MR Safety Measurements of Intracranial Fixation Devices at 7T

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Introduction

After brain surgery, cranial fixation systems are often implanted for craniotomized bone flaps. The widely used fixation system CranioFix® was tested to be MR safe only up to 3T [1]. As many tumor patients have one or more intracranial fixation implants, up to now these patients have to be excluded from 7T studies. In this work we demonstrate that the intracranial fixation implants can be considered as MR safe also at 7T for the hardware used.

Materials and Methods

To test the MR safety of the implants (CranioFix®, Diameter: 11 mm, 16 mm, and 20 mm, Aesculap AG, Tuttlingen, Germany) standard testing methods (ASTM [2-5]) were performed at a 7T System (Magnetom, Siemens, Erlangen Germany). To emulate a realistic scenario, the end plates were pushed together at the maximum cranial bone diameter (1 cm) and the fixation rod was shortened.

Displacement due to magnetic force: The tested objects were attached to an acrylic glass holder via a 140 mm-long thread. In the fringe field of the MR system both the magnetic force F_M and gravitational force F_G affect the object. At $\alpha > 45°$ F_M is stronger than F_G, and the object might be accelerated towards the point of strongest magnetic field. The z-position of the strongest displacement was 1383 mm distant from the isocenter where $B_0 = 4430$ mT and $dB/dz = 6.83$ T/m.

Torque: The implants were positioned at three angles referred to the B_0 field (0°, 90°, 45°) in a transparent plastic cup with an angle scale fixed at the bottom [6]. Possible torque was detected during slow movement of the patient table into the magnet.

Heating of the surrounding tissue: The effect of RF-induced temperature rise was measured with an optical fiber temperature measurement system (Fotemp, OPTOcon GmbH, Dresden, Germany, accuracy: 0.1°C). To perform the worst case scenario, two implants were positioned close together in phantom material with the same conductivity as human tissue. Three optical fibers were fixed close to the implants as shown in Fig. 1. A reference fiber was positioned 80 mm away from the implants (fiber 4). The set up was sited in a 24 channel head coil (Nova Medical, Inc., Wilmington, USA) with the implants as close as possible at the transmit coil (approx. 3 cm). The fixation rods of the implants were first placed parallel to B_0 and subsequently perpendicular to B_0. During TSE and GRE pulse sequences (TA = 20 min) with SAR = 100% (whole body SAR = 0.2 W/kg) temperature rise was recorded with a sampling rate of 5 s.

Image artifacts arising due to the implants: GRE (TR/TE= 8.8/3.14ms, α=14°, BW=310Hz/pix, pixel size=0.5×0.5×1 mm) and TSE (TR/TE= 12000/57ms, α=120°, BW=100Hz/pix, pixel size=0.5×0.5×1 mm) images were acquired. Artifact sizes were measured in the image with the maximum artifact width.

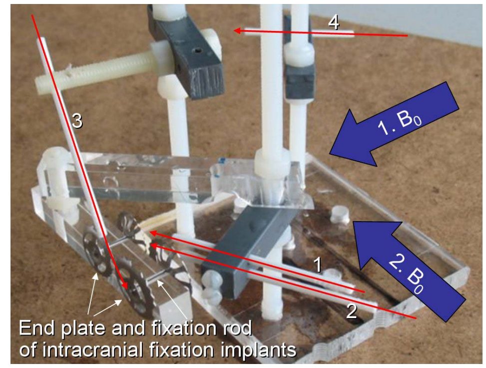

Fig.1: Setup of the temperature measurements. Fixation rods were first parallel and second perpendicular to the static magnetic field B_0. Red arrows mark the optical fibers for temperature acquisition.

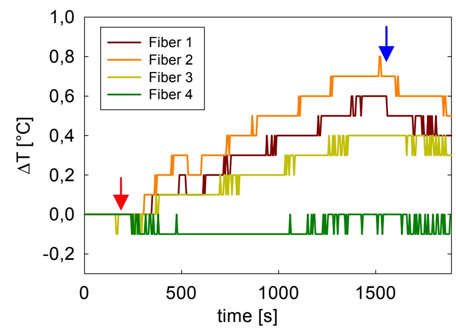

Fig. 2: Relative temperature rise ΔT measured by all fibers as function of time. Start/end of the TSE sequence is marked with a red/blue arrow.

Results and Discussion

Force measurements show a deflection angle of less than 7° and no torque could be detected. Figure 2 shows the maximum temperature rise appeared at fixation rods parallel to B_0 and TSE imaging. The highest ΔT = 0.8°C (fiber 2) was detected between the two implants. Figure 3 presents exemplary coronary and sagittal GRE and TSE images. The difference between artifact and object size does not exceed 6 mm at the end plates.

As the magnetic force is much less than the gravitational force, no torque could be detected, and the temperature rise during 20 min was less than 1°C the intracranial fixation implants can be considered MR safe. The image artifacts at standard pulse sequences are acceptable. Figure 4 shows the first image at 7T of a glioblastoma patient with an implanted intracranial fixation device. Although adjacent to the cerebral cortex, the implant does not affect identification of cortical structures. Moreover, the image assessed at 7T allows for distinguishing different layers of the cortex in the vicinity of a fixation device.

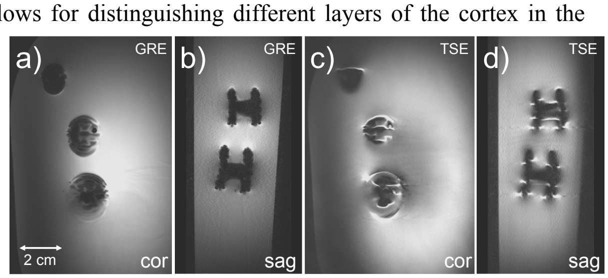

Fig. 3: Exemplary GRE a) coronary and b) sagittal images and TSE c) coronary and d) sagittal images of the implants.

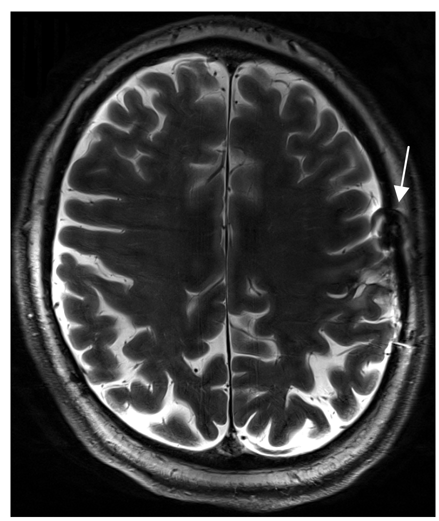

Fig. 4: T2w image of patient with intracranial fixation implant (white arrow).

Acknowledgement

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References

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