

## MAGNETIC RESONANCE IMAGING HAZARDS AND SAFETY GUIDELINES

**MRI USE IS ON THE RISE, AND SO IS THE NUMBER OF ADVERSE MRI INCIDENTS - BY AN ALARMING 185% OVER THE LAST FIVE YEARS.\* WHILE THE NUMBER OF INCIDENTS IS SMALL COMPARED TO THE NUMBER OF PROCEDURES PERFORMED, EVEN ONE IS TOO MANY FOR ANY CLINIC, HOSPITAL OR RESEARCH FACILITY.**

A comprehensive MRI safety program is a must for any health care provider with a zero tolerance for MRI errors. A zero tolerance protocol should be built on three basic steps:

- Assess the hazards
- Establish best practices in MRI suite safety and patient care
- Educate and train all physicians, clinic and hospital staff working in the MRI suite

Such a protocol will produce an educated and safety-aware MRI medical team that can develop, implement and maintain an environment of effective and safety-focused patient care. We offer a detailed look at MRI technology, risks and patient safety and care.

## CRITICAL MRI SAFETY EDUCATION

While the term MRI is now a familiar one, the technology and science behind magnetic resonance imaging is complicated. Science also holds the key to understanding the source of MRI risk exposures.

Clinical open and closed bore MRI machines produce magnetic force measured in teslas (T), a unit of magnetic flux. Most MRI machines range between 1.0 T to 1.5 T, with more powerful units at 3.0 T.



### MAGNETIC RESONANCE IMAGING (MRI) STATISTICS

- An estimated 20,000,000 to 30,000,000 MRI procedures have been performed in the past five years in the U.S.
- \*The FDA's Manufacturer and User Facilities Device Experience data published for 2008 over this period indicates that MRI adverse incidents have increased 185%.

Research MRI equipment ordinarily has higher field intensities ranging from over 3.0 T to over 9.0 T. (The Earth's surface magnetic field generates only about 50 microteslas [ $\mu$ T].)

A second measure of magnetic intensity is the *gauss*, which is about  $10^{-4}$  tesla (10,000 gauss (Gs) per unit of tesla). Magnetic fields are represented by gauss lines. Gauss lines show, for example, that field intensity diminishes with greater distance from the source of magnetism.

There are two features of a magnetic field that are the source of most MRI incidents:

- 1) projectile or missile effect and
- 2) translational attraction.

**Projectile or missile effect:** Ferrous-based materials, nickel alloys and most stainless steel materials are not compatible with the MRI environment. When these materials are exposed to a strong magnetic field, they can be pulled violently toward the magnetic source.

**Translational attraction** occurs when one point of an object in a magnetic field is attracted to a greater extent than the object's furthest point from the attracting source. This differential creates a more forceful attraction, increasing the speed with which the object may move toward the magnetic source.

**Surgical stainless steel needs a disclaimer regarding its compatibility with MRI machines and procedures:**

- Austenitic stainless steel *is* MRI compatible in general.
- Ferritic and martensitic types of stainless are magnetically active and are not MRI compatible.
  - These metallurgical types are not created by changes in alloy content, but in crystalline structure due to the heat-quenching and annealing process.
  - Implants, aneurysm and surgical clips, and other medical devices made of these materials are at best an imaging distraction, and at worst, can severely injure a patient.

Prescreening and documentation of any metal that could be subject to the MRI field must be a standard part of MRI protocol.

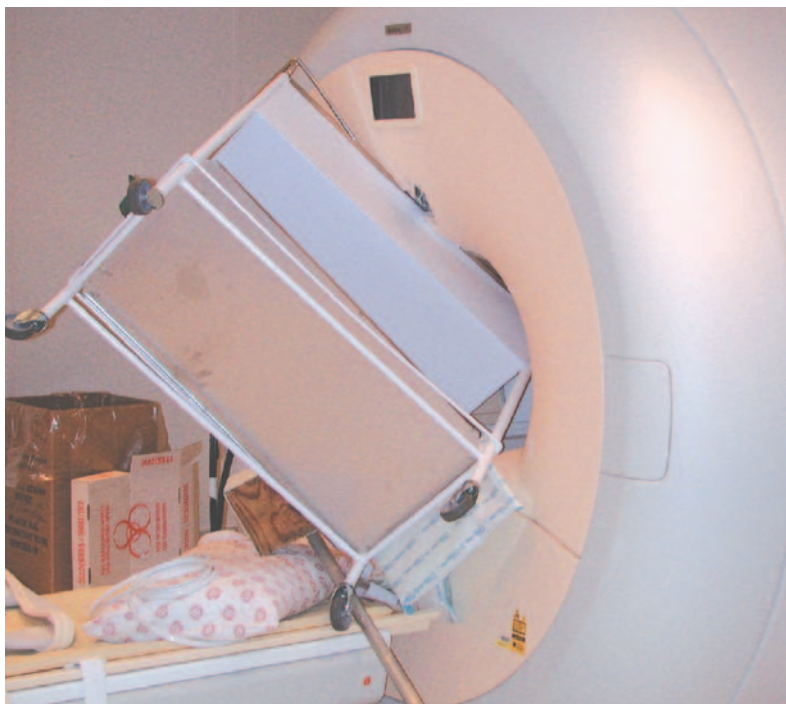
Clinical MRI machines can be shielded or unshielded. Higher tesla-rated research machines are generally shielded. Nevertheless, translational forces are still present, and assumptions about MRI compatibility with metallic objects are dangerous. While shielded MRI units are considered less prone to the projectile effect, introducing a magnetic reactive material into the compressed field can actually create a more severe reaction as the object crosses the compressed magnetic flux field. **Again, in any MRI environment, exercise extreme caution with all metallic objects.**

## HAZARDS IN THE MRI SUITE

Hazards to personnel and patients in the MRI suite can be categorized as follows:

### TRANSLATIONAL FORCES - THE MISSILE EFFECT

This effect is generally attendant upon ferromagnetic materials and the static field generated by an MRI system, and often manifests as the missile effect, which can involve non-compatible objects, such as wheel chairs, transport stretchers, file cabinets, electrical equipment and tools, powered and unpowered hand tools, stethoscopes, medical equipment carts, medical equipment (pulse oximeters, EKG, IV pumps, etc), communications devices, physician beepers, and miscellaneous (and often forgotten) patient and visitor objects that include hairpins, paper clips and pens.



A hairpin or paper clip within the 5-10 gauss line range could reach a velocity of 40 mph and will be attracted to the center of the MRI generated field (*x, y and z axis*) where the lines of force are equal.

### TORQUE FORCES

Torque forces run parallel to the translational force. Both are associated with ferromagnetic materials and the static field generated by an MRI machine. Attracted objects react by aligning parallel to the magnetic lines of force being generated by the MRI machine. The center of the MRI-generated field has the highest torque force, creating a serious exposure for all contraindicated items and MRI-conditional items in the MRI suite, depending on the tesla rating of the MRI. This effect has created life-threatening conditions for patients with some medical implants.



## INDUCED MAGNETIC FIELDS

Any metallic object introduced into a high flux field will induce a current if that object is moving and perpendicular to the force lines. That new induced current will create a secondary magnetic field that will oppose the original field.

The same metallic object introduced parallel to the force lines will generate no effect. While not as apparent as translational forces, induced magnetic fields can cause patients discomfort or anxiety due to reactive forces on MRI-safe medical implants.

All pacemakers and implantable cardioverter/defibrillators should be considered contraindicated under any circumstance. When these devices are exposed to an MRI environment, a life-threatening condition may be created within the five-gauss line. Intravascular catheters, intubation equipment, infusion pumps, orthopedic implants, stents and other devices should be verified as MRI-safe in the prescreening. The transportation of a patient should be designed to minimize potential torque from secondary magnetic fields by maintaining a parallel path to the lines of force. Any MRI-safe device must be verified as acceptable for the MRI tesla-rated machine and maximum closest safe distance from the machine.

## THERMAL HEATING

The static magnetic MRI field will tend to induce currents in any conductive materials, including those that may be non-ferrous. However, the human body is electrically conductive by nature and small RF fields will generate current that will be absorbed by the body as heat. The specific absorption rate (SAR) for the patient will depend on weight and body radius. The heating will be more prominent at the periphery of the body than at its core. This effect will also vary with the type of MRI scanning being done (angle, pulse frequency, fast spin echo, etc.).

The most serious exposure is located in the bore of the MRI machine and in the axis points, as they possess the highest potential torque forces. The use of extremity coils could aggravate the risk, but can be avoided through the use of MRI-safe polymeric foam padding. In addition, monitoring patient position in the MRI machine and

proximity to its inner wall should be included in patient care protocol.

The most common sources of thermal exposure tend to be looped/un-looped medical equipment leads, MRI accessories, and sensors. These include conductive loops touching the patient or crossing the extremities, clothing, and metalized drug delivery patches (OTC or prescription).

## PATIENT DISCOMFORT

- Secondary induced currents and subsequent secondary generated magnetic fields may cause brief and benign – but noticeable – reactions in the patient.
- Closed bore MRI machines can cause a patient discomfort if the patient is claustrophobic to any degree.
- Loud noises, light flashes and other sensory input may be perceived by the patient.
- Neonates (premature infants) and elderly patients may be at higher risk due to changes in ventilation and hemodynamic stability, and vasoactive infusion requirements. Close communication and cooperation between MRI staff and the attending anesthesiologist is critical.

## MRI ARTIFACTS

Discovered artifacts in the MRI scan may include a previously unnoted medical implant or foreign object that is ferromagnetic. These are most frequently stents, micro-coils and filters. Scanning may have to be terminated and the patient removed before the objects can be subjected to the effects of torque or an induced current magnetic field.



## QUENCHING

MRI machines are cooled by a super-cooling fluid (liquid helium). The release of the super-cooling fluid into the atmosphere is called quenching, and unintentional and intended magnet quenching can be catastrophic. Most clinical machines have a 700 to 1,000 liter-volume of this cryogenic. Its venting will cause oxygen in the MRI magnet room to condense around the vent pipe and accumulate in the MRI machine, posing a code red fire hazard.

Quenching is normally associated with de-energizing the machine, which is safer than a quenching during a scanning procedure. However, the room will still be subject to increased levels of oxygen near the machine. Not only should the patient be removed as quickly as possible during the de-energizing process, but any sources of possible ignition near the machine should be minimized. Room exhaust ventilation should be activated. Another risk is a quench vent pipe breach, which could flood the room with cryogenic fluids. This creates an asphyxiation hazard for the patient and attending staff.

If an emergency should arise in the MRI machine room, all staff and respondents must be aware of the potential risks of translational and torque induced effects on the patient. All code blue equipment must be located outside the five-gauss line to maintain an MRI-safe environment. Both code red and code blue situations will require preplanning with hospital medical staff and emergency response teams. Municipal firefighters should not be allowed into the room until the MRI is proven to be de-energized or they are MRI-safe – with magnetic equipment and clothing removed.

## CONTRAST AGENTS

Contrast agents, sometimes injected into patients as part of the MRI procedure, pose a distinct set of risks. *Agent administration, reaction issues, contrast*

*agent toxicity and post-procedure renal complications/renal disease (NSF) are outside the scope of this paper and will be addressed in another SOP publication.*

# ESTABLISHING AND IMPLEMENTING BEST PRACTICES

## 1. SAFETY GUIDELINES

All clinical and hospital-based MRI suites, regardless of the MRI manufacturer, field strength or imaging design, should establish, document and implement an MRI suite safety protocol. This should include training of all technologists and nursing staff, and education of all attending physicians (primary care, radiologists and anesthesiologists). The protocols should be reviewed by the MRI medical director both periodically and following each change in the MRI suite environment (changes in entrances to the MRI suite, additional equipment, replacing MRI machines, etc.)

An MRI safety officer should be designated to ensure that policies and procedures are followed; training and safety certification for technologists and MRI staff is completed and current; MRI incidents are investigated, documented and reported; and deficiencies corrected.

## 2. ACCESS ZONES

MRI suites should be designed to restrict access and limit exposure to static magnetic fields. Commonly, MRI suites restrict access by zone.

### ZONE I

Open to general public access, Zone I presents the least exposure to patients, visitors, attending physicians, fellows and medical students, and hospital staff (cleaning, maintenance, administration, etc.). This is also generally the reception and waiting area for the MRI suite. Its purpose is to channel patients and medical staff to the prescreening area (Zone II) and to restrict further entry into the MRI suite.

## **ZONE II**

This is the first interaction site for patient, visitor, attending physician and others with the technologist and nursing staff in the MRI suite. The purpose of this zone is to restrict further public access to the suite, provide direct supervision of patients and visitors by the MRI staff, and provide an opportunity to prescreen all patients and visitors (including attending physicians, anesthesiologists, hospital staff, etc.).

MRI prescreening includes patient medical history, insurance medical questions and completion of a specific MRI prescreening form. In this zone the patient is gowned and personal items secured or transferred to a relative or accompanying visitor. All gowns must be MRI-safe, i.e., free of metallic snaps, buttons or zippers, which set off ferromagnetic alarms.

If ambulatory, the patient is screened through a ferrous metal detector installed in Zone II. Non-ambulatory patients in walkers, wheelchairs or patient transport (stretchers or gurneys) need the transport equipment verified as MRI-safe or else exchanged for MRI-safe equipment. The prescreening area (Zone II) will generally have a metal detector and a 1000-gauss magnet to help screen medical equipment for non-ambulatory patients. Unconscious patients must be accompanied by a relative, guardian or other adult who should know the patient's medical history. The prescreening form must be completed by MRI personnel and signed by the patient or guardian/accompanying adult. It is then reviewed and accepted in writing by the MRI technologist prior to admitting the patient into the MRI room for the procedure.

Any indication in the patient's history of a metallic implant or foreign object requires an effort to identify the type and location of the implant or object. The investigation must assess MRI compatibility or MRI safety of the object or implant. The identification should include written documentation, including manufacturer labeling, model, type and serial number. Once identification is verified and accepted by the attending radiologist or MRI director, the procedure can continue. A history indicating medical treatment for orbital trauma or removal of ferrous-based

materials from either/or both eyes will require plain film X-ray or review and assessment by an attending radiologist before the procedure can continue.

MRI staff, including the MRI technologist, is directly responsible for enforcing strict adherence to MRI safety protocols for the MRI suite and for patient care and safety. If a reliable patient history cannot be verified and a physical exam by MRI personnel leads to serious questions that cannot be answered to their satisfaction, then a plain film X-ray, dual view orbit X-ray or CT scan may be required.

## **ZONE III**

Zone III is the entry zone to the MRI machine room – Zone IV. At this point the entrance into the MRI room is restricted physically and by protocol. Only the MRI technologist, MRI certified staff and prescreened attending physicians will accompany the patient into the MRI machine room. This area is the last barrier against an incident or injury due to an interaction of a static or active magnetic field and unscreened medical personnel, unscreened medical equipment or undiscovered ferromagnetic-active objects in the patient or in patient transporting equipment.

The portal or entrance in the MRI machine rooms must be monitored by a second ferromagnetic-sensitive detector and a locked and normally closed entrance door into the MRI machine room. Zone III can be a common open area into the entrance into Zone IV or a separate card-access room with complete visual access to Zone IV. The standard access method is a card access system for all Level II MRI personnel and approved/certified (prescreened) attending physicians.

If the ferromagnetic-sensitive detector sounds, the alarm will require verification of either an MRI-safe or compatible event or discovery of an MRI-unsafe condition in the patient, transport equipment or medical equipment, or attending medical staff (including the MRI staff). A 1000-gauss hand-held magnet should be used in combination with a physical investigation to determine the cause of the portal alarm in equipment. A handheld ferromagnetic detector can be used to detect ferrous materials on the patient.

All Zone III MRI personnel must be uniformed in MRI compatible "scrubs" (which preclude the use of identification badges in the MRI suite), MRI-safe shoes and undergarments. Personnel must avoid all jewelry, watches, metallic writing instruments and wireframe glasses. The purpose is to avoid a source of false alarms from the portal ferromagnetic detector.

Without exception, only certified MRI staff should be allowed free access between Zones III and IV through the use of access cards or keyed access. All medical staff must be prescreened prior to entry to Zone III to make sure no unscreened individuals will be allowed access to Zone IV. Appropriately

screened and trained medical personnel can administer CPR and initial life support in Zone III while the patient is being removed from the Zone IV environment on an expedited and urgent-care basis.

Zone III is the MRI machine or magnet room, which is always active. The entrance to this room is visually marked by signage in two languages on the normally closed room doors and on the floor indicating that the MRI machine is always on and the area is restricted. In addition to signage on the door and floor, there should be a flashing red warning light and lighted signage warning of severe hazards.

## **ZONE IV**

The MRI room should have a clear demarcation of the five-gauss line taped or painted on the MRI suite floor indicating the area beyond which requires MRI-safe (for the distance and tesla rating of the MRI) or MRI-conditional equipment or instrumentation.

Pulse Oximetry and MRI-safe anesthesia delivery and ventilation carts, or centrally supplied oxygen (wall-unit) should be considered for unconscious or anesthetized patients as standing medical orders. In the case of cardiac or respiratory failure or another medical emergency within Zone IV where medical intervention or resuscitation is required, trained MRI personnel should initiate basic life support and/or CPR while the patient is being removed expeditiously from Zone IV to a safe area in the MRI suite.

Code red situations will require the use of MRI-safe fire extinguishers and restriction of public first responders from Zone IV, until MRI safe conditions can be established or first responders verified as MRI safe. In a code red situation in Zone IV, first responders do not have free access to either Zone III or IV. Prior to arrival of firefighters or police, it may be advisable to grant appropriately trained hospital security personnel MRI Level II access so they can be called by MRI personnel at the time of the incident. Prior to any incident, local fire and police department personnel should be educated on the hazards of the MRI suite in emergency situations.

All Zone IV MRI access keys should be in a controlled key program, and the MRI portal key kept in a restricted access box in the MRI Control Room.

## **3. TRAINING PROTOCOLS**

All personnel working in Zones III and IV should successfully complete an MRI safety education program as established and approved by the MRI director. Initial training for all MRI personnel should be conducted as either live seminars for MRI personnel by the MRI director, or as a general conference for all clinical and hospital MRI personnel.

After the initial training, certification and documentation, annual refresher training can be conducted in live sessions or in an

electronic format under the direction of area MRI directors. Documentation of initial and annual refresher training in MRI safety and protocol is a key factor in maintaining an MRI-safe environment.

MRI safety protocol should include two levels of MRI access based on training level completed.

### **LEVEL ONE**

MRI personnel at this level must pass minimal training to ensure their own safety in Zones I, II and III. Typical tasks at this level include initial patient medical history, basic patient screening and other administrative function for visitors, patient family and hospital staff.

### **LEVEL TWO**

Level Two training is for MRI personnel who have had some educational background and more extensive training in MRI safety and who will be involved with patient safety and care in Zones III and IV. The training and focus of MRI education for these individuals should cover:

- Medical and non-medical equipment allowed to enter the MRI Zone IV room
- Review and documentation of all patient history and prescreening information
- Control of visitors, attending physicians and other medical staff entering Zones III and IV
- Management of code blue and code red situations
- Control and prevention of thermal burning and torque-induced trauma in patients or medical devices
- Control and reaction to artifact incidents

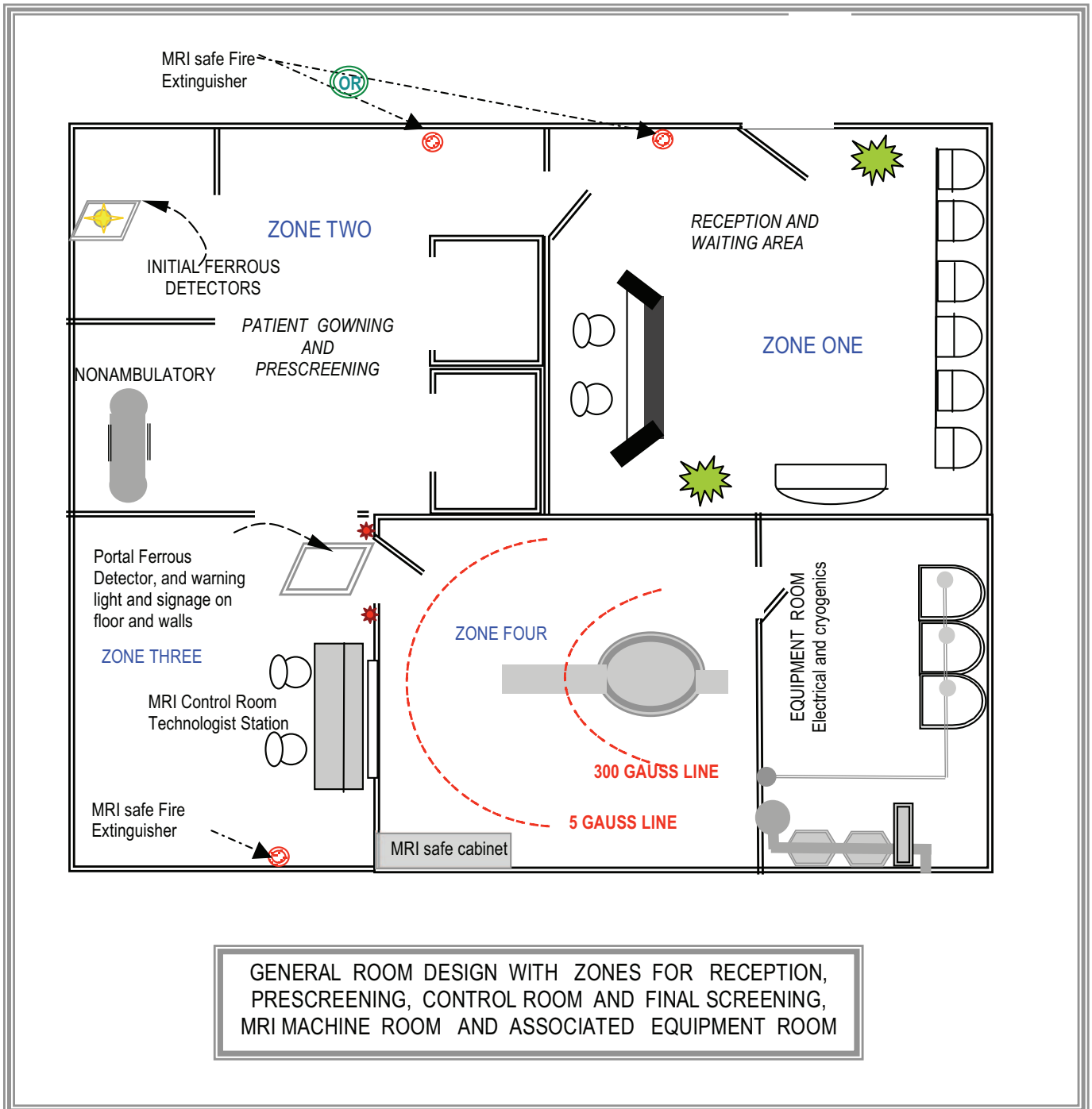
Essentially, the trained MRI technologist is the Zone IV gatekeeper for patients, visitors, equipment and attending physicians.

MRI experts strongly recommend that attending physicians have more than a general education on MRI suite safety and patient care, implying that frequent attendance at MRI procedures should require those physicians to be certified at Level Two in MRI safety.

## 4. MRI SUITE ROOM DESIGN

Architectural and design engineering for MRI suites has been established in standards published by the Joint Commission on the Accreditation of Healthcare Organizations (JACHO) and in American College of Radiology guidelines, as well as best practices in construction and design from the International Building Code, OSHA and other local and federal agencies.

MRI best practices cover architectural, structural, equipment, HVAC, plumbing, electrical, life safety, energy conservation, communications, waste management and transportation. Our diagram of a typical arrangement, which is also the basis for the design of a mobile MRI unit, appears below. Details on RF shielding, gas monitoring, and pressure relief and other safety features are not shown in this basic scheme.



# PATIENT AND NON-MRI PERSONNEL SCREENING

All patients, visitors, parents/guardians of patients and MRI Level One hospital personnel must first pass through the MRI screening process if they are entering Zones III or IV. They have free access to Zones I and II.

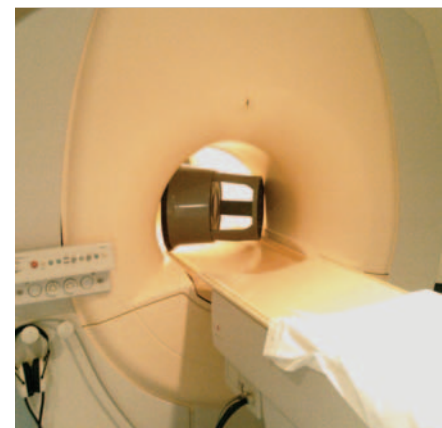
Only Level Two-trained MRI personnel should be permitted to perform and complete an MRI safety prescreening. All preliminary patient history, MRI safety screening (including initial ferrous detection), and MRI safety prescreening documentation must be completed and signed by the patient, guardian or attending physician. These forms must then be signed off as complete by the attending MRI Level Two personnel and further countersigned by the MRI Suite technologist or MRI director. This process should be completed prior to entry into Zone III.

If there is any indication of possible introduction of ferromagnetic material due to a medical implant or past treatment for injury, the use of plain film X-ray or CT scanning may be required. Any further investigation or documentation of implanted medical devices should be conducted and accepted by the MRI director or attending radiologist as MRI-safe or compatible for the specific MRI machine and procedure.

In addition to patient history, the screening process includes the use of an ECRI template form to discover any potential ferrous or metallic implants or medical devices in the patient. Classic examples of contraindicated items: cardiac pacemaker or implantable cardioverter/defibrillators, neurostimulators, aneurysm clips, undocumented stents, filters or micro coils, cochlear or otologic implants, penile implants, undocumented heart valves, electronic medical implants, undocumented orthopedic implants or joints, body art or jewelry, and ferrous or metallic foreign objects from industrial or military injuries. Attending police should remove and replace prisoner restraining devices or RF tracking bracelets. Pregnant patients in the first trimester are generally considered at risk from the procedure. The attending Ob-Gyn physician and radiologist must document a compelling medical reason to conduct an MRI procedure. *Pregnancy-related issues for both patients and health care practitioners are outside the scope of this paper.*

The use of non-discriminating metal detectors in the MRI suite is counterproductive, as most TSA style portable and gateway detectors cannot distinguish between magnetic reactive material and simple metal mass. Ferrous metal detectors are commercially available and should be the tool of choice for establishing MRI suite safety. A prescreening ferromagnetic detector gateway should be a part of the prescreening process in Zone II and used after the patient is appropriately gowned. A hand-held non-discriminating metal detector can be used to scan patients in wheel chairs and gurneys/stretchers for undisclosed metal objects, if the ferromagnetic detector indicates an alarm. These hand-held metal detectors should not, however, be considered primary screen tools.

This gateway can also be used to prescreen non-ambulatory or sedated patients in wheelchairs and gurneys. All wheelchairs, gurneys and patient transports should be MRI-safe. If not, the patient must be transferred to MRI-safe equipment. Intradepartmental transfers must be gowned in MRI-compatible gowns to start, or re-gowned in the MRI suite. Hand-held magnets, which have a 1000-gauss (10 to 15 ft-lb) rating, should be used to establish MRI compatibility if the initial gateway detector indicates an alarm. Hand-held electronic ferrous detectors are currently not



considered reliable for this purpose. Prescreening includes documentation that all medical equipment arriving with the patient is MRI-safe for the MRI machine's tesla rating and distance from the MRI machine. Standard procedure requires that non-emergency patients be prescreened by two MRI suite staff, of which one should be Level Two MRI safety certified.

After prescreening, all patients and non-MRI personnel must be accompanied by Level Two MRI personnel to Zones III and IV. MRI personnel will have continuous verbal and visual contact with the patient and attending physician and non-MRI medical staff. Family and non-MRI personnel should be excluded from entry to Zones III and IV. Without exception, all personnel, including all attending physicians, technicians and nursing staff entering Zones III and IV must be prescreened and have passed through the initial ferrous metal detector. The MRI technologist and MRI director have authority to control access to Zone IV, without exception. Emergency patients with attending physician and nurses should be screened by the technologist prior to entry into Zones III and IV.

The ferrous detector at the entrance to Zone IV typically can distinguish a magnetic reactive mass equivalent to a paper clip. It can approximate the general plane of location (upper third, middle third, or lower third) of the object. An active alarm from this portal detector should be investigated by the MRI technologist and a second MRI staff member to determine the cause. Assumptions of false alarms can be erroneous and dangerous.

The portal detector must be calibrated to minimize the risk of a false alarm. MRI Level

Two staff must avoid clothing, accessories or jewelry that could set off portal alarms. Best practices dictate no metal fasteners, badges, jewelry or street clothing be allowed for MRI Level Two personnel. All medical equipment, devices, instrumentation and patient care items must be MRI-safe to the satisfaction of MRI technologist before entry into Zone IV. All patient transport devices, anesthesia/ventilation carts, IV pumps, and pulse oximeters must be MRI-safe as documented by previous inspection, tagging and documentation.

In the event of the discovery of an MRI artifact, the procedure must be interrupted, the patient removed from Zone IV, and an investigation conducted into the source of the artifact. In concert with the attending radiologist, MRI director and technologist, the investigation will determine if the procedure will continue or alternate methods will be used to satisfy the diagnostic need.

## **PATIENT SAFETY AND CARE**

Patients who are sedated or unconscious, restless and uncooperative or younger than five require additional medical precautions. The attending anesthesiologist must be certified at Level Two in MRI safety education. Direct communication between the attending physicians (anesthesiologist, pediatric or other specialty physician, etc.) and the MRI medical team is critical to ensure a safe and effective procedure.

Prescreening, patient history and monitoring patient stability, both physical positioning and physiological condition, are key to maintaining patient safety. The MRI medical team must pay particular attention to detail in positioning the patient and monitoring equipment, including any additional medical support equipment (IV pumps, ventilation, medical gases, etc).

All introduced equipment must be MRI-safe within the five-gauss line. Consider installing docking stations for MRI-safe anesthesiology carts. All medical gases that must be administered from the cart should be in cylinders designed with support for the cylinder base and be fitted with substantial polymeric (nylon, or copolymers) strapping and strap snap-locks to prevent movement. Care must be taken in positioning all medical equipment, and under no circumstance should equipment touch the MRI machine's outside

casing or approach the 300-gauss line. This line is usually just outside the bore, but higher flux fields in unshielded MRI machines could have this flux contour well outside the machine bore.

Communication of MRI hazards and risk among MRI radiologist, attending physician, patient and other medical staff is critical in maintaining a clear understanding by all.

## CRYOGENIC ISSUES

All modern higher tesla-rated MRIs (1.0, 1.5 and 3.0 T) have superconducting magnets that are maintained at low Kelvin temperatures. Liquid helium is used and maintained as a cooling fluid by machine design and the application of modest pressure and refrigeration. In the event of an inadvertent or planned quenching of the MRI magnetic array, cryogenic gases will be released into the atmosphere. This is a potentially catastrophic emergency.

Evacuate all patients, and remove any patient undergoing an MRI diagnostic procedure from the machine bore quickly and safely. The entire MRI suite should be evacuated and everyone moved to a designated safe area. This could be a location near the MRI suite or clinic building previously reviewed and designated or designed for this purpose. Prior to the arrival of emergency response teams from either the clinic or public safety departments, the MRI technologist must confirm the static magnetic field has dissipated and the Zone IV room is safe for entry by the response teams.

Pay close attention to Zone IV oxygen monitoring and alarms. The release of cryogenic gas through the quench vent pipe to the atmosphere will cause condensation or fogging in the room. Some of this fogging will be atmospheric moisture and carbon dioxide condensation. Within the machine frame nearer the quench pipe, icing and condensed oxygen may form. This may create a very localized oxygen-rich environment, increasing the fire risk near the machine. Ventilation of the Zone IV room will minimize this hazard.

## SUMMARY OF SAFETY GUIDELINES

1. Maintain an operator's manual for the suite's MRI machines in the control room. The manual should include all manufacturers' bulletins and advisory information as well as a log sheet to document updates for equipment and software.
2. Maintain an MRI safety manual for operations and protocols in the control room. Include all safety training documentation for MRI staff and attending physicians, noting MRI safety education levels and dates of certification and acceptance by MRI director or radiologist.
3. All MRI operators and staff (technologist, technician, nurse practitioners, nurses, etc.) should complete **MRI initial safety training and annual refresher courses**. The initial and subsequent refresher MRI education course or seminars should be established, documented and supervised by the MRI director and MRI radiologist.
4. All MRI staff must take responsibility for providing an MRI-safe environment for staff and patient alike.
5. **The first protocol: *No one enters the magnet room (Zone IV) without the approval of the MRI technologist - without exception.***
6. **The second protocol: *No one enters the magnet room (Zone IV) without being prescreened or being certified at MRI Safety Level Two status - without exception.***
7. **The third protocol: *Everyone must know that the machine is always on.***
8. All equipment and devices brought into Zone IV must be either MRI-safe or compatible, and have been prescreened by MRI Level Two staff.
9. Patient care and safety are at core of all MRI procedures and MRI staff actions.
10. Direct verbal and written communications between MRI staff and attending physicians are critical to maintaining patient care and safety.

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