Effect of Cranial Fixation Plates on Brain MR Imaging at 7T in Neurosurgical Patients

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Target Audience: Researchers with interest in clinical UHF imaging and implant safety.

Introduction:

In the last years, the quantity and applicability of ultra-high-field (UHF) magnetic resonance imaging (MRI) studies has increased rapidly, demonstrating diagnostic benefits especially in neuro imaging[1, 2]. Today, MRI is the primary diagnostic tool in neurosurgical patients and mandatory in scans before and after tumor resection. Recently, commonly used titanium cranial fixation plates were classified as MR conditional in simulations and safety studies on head models[3-5]. However, artifacts caused by cranial implants have not yet been quantified in vivo. The presence of metal leads to strong susceptibility variations between the metal and surrounding tissue, resulting in rapid signal dephasing. Also, the metal induces resonance frequency changes, so that MR signal can be shifted away (signal loss) or accumulated in a particular region (pile-up artifact). The incomplete inversion of magnetization in MPRAGE sequences also manifests as hyperintense regions close to implants[6]. In this prospective in vivo study, we aimed to identify potential problems and evaluate imaging artifacts after neurosurgical implantation of cranial fixation plates at 7 Tesla (T).

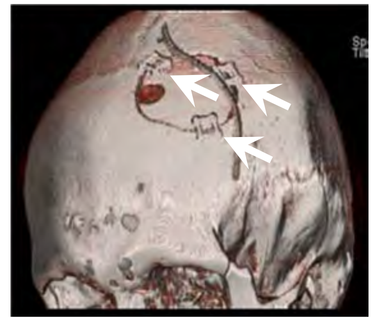

Fig. 1: *CT surface rendering showing implant positioning.*

Material and Methods:

Five patients treated for various intracranial pathologies were included in the study after written informed consent between April 2013 and October 2014. The study was conducted according to the principles expressed in the Declaration of Helsinki and was approved by the local university institutional review board. All patients underwent craniotomy for neurosurgical treatment of intracranial pathologies. For cranial bone flap fixation, three square miniplates (Biomet Microfixation, Jacksonville, FL) were used (Fig. 1). Imaging at 3T and 7T was obtained in three examinations per subject: Preoperative (1-2 days prior to surgery), postoperative (within 72 h after the surgery), and long-term postoperative (3-4 months after the surgery). MRI scans were performed at 3T (Magnetom Skyra 3T, Siemens) with a 64-channel head/neck receive array, and at 7T (Magnetom 7T, Siemens) with a custom-built 8-channel transmit/receive head coil that had also been used in a safety assessment for these implants[3]. Acquired sequences included B1 mapping, time-of-flight (TOF), magnetization-prepared rapid acquisition gradient-echo (MPRAGE), susceptibility weighted imaging (SWI), echo-planar imaging (EPI), and PD/T2 weighted turbo spin echo (TSE). Image quality and presence of artifacts, especially in the intracerebral resection area, were rated by two neuroradiologists in consensus reading.

Results:

All 3T and 7T scans were performed successfully without any relevant side effects. Two patients suffered from meningiomas, one patient had multiple cavernous malformations, one presented with a low grade glioma, and one patient suffered from hemifacial spasm. One patient had to be excluded from the immediate postoperative 7T scan because of his medical condition and need for intensive care monitoring. None of the individuals reported discomfort or heat sensations in the implant area during the postoperative 3T or 7T scans. No evidence of implant migration was found. B1 mapping yielded only minor differences of 5% in transmitter reference voltage between individual scans per subject. Small artifacts around the cranial fixation plates occurred in TOF and MPRAGE, but depiction of adjacent brain tissue was not affected as shown in Figure 2. There was no difference between the immediate postoperative scans and the subsequent 3-month follow up scans. In SWI, local artifacts were accentuated with involvement of cortical structures adjacent to the dura. The typical size of susceptibility artifacts at 7T ranged between 12-20 mm, similar to corresponding artifact dimensions found at 3T (Figure 3). As expected, artifacts were clearly visible in the 7T EPI and TSE images, but remained within the direct vicinity of the metal objects, not affecting image quality in any of the datasets within brain tissue. Even EPI images were not disturbed due to susceptibility changes more than usual in the regions of interest. There was no difference between the immediate postoperative scans and the 3-month follow-up scans.

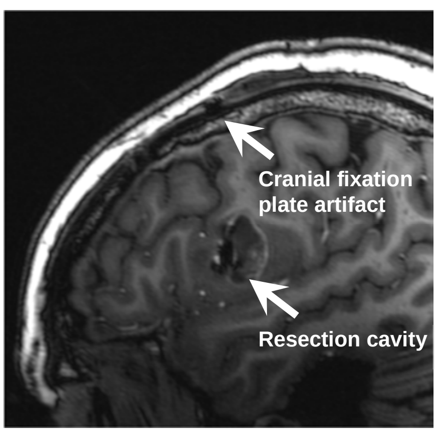

Fig. 2: *Minor artifacts in the MPRAGE with the visualization of brain tissue.*

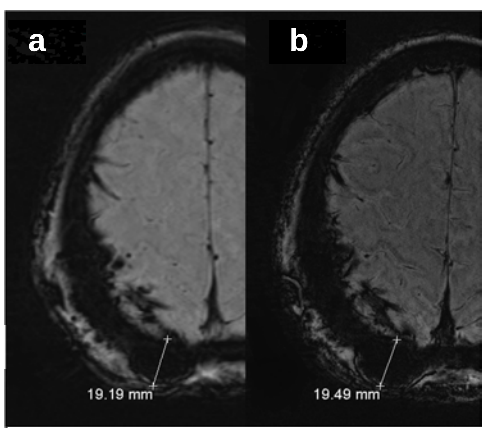

Fig. 3: *Cortical interferences of comparable extent in the SWI at (a) 3T and (b) 7T.*

Discussion and Conclusion:

Titanium cranial fixation plates, regularly used for bone flap fixation during neurosurgical procedures, only caused minor artifacts in postoperative TOF and MPRAGE at 7T, comparable to artifacts at 3T. Postoperative depiction of adjacent cortical structures in SWI was impaired by susceptibility artifacts, comparable to artifacts at 3T. Diagnostically useful images were obtained in all settings, demonstrating less image impairment than might be expected at 7T and indicating the suitability to implement 7T into routine clinical diagnostics in the near future.

References: 1. Kraff et al. J Magn Reson Imaging. 2014 Jan 30. 2. van der Kolk et al. Eur J Radiol. 2013 May;82(5):708-18. 3. Kraff et al. Med. Phys. 2013;40(4):042302. 4. Sammet et al. Magn. Reson. Imaging 2013;31(6):1029-34. 5. Rauschenberg et al. ISMRM 2010, abstract 778. 6. Hargreaves et al. AJR Am J Roentgenol. 2011;197(3):547-55.

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