Weekend Educational Course: A Practical Guide to MR Safety

MR Safety: Where Do the Risks Come From?

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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 currents in nerves, peripheral and cardiac nerve stimulation, noise),
- of the radio frequency field (interaction with tissue: warming (SAR), interaction with metals and conducting material: induction, heating, sparking, burns with 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 in the range used for MR causing health problems have not been reported [1]. However, the static field B_0 causes the hazard of most concern. It is always on as it is commonly produced by a superconducting coil. Ferromagnetic objects may be accelerated towards the magnet and hurt persons 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. The main concern is heating due to eddy currents, 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 in 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

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.

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