

## ***Weekend Educational Course: A Practical Guide to MR Safety***

### **MR Safety: Where Do the Risks Come From?**

Harald Kugel, Ph.D., Department of Clinical Radiology, University of Muenster, Germany  
kugel@uni-muenster.de

#### **Introduction**

Magnetic resonance techniques are considered to be not harmful. The three electromagnetic fields used for MR - static magnetic field, switched gradient fields, and radio frequency field - do not result in irreversible changes of the tissue, as long as certain limits are not exceeded. However, the applied fields show interactions, which may cause severe hazards for patients, staff, and material, if they are not properly accounted for or if MR examinations are performed carelessly.

#### **Objective**

Information about the potential dangers

- of the static magnetic field (interactions with cells and tissues, interactions with ferromagnetic objects, force and torque, requirements for MR safe implants and devices),
- of the low frequency switched gradient field (induction of low frequency (= audio frequencies) currents in nerves, peripheral and cardiac nerve stimulation, noise),
- of the radio frequency field (interaction with tissue: warming (RF absorption, SAR); interaction with metals and conducting material: induction, heating, sparking, burns caused by current loops with skin contact; requirements for MR safe implants and devices),
- of the cryo system (loss of cooling/quench, handling of cryogenic agents).

#### **1. Risks associated with the static field $B_0$**

Up to now reproducible permanent effects of static magnetic fields within the range used for MR that cause health problems have not been reported [1]. However, the static field  $B_0$  causes the hazard of most concern. As it is commonly produced by a superconducting coil, it is always switched on. Ferromagnetic objects may be accelerated towards the magnet and hurt persons lying in the scanner or standing near the bore opening. Ferromagnetic implants may be dislocated, damaging tissue. Fatal outcomes have been reported [2,3]. The field extends with significant strength several meters around the scanner, a field strength is 0.5 mT defines the border of the 'controlled access area', which must be blocked to the general public [4] to prevent impairment of active implants, e.g. pacemakers.

#### **2. Risks associated with rapidly switched magnetic fields (gradient fields)**

Concerning safety, two effects are of relevance. The first is peripheral nerve stimulation. Its occurrence depends on gradient steepness and switching time. The exact function depends on the model applied [5], and people are differently susceptible to stimulation [6]. Peripheral nerve stimulation is not by itself dangerous, but it is taken as last noticeable limit before the possible generation of stimulation in vital nerves, e.g. cardiac nerves, which must be avoided at any case. The second effect is noise production. Noise levels of 99 dB(A) may be reached, sometimes even more, and hearing damage is possible [7].

#### **3. Risks associated with the pulsed radiofrequency field $B_1$**

The radio frequency field has a significant power only inside or adjacent to the excitation coil. In most case the body coil is used for excitation, so that the RF field stretches over a significant

portion of the body. The main concern is heating due to eddy currents, which can be rather high especially in the presence of metallic implants. The danger of heating hazards is commonly underestimated. Most MR accidents reported in the FDA collection of reports on adverse events (the Manufacturer And User facility Device Experience, MAUDE [8]) refer to burns [9]. Heat release at skin-skin contacts in loops formed by arms or legs may cause severe burns at the contact point. Even second or third degree burns have been reported [10]. In metallic implants the current is higher than in surrounding tissue. At crossover points of the current into or out of the implant the local current density in the tissue may be so high that burns are possible. Similar effects may occur in wires outside the tissue, but inside the excitation coil. Especially at bad connections sparking may occur, which in the extreme case may ignite inflammable material [11].

#### **4. Risks associated with the cryogenic system**

In addition to the electromagnetic fields cryogenics used in superconducting magnets must be considered. The cryogenic system poses a risk only in case of a quench, which in most sites never happens. However, careful maintenance of the cryo system and the quench lines is mandatory to prevent the danger of an in-room quench. This has happened a couple of times, and severe damage to buildings is reported.

#### **References**

- [1] Schenck JF (2005) Physical interactions of static magnetic fields with living tissue. *Progress in Biophysics and Molecular Biology* 87:185-204
- [2] Chen DW (2001) Boy, 6, Dies of skull injury during MRI. *The New York Times*, July 31, 2001
- [3] Klucznik RP, Carrier DA, Pyka R, Haid RW (1993) Placement of a ferromagnetic intracerebral aneurysm clip in a magnetic field with a fatal outcome. *Radiology* 187:855-85
- [4] International Electrotechnical Commission, IEC (2010) Medical electrical equipment - Part 2-33: Particular requirements for the basic safety and essential performance of magnetic resonance equipment for medical diagnosis. International Standard IEC 60601-2-33:2010: International Electrotechnical Commission, Geneva
- [5] Schaefer DJ (1998) Safety aspects of switched gradient fields. *Magn Reson Imaging Clin N Am* 6:731-748
- [6] Bourland JD, Nyenhuis JA, Schaefer DJ (1999) Physiologic effects of intense MR gradient fields. *Neuroimaging Clin N Am* 9:363-377
- [7] McJury M, Shellock F (2000) Auditory noise associated with MR procedures: A review. *J Magn Reson Imaging* 12:37-45
- [8] MAUDE Manufacturer and user facility device experience  
[www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/TextSearch.cfm](http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfmaude/TextSearch.cfm)
- [9] Hardy PT, Weil KM (2010) A review of thermal mr injuries. *Radiologic Technology* 81:606-609
- [10] Knopp MV, Essig M, Debus J, Zabel HJ, van Kaick G (1996) Unusual burns of the lower extremities caused by a closed conducting loop in a patient at MR imaging. *Radiology* 200:572-575
- [11] Kugel H, Bremer C, Püschel M, Fischbach R, Lenzen H, Tombach B, Van Aken H, Heindel W (2003) Hazardous situation in the MR bore: Induction in EEG leads causes fire. *Eur Radiol* 13:690-694