Towards clinical ultrahigh field musculoskeletal MRI: comparison of shoulder imaging at 1.5T, 3.0T and 7.0T

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Target audience: This work is of interest for clinical scientists, applied scientist and experts in musculoskeletal MR at 7.0 T.

Purpose: In today's clinical practice MRI is the primary modality for diagnostic imaging of the shoulder using field strengths of $B_0 \leq 3.0$ T. Notwithstanding these capabilities shoulder MRI remains challenging due to the subtlety of anatomical structures and of lesions. In particular, small lesions or fiber structures are difficult to localize. Recognizing these challenges together with the opportunities of ultrahigh field MRI, it is conceptually appealing to pursue shoulder MRI at 7.0 T. For all these reasons this work examines the feasibility of sub-millimeter in-plane spatial resolution shoulder MRI at 7.0 T with the ultimate goal to enhance the identification of capillary structures. For comparison, shoulder MRI is performed at 1.5 T and 3.0 T for the same volunteers.

Methods: Five volunteers were investigated at 1.5 T, 3.0 T and 7.0 T using whole body MR scanners (1.5T, Magnetom Avanto, 3.0T, Magnetom Verio, 7.0T, Magnetom (Siemens, Erlangen Germany). At 1.5 T and 3.0 T a body coil was used for excitation while a 4 channel shoulder coil (Siemens, Erlangen, Germany) was used for reception. At 7.0 T a 12 channel transceiver RF coil array dedciated for shoulder imaging was employed. The array comprises three modestly shaped sections to conform to an averaged shoulder. Each section contains 4 loop elements. The elements are organized in a 2 x 2 matrix. A circular polarized mode with phases according to the angular position of the modules was employed. All elements were connected to multipurpose transmit/receive switch boxes with integrated low-noise preamplifiers. No specific tuning and matching or subject transmission field shaping was applied [1]. For all field strengths the same imaging protocols were applied, with the exception that spatial resolution was improved at higher field strength. All volunteers were examined with fat saturated T1 weighted 3D spoiled gradient echo (T1w), 3D dual contrast steady state gradient echo (3D-DESS), using transversal, sagittal and coronal slices. For image quality assessment ROI placed in the anterior and dorsal labrum located between the humerus and glenoid were used.

Results: With 3D DESS imaging the labrum structures were very well delineated with the microstructure being enhanced with increased spatial resolution at higher field strengths as outlined in Fig. 1 and Fig. 2. In 2 of 5 volunteers a small lesion was identified in the labrum. With growing field strength subtle lesions could be better depicted. In particular, small hyperintense areas between the labrum and the glenoid which were caused by the liquid, only seen in 3D DESS were better appreciated at 3.0 T and 7.0 T. At 7.0 T the local 12 channel transceiver coil array provided excellent signal uniformity for transversal and coronal slice. For sagittal slices signal non-uniformities across the shoulder were observed. For the latter the anatomy and a different presentation of the bone marrow within the humeral head with effect to the signal of the surrounding tissue might be responsible for the non-uniformities.

Discussion and Conclusion: Bringing musculoskeletal ultrahigh field MR into the clinic remains challenging. Notwithstanding this challenge our results demonstrate that a modular 12 channel transceiver array using modestly curved building blocks that conform to an average shoulder supports sub-millimeter in-plane spatial resolution MRI of the shoulder at 7.0 T. The sensitivity gain inherent to 7.0 T facilitates an enhanced spatial resolution which benefits the delineation of labrum structures. B_1^+ non-uniformities - observed for sagittal slices with our setup - remain a concern for shoulder MR at 7.0 T. While today's lion's share of UHF-MR examinations covers brain and neuroscience applications, in musculoskeletal MR is another field that can benefit from UHF-MR. Our results provide encouragement and may be expected to continue to drive clinical UHF-MR research with the ultimate goal to advance the capabilities of shoulder MR.

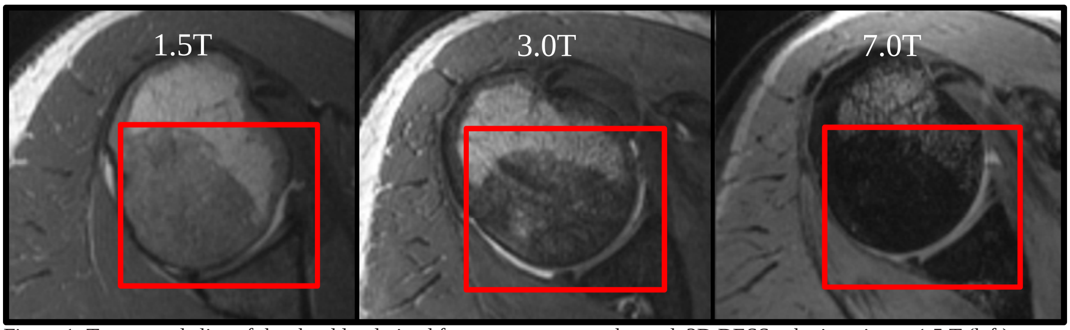

Figure.1: Transversal slice of the shoulder derived from non contrast enhanced, 3D DESS echo imaging at 1.5 T (left), 3.0 T (middle) and 7.0 T (right). The ROI marked red marks the region of interest of the anterior and dorsal labrum used for imaging quality assessment. Imaging parameter were TR=15.85ms, TE=5.41ms, TA=2:14 min, voxel size (0.6 x 0.6 x 1.5) mm³ at 1.5 T; TR=15.85ms, TE=5.41ms, TA=1:12 min, voxel (0.6 x 0.6 x 1.5) mm³ at 3.0 T and TR=15.85ms, TE=5.41ms, TA=1:10 min, voxel (0.6 x 0.6 x 1.5) mm³ at 7.0 T.
For all field strengths a flip angle=25° was applied.

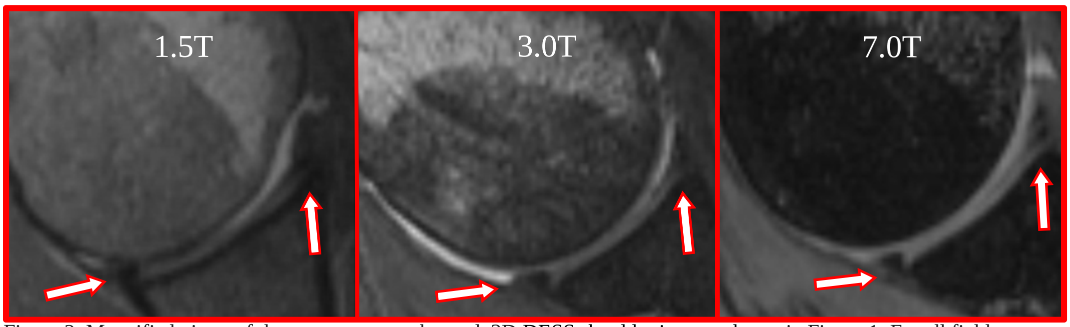

Figure.2: Magnified views of the non contrast enhanced, 3D DESS shoulder images shown in Figure 1. For all field strengths high image quality was obtained. At 7.0 T an improved delineation of the labrum structure between humerus and glenoid was observed. The local 12 channel transceiver coil array provided excellent signal uniformity at 7.0 T.

References: [1] Graessl et al ISMRM, No.1820, 2014; [2] Umutlu et al 7 Tesla MR Imaging, RöFo, 2014; 186:121-129