HIGH SPATIAL RESOLUTION FREE BREATHING 3D T2 MAPPING FOR EDEMA DETECTION IN RADIO FREQUENCY ABLATION

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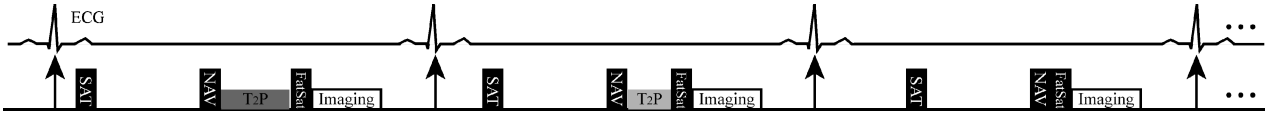
Introduction: Radio frequency ablation (RFA) has become first-line therapy for many cardiac arrhythmias. Differentiating between viable myocardium, scar and injured tissue (edema) in both ventricles and atria can very helpful in predicting the recurrence of arrhythmias. Late Gadolinium enhancement (LGE) [1] and phase sensitive inversion recovery (PSIR) [2] are well established methods of delineating scar. Black-blood fast spin echo (BB-FSE) [3] is also an established method for visualizing myocardial edema. However, BB-FSE (e.g. T2-STIR) also has some drawbacks such as signal heterogeneity due to phased array coils, confounding residual signals from slow-moving blood and subjective image interpretation. [4,5] Alternatively, T2 mapping has been shown to solve these issues but current approaches in cardiac imaging constrain spatial resolution due to breath-holding.[5,6] T2-mapping may also provide additional sensitivity to edema in the presence of contrast media. As both atrial and ventricular ablation protocols have become increasingly complex (e.g. for atria fibrillation and non-mappable ventricular tachycardia), the need for 3D high resolution imaging is clear. We propose a 3D navigator gated imaging sequence designed for T2 mapping and the detection of edema. We hypothesize that T2mapping may be provide a feasible method for the detection of edema in the presence of contrast media.



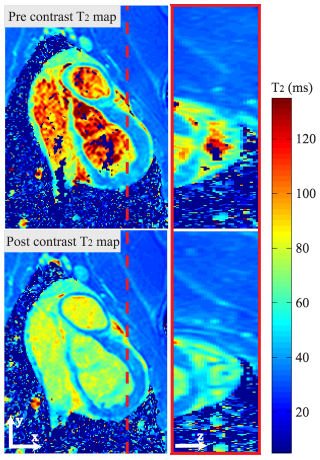
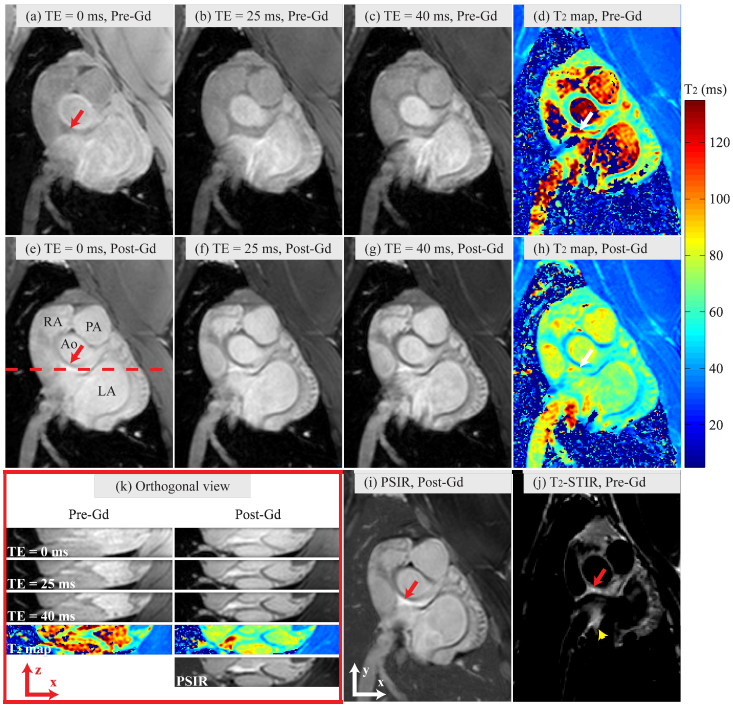


Figure 1 (Top): Schematic of the navigator-gated 3D differentially T2-Weighted sequence. T_2Prep echo time is varied per volume. SAT – spatial saturation, NAV – respiratory navigator, FatSat – fat saturation, T_2P – T2 preparation with varied echo time.

Figure 2 (Left): Pre and post contrast 3D T2 maps of the atria of a swine model after RF ablation. Note signal homogeneity in the myocardial walls. Dashed line indicates the corresponding intersection planes in right.

Figure 3 (Bottom): Representatively images from pre (a-c) and post contrast (e-g) co-registered volumes acquired with different T2-weightings (T_2Prep TEs = 0, 25, 40ms), the corresponding T2 maps (d, h). The PSIR (i) and the T2-STIR (j) corroborate presence of edema with signal enhancement (red arrows). Red dashed line (e) indicates x-z intersection planes (k) for (a-i)



Theory: *Pulse sequence*: A series of T2-prepared 3D volumes were acquired in an interleaved manner during diastole every heartbeat (Fig. 1). Different T2-weightings were achieved by using T_2Preps with different echo times before data acquisition. A 'reset' non-selective spatial saturation pulse was applied right after R wave detection with fixed time interval between saturation pulse and imaging. This method is an extension of that originally proposed by Giri et al [5], which acquires a single-shot SSFP image every 3 heartbeats, with 2 'idle' heartbeats to allow full magnetization recovery. To remove time limits imposed by breath-holds and achieve desired spatial resolution and coverage, respiratory navigators were used for respiratory compensation. Navigators were acquired immediately before T_2Prep to avoid disturbance of the liver signal. Interleaving volumes with different T_2Prep guaranteed registered volumes, all subject to the same physiological variations. 3D T2 maps were calculated per voxel using linear regression with 3+ volumes.

Methods: Under IACUC-approved protocol, RFA lesions were made in/around the left atrium of a swine. Imaging took place 2hrs post ablation using a 3T system (Philips Medical Systems, Best, Netherlands) and a 32-channel cardiac phased array (InVivo, Gainsville FL). T2-mapping of the atria was carried out before and after the injection of contrast agent (0.2 mmol/kg, Magnevist). Three interleaved volumes were acquired with T_2Prep TEs = 0, 25, 40ms. T2-STIR images were acquired at similar spatial locations (Imaging parameters: TE 40ms, 1 TR per heartbeat, TSE factor 12, FOV 250×195×56mm^3, voxel size 1.25×1.0×4.0mm^3 reconstructed to 0.97×0.97×4.0mm^3). Post contrast independently navigated 3D PSIR images [7] and a second 3D T2-mapping were acquired ~17 and ~26 minutes post infusion, respectively. Typical imaging parameters of the 3D gradient echo sequences were: TR/TE 5.4/2.6ms, flip angle 18°, diastolic window 81ms, FOV 250×192×42mm^3, voxel size 1.25×1.0×3.0mm^3 reconstructed to 0.65×0.65×1.5mm^3. Prescribed scan time for T2-mapping was around ~6 minutes assuming 100% navigator efficiency. Locations of RFAs in the atria were confirmed by visual inspection after excision.

Results: Normal myocardium pre and post contrast T2 maps (Fig. 2) demonstrate that T2 in normal myocardium before, and 26 min post infusion were 53.7±1.8ms and 42.3±4.2ms, respectively. Other areas of interest were: aortic wall (pre: 53.6±5.6ms, post: 47.2±6.5ms), area of RF ablation (pre: 99.6±11.4ms, post: 64.3±4.3ms). Enhanced signal intensity in pre contrast T2 map was confirmed by T2-STIR images and LGE-PSIR image (Fig. 3 with arrows), though T2-STIR had confounding regions of enhancement due to slow blood flow (yellow arrow heads).[8]

Conclusion: The presented method can achieve high-resolution 3D T2 maps using differentially T2-weighted interleaved acquisitions. T2 results are comparable to those previously published. Pre contrast maps appear to be sensitive to edema, though more validation including comparison to standard 2D T2W imaging is required. The 3-dimensionality T2 maps should allow for better determination of anatomically complex structures like RFA lesions.

References: [1] Kim et al, N Engl Jour Med 2000 343: 1445; [2] Kellman et al, MRM 2002 47: 372; [3] Simonetti et al, Card Radiol 1996 199: 49; [4] Abdel-Aty et al, JMRI 2007 26: 453; [5] Giri et al, JCMR 2009 11: 56; [6] Kellman et al, MRM 2007 57: 891; [7] Lee et al, SCMR 2011; [8] Vergara, et al. J Cardiovasc Electrophysiol 2010:2.