7 Tesla MRI of the hip joint in patients with avascular necrosis

Oliver Kraff[1,2], Stephan Orzada[1,2], Mark E Ladd[1,2], Stefan Landgraeber[3], Thomas C Lauenstein[2], and Jens M Theysohn[2]

[1]*Erwin L. Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, Germany,* [2]*Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Essen, Germany,* [3]*Department of Orthopedic Surgery, University Hospital Essen, Essen, Germany*

Introduction: Magnetic resonance imaging plays an important role in assessing abnormalities of the hip joint. While the feasibility of 7 Tesla hip imaging has been shown by Ellermann et al. in 2010 [1], the aim of this study was to compare various gradient and spin echo sequences of a typical, clinical examination protocol to stage patients with avascular necrosis (AVN). AVN often leads to destruction of the joint articular surfaces making high-resolution imaging mandatory.

Method and materials: Five healthy volunteers and five patients with AVN were imaged at 7T (Magnetom 7T, Siemens Healthcare) using an eight-channel transmit-receive body coil [2]. For RF shimming, relative B1 maps were used to adjust the phase of each individual channel to obtain homogeneous excitation of the region of interest [3]. Identical sequences (MEDIC, DESS, PD/T2w TSE, T1w TSE, and STIR) were acquired at 3T (Skyra, Siemens Healthcare) by keeping resolution and TA fixed. Imaging parameters are provided in Table 1. 7T images were evaluated regarding robustness against B1 inhomogeneities (4-point scale: 3/2=no/slight intensity/contrast variations, 1/0=strong degradation outside/inside ROI), and regarding contrasts between cartilage, bone marrow, cortical bone, and fluid ($CR = S_1-S_2 / S_1+S_2$)). Results were compared to 3T, and subjective differences in the depiction of lesions were noted.

	TR/TE [ms]	Flip angle	Resolution [mm^3]	TA [min:sec]
MEDIC	1000/15	30°	0.8 x 0.8 x 1.5	5:28
DESS	11/4.2	15°	0.4 x 0.4 x 1.5	6:58
PD/T2 TSE	4350/29-88	180°	0.8 x 0.8 x 3.0	3:26
T1 TSE	900/8.3	180°	0.8 x 0.8 x 2.0	1:35
STIR	5000/31; TI 250	180°	1.0 x 1.0 x 3.0	3:32

Table 1: *Imaging parameters.*

Results: Overall, the regions of interest could be imaged with reproducible high quality at 7T (except for STIR) by shifting B1 inhomogeneities to neighboring areas. While almost absent at 3T, all sequences at 7T showed signal variations, with DESS proving most robust (grade 3.5) and STIR least favorable (grade 2.0). STIR images were impaired by variations in signal homogeneity and fat suppression. MEDIC, PD/T2w, and T1w imaging showed strong signal dropouts, which could be adequately shifted away from the FOV. 7T MRI exhibited strong contrasts between cartilage and fluid for MEDIC, DESS, PD, and T1w imaging and also between cortical bone and marrow for T2w and STIR imaging. 3T MRI provided stronger contrasts between cartilage and bone for MEDIC and DESS imaging. Due to the higher contrast ratios at 7T, necrotic areas appeared more distinct compared to 3T.

Fig. 1

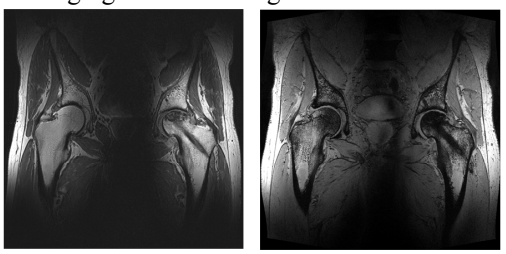

Fig. 2

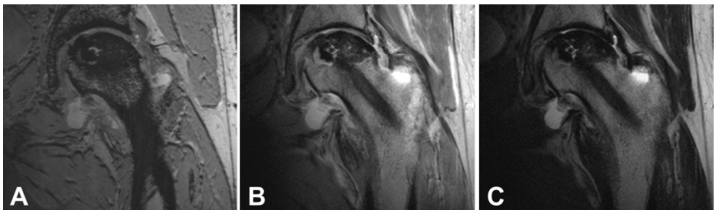

Fig. 3

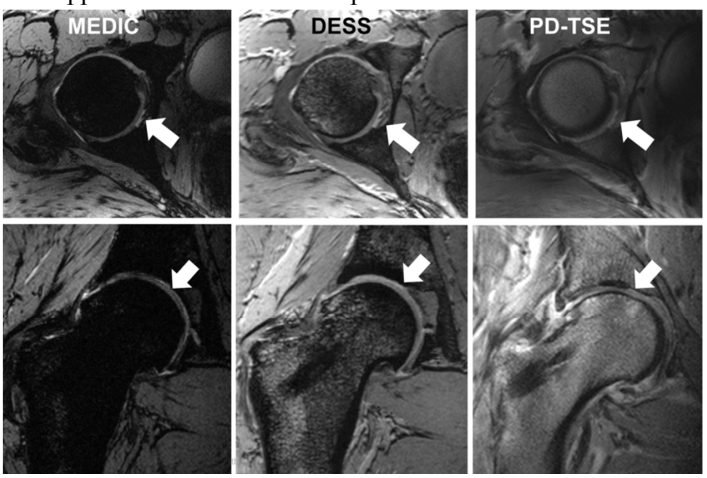

Fig. 1: *Coronal views of a T1 TSE (left) and DESS (right) sequence at 7T showing AVN of the left hip. B1 inhomogeneities were successfully shifted away from the femoral heads. The black band in the left hip marks bone loss due to needle insertion during treatment prior to imaging.*
Fig. 2: *A lesion in the femoral head could be very well depicted at 7T with DESS (A), PD- (B), and T2-weighted (C) TSE.*
Fig. 3: *Highest contrast ratios between cartilage and fluid (arrows) were obtained in MEDIC (CR = 0.5), DESS (CR = 0.6) and PD-TSE (CR = 0.2). Top row shows 7T images of a healthy volunteer compared to corresponding images of a patient (lower row).*

Conclusion: Pathologies of the femoral head could be displayed in great detail at 7T, while sacrificing image quality of the surrounding soft tissue (a consequence of RF shimming). While gradient echo sequences and TSE rendered homogeneous signal and high contrast in the region of interest, the STIR sequence needs further improvement. For gradient echo images, overall image quality was comparable to 3T. The proposed examination protocol could be used for future high-resolution staging of patients with AVN.

References: [1] Ellermann J, et al., ISMRM 2010, #849; [2] Orzada S, et al., ISMRM 2009, #2999; [3] van de Moortele PF, et al., ISMRM 2009, #367