disposal also means having potentially 15 points of the curve that represent the same cardiac phase. By selecting images of the diastolic phase it becomes possible to register images with different TIs fairly easy and produce a proper T1 mapping, which could be problematic if we used less R-R intervals [1]. The resulting TI values were TI = 91, 255, 418, 582, 745, 909, 1072, 1236, 1399, 1563, 1726, 1890, 2053, 2217, 2380ms for a BPM=320. Other parameters were resolution = 256x256, NEX = 6, FOV = 60x60mm, in-plane voxelsize = 0.23x0.23mm and scantime = 6 minutes. After performing the MRI scan the inner and outer boundary of the myocardium were drawn and a map was created using a Maximum Likelihood (ML) estimator approach which takes the Rician noise distribution of the magnitude MR images into account. This ML approach also yields the Cramer-Rao Lower Bounds on the uncertainty of the fits, the square root of which (srCRLB) can be interpreted as a lower bound on the standard deviation of the T1 and thus gives an errorbound in ms. To align the images from subsequent days, a two-stage registration procedure was used. First, five anatomical landmarks of the myocardium were selected which were used in a rigid point based registration. The resulting transformation was used as an initialization for an intensity based mutual information registration. The myocardium region was divided into six standardized regions [2] based on the anatomical landmarks the user selected for the registration. The mean T1 and the standard deviation were then calculated per segment to study reproducibility.

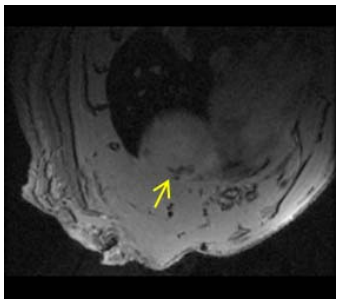

Figure 1: A PDW image showing the location of the Gd injection

Results Figure 2 shows the T1 values for the six segments of the myocardium of the healthy rat. The inferior and inferoseptal regions suffer from a high variation on T1s, which can be caused by the known susceptibility artifacts at the heart-lung interface [5], which are more severe at high field strengths. The Gd injection was placed in the anterior segment, where the variation is low and reproducibility good. The mean estimated T1 in the anterior segment was 956 ms ± 45.9 ms. Figure 1 shows a PD weighted image of the myocardium of the injected rat with an arrow pointing to the Gd area. Figure 3 shows the estimated T1 recovery curves for a region drawn in this Gd area and a region in healthy myocardium. The estimated T1 (mean ± srCRLB) for the Gd is 728 ± 129 ms and for the myocardium 827 ± 122 ms.

Conclusion The mCINE-IR technique offers a reproducible T1 estimation of both healthy tissue and injected Gd labelled cells in the rat myocardium at 7T making longitudinal studies feasible.

[1]*Milanesi M et al., ISMRM 2011* ***[2]*** *Nacif M.S. et al., J Magn Res Imag Sep 23 2011* ***[3]*** *Goldfarb J.W. et al., MRM 2005;53.* ***[4]****Guenoun J et al. Cell Transplant. 2011* ***[5]*** *Atalay, M.K. et al., Magn Reson Med 2011; 45*

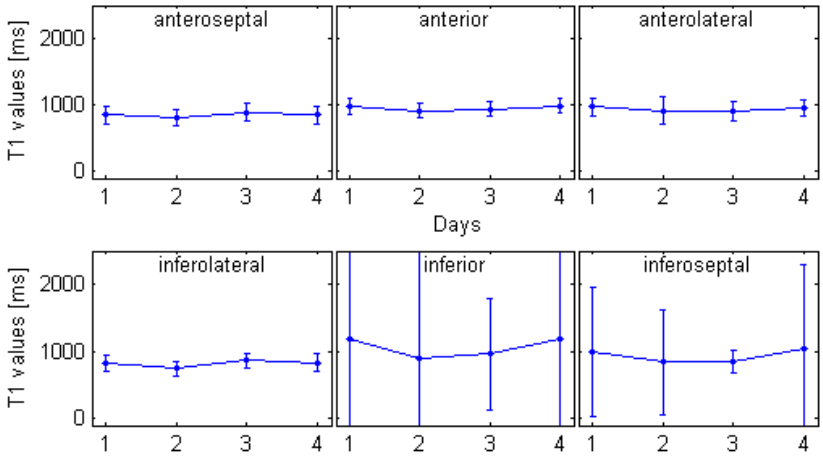

Figure 2: The mean and std of the T1s in the six segments

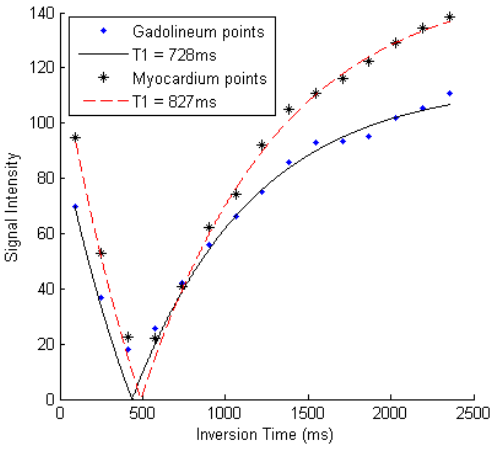

Figure 3: Estimated T1 recovery curves in a Gd and a myocardium region