Introduction

T$_2$ weighted imaging identifies changes in myocardial water mobility and has been used to differentiate acute from chronic myocardial infarction and for characterizing tissue changes with myocarditis. In this study, we evaluate a technique for rapid T$_2$ quantification in a single breath-hold per slice using a tailored half-Fourier single-shot turbo spin echo (HASTE) sequence for measuring T$_2$ values in healthy myocardium and regional T$_2$ changes in acute myocardial infarction.

Methods

HASTE T$_2$ Sequence: The HASTE sequence was modified by adding a variable number of dummy 180º refocusing pulses between the 90º excitation and image acquisition. Three images with echo times of 27.0, 54.2 and 81.4 ms (corresponding to 0, 8, and 16 dummy pulses respectively) were acquired in a clinically useful breath-hold duration (10–15 seconds). Double inversion dark blood with a slice width double the imaging slice width was used to null the blood pool signal. A minimum delay of 4 seconds between images minimized T$_1$ weighting. Total acquisition time per image was one R-R interval with a typical acquisition window of ~200ms.

In Vivo Human Study: 10 healthy volunteers (7 male, 33.7±9.2 yrs) and 11 patients with acute myocardial infarction (8 male, 58.2±8.3 yrs, 2.4±1.2 days post infarction) were imaged on a Siemens Avanto 1.5T MRI system with informed consent and IRB approval. After basic localization, T$_2$ maps were acquired for 3 short-axis slices at the basal, mid-ventricular, and apical levels. ECG gating was used with a trigger delay appropriate for mid-diastolic imaging. Slices had in-plane resolution of 1.875 × 1.875 mm$^2$ with 8.0 mm thickness. A 32 channel coil (16 elements anterior and 16 posterior) was used for signal reception. Late enhancement imaging using a segmented gradient echo sequence following injection of Gadolinium (Magnenivist, typical 0.2 mmol/kg body weight) was performed on patients but not healthy subjects.

T$_2$ Analysis: For each short axis slice, manually traced epicardium and endocardium contours defined the myocardial tissue, with positional adjustments made on each echo time image to account for residual breathing motion (custom software, MATLAB). These contours were used in conjunction with the right ventricle insertion point for modified AHA segmentation. Each short-axis AHA segment was circumferentially subdivided into 5 segments for increased circumferential resolution. The average signal intensity within each segment at the three TE values was fitted to a mono-exponential decay function using least squares minimization.

Results

Healthy Subjects: Inadequate dark blood suppression in the apical slice generated image artifacts that resulted in anomalous T$_2$ values for one healthy subject that was excluded from subsequent analysis. For all subjects (patients and controls), a total of 1600 segments were analyzed, each containing 31.0±10.2 pixels. Fig. 1a shows a bullseye plot of average T$_2$ for healthy subjects (overall average 56.9±6.1 ms). Segments from the apical slice had higher T$_2$ values than those from the basal slice (60.0±6.3 ms vs. 54.9±5.6 ms, p<0.001 Student’s t-test). In the basal slice, segments in the lateral (free) wall had reduced T$_2$ times compared with other segments in the slice (52.6±4.4 vs. 56.1±5.7 ms, p<0.001).

Acute Myocardial Infarction: The T$_2$ map for a patient 5 days post myocardial infarction (proximal right coronary artery (pRCA)) is shown in Fig. 1b. Significant T$_2$ enhancement is seen in inferoseptal regions and overlaps with pRCA perfusion territory and late gadolinium enhancement (Fig. 1c). All 11 patients showed large regions of significant T$_2$ increase using a threshold of 3 standard deviations (i.e. 18.6 ms) above the mean for abnormal segments. The number of abnormal segments in each patient, out of 80, are {75, 39, 30, 5, 19, 22, 6, 11, 35, 15, 36}. At this threshold, 3.75% of segments in healthy subjects were classified abnormal, but with no more than two contiguous abnormal segments.

Discussion

Overall myocardial T$_2$ for healthy subjects is in good agreement with previously reported T$_2$ values. Whole-heart T$_2$ maps for 9 healthy subjects show consistent regional variations with elevated T$_2$ in the apical slice and reduced T$_2$ in the lateral wall of the basal slice. Existence of regional variations in T$_2$ would be important in interpreting clinical findings, but may reflect artifacts such as incomplete block blood suppression, particularly at the apex, or motion artifacts at the base, and additional studies are needed to validate these findings. All 11 myocardial infarction patients showed large contiguous regions of significantly increased T$_2$ (~18.6 ms above the normal volunteer means), ranging from 6% to 94% of the myocardium.

References