

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

Target Audience

People working with an MR scanner

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 (= audio frequency) switched gradient fields (induction of current pulses in nerves, peripheral nerve stimulation, possible 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]. Transient effects causing slight indispositions are possible, usually related to movements in inhomogeneous sections of the field. 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 of 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 B₁

The radio frequency field has a significant power only inside or adjacent to the excitation coil. In most cases 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 also 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.

Conclusion

To prevent accidents and damages everybody working with an MR scanner must be informed about possible risks originating from the electromagnetic fields and the cryogenics of the MR system.

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