Myocardial T_2 Using Single-Shot Turbo Spin Echo: Regional Trends in Healthy Controls and Myocardial Infarction

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Introduction

T_2 weighted imaging identifies changes in myocardial water mobility and has been used to differentiate acute from chronic myocardial infarction[1] and for characterizing tissue changes with myocarditis[2]. 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[3] 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[3]. Three images with echo times of 27.0, 54.2 and 81.4ms (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 (Magnevist, 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[4]. 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±6.1ms). 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.

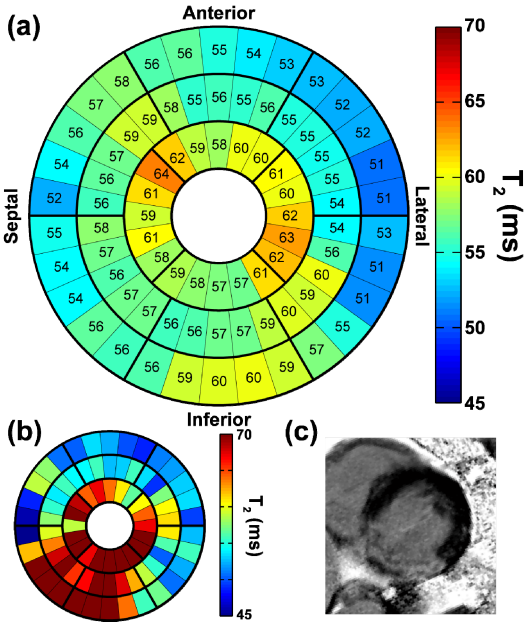

Fig. 1 (a) Average T_2 for 9 healthy subjects; average over all segments is 56.9±6.1ms. Concentric rings depict apical, mid, and basal slices in the outward direction. T_2 map **(b)** and late gadolinium enhancement **(c)** for a patient with pRCA myocardial infarction. Elevated T_2 values in inferoseptal regions overlap with late enhancement.

Discussion

Overall myocardial T_2 for healthy subjects is in good agreement with previously reported T_2 values[3,5,6]. 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 incomplete black 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

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