MRI MAGNET SAFETY

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MRI is an imaging technique that involves no ionizing radiation (that is, radiation that can cause chemical reactions or damage DNA, like X-rays, CT, PET). Instead, MRI only uses static magnetic fields (the main field), slowly changing magnetic fields (gradients), and RF (radio frequency) electromagnetic fields. Because of this, subjects (including babies) can be repeatedly scanned with no harm, as long as standard safety procedures are followed.

There are two primary features of an MRI magnet that under special circumstances have the potential to cause injury -- the strong magnetic field and the RF transmit field. Here are the main points. MRI users must memorize the entire contents of this short document.

(1) The strong magnetic field

The strong magnetic field is harmless to living tissue. The danger comes from loose metal objects.

There are two counterintuitive features of the strong magnetic field surrounding an MRI magnet.

The first is that the field is ALWAYS ON, even when the magnet is not making noise, and even when all electrical power has been cut, with the all the room lights off and every single LED on the magnet off. The main superconducting coils are not 'plugged in'.

The second counterintuitive feature of the magnetic field around an MRI magnet is that its strength, as measured by the pull on a small piece of iron like a pair of pliers, goes from almost nothing to WAY beyond what you can manage to hang onto with your hands over a distance of a few feet. There is no bodily sensation upon entering this danger zone. Cinematic representations of magnetic fields are extremely misleading. Rely instead on your experience with a refrigerator magnet.

The primary danger due to the magnetic field is that it exerts an extremely strong force on ferromagnetic materials such as, but not restricted to, iron. Counterintuitively, some iron-containing alloys are non-magnetic (e.g., some kinds of stainless steel). If in doubt, test in the console room with the small magnet that is kept there.

Another key fact is that the attractive force is proportional to the weight of the ferromagnetic object. For iron objects, the force reaches 150 times the weight of the object for a 3T magnet. Thus, a small object without much iron in it (e.g., a small screw), can be controlled in one hand (with careful attention). A small chunk of iron weighing 5 pounds, by contrast, will experience a force approaching half a ton, easily enough to crush a bone, utterly foreign to everyday experience.

Finally, with even a small, controllable piece of iron or other ferromagnetic material, if it is accidentally released near the magnet, it will rapidly accelerate toward the center of the bore.

If nothing is in the bore, little damage may result, and hospitals routinely pull small piles of metal hair clips off of MRI magnets every year.

If an expensive head coil or motion camera or mirror is in the bore, the small flying object could damage it.

But if a *person* is in the bore ready to be scanned, they may be injured, even by a very small flying object, because it will 'aim' for near the center of the bore, right where their head is. A larger object can be lethal. The shattered glass from a flying laptop screen has caused severe facial lacerations in an fMRI experiment. A small forgotten oxygen tank underneath a hospital gurney has killed a hospital patient.

Thus, the first, more important safety take-home message is therefore: *once a person gets anywhere close to the edge of the bore, the danger from flying metal objects begins and doesn't stop until the person is safely out of the bore and away from the magnet*. As an experimenter, this danger profile is a bit counterintuitive because when the subject is finally all set up and ready to scan, or, just after an experiment finishes, it is easy to instinctively let one's guard down, right at the most dangerous times.

Finally, many humans now have metallic implants, especially as they get older. Even a small ferromagnetic object could be lethal in soft tissue (e.g., the brain). Though most permanent implants in soft tissue are MRI-safe (e.g., non-brain stents, hemostatic clips, copper coil IUD's), you must get permission from the scanner center director to scan such a subject. Non-electronic orthopedic implants (e.g., hip replacements) and bone screws are firmly attached to bone, are non-magnetic, and are generally safe to scan.

You must also screen for accidental metal implants (e.g., metal shavings caught behind the eye that could slice the optic nerve, bullets, shrapnel).

Flying metal object accidents rarely happen soon after researchers first encounter a magnet because they are still (rightly) scared of it. Similarly, after long experience with a magnet, magnet safety becomes second nature. The most dangerous time is when the initial fear of the magnet has worn off, but a person does not yet have the wisdom of years.

In the extremely unlikely emergency situation where someone has become trapped in a life- or limb-threatening position between a large metal object and the magnet, you can use the "quench" button (one is in the console room at the upper left side of the viewing window, and one is inside the magnet room, on the left wall) to immediately "quench" the superconducting magnetic field. This rapidly vents all of the liquid helium in the magnet, results in a minimum of several weeks downtime, and will cost us over $100K to repair. Do *not* quench the magnet if there is no threat to life or limb and a metal object has merely become stuck to the magnet.

In the event of an electrical fire, there is a red electrical shutoff button in the console room and another inside the magnet room on the inside of the front wall. These will *not* quench the magnet.

(2) The strong RF transmit field

The second main feature of an MRI machine that can lead to injury is the strong RF transmit field. Under normal circumstances, this has very minor effects on tissue, and the amount of RF energy deposited into tissue is strictly monitored and controlled by the magnet hardware and software.

However, if a long metal wire, or especially a loop of wire, is introduced into the magnet, it can absorb a lot more RF energy from RF transmit pulses than the human body can. It will then re-radiate this energy. If the wire loop is near the body, this re-radiated energy can cause a burn.

To avoid injury, long wires or wire loops must never be placed into the bore with a subject. To make a wire MRI-compatible (e.g., an MRI-compatible EEG lead) proper amounts of resistance is added to them at intervals to prevent them from resonating with the RF field and therefore picking up excess RF energy.

Finally, tattoos are generally safe to scan. In extremely rare cases, tattoos can absorb RF and cause local heating, so in cases of permanent cosmetic tattoos (e.g., eye liner, full upper body), subjects should monitor for any heating. The total RF power deposited by most standard anatomical and functional MRI scans (e.g., FSPGR, MPRAGE, gradient echo EPI for fMRI, spin-echo EPI for DTi) is quite low. High RF power sequences are fast/turbo spin echo sequences (e.g., FSE, SPACE), which can deposit 20x the RF power of a gradient echo sequence.