Experience in imaging healthy volunteers and patients with implants at 7T

Yacine Noureddine[1,2], Andreas K. Bitz[2,3], Markus Thürling[2,4], Karsten H. Wrede[5], Mark E. Ladd[2,3], Gregor Schaefers[1], and Oliver Kraff[2,6]

[1]MR:comp GmbH, Dept. of Consulting, MR safety testing Laboratory, Gelsenkirchen, NRW, Germany, [2]Erwin L.Hahn Institute for MRI, University Duisburg-Essen, Essen, NRW, Germany, [3]Division of Medical Physics in Radiology, German Cancer Research Center (DKFZ), Heidelberg, BW, Germany, [4]Department of Neurology, University Duisburg-Essen, Essen, NRW, Germany, [5]Clinic for Neurosurgery, University Hospital Essen, Essen, NRW, Germany, [6]Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Essen, NRW, Germany

Introduction: Over the last decade the number of in vivo human MRI studies at 7 T has increased dramatically, and recent results in neuroimaging indicate that this field strength will probably become a diagnostic modality in the near future[1]. Since 7 T examinations are not yet medically indicated and there is only limited MR conditional labeling information about the safety of implants as well as the contraindication by MR manufacturers for metallic and electrically conductive structures, many 7 T research centers conservatively exclude all subjects with implants, regardless of type or location. This tendency motivates the safety assessment of implants. Some sites have already started to perform dedicated safety tests of implants[2,3,4] or have included carefully selected subjects with implants. This study presents our experience in imaging patients and healthy volunteers with implants other than dental implants at 7 T.

Material and Methods: Over the last seven years, 39 patients and healthy volunteers with miscellaneous implants who were cleared for 7 T MRI by a case-by-case decision from a local panel of MR safety experts underwent imaging at our institution. 19 subjects presented with orthopedic implants, three with vascular or biliary prostheses, two with removable infusion pumps, 13 with intrauterine devices, and two with extracranial neurosurgical implants.

Orthopedic implants: One subject had a biopolymer screw to support the anterior cruciate ligament (ACL) and another subject an endobutton (12 mm x 4 mm) made of titanium (Fig. 1), also for reconstruction of the ACL. A CP birdcage knee coil (Invivo Corp., FL) was used for imaging in these two cases, with the implants located directly in the exposure volume of the transmit coil. For the remaining 17 subjects, implants were located at least 40 cm from the exposure volume of the transmit coil. Three subjects presented with knee implants: one subject had a total knee prosthesis (Smith and Nephew, Legion Oxinium) in both legs and two had titanium screws. Four had an implant in the ankle area, two had titanium osteosynthesis plates and two had several titanium screws to fix the ankle joint. Two subjects had titanium screws in their wrist, and four other subjects reported titanium screws in their feet. One subject had an osteosynthesis plate in the clavicle and another reported titanium screws in the cervical vertebrae. The last three subjects reported implants in the hip area: one subject had a total hip prosthesis (DePuy, ASR TM), and two subjects reported titanium screws in this area. Subjects were imaged with an 8-ch loop coil (Rapid Biomed, Germany) (5), with a CP birdcage Tx / 32-cha Rx array head coil (Nova Medical, NY) (10), and with two custom-built 8-ch TxRx stripline coils for the body (1) and for the head (1).

Vascular and biliary prostheses: Three subjects reported stents. The first subject had a biliary stent (Advanix™, Boston scientific, Natick, MA) directly located in the exposure volume of the transmit coil. The liver of the subject was imaged with a custom-built 8-ch TxRx stripline body coil and the stent made of polyethylene was located in the area of the gallbladder. For the other two subjects, the stents were not located in the exposure volume of the transmit coil: one subject had a stent in the femoral artery while undergoing a head examination, and the other subject reported a Y-stent and a coronary stent and was also imaged in the head area. The stents were made of non-ferromagnetic materials.

Extracranial neurosurgical implants: Two subjects reported extracranial neurosurgical implants. One subject reported three miniplates at the top of the skull as shown in Fig. 2d. The miniplates (Biomet Microfixation, Jacksonville, FL) are quadratic (12.5 mm x 12.5 mm), 1 mm thick, and each plate can be fixed with 4 screws of 4 mm length. The patient was imaged with a custom-built 8-ch TxRx stripline head coil. The patient was scanned three times, once before surgery and then twice after surgery (within 72 hours and 3 months post-surgery). The second subject reported three miniplates (MatrixNeuro, model 04.503.075, Synthes, West Chester, PA, USA) made of titanium with a dimension of 21 mm x 11 mm and a thickness of 0.4mm. The subject was imaged with a CP birdcage Tx / 32-ch Rx array head coil (Nova Medical, NY).

Intrauterine devices: Among the 13 subjects with such implants, seven reported a hormonal uterine device (Mirena). Three others reported a NuvaRing®, and the final three subjects reported non-hormonal copper uterine devices. None of the intrauterine devices were located directly in the exposure volume of the transmit coil.

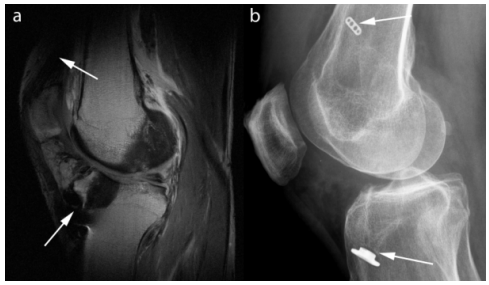

Fig. 1: Images of a patient (m, 36y) with a titanium endobutton for the reconstruction of the anterior cruciate ligament. Signal loss is clearly visible in the PD-weighted turbo spin echo sequence (a, arrows). In (b), the corresponding CT image is shown.

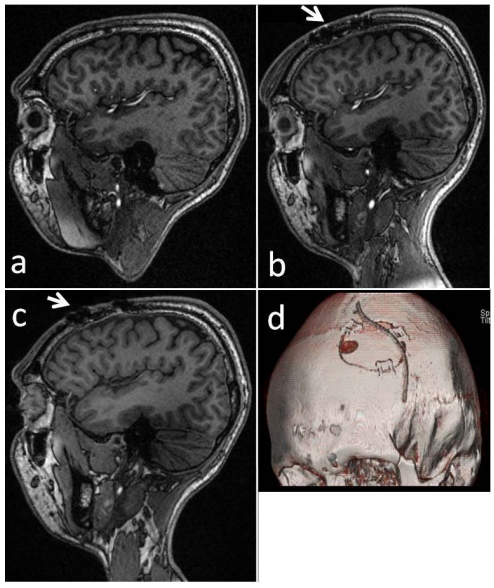

Fig. 2: Comparison of 7T images obtained in a patient with 3 miniplates. In (a) the patient was imaged before surgery (without implant) and in (b) and (c) the subject was imaged 72 hours and three months after surgery, respectively. In (d) a surface rendering of a CT scan shows details of the implant positioning.

Infusion pumps/needles: Two subjects had an infusion pump (Medtronic, MiniMed Paradigm Pumps, model MMT-512WWL). For both of them, the pump was removed and only the cannula and a polytetrafluoroethylene (Teflon) needle remained in place. Since the needle was made of non-metallic material, the subject was cleared for imaging. Furthermore, the needles were not directly in the exposure volume of the transmit coil.

Results: None of the 39 subjects reported any discomfort related to heating or force during or after imaging**.** Most of the subjects were imaged at 1.5 T or 3 T prior to the 7 T examination. For the orthopedic implants, artifacts were clearly visible in the subject with a titanium endobutton in the knee as shown in Fig. 1a. In Fig. 1b the corresponding CT image is given. For the subject with a polymer screw, no artifacts in the vicinity of the screw were visible. The presence of the neurosurgical implants resulted in small artifacts in their direct vicinity but did not influence image quality within the brain parenchyma as shown in Fig. 2.

Discussion & Conclusion: Since 7 T examinations are not yet medically indicated and since there is only limited information available about the safety of implants at 7 T, imaging should only be performed in carefully selected volunteers and after acquirement and evaluation of substantial information about the implants. The region of interest of the scan has to be compared with the exact location of the implant. This is particularly relevant at 7 T since only local transmit coils are used and RF heating is highly correlated with the exposure volume of the transmit coil. However, also travelling wave effects must be considered at 7 T. Implants made of non-metallic materials such as Mirena and Nuvaring intrauterine devices, Advanix stents (polyethylene), and Teflon needles are not expected to generate force and torque. For infusion pumps, particular vigilance was observed by determining the exact needle material, since it is well known that some needle material may be made of metal. At our institution, a case-by-case decision was made in consensus by a safety panel consisting of three well-experienced MR physicists for all subjects with implants, depending on size, geometry, and location of the implant with respect to the RF coil. In selected cases, e.g. for the neurosurgical implants, a dedicated safety assessment[2] was performed prior to clearance for imaging. Our initial experience at 7 T indicates that the exclusion of all subjects with implants from 7 T examinations is not compulsory. The examination of certain subjects with implants can be performed after careful evaluation of implant type and location.

References: [1] NMR Biomed 2012; 695-716 [2] Med Phys 2013;40(4):042302 [3] PloS One 2012;7(11):e49963 [4] Magn Reson Imaging 2013;31(6):1029-103