Effects of 7 Tesla MRI on postural stability with and without RF, gradient switching, or B0 exposure

J. M. Theysohn[1,2], O. Kraff[1,2], S. Maderwald[1,2], M. Gerwig[3], D. Timmann[3], F. Schmitt[4], L. Schaefer[1,2], S. Blex[1,2], E. R. Gizewski[1,2], M. Forsting[1,2], M. E. Ladd[1,2], S. C. Ladd[1,2], and A. K. Bitz[1,2]

[1]Department of Diagnostic and Interventional Radiology and Neuroradiology, University Hospital Essen, Essen, NRW, Germany, [2]Erwin L. Hahn Institute for Magnetic Resonance Imaging, University Duisburg-Essen, Essen, NRW, Germany, [3]Department of Neurology, University Hospital Essen, Essen, NRW, Germany, [4]Siemens Healthcare, Erlangen, Germany

Introduction:

Magnetic resonance imaging [MRI] is known as a safe diagnostic imaging procedure without harmful long-term effects for personnel or patients when conducted in accordance with safety regulations (IEC, FDA). As far as is currently known, this also applies to ultra-high-field MRI with static magnetic field strengths of 7 Tesla and above, which are currently only used in research. Nevertheless, transient side-effects are reported more frequently at higher field strengths, and are often associated with the insertion into and movement through the magnetic field. Dizziness is among the most often reported sensations, the most probable mechanism being the induction of electrical currents inside the inner ear due to the movement of the electrically conducting tissue of the head inside the spatially varying magnetic field [1]. Furthermore, subjects often report a subjective postural instability after the examination, even outside the scanner room, which until now has not been fully explained or investigated. The current study aims at quantitatively assessing this subjective effect by measuring postural instability before and after exposure to different aspects of a 7 Tesla MRI examination.

Methods:

In total, forty-nine neurologically healthy volunteers (35m, 14f, mean age 32y) underwent a Romberg's test before, 5 minutes after, and 15 minutes after 7 Tesla exposure. The following different exposure scenarios were evaluated: complete examination (n=20); examination without radio-frequency radiation (n=19, "RF sham"); examination with neither RF nor gradient switching (n=10, "MF"); exposure to only movement into the center of the magnet and back out (n=10, "PTAB") with no extended duration in the isocenter; and finally, exposure to no MR electromagnetic fields while lying on a bed (n=10; "control"). All exposures except "PTAB" lasted for 30 minutes. The MR examination was performed with a whole-body 7T MRI (Magnetom 7T, Siemens Healthcare, Erlangen, Germany) and an eight-channel transmit/receive head coil (Rapid Biomed, Wurzburg, Germany). The Romberg's test was performed while standing on a 20 cm thick foam cushion with feet close together and with open or closed eyes while wearing ear plugs (to dampen surrounding noise). When standing on the cushion with eyes closed, stance stability is heavily dependent on vestibular system function [2]. Analysis of the body motion was performed with an ultrasound real-time measuring system (Zebris Medical Systems, Germany), recording 3D positions of sensors fixated to the lumbar spine. Each condition was measured for 30 seconds. Data were evaluated to determine the sway path length. Mean values were compared for the different time points and regarding the different eye states (open/closed) using one-way ANOVA for repeated measurements and post-hoc Bonferroni correction for statistical evaluation.

Results and discussion:

In Fig. 1 the sway path length is shown as a measure for postural stability for all volunteers. Results for tests with eyes open show no significant differences in postural stability between experiments before and after MR examination. However, for eyes closed the sway path showed variations. After complete exposure the sway path was significantly (p=0.0003) increased 5 min after the MRI examination, indicating a postural instability which was normalized after 15 min. An analogous strong tendency (p=0.1, borderline significance) was also apparent for exposure without RF. Interestingly, preliminary results after evaluation of the first ten volunteers showed decreased sway path values 5 minutes after exposure for groups with only extended B_0 exposure (MF) and transient movement through B_0 (PTAB). The control group showed no significant variations. The different results with "eyes closed" compared to "eyes open" indicate that the instability can be attributed to the vestibular system. Since results with and without RF were similar, RF does not appear to be responsible for the increased sway, as expected. Reduction of the sway path length after magnetic field exposure alone is not anticipated. To increase the statistical power of this finding, additional volunteers are currently being included into the study. Since no significant effects were measured for the control group without MRI exposure, physiological effects due to orthostatic regulation after returning to the upright position do not seem to have an effect.

Conclusion:

The results show that exposure to a complete 7 Tesla MRI examination of the head only temporarily causes a dysfunction or over-compensation of the vestibular system. This effect does not seem to be related to exposure to the 300MHz RF energy. Investigation of a larger number of volunteers and a comparison to lower field strengths will be the aim of further work.

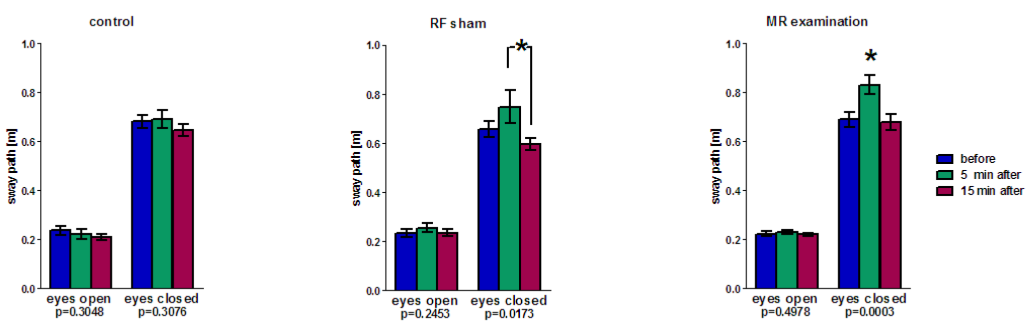

Fig 1: Statistical evaluation of sway path length as indicator of postural stability: mean ± SEM; one-way ANOVA for repeated measurements; post-hoc Bonferroni (* p<0.05).

[1] Glover PM, et al. Magnetic-field-induced vertigo: a theoretical and experimental investigation. Bioelectromagnetics. 2007. 28:349-361.
[2] Mirka A, Black FO. Clinical application of dynamic posturography for evaluating sensory integration and vestibular dysfunction. Neurol Clin. 1990 May;8(2):351-9. Review