ON THE SUBJECTIVE ACCEPTANCE DURING CARDIOVASCULAR MAGNETIC RESONANCE IMAGING AT 7.0 TESLA

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Target audience: This work is of interest for clinicians, clinical scientists, basic researchers and engineers interested in the subjective acceptance during cardiac MR (CMR) at ultrahigh fields (UHF, $B_0 \geq 7.0$ T).

Purpose: A growing number of reports refer to explorations into cardiac magnetic resonance (CMR) at ultrahigh magnetic fields (UHF, B0 ≥ 7.0 T). Practical concerns evoked by the physical size and the mere bore length of today's 7.0 T MR scanners and the paucity of data about ergonomic constraints, (dis)comfort and sensory side effects are driving the notion that UHF-MR constitutes a challenge for subject tolerance of 7.0 T examinations *per se*. Recognizing this potential, UHF-MR institutions observe subjective acceptance during UHF-MR examinations very carefully (1-4). *En route* to broader UHF cardiac MR studies it is of relevance to examine how UHF-CMR examinations are tolerated by subjects. Recognizing the particularities of cardiac MR this study examines the subjective acceptance during UHF-CMR examinations. To meet this goal, a cohort of 161 healthy subjects who underwent a cardiac MR examination at 7.0 T in our institution was asked to fill out a questionnaire under supervision of a study nurse.

Methods: Within the period January 2012 to June 2014 a total of 161 healthy volunteers (40 female, 121 male) without any known history of cardiac disease underwent UHF-CMR. For the assessment of the subjective acceptance a questionnaire was used to examine the participants experience prior, during and after the UHF-CMR examination. For this purpose, subjects were asked to respond to the questionnaire in an exit interview held immediately after the completion of the UHF-CMR examination under supervision of a study nurse to ensure accurate understanding of the questions. All questions were answered with "yes" or "no" including space for additional comments. All cardiac MR experiments were conducted on a 7.0 T whole body MR scanner (Magnetom, Siemens Healthcare, Erlangen, Germany). For signal excitation and reception local surface transmit/receive RF coil configurations tailored for ^{1}H cardiac MR were employed (Figure 1) including (i) a modular 32-channel transmit/receive loop coil array (5), (ii) a sixteen channel transmit/receive loop coil array (6,7), (iii) an eight channel transmit/receive bow tie antenna array (8) and (iv) a sixteen channel transmit/receive bow tie antenna array (9). During the examination, the heart rate of each subject was monitored using an MR compatible stethoscope (MRI.TOOLS GmbH, Berlin, Germany) and pulse oximetry (10-13). For acoustic noise protection each subject received earplugs (3M™ earplugs 1100, Neuss, Germany, noise reduction = -37dB) and headphones (Siemens Healthcare, Erlangen, German, noise reduction=-14dB). The UHF-CMR protocol included the following protocol as a minimum: slice positioning was carried out following international consensus. Based on the four-chamber view, a mid-ventricular short axis view positioned parallel to the mitral valve plane was planned as a minimum for high spatial resolution CINE imaging. Alternatively a stack of mid-ventricular short axis views covering the complete LV in diastole was positioned parallel to the mitral valve plane. Short axis and long axis CINE views were acquired using single breath-hold 2D CINE FLASH imaging.

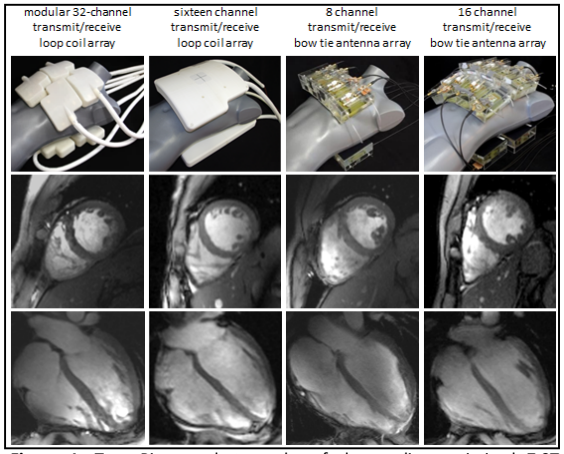

Figure 1: Top: Picture photographs of the cardiac optimized 7.0T transceiver RF coil arrays to illustrate the coil design and the coil geometry together with the coil positioning used in the UHF-CMR setting. The RF coils employed include a 32 channel loop coil, a 16 channel configuration and an eight channel and 16 channel bow tie antenna array configuration. **Middle:** Short axis views, **bottom:** four chamber views of the heart derived from 2D CINE FLASH acquisitions using the RF coil configurations in the top row and a spatial resolution of (1.4x1.4x4) mm^3 and parallel imaging (R=2, GRAPPA reconstruction).

Results: No subject aborted the UHF-CMR examination. Throughout the study, there were no injuries or other incidents. No severe side effects as vomiting or syncope after scanning occurred. No increase in heart rate was observed during the UHF-CMR exam (mean heart rate of 64 ± 7 bpm) versus the baseline clinical examination (mean heart rate: 69 ± 12 bpm). The mean examination time per subject was 64 ± 27min. Examples of short axis views acquired with the four RF coil configurations are demonstrated in Figure 1. Transient muscular contraction was documented in 12.4% of the questionnaires (Figure 2). This phenomenon was reported 2.5% out of all female and 15.7% out of all male subjects. Muscular contraction was reported to occur only during periods of scanning with the magnetic field gradients being rapidly switched (Figure 2). Dizziness during the study was reported by 12.4% of the subjects (Figure 2). This effect was noticed by 3 female (7.5% of female subjects) and 17 male (14% of male subjects) subjects. Taste of metal was reported by 11.2% of the study population (Figure 2) with no gender differences Light flashes were reported by 3.7% of the entire cohort (Figure 2). This includes 5 female (12.5%) and one male (0.8%) subject. Feeling of heat was reported by 3 subjects (female: 2.5%, male 1.7%). Feeling of cold was outlined by 10 subjects, which represents 6.2% of the study population. In detail, cold was pointed out by 12.5% of the female and by 4.1% of the male subjects. 13.7% of the subjects reported side effects/observations which were not explicitly listed in the questionnaire but covered by the question about other side effects.

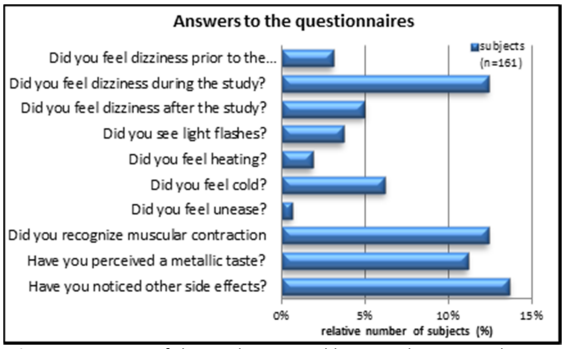

Figure 2: Synopsis of the results reported by 161 subjects on subjective acceptance of UHF-CMR. The most mentioned side effects reported were transient muscular contraction during scanning (12.4%) and dizziness experienced during the study (12.4%).

Discussion: This study adds to the literature by detailing the subjective acceptance of cardiac MR examinations at 7.0 T. The most important finding is that all subjects tolerated the UHF-CMR examinations, which is confirmed by no volunteer aborting the examination. Among the two most common experiences that generated discomfort was transient muscular contraction or involuntary muscle twitching due to peripheral nerve stimulation. This observation does not accord with previous reports on the subjective tolerance obtained for UHF brain MR (1,3), which outlined lower incidence rates of transient symptoms of muscular contraction and peripheral nerve stimulation. Vertigo was found to be the second effect among the two most frequent causes for discomfort in our UHF-CMR study cohort. The incidence rate for vertigo and dizziness of 12.4% observed in our UHF-CMR study is significantly lower than the 25-34% incidence rate for vertigo and dizziness obtained for brain UHF-MR (2,14).

Conclusion: To conclude, 7.0 T cardiac MR examinations were well tolerated by the cohort of healthy subjects included in this study. Broader observational and multi-center studies including patient cohorts with cardiac diseases together with the use of consistent and simple questionnaires harmonized among UHF-MR institutions (3) are required to provide further insights into the subjective acceptance of UHF examinations.

References: [1] Heilmaier C, et al,Bioelectromagnetics 2011; [2] Versluis MJ, et al, J Magn Reson Imaging 2013; [3] Rauschenberg J, et al, Investigative radiology 2014; [4] Cosottini M, et al, Eur Radiol 2014; [5]Graessl A, et al, Magn Reson Med 2014; [6] Thalhammer C, et al, J Magn Reson Imaging 2012; [7] Winter L, et al, Eur Radiol 2012; [8] Winter L, et al, PloS one 2013; [9] Graessl A, et al,ISMRM 2013; [10] Frauenrath T, et al, Acta Acustica united with Acustica 2008; [11] Frauenrath T, et al, Investigative radiology 2009; [12] Frauenrath T, et al, Journal of cardiovascular magnetic resonance 2010; [13] Becker M, et al, Eur Radiol 2010; [14] Theysohn JM, et al, MAGMA 2008.