Magnetic Resonance Safety at MRN

1. MRN Research Committee

- The Mind Research Network (MRN) maintains MR (magnetic resonance) safety policies and procedures which are established, maintained, and routinely reviewed by the MRN Research Committee.
- Research Committee members are individuals with expertise and responsibility regarding the safe operation and safety hazards unique to the magnetic environment as well as the safety-related policies and procedures of MRN.
- Introduction of any significant changes in MRI (magnetic resonance imaging) system hardware or software that will significantly change the safety parameters in the MR imaging environment (e.g. adding faster/stronger gradient capabilities, higher RF duty cycle sequences), is reviewed by the Research Committee prior to implementation. In this review process, national and international standards and recommendations are considered prior to establishing internal guidelines, policies, and procedures.
- It is the responsibility of the MRN Research Committee to ensure that MRI safety guidelines are established and maintained on a current basis, and are appropriate for the various MR systems operated by MRN. Furthermore, it is the responsibility of MRN administration to ensure that the policies and procedures established by the Research Committee are implemented and adhered to consistently by all MRN personnel.
- Adverse events that occur in the process of MR imaging are reported to the Chair of the Research Committee in written form (incident report) within 24-hours.
- All mild to moderate incidents and adverse events are discussed at the next bi-monthly meeting of the Research Committee. A serious adverse event will result in an immediate meeting of the Research Committee.
- The Research Committee is responsible for the development of an MRI Safety training program for all MR users.
- In the event that an unsafe condition arises or the safety policy is violated, the Research Committee has the authority to revoke approval of the study and protocol involved until such time as the condition is corrected.

2. Potential Hazards and Risks in a MRI Environment

- **Static magnetic field risk**: Per FDA CDRH memorandum of 7-14-2003: “Studies conducted at 8T or less are not considered significant risk.” The MRN MR facilities maintain a safety policy to safeguard participants and staff members from incidental risks. The strongest static magnetic field of the scanners at MRN is 3.0T and is therefore classified as posing no significant risk to human subjects when all necessary safety precautions are followed.

  The static magnetic field of the MRI system is exceptionally strong; a 1.5T magnet generates a magnetic field that is approximately 21,000 times greater than the earth's natural magnetic field. In such an environment ferromagnetic metal objects can become airborne as projectiles. Small objects, such as paper clips and hairpins, have a terminal velocity of 40 mph when pulled into a 1.5T magnet and therefore pose a serious risk to the participant and anyone else in the scan room. The force with which projectiles are pulled toward a magnetic field is proportional to the mass of the object and distance from the magnet. Even surgical tools such as hemostats, scissors and clamps, although made of a material known as surgical stainless steel, are strongly attracted to the main magnetic field. Oxygen tanks, gurneys, floor buffing machines, and construction tools are highly magnetic and should never be brought into the scan room. MRN’s 3T scanner room has oxygen available which is piped into the scanner room through the wall to a wall mounted O2 regulator. There is also a non-ferrous gurney available, which is MRI compatible.

Consumer products such as pagers, cell phones, cameras and analog watches may be damaged by the magnetic field. Pacemakers may be reprogrammed or turned off by the magnetic field. The magnet field erases credit cards with magnetic strips. Participants with ferrous intra-cranial vascular clips may be at risk of injury due to the possible movement of the clip. It is essential, at all times, to be aware of these and other serious risks associated with the unique environment of an MRI scanner. See Contraindications for MRI in Section 12.

- **Pulse gradient magnetic field risk:** The time-varying or gradient magnetic fields used in MRI can, in some instances, induce stimulation of peripheral nerves, thereby producing sensations such as twitching or tingling. In very rare instances, this nerve stimulation can be painful. Nerve stimulation is particularly likely when individuals are positioned in a way that forms a closed loop, such as with hands clasped or arms folded. It should be noted that the parameter of interest, dB/dt (the rate of change in the magnetic field per unit of time) is not a function of the strength of the static magnetic field, so evaluating the risk of nerve stimulation in a 3T MR scanner involves the same considerations as evaluating risk in other MR systems operating at lower magnetic field strengths. Thus, only the gradient system needs to be evaluated to determine the risk of producing nerve stimulation. The gradients used in the 3T and 1.5T MR systems in use at MRN will typically be operated at levels below those considered to be negligible according to the FDA guidelines. The system, like most commercially available FDA-approved systems, does have the capacity to exceed this level, but it includes the same safeguards that are included in other FDA-approved clinical systems. In addition, MR operators are trained to educate participants about the possibility of peripheral nerve stimulation and to position them in such a way that the risk is minimized.

- **Radio-frequency (RF) field risk:** The radio-frequency field may induce currents in wires that are adjacent or on the participant, causing skin burns. It may induce currents in intracardiac leads, resulting in inadvertent cardiac pacing. Prolonged imaging may cause the participant's core body temperature to rise. In practice, significant participant heating is only encountered in infants. When using equipment with wires or cables attached (e.g. hand input device, EEG cap, EKG leads, etc.) the MR Operator, the PI or their designee must be extremely careful not to allow the wire or cable to form a conductive loop with itself or with the participant. Coupling of a transmitting coil to a receive coil may also cause severe burns.

  To prevent participants from experiencing excessive heating and possible burns in association with MR procedures, the following guidelines will be followed at MRN:

  (1) Prepare the participant for the MR procedure by conducting a standard safety screening and ensuring that there are no unnecessary metallic objects contacting the participant’s skin (e.g., metallic drug delivery patches, jewelry, necklaces, bracelets, or key chains).

  (2) Prepare the participant for the MR procedure by using insulation material (i.e., appropriate padding) to prevent skin-to-skin contact points and the formation of “closed-loops” from touching body parts.

  (3) Insulating material (minimum recommended thickness, 1-cm) should be placed between the participant’s skin and transmit RF coil that is used for the MR procedure (alternatively, the RF coil itself should be padded). For example, position the participant so that there is no direct contact between the participant's skin and the body RF coil of the MR system. This may be accomplished by having the participant place his/her arms over his/her head or by using elbow pads or foam padding between the participant's tissue and the body RF coil of the MR system. This is especially important for those MR examinations that use the body coil or other large RF coils for transmission of RF energy.

  (4) Use only electrically conductive devices, equipment, accessories (e.g., ECG leads, electrodes), and materials that have been thoroughly tested and determined to be safe and compatible for MR procedures.

(5) Carefully follow specific MR safety criteria and recommendations for implants made from electrically-conductive materials (e.g., bone fusion stimulators, neurostimulation systems) at www.mrisafety.com. If there is any unresolved question of safety, the MRN Medical Director must be contacted prior to MR imaging.

(6) Before using electrical equipment, check the integrity of the insulation and/or housing of all components including surface RF coils, monitoring leads, cables, and wires. Preventive maintenance should be practiced routinely for such equipment.

(7) Remove all non-essential electrically conductive materials from the MR system (e.g., unused surface RF coils, ECG leads, cables, wires).

(8) Keep electrically conductive materials that must remain in the MR system from directly contacting the participant by placing thermal and/or electrical insulation between the conductive material and the participant.

(9) Keep electrically conductive materials that must remain within the body RF coil or other transmit RF coil of the MR system from forming conductive loops. Note: The participant's tissue is conductive and, therefore, may be involved in the formation of a conductive loop, which can be circular, U-shaped, or S-shaped.

(10) Position electrically conductive materials to prevent "cross points". For example, a cross point is the point where a cable crosses another cable, where a cable loops across itself, or where a cable touches either the participant or sides of the transmit RF coil more than once. Notably, even the close proximity of conductive materials with each other should be avoided because some cables and RF coils can capacitively-couple (without any contact or crossover) when placed close together.

(11) Position electrically conductive materials to exit down the center of the MR system (i.e., not along the side of the MR system or close to the body RF coil or other transmit RF coil).

(12) Do not position electrically conductive materials across an external metallic prosthesis (e.g., external fixation device, cervical fixation device) or similar device that is in direct contact with the participant.

(13) Allow only properly trained individuals to operate devices (e.g., monitoring equipment) in the MR environment.

(14) Follow all manufacturer instructions for the proper operation and maintenance of physiologic monitoring or other similar electronic equipment intended for use during MR procedures.

(15) Electrical devices that do not appear to be operating properly during the MR procedure should be removed from the participant immediately.

(16) Closely monitor the participant during the MR procedure. If the participant reports sensations of heating or other unusual sensations, discontinue the MR procedure immediately and perform a thorough assessment of the situation.

(17) RF surface coil decoupling failures can cause localized RF power deposition levels to reach excessive levels. The MR system operator will recognize such a failure as a set of concentric semicircles in the tissue on the associated MR image or as an unusual amount of image non-uniformity related to the position of the RF coil.

- **Electrical Hazards:** The MR Scanner will be evaluated regularly for electrical hazards by the manufacturer's Field Engineer, as detailed in the service agreements with the MR system manufacturer. All modifications to the equipment will be performed only by approved personnel such as the Field Engineer or the Technical Project Manager and will be properly evaluated for electrical safety. Safety tests will be carried out on a regular basis by the Field Engineer with regard to radiofrequency and magnetic field levels, as detailed in the service agreements with the MR system manufacturers. After safety tests are completed, the service engineer will leave a comprehensive service report relating all results and actions taken to restore any faults in the MR system.

- **Cryogen risk:** A superconductive magnet in the MR scanner uses cryogens to supercool the electrical conductor that creates the magnetic field. Temperatures as low as -269°C (-452°F) are achieved to create the proper superconducting environment within the magnet. A quench, which is a sudden boil-off of the entire volume of cryogenic liquid, causes a rapid loss of the static magnetic field. During a planned or accidental shutdown of the magnetic field (quench) the liquid Helium in the magnet turns into gas and may escape into the scan room displacing the oxygen in the room leading to asphyxia.

  Cryogen Safety Procedures
  - All dewars and gas cylinders must be non-magnetic.
  - Dewars should be stored in a well-ventilated area.
  - Gas cylinders should be stored upright and secured to the wall with a chain and a metal protective cap in place. (If the cylinder falls over or the valve is knocked off, the container may be capable of self-propulsion and may have sufficient power to penetrate walls.)
  - The valves of dewars and cylinders should never be tampered with.
  - Because cylinder caps may be metal, they should be removed before bringing MR-safe cylinders into the magnetic environment.
  - If possible, all personnel should stay out of the magnetic environment when a qualified engineer is filling cryogens into the magnet. If MR personnel must be present, they must wear proper gloves, a face shield and ear protection.
  - Flammable material must not be allowed near the cryogen containers.
  - All personnel working with liquefied cryogens must wear protective clothing including safety gloves, face shield, cotton or linen lab coat or overalls and non-magnetic safety shoes.

3. Static magnetic field issues: Access Restriction

- **Magnetic field distribution (Fringe Field):** The stray magnetic field outside the bore of the magnet is known as the fringe field and this is a 3 dimensional field measured in Gauss. MRI systems are shielded to confine the fringe field within the scan room. Magnetic fields, which are less than 5 Gauss, are inconsequential to MRI safety. In most systems the 5 Gauss field is confined within the scan room and therefore its fringe field does not affect any area external to the magnet room.

  The 30 Gauss field demarcates the point where projectile hazards become significant and only MRI compatible equipment can safely enter this region.

  Each MRI system has its own unique fringe field due to varying magnetic design, shielding characteristics, and field inhomogeneity, and therefore each scanner is supplied with a schematic which clearly defines the fringe field of the magnet. The schematic must demarcate the 30 Gauss line and 5 Gauss line.

- This section summarizes the different zones of the MRN MR suite and mobile MRI and points out specific safety issues, which are of greatest concern.
  The MRI suite and mobile MRI are divided into 2 zones:

- **Unrestricted Zone:** Uncontrolled, and freely accessible to the general public. This area is typically outside of the MRI environment itself, and is the area through which participants, researchers and other employees access the MRI environment.
- **Restricted Zone:** This area is the region in which free access by unscreened personnel and/or equipment can result in serious injury or death as a result of interactions between the individuals/equipment and the MRI scanner's particular environment, including but not limited to its static and time varying magnetic fields. The 5 Gauss field designates where the **Restricted Zone** begins. The distance of the 5 Gauss field from the iso-center of the magnet will vary, depending on the characteristics of the magnet. The Restricted Zone is clearly marked and demarcated as being potentially hazardous, and physically restricted from general public access. All access to the Restricted Zone is strictly controlled and supervised by trained personnel. The magnet room is always locked when unattended.
  As part of the **Restricted Zone** site restriction and equipment testing and clearing responsibilities, all MRI sites have access to a hand magnet for screening purposes (>=1000 gauss). This enables the staff to test external and even some superficial internal devices or implants for the presence of grossly detectable ferromagnetic attractive force.
  Only MR compatible equipment approved by the MRI Core may be brought into the Restricted Zone.

- **Signage:** Standardized signs visualizing a magnetic field and the restriction of ferromagnetic objects are placed at the entrance of the **Unrestricted and Restricted Zones**.

4. Screening: Research Participants/MRI Personnel/Non-MRI Personnel

- **Research Participant screening:** Participants entering the MRI suite for a research exam are screened for contraindications such as pacemakers, metal foreign bodies in the eyes and cranial aneurysm clips. A standard MRI safety screening form is filled out prior to a person entering the Restricted Zone. It is the responsibility of the scan operators to review the MRI safety screening form prior to allowing a person into the Restricted Zone. All contraindications are brought to the attention of the PI and Medical Director. Participants with a history of foreign bodies in the eyes will require a clear x-ray of the orbits prior to being admitted to the Restricted Zone. Participants with a cranial aneurysm clip will require a written report from the referring physician stating the name of the clip and the date of placement prior to being admitted to the Restricted Zone. It is the responsibility of the study principal investigator to contact the MRN Medical Director if any question of safety exists and under no circumstances should a scan proceed until all safety questions are completely resolved.
- **MRI Personnel (equipment operators) screening:** All MRI Personnel undergo an MRI screening process as part of their employment interview process to ensure their own safety in the MRI environment. A signed approved screening form will be kept on file for every MRI operator. For their own protection and for the protection of the ancillary staff, all MRI Personnel must immediately report to their supervisors any trauma, procedure, or surgery that they experience and whether any ferromagnetic metallic object/device may have been introduced to their bodies. This will permit an appropriate screening to be performed with the employee to determine the safety of permitting those MRI Personnel into the environment.
- **Non-MRI Personnel screening:** Screening procedure is the same as the Research Participant screening. All Non-MRI Personnel (e.g. research assistants, volunteers, visitors, varied site employees, and professionals) with implanted cardiac pacemakers, auto-defibrillators, diaphragmatic pacemakers, and/or other contraindicated devices (e.g. certain IUDs) should be precluded from the Restricted Zone.

  Individuals undergoing an MRI procedure must remove all readily removable metallic personal belongings and devices on their bodies (e.g., watches, jewelry, removable body piercing, contraceptive diaphragms, drug delivery patches, and clothing items which may contain, metallic fasteners, hooks, zippers, loose metallic components or metallic threads), It is therefore MRN policy to require that any individual undergoing an MRI wear a site-supplied gown or scrubs.

5. Staff Training Program

- **MR Personnel (equipment operators) training**: Approved operators of the MR equipment at MRN understand that safe operation within MRN and the administration of this safety policy is their responsibility while at MRN. Any violation of this policy will be documented in writing. Operators of the MR equipment must complete the following steps to become approved operators:
    - Complete online safety training (as described in the MRI Use Policy),
    - Complete technical training,
    - Demonstrate technical competence under supervision of the MRI Core Manager, and
    - Complete and obtain certification for basic CPR training.
- **Research and other personnel training:** Non-MR Personnel will be permitted to enter the MR environment for the purpose of performing approved research studies and accompanying screened and approved research participants for MR procedures upon successful completion of the online training and safety test. Training must be renewed every two years.

6. Cardiac, Respiratory Arrest, or other medical emergency

MRN is a 911 site. In the case of a life threatening emergency, immediately call 911. The MR suite is equipped with emergency medical supplies including: a Basic Life Support kit, an anaphylaxis kit and an AED (automated external defibrillator). These supplies are located in a labeled cabinet in the **Unrestricted Zone**. Many of these supplies can be dangerous in the **Restricted Zone**. For this reason, in any medical emergency, all individuals should be removed from the MRI suite to a predetermined magnetically safe location in the **Unrestricted Zone** before resuscitation begins. **Restricted Zone access must be maintained during resuscitations and other emergent situations**.

7. Magnet Quench

Quenching is the process whereby there is a sudden increase in temperature in the magnet coils, so that they cease to be super conducting and become resistive, thus eliminating the magnetic field. This results in helium escaping from the cryogen bath extremely rapidly. It may happen accidentally or may be manually instigated in the case of an emergency. Quenching may cause severe and irreparable damage to the super conducting coils, and so a manual quench should only be performed in extreme cases when a certified MRI operator is involved in the decision to quench. A fire in the scan room may be a cause to quench the magnet, in order for fire fighting personnel to safely enter the room. All systems should have helium-venting equipment, which removes the helium from the MR room to the outdoor environment in the event of a quench. However, if this fails, helium will vent into the room and replace the oxygen. For this reason all scan rooms contain an oxygen monitor that sounds an alarm if the oxygen falls below a certain level. Under these circumstances immediate evacuation of the participant and personnel is necessary. It is noted that if the scan room door is closed when a quench occurs and helium escapes into the scan room, the depletion of oxygen causes a critical increase in pressure in the room compared with the control area. This produces high pressure in the scan room, which may prevent opening of the door. If this should happen, the glass partition between the scan and control rooms should be broken to release the pressure. The scan room door can then be opened as usual and the participant evacuated. In such a case the participant will be immediately evacuated and evaluated for asphyxia, hypothermia, and ruptured eardrums.

8. Acoustic Noise

As current is passed through the gradient coils during image acquisition, a significant amount of acoustic noise is created. Although these levels are anticipated to be well below the OSHA standards whereby a hearing loss prevention program must be started (80 dB over 8 hours or half the exposure time for each additional 5 dB exposure), it can cause some reversible and irreversible effects. These effects include communication interference, annoyance, transient hearing loss and in people who are susceptible to hearing impairment, permanent hearing

loss. As recommended by the FDA, research staff will take steps to alleviate the noise levels experienced by participants. It is recommended that all participants are provided with earplugs or acoustically shielded headsets.

9. Radio frequency and gradient fields

In contrast to the main magnetic field, Radio Frequency (RF) and gradients are only present during scanning. RF energy (64 MHz, which is between AM and FM radio frequency) is exchanged with the participant in order to create MR images. A relatively powerful amplifier (25kW) generates this energy, and software controls are in place to limit the amount that participants are exposed to. RF absorption may cause heating of body tissues. This can be expressed in terms of specific absorption rate (SAR), which is the FDA limit for RF exposure and is primarily set to avoid warming of the participant. The recommended SAR level for imaging in the U.S. is 0.4W/kg (whole body) and 3.2W/Kg (head). The RF field is focused within the bore of the magnet and is negligible external to it.

While software that is part of the MRI scanner limits RF exposure to safe levels, looped conductors (e.g. wires) within the bore of the magnet can focus these RF fields, producing elevated energy deposition. These concerns are greatest on high field scanners and have been known to cause substantial burns. Accordingly, looped conductors within the bore must be avoided by any means possible.

Care should be taken to ensure that participants' tissues do not directly come into contact with the inner bore of the magnet during the MR imaging process. Pads and similar insulating devices are provided for this purpose. It is also important that the participant's own tissues do not form large conductive loops. Therefore, care should be taken to ensure that the participant's arms and legs not be positioned in such a way as to form a large caliber loop within the bore. For this reason it is preferable to instruct participants not to cross their arms or legs in the MR scanner.

10. Pregnant Participants

There are no known adverse effects of MRI on a developing fetus. However, if there indeed are any adverse effects, it is likely that the fetus might be more vulnerable early in pregnancy when cells are more rapidly dividing. The current FDA position is that "If the information to be gained by MR would have required more invasive testing, MRI is acceptable. In light of the high risk potential for pregnant participants in general, delay of the MR exam until after the first trimester is preferable. The American College of Gynecology and Obstetrics recommends that pregnant participants should be reviewed on a case-to-case basis, and the risk-benefit ratio needs to be made by the physicians involved."

It should be noted that numerous fetuses have undergone MRI without any abnormalities at birth, or up to 4 years of age. Gadolinium enhancement is at present best avoided when examining a pregnant participant. At MRN, pregnancy screening should be conducted according to the MRI Use Policy.

11. Pregnant Employees

MR is too new to make an informed decision on magnetic safety for pregnant employees. At MRN, it is recommended that pregnant employees do not enter the Restricted Zone.

12. Contraindications for MRI

All persons coming in contact with the magnetic field should be appropriately screened for contraindications using the MRI Safety Screening Form. An online reference is www.mrisafety.com.

The following devices are absolutely contraindicated for MR imaging because they are magnetically, electrically, or mechanically activated or affected:

- **Pacemakers for MRI**: Even field strengths as low as 5 Gauss are sufficient to cause deflection, programming changes, and closure of the reed switch, which converts a pacemaker to an asynchronous mode. In addition, participants who have had their pacemaker removed may have pacer wires left within the body, which could act as an antenna, and cause cardiac fibrillation (by induced currents).
- **Neurostimulators**; there are two types:
    - Passive receivers: neurostimulators that receive RF energy that is magnetically coupled from an external device by means of a coil placed over the implanted device.
    - Hermetically encased pulsed generators: neurostimulators that contain a battery and are programmed by an external device to produce the various stimulus parameters.

  Because of the specific design and intended function of neurostimulators, the electromagnetic fields used for MR procedures may produce problems with the operation of these devices. Malfunction of a neurostimulator that results from exposure to the electromagnetic fields of an MR system may cause discomfort or pain to the participant.
- **Cochlear implants**: Some types of cochlear implants employ a relatively strong cobalt samarium magnet used in conjunction with an external magnet to align and retain a radio frequency transmitter coil. Other types of cochlear implants are electronically activated. Consequently, MR procedures are strictly contraindicated in participants with these types of implants because of the possibility of injuring the participant and/or damaging or altering the function of the cochlear implants.
- **Bone growth stimulators**: These devices usually have an external electronic component that attaches to electrodes implanted in areas of fractured bones and are used to enhance and facilitate the rate of bone healing. Similar to neurostimulators, participants with bone growth stimulators should not undergo MR procedures until data are available to support that there are no hazards associated with the presence of these devices in participants during the operation of MR systems. Currently there is no neurostimulator or bone growth stimulator that has received the FDA designation of being "MR-compatible".
- **Implantable drug infusion pump**: A drug infusion pump is used for automatic delivery of agents such as antineoplastic agents, morphine, or narcotics. The infusion pump has ferromagnetic components, a magnetic switch, and is programmed by telemetry. The presence of these features in a device is usually considered a sufficient reason for the device being designated as contraindicated for participants undergoing MR procedures.
- **Implantable cardiac defibrillators**: Implantable cardiac defibrillators are used to treat participants with sustained ventricular arrhythmias that are refractory to antiarrhythmic pharmacological treatment. These devices use an external magnet to test the battery charger and to activate and deactivate the system. Deactivation of an implantable cardiac defibrillator is accomplished by holding a magnet over the device for approximately 30 seconds. Obviously, magnetic fields of MR systems would have a similar effect on implantable cardiac defibrillators and, therefore, participants with these devices should avoid exposure to MR systems. In addition, because implantable cardiac defibrillators also have electrodes that are placed in the myocardium, participants should not undergo MR procedures because of potential burns and other risks related to the presence of these conductive materials.
- **Intra-ocular ferrous foreign bodies**: Intra-ocular metal foreign bodies are a cause of major concern in MR safety. It is not uncommon for participants who have worked with sheet metal to have metal fragments or slivers located in and around the eye. Since the magnetic field exerts a force on ferromagnetic objects, a metal fragment in the eye could move or be displaced and cause injury to eye or surrounding tissue.

The following are potential contraindications for MR imaging:

- **Intra-cranial vascular clips**: Some intra-cranial aneurysm clips are absolute contraindications in MR imaging. The surgical management of intra-cranial aneurysms and arteriovenous malformations by the application of aneurysm clips is a well-established procedure. The presence of an aneurysm clip in a

participant referred for a MR procedure represents a situation that requires the utmost consideration because of the associated risks.
Certain types of intra-cranial aneurysm clips (e.g., those made from martensitic stainless steels such as 17-7PH or 405 stainless steel) are prone to torque in a MR produced magnetic field. The displacement of these clips may damage the vessel, resulting in hemorrhage and/or death. Intra-cranial clips made of a material known as titanium are now commonly used and have proved safe for MR.
To minimize the possibility of inadvertently imaging a participant with a magnetically active metallic implant, participants must provide information about the type and identity of their particular implants.

- **Penile implants**: Some penile implants evaluated for ferromagnetic qualities had substantial deflection forces measured when exposed to a 1.5T magnetic field. Although it is unlikely that a penile implant would severely injure a participant undergoing an MR procedure because of the manner in which it is used, it would undoubtedly be uncomfortable. For this reason, subjecting a participant with one of these implants to an MR procedure is inadvisable.
- **Shrapnel**: Most pellets and bullets tested for MR compatibility are composed of non-ferromagnetic materials. Ammunition that proved to be ferromagnetic tended to be manufactured in foreign countries and or used for military applications. However, because pellets, bullets, and shrapnel may be contaminated with ferromagnetic materials, the risk versus benefit of performing an MR procedure in a participant should be carefully considered as well as whether or not the metallic object is located near a vital anatomic structure. At MRN, imaging of subjects with known bullets or shrapnel is not allowed unless in rare cases when it is cleared by the Medical Director.
- **Halo**: Halo vests pose several risk factors which include deflection and subsequent dislodging of the halo, heating due to RF absorption, electrical current induction within the halo rings, electrical arcing and severe artifactual consequences which could render the imaging acquisition useless. Non-ferrous and non-conductive halo vests, which are MR compatible, are commercially available.
- **Coronary stents within 6 weeks of implantation**: Various types of intra-vascular stents have been evaluated for safety with MR systems. Several of these stents have demonstrated magnetic field interactions associated with exposures to MR systems. Fortunately, these particular devices typically become incorporated securely into the vessel wall within 6 weeks after their introduction. Still, all stents must be cleared prior to imaging and if there is any question (for example if a prolonged research scan is being done), the MRN Medical Director should be consulted.
- **Pregnancy**: See Pregnant Participants and Pregnant Employees in section 10 and section 11 respectively.

13. Fire Hazards

General Safety Procedures

- Necessary equipment (fire extinguishers, etc) is stored within the MR facility to manage all classes of fire. All equipment will be non-magnetic.
- To protect against the possibility of fire, no flammable liquids in excess of five gallons can brought into the magnetic environment.

Fire Procedures with MR Operators On-Site:

- Call 911. Notify MR Operators immediately.
- MR Operators will know and, if necessary, implement all of the fire emergency related procedures, including an evacuation plan and its proper execution. The East entrance has been assigned as the point of exit for evacuation of the clinics and MR facilities during a fire. MEG personnel should exit using the South doors.
- The MR Operators will evaluate the need for an emergency magnet quench.

In the event of a fire **inside the scanner room**:

- MRI safe fire extinguishers are located in the MRI control room and just outside the MRI suite. These should be used if the fire is small and extinguishable.

- MR Core Manager will evaluate the need to quench the magnet. They will direct entry and exit into the Magnetic Environment until the magnetic field strength reaches zero.

Fire During Off Hours or No Operators On Site:

- Call 911
- If the fire is in the scanner room, quench the magnet.
- Contact the Facilities Director (Dave Griego @ 505.235.8460) immediately who will execute the MRN Emergency Response Plan. Once contacted, the Facilities Manager will instruct fire fighting personnel and security staff as to the means of entry into the MR Facilities and the Magnetic Environment as well as the proper means of quenching the magnet, if necessary.
- For purposes of access in an emergency, the Campus Police and Security Department will have access to the MR Facilities.