Infarcted Myocardium Detected by Phase-Sensitive Inversion Recovery Using Gadolinium Delayed Hyperenhancement

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Introduction Gadolinium delayed hyper-enhancement (DHE) detected by inversion recovery (IR) imaging has been used extensively to delineate the infarct size. One problem associated with DHE-IR detection is the apparent infarct size varies with inversion time (TI) [1,2]. This is due in large part to the inability of conventional magnitude images to distinguish between the positive and negative signal intensities generated in the IR experiment. Phase sensitive detection has been shown to resolve this problem in human studies [2]. However, the previously described techniques are not applicable for mouse/rat infarction models due to the high heart rates of rodents. We present a multi-slice pulse sequence that samples magnetization immediately after spin inversion and after a delay suitable for nulling of normal myocardium. The image of short TI was used to restore the phase information in the image acquired at the longer TI. The infarct size quantified by this technique was compared to the post mortem histological results.

Methods Left ventricular myocardial infarction was generated in five male CD-1 rats by ligation of the left anterior descending artery for 1 hour followed by reperfusion. MR images were acquired using a 60-mm volume coil interfaced to a 4.7T horizontal bore Varian spectrometer. The animal was anesthetized with 1-3% isoflurane in oxygen during MRI and its ECG and core body temperature were monitored. The core temperature was maintained at 37±0.2°C by directing warming air to the magnet bore. A multi-slice IR fast gradient echo sequence was implemented that samples 4 lines of k-space at two inversion times following a slice-selective inversion pulse. This sampling scheme was repeated until all k-space lines were sampled. The parameters used were TR=6 ms, TE=3ms (the effective TR was decided by the heart rate, 0.13-0.15s), flip angle=20°, matrix=128^2, FOV=8 x 4 cm and signal averages=8. This yielded a total acquisition time about 20 minutes for 5 slices. Images were acquired prior to, and 10-20 minutes post injection of Gadodiamide (Omniscan) at a dose of 0.3-0.6 mmole/kg. Two IR images were obtained for each slice location and were processed offline by a phase detection program in IDL. To restore the sign of the magnetization of the 2nd TI image, the phase information from the 1st TI image was applied and the real part of the 2nd IR image was used for display. After imaging, the heart was removed and perfused retrograde through the ascending aorta with saline followed by 6 ml 1.5% 2,3,5-triphenyl tetrazolium chloride (TTC) (Sigma) solution [3]. The heart was then placed in a -80°C freezer for 15 minutes and approx. 1 mm-thick slices were cut perpendicular to the long cardiac axis. The slices were then placed side by side between two glass slides, which were scanned on both sides. The infarcted area (nonstained pale/white region) was measured on both sides and averaged for each slice, and summed from all slices using ImageJ software.

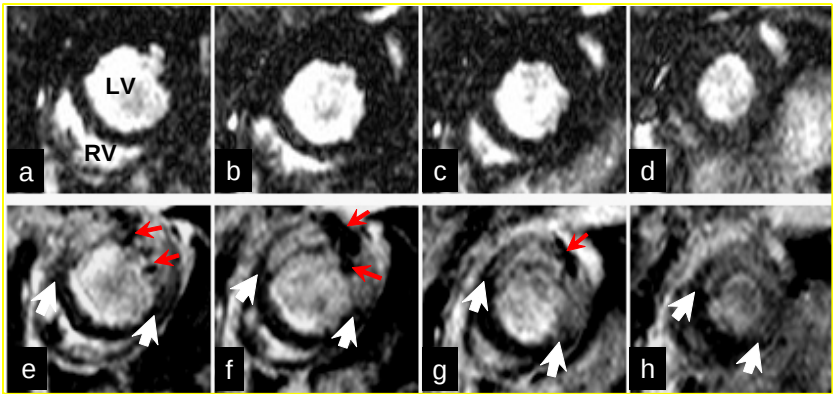

Fig.1. Delayed hyper-enhancement of infarcted myocardium 24 hours after MI surgery and injection of SPIO labeled cells. Note that regions of signal loss pointed by read arrows correspond to locations grafted with stem cells labeled with SPIO particles (results on stem cells tracking were presented in a separate abstract).

Results Fig.1 shows pre-contrast multi-slice images from an infarcted rat heart (panel a-d, basal to apical) and post-contrast images (e-h) from the same heart. Signals from both infarcted and normal myocardium were nulled on pre-contrast images while the infarcted region was enhanced on post-contrast images as delineated by white arrows. Preliminary results suggest that infarct size quantified by imaging compares favorably with that by postmortem TTC staining.

Discussion Multi-slice capability of this imaging technique permits estimation of the infarct size in one experiment with relatively high SNR. Partial k-space sampling (4 lines per heart beat) allows equal TI for the 2nd IR image of each slice and it also leads to the almost identical delay-time after contrast agent injection for the each slice. The correlation between infarct size estimated by this imaging method and by TTC staining is being investigated.

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References 1.*Circulation* **104** 2838-2842 (2001). 2. *Magn Reson Med* **47** 372-383(2002). 3. *Pathophysiology* **9** 249-256 (2003).