Toward Assessment of Iron Overload Diseases at 7.0 T: Myocardial T_2^* Mapping To Derive Global and Segmental T_2^* Norm Values For Healthy Subjects at 7.0 T

Fabian Hezel[1], Antonella Meloni[2], Jeanette Schulz-Menger[1,3], Petra Keilberg[2], Peter Kellman[4], Massimo Lombardi[2], and Thoralf Niendorf[1,3]

[1]*Berlin Ultrahigh Field Facility, MDC Berlin, Berlin, Germany,* [2]*Cardiovascular MR Unit, Fondazione G. Monasterio CNR-Regione Toscana and Institute of Clinical Physiology, Pisa, Italy,* [3]*Experimental and Clinical Research Center (ECRC), Charité Campus Buch, Humboldt-University, Berlin, Germany,* [4]*Laboratory of Cardiac Energetics, National Institutes of Health/NHLBI, Bethesda, MD, United States*

Introduction: Parametric MR mapping for non-invasive myocardial tissue characterization is a driving force for Cardiovascular MR (CMR) explorations at high and ultrahigh fields (1,2,3). Access to susceptibility weighted myocardial imaging at high fields bears the potential to extend the CMR capabilities for assessment of ischemic heart disease, evaluation and monitoring of iron overload diseases or quantification of global and segmental myocardial iron content. To this end T_2^* mapping at 1.5T represents is of proven clinical value for non-invasive assessment of cardiac iron content. Because of the super-linear relationship between magnetic field strength and microscopic B_0 inhomogeneities it is conceptually appealing to pursue myocardial T_2* mapping at ultrahigh magnetic field strengths (7.0 T). With the increased magnetic field strength T_2^* relaxation rates of healthy myocardium obtained at 1.5T and 3.0T need to be revised (4). For all these reasons this study focuses on myocardial T_2* mapping at 7.0 T to determine T_2^* relaxation times for normal myocardium in healthy subjects with the ultimate goal to establish a lower limit of normal T_2^* at 7.0T.

Methods: Volunteer studies (n=10, 4 males, 27.8 ± 2.6 years) were performed on a 7.0T whole body MR system (Magnetom, Siemens Healthcare, Erlangen, Germany) using a 16-element TX/RX coil array tailored for CMR (5). T_2^* weighted imaging was conducted using a breath-held, segmented spoiled multi echo gradient echo technique (matrix size 174x224, in-plane spatial resolution=1.6 x1.6 mm^2, slice thickness=4 mm, TR=13.3 ms). For each subject a series of T_2^* weighted images was acquired for an apical, mid-ventricular and a basal short axis view at end-diastole and end-systole with TEs ranging equidistantly from 1.56 ms to 9.72 ms. The nominal flip angle was adjusted to 20° in order to offset SAR constraints and to preserve myocardial signal by reducing T1-saturation effects. A MR-stethoscope (MRI.TOOLS GmbH, Berlin, Germany) was used for prospective cardiac gating (6). To reduce macroscopic susceptibility effects a volume selective first and second order shim was applied covering the heart. A custom-written software (HIPPO MIOT®, Pisa, Italy) (2,5,9) was used for data analysis. For this purpose, the left ventricle was segmented into a standardized model comprising 16-segments. T_2^* was calculated for each segment. Mid-ventricular septum and global T_2^* values were also determined.

Results: All subjects tolerated the examination well. No adverse effects were reported. B_0 mapping showed residual field variations ranging between 80Hz to 100Hz across the left ventricle as shown in Fig. 1. This compares very well with B_0 offsets previously reported for 1.5T (7) and 3.0T (8) and indicates that B_0 inhomogeneities did not dominate T_2^* effects. For T_2^* mapping the low flip angle induced very moderate blood myocardium contrast. No severe susceptibility artifacts were detected in the inferolateral myocardium and in the anterior lateral wall. For lateral myocardial areas close to the heart/lung interface susceptibility related signal void was observed for TE > 6.12 ms, with only minor effect on the T_2^* maps. The heart/lung interface and main cardiac vein induced dephasing effects, which lead to non-uniform T_2^* distribution in the affected regions. For a mid-ventricular slice the lateral wall (segment 11,12) revealed T_2^* values of about 17 ms as shown in Figure 3. 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 the mid-ventricular septum (segments 8 and 9) T_2^* was found to range between 12.0 ms and 28.0 ms (mean=18.6 ms, SD=4.3 ms). The lower limit of normal T_2^* was 10 ms. For anterior (segments 1, 7 and 13) and posterior regions (segments 4, 10 and 15) T_2^* values of 20.5±5.6 and 15.4±5.5 ms were detected. Global heart T_2^* values ranged from 11.9 ms to 24.0 ms (mean=16.9 ms, SD=3.2 ms). The global lower limit of normal T_2^* was found to be 10.5 ms. To evaluate the inter-observer variability, the images were presented in random order to another operator, who was blinded to the results obtained by the first operator. The difference between two analyses was quantified by the interclass correlation coefficient (ICC) which was >0.75 for all measurements.

Discussion and Conclusions: Our findings demonstrate that myocardial T_2^* mapping and aassessment of global and mid-ventricular septum T_2^* values is feasible at 7.0T. Image quality achievable for T_2^* mapping at 7.0 T is not always exclusively defined by SNR considerations. To be more specific, some of the inherent SNR advantages of ultrahigh field MRI are offset by T_1 prolongation. This is useful to improve blood/myocardium contrast for cardiac chamber quantification and LV function. Myocardial. T_1 lengthening, however, is not beneficial for myocardial T_2^* mapping since saturation effects are more pronounced versus 1.5 T and 3.0 T. The use of ultrahigh field related short echo times in combination with volume selective shimming and small voxel size helped to make the susceptibility weighting being dictated by microscopic B_0 inhomogeneities rather than macroscopic B_0 effects. It is a recognized limitation of this pilot study that healthy subjects were involved only. This was an essential precursor to a clinical study to establish lower limits for normal T_2^* values. We anticipate to extend our efforts towards clinical studies including thalassemia major (TM) patients whose T_2^* relaxation times will be benchmarked against the norm values of healthy subjects reported here.

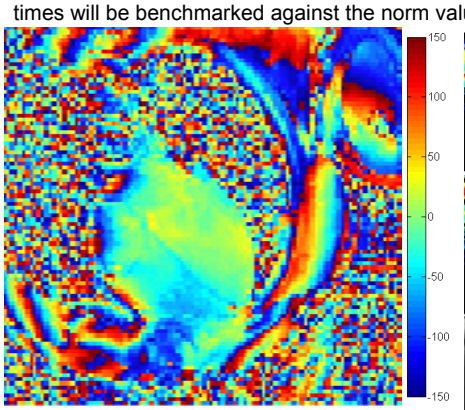

Figure 1: *B_0 map derived from a long axis four chamber view. A phase shift of 80-100 Hz was observed for the left ventricle*

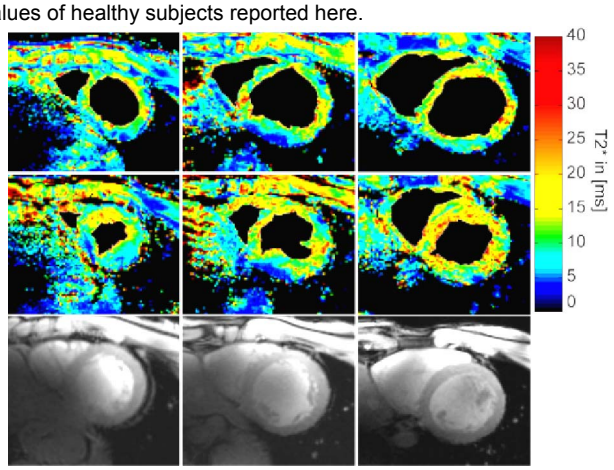

Figure 2: *Representative end-diastolic (top) and end-systolic T_2^* maps for apical (left), mid-ventricular (middle) and basal (right) short axis views. The overall image quality derived for T_2^* weighted imaging using GRE CINE at 7.0 T is shown at the bottom row.*

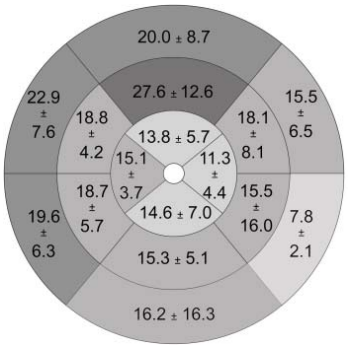

Figure 3: *Synopsis of segmental T_2^* values derived from normal myocardium of healthy subjects.*

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