

## Hazards of the MR Environment

***"It is not possible to prove safety, one can only disprove it." -- E. Kanal, 1996***

Magnetic Resonance Imaging (including spectroscopy, conventional, and fast imaging techniques) have been in use for over a decade and are viewed as medical procedures associated with acceptable and well controlled risks. Technological advances in MRI (higher static fields, faster gradients, stronger RF transmitters) have occurred rapidly, and many questions regarding the safety of these developments remain unanswered. This document provides an introduction to some of the safety concerns associated with MR research and related pages address the practical implications of these safety issues:

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### **Static Magnetic Fields:**

**Projectiles.** The most immediate danger associated magnet with the environment is the attraction between the magnet and ferromagnetic metal objects. Ferromagnetic metal objects can become airborne projectiles when placed in a strong magnetic field. The strength of the field increases superlinearly with

distance from the magnet bore, and even hand-held objects can be jerked free very suddenly as the holder moves closer to the magnet (Small objects, such as paper clips and hairpins, have a terminal velocity of 40 mph when pulled into a 1.5T magnet). In addition to the possibility of severely injuring someone, it is not good for the magnet to be bombarded with difficult to remove small metal 'missiles'. Remember, even when you are not scanning, the magnet is not "off". NEVER bring any metal objects into the scanner rooms.

**Metal in the Body.** Metallic objects in the body can also have dangerous effects when placed in a magnetic field. Ferromagnetic metal implants or fragments may twist or move, causing internal injury. Even non-ferromagnetic metal (including metal on clothing) can heat up during scanning, and cause burns or discomfort. Many of the Athinoula A. Martinos Imaging Center's subject screening criteria are aimed at avoiding these hazards. In addition, metal in or near the body (such as dental implants) can produce artifacts, which adversely effect image quality.

### **Gradient Magnetic Fields:**

**Nerve Stimulation.** Another concern in MR Imaging is related, not to the strength of the static magnetic field, but to the transient application of magnetic field gradients that can induce current in conductive materials, including biologic tissue. The induced current is greater in peripheral tissue because the amplitude of the gradient is highest farther away from the magnet's isocenter. Mild skin sensations and involuntary muscle contractions, which are thought to be the result of direct neural stimulation, have been reported rarely during echo-planar imaging (EPI). This can usually be alleviated by simply repositioning the subject in the scanner.

**Acoustic Noise.** Another potentially hazardous effect related to gradient magnetic fields is the acoustic noise produced as current is passed through the gradient coils during image acquisition. For anatomical imaging, the noise is mostly of low frequency and has a "clunking" sound; for EPI, the noise can be of very high frequency (600-1400 Hz) and sounds like a loud "beep". Generally, the higher gradients used with higher magnetic fields and with EPI produce more intense noise. Prolonged exposure to this noise will damage the unprotected

ear. Even conventional scanning procedures, which produce noise within the recommended FDA safety guidelines, have been documented to cause reversible hearing loss in patients who did not wear ear protection\*. All research subjects should therefore wear hearing protection, in the form of earplugs or headphones, during scanning (both are recommended on the 3T). Also, researchers, or a parent accompanying the subject, must wear earplugs if they are in the magnet room during scanning. Earplugs must be the right size and properly inserted into the ear canal to obtain their full effect. This requires instruction and practice. It is the responsibility of the researcher to see that the subject is aptly fitted with hearing protection. Additional packing of the head with foam cushions further dampens the noise and is recommended in the 3T environment. Additional noise in the magnet environment comes from the magnet coolant pump, air handling system, and patient fan. While not dangerous, these other sources of noise can be annoying to subjects and can interfere with communication.

### **Radiofrequency (RF) Electromagnetic Fields:**

**Tissue Heating.** An RF pulse (a short burst of an electromagnetic wave originating from the RF coils) is used in MRI to "excite" tissue protons by an exchange of energy. This absorption of RF energy can potentially cause heating of the tissue. Absorption of RF power by the tissue is described in terms of Specific Absorption Rate (SAR), which is expressed in Watts/kg. (In the US, the recommended SAR level for head imaging is 3.2 Watts/kg.) SAR in MRI is a function of many variables including pulse sequence and coil parameters and the weight of the region exposed. However, the actual increase in tissue temperature caused by exposure to RF radiation is dependent on the subjects' thermoregulatory system (*e.g.* tissue perfusion, etc.). The risk of exposing subjects with compromised thermoregulatory function (*e.g.* elderly patients and patients taking medications that affect thermoregulation, such as calcium-blockers, beta-blockers, diuretics, or vasodilators) to MR procedures that require high SARs has not been assessed.

**Electrical Burns.** RF fields can cause burns by producing electrical currents in conductive loops. When using equipment such as surface coils, ECG or EEG leads, the investigator must be extremely careful not to allow the wire or cable to form a conductive loop with itself or with the subject. Coupling of a

transmitting coil to a receive coil may also cause severe burns.

### **Other Concerns:**

**Pregnancy.** There are no known adverse effects of MRI on developing fetuses. Most early studies on pregnant animals were negative for teratogenic effects, and a recent survey found no association between working in the MR environment and a number of pregnancy outcome variables\*. However, given the scarcity of data on the subject and the high susceptibility of the developing fetus to damage in general, we believe it is not worth the risk for pregnant women to participate as subjects in MR research studies. Most clinical units allow pregnant employees to enter the scan room, but not to remain in the room while the RF and gradient fields are applied during image acquisition. Pregnant researchers at the Center will regulate their own exposure to the magnets.

\*For references see Shellock and Kanal, 1996, Ch. 5

### **Additional Information**

If a subject or patient has any medical devices, you must get clearance from [Steven Shannon](#)

For other information regarding MRI safety, please go to

[MR Safety Website \(Dr. Kanal\)](#)

[MRIsafety.com](#)

### **Contact Info**

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