

## Introduction

Ultrahigh-field MR techniques are in the research spotlight for quantitative CMR applications which aim at parametric mapping for non-invasive tissue characterization (1). Because of the super-linear relationship between magnetic field strength and microscopic  $B_0$  inhomogeneities, access to susceptibility weighted myocardial imaging at 7.0 T (i) would extend the capabilities of quantification of myocardial iron content, (ii) would make it easier to differentiate healthy tissue from myocardial regions underlying perfusion deficits due to the multi-fold increase in BOLD sensitivity together with the enhanced differences in  $T_2^*$ . For this reason it is conceptually appealing to pursue myocardial  $T_2^*$  mapping at ultrahigh magnetic field strengths ( $B_0 > 7.0$  T). To meet this goal this work examines the applicability of a 2D spoiled gradient-echo multi-echo based approach for fast CINE  $T_2^*$  mapping of the heart in conjunction with the use of slices thicknesses as thin as 2.5 mm and an in-plane spatial resolution of 1.5 mm to reduce dephasing due to macroscopic  $B_0$  inhomogeneities, such as the lung/heart interface.

## Methods

Volunteer experiments were performed on a 7.0 T whole body MR system (Magnetom, Siemens, Erlangen, Germany) together with a dedicated 16-element TX/RX cardiac coil array using a prospectively triggered spoiled 2D gradient echo technique (slice thickness=2.5 mm, nominal flip angle=40°, acquisition matrix 144x192, in-plane resolution (1.5 x1.5) mm<sup>2</sup>, 25 cardiac phases, TR=19 ms, bandwidth= 1030 Hz/Pixel, GRAPPA (R=2)). TEs were set to multiple of 1.02 ms ranging from 3.06 ms to 11.22 ms and were obtained during three breath hold periods.  $B_0$  inhomogeneities were reduced by applying volume selective shimming. An MR-stethoscope (MRI.TOOLS, Berlin, Germany), which is immune from interference with electromagnetic fields and to magneto-hydrodynamic effects was used for cardiac gating (2). Images were processed with MATLAB (Mathworks, Natick, MA, USA) routines including a rigid landmark-based co-registration, a segmentation of the left ventricle. Mono-exponential fitting using nonlinear least squares optimization implemented by Trust-Region algorithm was applied for pixel-by-pixel  $T_2^*$  quantification.

## Results

The flip angle of the excitation pulse was adjusted to preserve myocardial signal by reducing T1-saturation effects, which resulted in a low contrast between the blood pool and the surrounding myocardium as illustrated in Figure 1. No severe susceptibility artifacts were detected in the inferoseptal myocardium and in the anterior lateral wall for TE ranging between 3.06 and 11.22 ms. For lateral myocardial areas close to the heart/lung interface susceptibility related signal void was observed for TE > 6.12 ms as demonstrated in Figure 1d-i.  $T_2^*$  maps showed significant non-uniformity in  $T_2^*$  across the myocardium as depicted in Figure 2. Within the septum epicardial layers revealed  $T_2^*$  values of (13±2) ms and endocardial layers showed increased  $T_2^*$  values up to (23±7) ms. The lateral wall revealed  $T_2^*$  values below 8 ms. This includes infero lateral wall regions at the heart-lung interface along  $B_0$  which can be very well distinguished from areas around a cardiac vein located at the anterolateral wall. For anterior and posterior regions  $T_2^*$  values of (15±5) ms were detected. It should be also noted, that  $T_2^*$  varied across the cardiac cycle as illustrated in Figure 2a), 2b) and 3. For example, the anterior segment showed a  $T_2^*$  values of about 10 ms for endsystolic phase and about 22 ms for enddiastolic phase.  $B_0$  field map analysis showed a residual field variation of approximately 150Hz across the the heart implying a reasonable  $B_0$  shim since previous studies report  $\Delta B_0$ =(80-100) Hz for 3.0T (3).

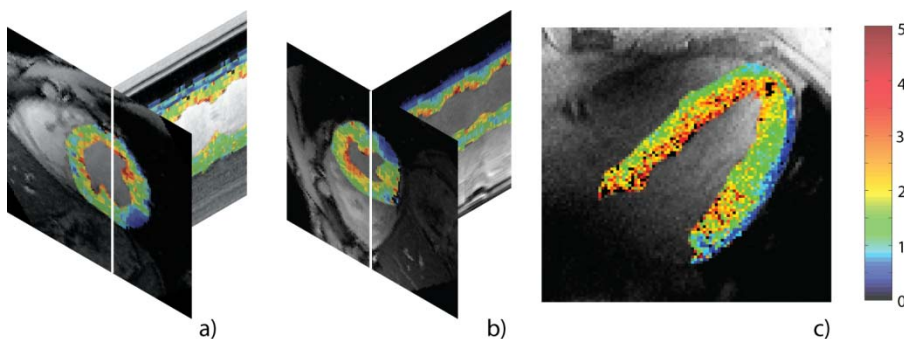
## Discussion

Our findings demonstrate the applicability of a 2D spoiled gradient-echo multi-echo based approach for rapid CINE  $T_2^*$  mapping of the heart by transferring the baseline SNR advantage of 7.0 T into the use of 2.5 mm slices thicknesses and an in-plane spatial resolution of 1.5 mm. The use of ultrahigh field related short echo times in combination with volume selective shimming and high spatial resolution helped to make the susceptibility weighting be dictated by microscopic  $B_0$  inhomogeneities rather than macroscopic  $B_0$  effects, thus making the BOLD effect due to physiology of interest more pronounced. The ability to monitor changes in tissue oxygenation using  $T_2^*$  sensitized imaging/mapping offers the potential to address some of the spatial and temporal resolution constraints of conventional first pass perfusion imaging and holds the promise to obviate the need for exogenous contrast agents. Also, the proposed approach bears the potential to be useful for quantification of myocardial iron content, assessment of endothelial function, detection of stress induced angina pectoris and for of tracking superparamagnetic iron-oxide labeled cells or devices. In conclusion, we anticipate the extension of this work to a broader clinical study at 7.0 T to exploit the susceptibility sensitivity advantage at ultrahigh fields with the ultimate goal of moving towards 3D  $T_2^*$  mapping of the heart.

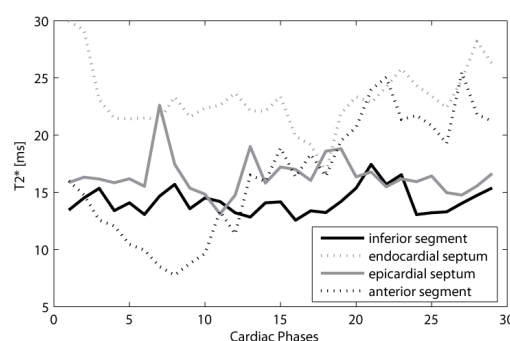
**References:**1) Niendorf, T et al European Radiology : (2010-07-31) 2) Frauenrath T et al Investigative Radiology 44 (9): 539-547 (2009-09), 3) Schär M et al Magn Reson Med. 2004 Apr;51(4):799-806.



**Figure 1:** End systolic Short-Axis Views of multiecho acquisition. TE is increased by 1.02 ms from a) to i) starting with 3.06 ms.



**Figure 2:** Representative Short Axis with corresponding  $T_2^*$  maps overlaid and with M-mode like representation of cardiac cycle along white line. a) enddiastolic phase and b) 90° rotated endsystolic phase and c) 4 chamber view with overlaid  $T_2^*$  Map



**Figure 3 :**  $T_2^*$  values over cardiac cycle for different regions of interest in the myocardium. 90° rotated endsystolic phase