Improved Method for Assessing Myocardial Infarction in Rodents at 9.4T using Delayed Enhancement-MRI

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Introduction: MRI is becoming a widely used tool in cardiovascular research involving small animals, and is regarded as the gold standard for assessing many functional parameters, such as ejection fraction. However, the assessment of myocardial infarction by delayed enhancement (DE) using gadolinium contrast agents, has not seen as widespread use in small animal research, and studies have primarily used standard short TR T_1-weighted imaging sequences. In clinical cardiac MRI, inversion recovery sequences provide the optimum contrast between MI and healthy myocardium. Relatively few studies have reported on their use in small animals, due to the problems associated with rapid heart and respiratory rates and the relatively long T_1 recovery times that are exhibited at high fields [1-3]. In this abstract we report on the implementation of an inversion recovery sequence on a 9.4T experimental system in order to assess myocardial infarction in rats 2 hours post MI.

Methods: Animal preparation: All experiments complied with the UK Animals (Scientific Procedures) Act, 1986 and local ethical guidelines. Male Wistar rats were anaesthetised with sodium thiopentone (i.p.) and underwent 30 minutes of myocardial ischaemia by ligation of the left anterior descending coronary artery followed by 2 hours of reperfusion. Imaging was performed on a 9.4T Varian (VNMRS) system using a 72mm de-tuneable transmit coil and a four-element phased array receive coil (Rapid Biomedical GmbH). For delayed contrast enhancement 0.6 mmol/kg Gd-DTPA (Magnevist, Schering AG, Germany) was injected through the external jugular vein after initial baseline scanning.
Cardiac MRI: Cine cardiac data was acquired using a double gated spoiled gradient echo sequence (TE/TR=1.3/6-8ms, 20 cine frames, 200µm in-plane resolution, slice thickness=1mm, NA=1) in order to assess contractile dysfunction. Following contrast agent administration a fast multi-TI inversion recovery sequence (Figure 1a) was used to acquire multiple TI images following a double gated non-selective adiabatic inversion pulse. Typically 6 TI values ranging from 150-900ms, either using a single selected slice containing both MI and healthy myocardium or multiple sequential slices, were acquired at each TI point. All TI frames were ECG gated, ensuring images are collected from the same part of the cardiac cycle. An optional QRS delay can be included to capture either ES or ED views. Additional parameters: matrix=192, FOV=40mm, slice=1mm TE=1.3ms, TR=~1s (depending upon respiratory rate), low FA=10°, Averages=1, TA~3 minutes. This was followed by a single TI multi-slice acquisition with FA=90º, where TI is selected from the initial multi-TI image set to achieve maximum contrast.

Results and Discussion: Figure 1a illustrates the fast IR sequence employed to initially assess optimum TI prior to acquisition of high SNR multi-slice imaging of delayed enhancement. Typically 6 TI images are acquired on the recovery curve following adiabatic (non-selective inversion) at intervals of R-R. The inset images reveal that 2 R-R intervals provide the nearest ECG trigger point that will offer maximum infarct-myocardium contrast, i.e where the healthy myocardium has been approximately nulled. Using this a single TI multi-slice stack is acquired using full FA=90º achieving the highest SNR/contrast available between infarct region and healthy myocardium, refer to figure 1b.
Figures 2a-d include a single end-diastolic (a) and end-systolic (b) frame from the cine data revealing severe contractile dysfunction (EF=41%), while the corresponding delayed enhanced image (c) and *ex vivo* TTC staining (d) all appear to show good correlation to each other.

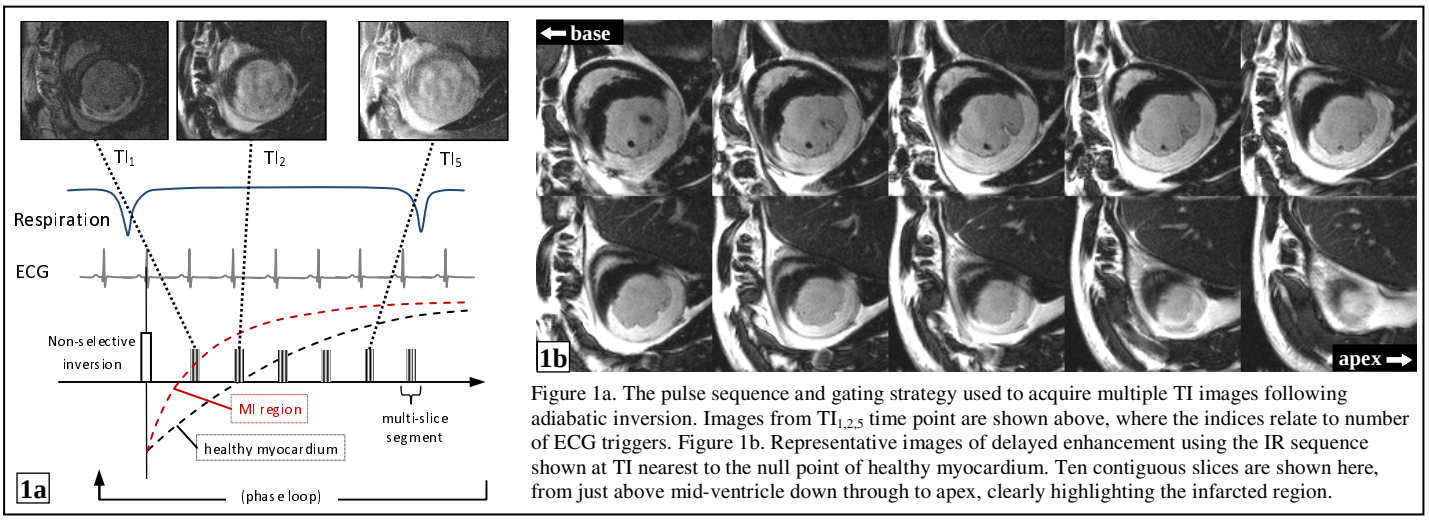

Figure 1a. The pulse sequence and gating strategy used to acquire multiple TI images following adiabatic inversion. Images from $TI_{1,2,5}$ time point are shown above, where the indices relate to number of ECG triggers. Figure 1b. Representative images of delayed enhancement using the IR sequence shown at TI nearest to the null point of healthy myocardium. Ten contiguous slices are shown here, from just above mid-ventricle down through to apex, clearly highlighting the infarcted region.

Conclusion: Inversion recovery sequences provide optimum contrast in DE-MRI, enabling accurate discrimination between infarct regions and healthy myocardium, which is the reason why they are the gold standard method in the clinical setting. Here we demonstrate that they can also be applied to small animal models of MI despite their rapid heart and respiratory rates and long T_1 relaxation times at high field. We have established a protocol that utilises a fast multiple-TI method allowing for optimum TI selection for a subsequent high contrast multi-slice set of delayed enhancement images to be acquired, with a total acquisition time of under 10 minutes.

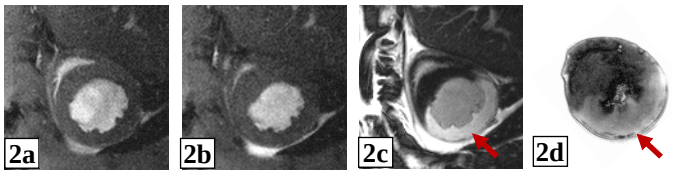

Figure 2. Shows end-diastolic (a), end systolic (b) frames from cine data alongside IR delayed enhancement image (c) and corresponding TTC histology section (d), revealing a large region of infarction (red arrow).

References: [1] French BA et al, JCMR 2005;7:172. [2] Chapon C et al, JCMR **10**:6. [3] Price A et al, Proc. ISMRM 2007 #2528.