Dynamic MRI Contrast-Enhancement Time Course Measurements of the Myocardium: Results from Patients with Chronic Myocardial Infarcts

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Introduction: Recent studies have shown that MR imaging after the administration of contrast material can be used to accurately distinguish between reversible and irreversible myocardial ischemic injury(1). Other studies have shown discrepancies between enhancement region size with different imaging parameters and imaging times(2). Research has been performed to dynamically measure contrast agent concentrations over time in blood and many other organs, but studies involving the myocardium (3,4) have only provided a limited number of temporal measurements (eg. 10 min and 20 min).

We sought to develop and show the feasibility of a method capable of dynamically measuring contrast agent concentrations in the blood pool of the left ventricle, irreversibly injured myocardium and normal myocardium during a one hour time period. Once contrast agent concentrations are known, imaging parameters can be optimized, recommendations for the optimal time to commence imaging after contrast agent administration and the necessary changes in inversion time for normal myocardial nulling can be specified. Lastly, new information may be contained in the wash-in and wash-out data over an extended time period.

Methods: Eleven subjects (age: mean=65 years; range=43-84) with known chronic myocardial infarcts (mean age of infarct: 7 years;range=2-21 years) who had undergone a previous MR or SPECT viability examination demonstrating an infarct participated in the study. Imaging was performed using a 1.5T clinical scanner (Siemens Magnetom Sonata). A 2D multi-phase inversion recovery slice-selective segmented True-FISP sequence(3) was used (TR=2.5, TE=1.1, FA=50, BW=965 Hz/pixel, voxel size=2.5x1.8x8.0mm^3). A single slice was positioned based on the previous MR/SPECT study to include regions with both injured and normal myocardium. Each breath-hold yielded 19-24 images with increasing inversion times at intervals of 37ms. 0.2 mmol/kg of gadodiamide (Omniscan) was injected at 2 ml/s followed by a 15ml saline flush. Imaging commenced directly after the administration of the contrast agent and continued for up to one hour with acquisitions occurring approximately every minute.

Images were transferred to a standalone SUN workstation and a custom JAVA computer program was used for segmentation and T1 calculations. For each acquisition, epicardial and endocardial myocardial borders were hand drawn and a signal intensity threshold was set for each image. The T1s of normal and irreversibly injured myocardium as well as the left ventricular blood pool were calculated using a multidimensional unconstrained nonlinear minimization (Nelder-Mead) applied to the IR True-FISP signal intensity equation (5).

Results: Imaging was successfully performed in each case (mean imaging duration = 47 minutes). Each breath-hold yielded a number of images with consecutive inversion times demonstrating the infarct with changing signal intensity for the consecutive TIs (Figure 1). Typical enhancement curves for a single subject are shown in Figure 2. Results from all subjects are plotted in Figure 3. In five cases, the area of infarction could be identified before contrast administration as has been previously reported (3). T1 values for viable and infarcted myocardium continued to diverge out to one hour after contrast injection.

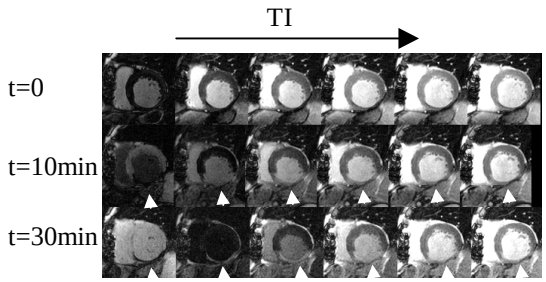

Figure 1: Representative images from a patient with an inferior wall infarct. Note: only 3 of 60 temporal acquisitions and 6 of 24 inversion times are shown.

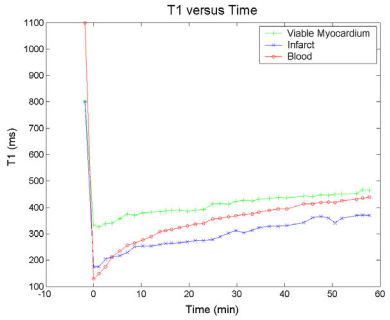

Figure 2: T1 curves from a single subject.
Note: the washout of the normal myocardium is faster than the infarcted tissue.

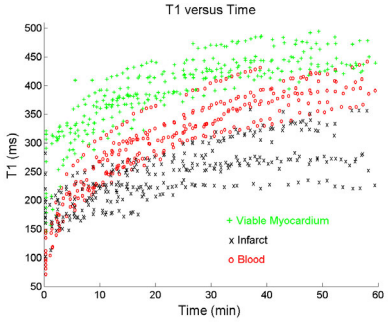

Figure 3: Temporal results for all of subjects. Note that the best separation between the three regions occurs after 30 minutes.

Conclusions: Myocardial contrast-enhancement can be monitored with a temporal resolution of approximately one minute. The use of a multi-phase IR True-FISP technique yields multiple images with increasing inversion times which permit calculation of regional myocardial T1 values. Images were of sufficient quality to segment enhancing regions and calculate inversion times for optimal nulling of viable myocardial tissue.

After a delay of approximately 10 minutes, gadolinium concentrations fall progressively in the blood and viable myocardium creating increased image contrast with infarcted myocardium. Data suggests that improved contrast between necrotic tissue and the LV blood pool is achieved at imaging times after 30 minutes

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