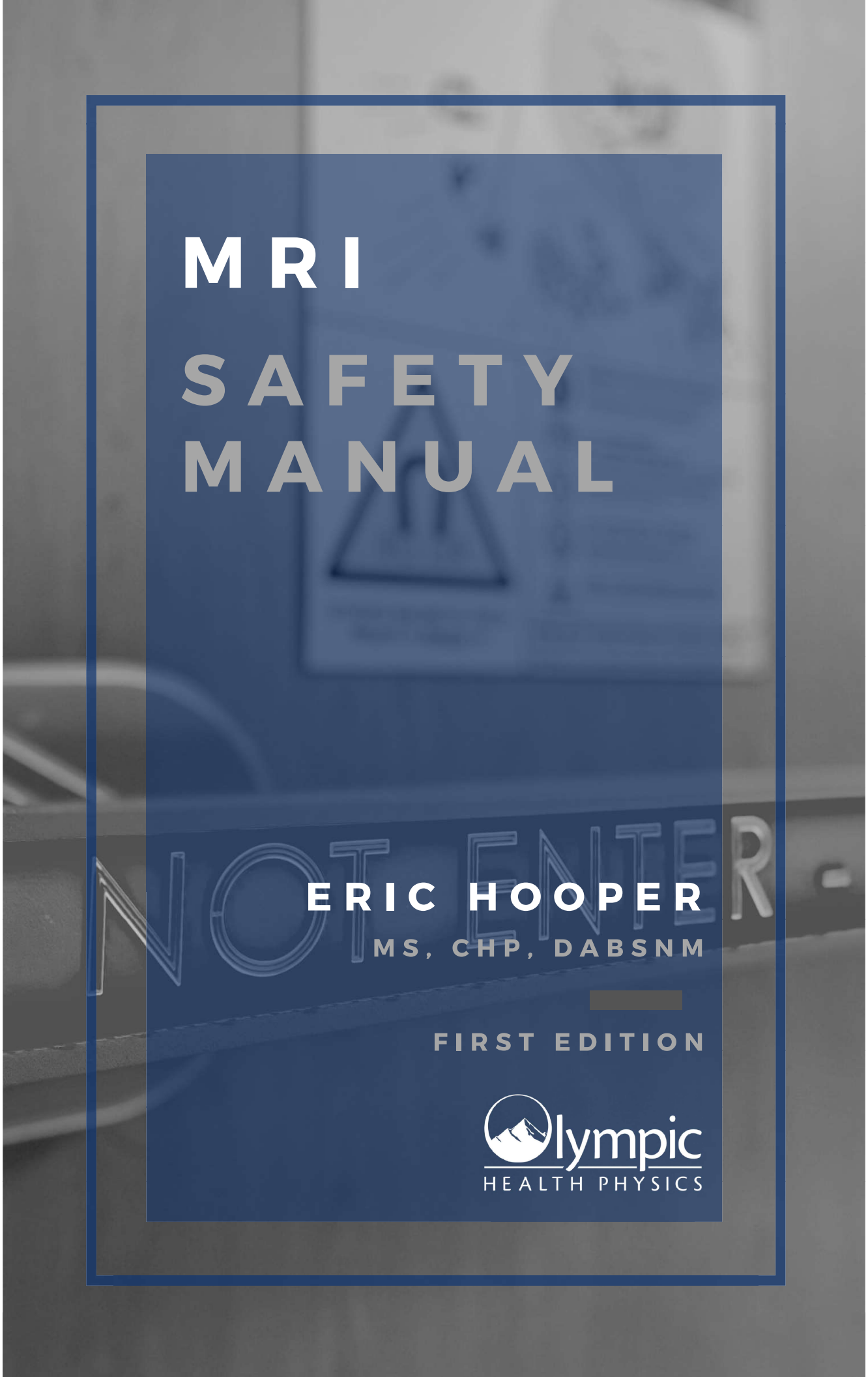

MRI SAFETY MANUAL

ERIC HOOPER
MS, CHP, DABSNM

FIRST EDITION

Olympic
HEALTH PHYSICS

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MRI Safety Manual

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Acronyms

0.5 mT (0.0005 T)	5 Gauss Line
ACR	American College of Radiology
AED	Automated Emergency Defibrillator
ARRT	American Registry of Radiologic Technologists
ASTM	American Society for Testing Materials
BLS	Basic Life Support
CPR	Cardiopulmonary Resuscitation
dB	Decibel
FDA	Food and Drug Administration
GBCA	Gadolinium Based Contrast Agent
MR	Magnetic Resonance
MRI	Magnetic Resonance Imaging
MRMD	Magnetic Resonance Medical Director
MRSC	Magnetic Resonance Safety Committee
MRSO	Magnetic Resonance Safety Officer
RF	Radio Frequency
SAR	Specific Absorption Rate
T	Tesla
W/kg	Watt/kilogram

Introduction

Magnetic Resonance is an ever changing, evolving technology. There are potential risks in the MR environment, not only for the patient but also for the accompanying family members, attending health care professionals, and others who find themselves occasionally or rarely in the magnetic fields of MR scanners, such as security, housekeeping personnel, firefighters, police, etc. This manual has been developed to help guide the MR staff regarding these issues.

It is the intent of this MR Safety Manual to

- Protect and educate all patients as well as direct and ancillary personnel about the possible risks associated with the MR Suite including but not limited to static, time-varying magnetic fields and RF pulses.
- To be in compliance with the most up to date MR safety information provided by the American College of Radiology and other similar organizations.
- Prove helpful as the field of MRI continues to evolve and mature, providing MR services that are among the most powerful, yet maintaining a focus on quality and safety.

The safety policies and procedures outlined in this manual are based on recommendations of the American College of Radiology (ACR), guidance from the Food and Drug Administration (FDA), and best practices. The ACR 2013 publication, *ACR Guidance Document for Safe MR Practices 2013* and *ACR Manual on MR Safety, Version 1.0, 2020*, www.acr.org, were used as primary references for development of the MRI Safety Manual and associated policies and procedures.

Magnetic Resonance Imaging

Introduction

Magnetic resonance (MR) tomography uses the magnetic characteristics of certain nuclei in the body, and especially the hydrogen nucleus (protons) to generate images. It is based on the premise that these nuclei exhibit a magnetic moment. The hydrogen atom is an elementary part of water and fat and is, therefore, the most prevalent element in the human body. When a person is placed in the scanner, the magnetic movement of the hydrogen nuclei aligns with the direction of the magnetic field. A radio frequency (RF) field is briefly turned on and off to cause the magnetic moment to realign briefly. The scanner detects the motion of the magnetic moments of the protons as they return to their equilibrium position along the strong magnetic field of the scanner.

Static Field Strength

When the MRI scanner is on, the static magnetic field (the main magnetic field of the scanner) is always present. Magnetic field is measured in units of Tesla (T). One Tesla equals 10,000 gauss and is 20,000 times stronger than the magnetic pull of the earth. Field strength increases in a nonlinear manner as an object gets closer to the bore (or center) of the magnet. The magnetic attraction of the MR scanners for ferromagnetic objects can result in a missile or projectile effect as these objects are pulled toward the bore of the magnet with great force. In addition to the hazard of projectiles, the static magnetic field can cause ferromagnetic objects within the body (such as aneurysm clips, metal slivers, etc.) to move or torque, potentially resulting in serious injury.

The static field can also disrupt the function of electrically, magnetically, or mechanically activated implants such as some pacemakers. Currently, there are pacemaker devices that can be scanned safely according to conditions set out by their manufacturers. For this reason, all MRI manufacturers are required to identify a 5-gauss pacemaker exclusionary zone to avoid the possibility of pacemaker dysfunction. This exclusionary zone extends from the center of the magnet in all directions to the distance at which the field strength equals 5 gauss (0.5 mT or 0.0005 T).

Risks Associated with Magnetic Resonance Imaging (MRI)

Missile Effect

The missile effect or projectile effect refers to the capability of the fringe field of the static magnetic field to attract a ferromagnetic object, drawing it rapidly into the scanner with considerable force. When this occurs, the missile effect can pose a significant risk to anyone in the path of the projectile and cause significant damage to the scanner.

To guard against accidents from metallic projectiles, personnel should remove all ferromagnetic/paramagnetic metallic personal belongings (hearing aids, analogue watches, jewelry, etc.) before entering the magnet room, as well as any clothing with magnetic fasteners.

All equipment to be taken into the scanner room, housekeeping supplies (bucket, broom, mop, etc.), maintenance equipment, tools, and emergency equipment (gurney, fire extinguisher, etc.) must be

made of nonferrous material and be classified as either MR safe or MR Conditional according to manufacturer instructions and labeled accordingly.

Rotational and Translational Forces

Rotational force is a force that causes a ferrous object to turn and align along the magnetic field. Translational force is a force that causes a ferrous object to be pulled toward the center of the magnet.

Implants and devices that are not proven MR safe pose a serious health risk due to torque and heating. All implants and devices must be documented as either MR safe or MR Conditional before being permitted in the MRI Suite. Information and guidelines can be found at www.MRISafety.com and/or other resources.

To prevent damage or injury due to torsion or translational forces, all individuals who enter the magnet room must be prescreened to determine if they have any ferrous material in their body. Comprehensive safety screening reviews potential injuries involving ferrous material and the presence of ferromagnetic devices or implants (clips, screws, shunts, etc.) as well as cosmetic concerns such as permanent eyeliner, tattoos, hair weaves or braids, and permanent retainers.

Cryogenic Liquids

The coils of the superconducting magnet are immersed in liquid helium to prevent excessive heat buildup. Under normal operation, the helium slowly boils off and more liquid helium must be added only after several years' time. Risks associated with liquid helium include burns due to accidental direct contact with the cryogen or hypoxia as a result of a leak or quench.

A quench involves the rapid release of helium and results in loss or decrease of the magnetic field. A manual quench can be performed by trained personnel in the event of an emergency, such as a person being pinned to the magnet. In extraordinary circumstances, an uncontrolled quench can occur. If the helium gas enters the magnet room, the oxygen level in the magnet room may significantly decrease, causing a hypoxic environment. To reduce the risk of hypoxia due to the rapid release of helium, the MRI Suite that houses the magnet has a quench vent pipe which under normal circumstances controls the release of helium safely into the environment outside of the building.

Radiofrequency Fields

The MRI signal is created by RF pulses through a transmit core. Conducting materials within the RF field may result in a concentration of electrical currents sufficient to cause excessive heating and tissue damage. Absorption of RF power by tissue is described in terms of Specific Absorption Rate (SAR) which is expressed in Watts/kilogram (W/kg).

According to the FDA, the SAR must be no greater than 4 W/kg averaged over the whole body for any 15-minute period, 3 W/kg averaged over the head for any 10-minute period, 8 W/kg in tissue in the head or torso, or 12 W/kg in tissue in the extremities for any period of 5 minutes.

Acoustic Noise

Movement of the gradient coils due to switching of the gradient magnetic field is the main source of

considerable acoustic noise within the scanner room, registering up to 140 decibels (dB). Participants in MRI studies are required to wear disposable foam ear plugs and/or headphones (both, when possible). Ear plugs can reduce noise by 30 dB. Other individuals who must remain in the room while scanning (e.g., parent) will also be given earplugs and instructed as to their proper usage.

Designation of the MR Medical Director

Role & Responsibilities

The MRI Medical Director is a Radiologist, who oversees development and implementation of safety and compliance programs for the MRI Suite. Specific responsibilities of the MRI Medical Director with regard to MRI safety are to:

- Assumes overall and ultimate responsibility for MR facility operational safety
- Appoints the MRSO(s)
- Develops, implements, and maintains specific policies and procedures pertaining to safe operation of MR services
- Implement and maintain appropriate MR safety and quality assurance programs
- Develops appropriate record keeping and analysis of adverse events (with the MRSO(s) and MRSE as needed)
- Develops an appropriate ongoing assessment of risk for the facility
- Develops an appropriate investigation and recording of all reported MR safety adverse events
- Ensuring that adequate written safety procedures, emergency procedures, and operating instructions are issued
- Ensuring the implementation and monitoring of appropriate measures for minimizing risk to staff and patients
- Development and continuing evaluation of a safety framework for the MR environment
- Knowledgeable and responsible for the local rules and procedures to ensure the safe use of MR equipment
- Develops, implements, and maintains the MR Safety program and MR Quality Assurance programs, evaluations, and audits
- Identifying hazards posed by the MR equipment and monitoring the measures taken to protect against such hazards
- Providing and/or ensuring the provision of MR safety education and training in cooperation with and as per facility policies and maintaining records of personnel education
- Ensuring that there is a clear policy for purchasing, testing, and clearly marking of all equipment that will be taken into Zones III and IV
- Providing expertise in root cause analyses, solutions meetings, etc., related to MR adverse events

The MRI Medical Director for the facility will be _____.

MRI Site Access Restrictions & MRI Zones

The ACR established the four-zone concept as defined in the ACR Manual on MR Safety: 2020. The four-zone concept provides for progressive restrictions in access to the MRI scanner. All MRI Suites are marked with Zone signs

Zone I: General public freely accessible to the public. This area is typically outside the MR environment.

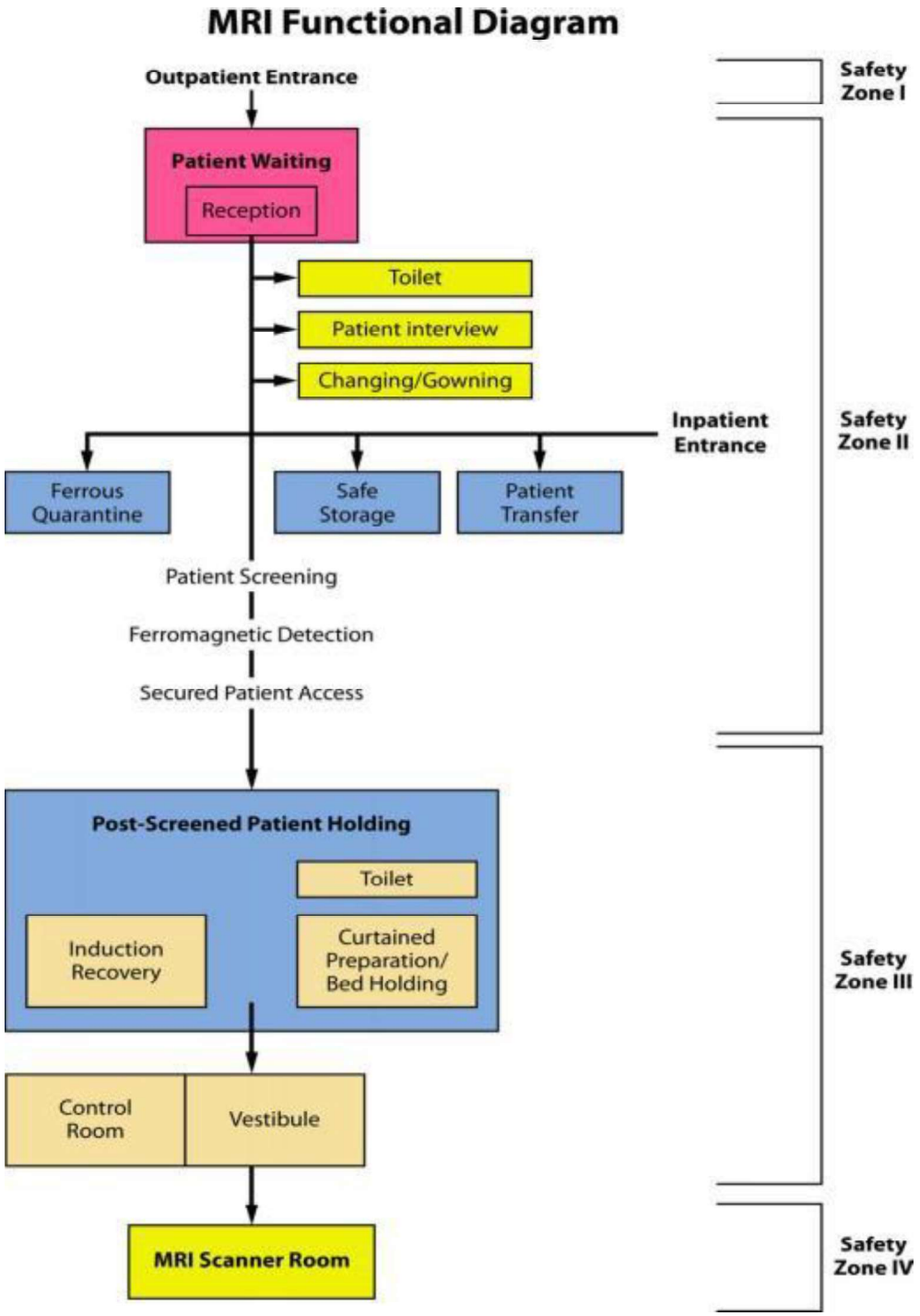
Zone II: Limited Access: This is the Zone located between the public uncontrolled Zone I and the strictly controlled Zone III. This area has limited access - available to patients, family members and hospital personnel who have been safety trained or safety screened by Level II MR personnel. It is in Zone II that the answers to MR screening questions, patient histories, medical insurance questions, etc. are typically obtained.

Zone III: The MR scanner (Zone IV) itself is located adjacent to this space. Zone III can be defined as regions from which potentially hazardous energies (related to the MR imaging process) may be accessed. Zone III regions should be physically restricted from general public access by, for example, key locks, passkey locking systems, or any other reliable, physically restricting method. Only MR personnel shall be provided free access, such as the access keys or passkeys, to Zone III. Patients, family members, or hospital staff that has undergone safety screening or safety training will be allowed access to this area only when accompanied by appropriate MR personnel.

Zone IV: Is the room housing the MR scanner itself. Zone IV should also be demarcated and clearly marked as being potentially hazardous due to the presence of very strong magnetic fields. Zone IV, by definition, will always be located within Zone III as it is the MR magnet and its associated magnetic field which generates the existence of Zone III. Only patients and family members, or staff accompanied by Level 2 MR personnel who have undergone safety screening or safety training will be admitted to this Zone.

Zone IV should be demarcated with a "Danger – The Magnet Is Always On" sign

Non-MR Personnel should be accompanied by, or under the immediate supervision of and visual contact with, one specifically identified MR person for the entirety of their duration within Zone III and a Level 2 MR person in Zone IV restricted regions.



Sample floor plan illustrating site access restriction considerations

Additional Precautions

- The MRI technologists will control access to the MRI unit.
- All patients, family, visitors, and personnel entering the MRI Zone 4 must be screened by MRI staff prior to entry. The area around the MRI department is a restricted/monitored space.
- Only equipment that has been purchased specifically for MRI and assessed by MRI staff as safe will be allowed into the MRI unit (Zone IV). MRI Safe stickers will be attached to all non-ferrous equipment.
- The door to the unit will be closed at all times and restricted by badge and/or locked access.
- In the case of a patient requiring emergency intervention, the patient will be removed from the MRI suite (Zone IV) while still on the MRI table and into the Medical Imaging Holding area for treatment.

Patients, Visitors, and Non-MR Personnel Screening

Background

To ensure the safety of patients, families, and staff while in the MRI environment.

All people entering the MRI scan room (Zone IV) will complete the appropriate screening form. The MRI technologist reviews the form and verifies whether it is safe for that person to enter the MRI scan room (Zone IV).

Patient Screening

All patients will complete the MRI Safety Screening form and have it reviewed by the MRI Technologist before entering Zone IV.

If the patient is unable to complete the MRI Safety Screening Form due to physical or mental incapacity, family and/or legal guardian can complete and sign the MRI Safety Screening Form. If family and/or legal guardian is not available, the supervising radiologist determines if the patient can be safely imaged. In the absence of a completed MRI Safety Screening Form, the technologist cannot perform the procedure until a supervising radiologist can provide approval. The performing technologist documents the name of the approving radiologist on the screening form and in the medical record.

The manufacturer name and model of the implanted device(s) are used to check for MRI compatibility. If the patient has any implant with an unknown make or model or if the MRI Technologist is unable to determine the conditions of the implant, the supervising radiologist determines whether or not the patient can safely be imaged. Such decision by the supervising radiologist is noted by the technologist on the MRI Safety Screening Form and Medical Record.

Screening Procedure

The following procedures should be performed to ensure patients, visitors, and non-MR personnel are properly screened before entering Zone IV.

Outpatients

1. All outpatients complete an MRI Safety Screening Form at the time of check-in at the reception desk.
2. The MRI Technologist reviews the MRI Safety Screening Form and verifies with the patient prior to scanning.
3. If there is a question on MR safety based on above, MR Technologist should consult with local MRSO (MR Safety Officer) first, who can subsequently consult with supervising Radiologist or MR Medical Director.
4. The MRI Technologist will direct the patient to remove all readily removable metallic personal belongings and devices on or in them, i.e., watches, jewelry, pagers, cellphones, body piercings (if removable), dentures, hearing aids, cosmetics containing metallic particles, and clothing items which may contain metallic fasteners, hooks, zippers, loose metallic components, or metallic threads.

5. Patient should change into department provided gown and pants.
6. The MRI Technologist will sign and date MRI Safety Screening Form.

Inpatients & Emergency Department Patients

1. All inpatients and Emergency Department patients complete, or are assisted with the process of completing, an MRI Safety Screening Form prior to transport to the MRI department.
2. The patients Nurse will fill out the Inpatient/ED RN section of the screening form.
3. The Nurse will fax the completed screening form to MRI for review. The patient will not be transported to MRI until screening form has been received.
4. If there is a question on MR safety based on above, the MR Technologist should consult with the supervising Radiologist or MR Medical Director.
5. The patients' Nurse will direct the patient to remove all readily removable metallic personal belongings and devices on or in them, i.e., watches, jewelry, pagers, cellphones, body piercings (if removable), dentures, hearing aids, cosmetics containing metallic particles, and clothing items which may contain metallic fasteners, hooks, zippers, loose metallic components, or metallic threads.
6. The Nurse will ensure the patient has changed into hospital provided gown and pants.
7. The Nurse will remove all EKG leads, and other MRI-unsafe medical equipment. Replace with MRI-conditional or MRI-safe equipment. The Nurse may call the MRI department for assistance or clarification as needed.
8. The MRI Technologist will review the safety screening form and verify with the patient prior to scanning.
9. The MRI Technologist will sign and date MRI Safety Screening Form.

Family & Visitors

1. All family and visitors will complete an MRI Safety Screening Form before entering Zone III.
2. The MRI Technologist reviews the MRI Safety Screening Form and verifies with the family or visitor prior to entering Zone III.
3. If a contraindication is present, the MRI Technologist may allow access to Zone III but will deny access to Zone IV.
4. The MRI Technologist will direct the family or visitor to remove all readily removable metallic personal belongings and devices on or in them, i.e., watches, loose jewelry, pagers, cellphones, body piercings (if removable), hearing aids.
5. All family or visitors in Zone III or Zone IV will be under the direct supervision through visual contact with the MRI Technologist. A maximum of 1 family member or visitor will be allowed access to Zone IV.
6. The MRI Technologist will sign and date MRI Safety Screening Form.

Non-MR Personnel

1. All non-MR personnel will be instructed to complete the non-MRI Personnel Log before entering Zone IV.
2. The MRI Technologist reviews the non-MRI Personnel Log and verifies with the non-MR personnel prior to entering Zone IV.

3. The MRI Technologist will direct the non-MR personnel to remove all readily removable metallic personal belongings and devices on or in them, i.e., watches, loose jewelry, pagers, cellphones, body piercings (if removable), hearing aids.
4. All non-MR personnel in Zone III or Zone IV will be under the direct supervision through visual or verbal contact with the MRI Technologist.
5. The MRI Technologist will review and initial the non-MRI Personnel Log before allowing access to Zone III or Zone IV.

Pediatric Considerations

Children may not be reliable historians and, especially for older children and teenagers, should be questioned both in the presence of parents or guardians and separately to maximize the possibility that all potential dangers are disclosed. Therefore, it is recommended that they be gowned before entering Zone IV to help ensure that no metallic objects, toys, etc. inadvertently find their way into Zone IV. Pillows, stuffed animals, and other comfort items brought from home represent real risks and should be discouraged from entering Zone IV. If unavoidable, each should be carefully checked with a powerful handheld magnet and/or ferromagnetic detector and perhaps again in the MR scanner before permitting the patient to enter Zone IV with them to ensure that they do not contain any objectionable metallic components.

MRI SAFETY SCREENING FORM

WARNING! Before entering the MRI environment, you must remove **all** metallic objects (hearing aids, dentures, cell phone, glasses, hair pins, watch, safety pins, money clip, credit cards, pens, pocket knives, etc.). For your safety, you are required to wear a hospital provided gown as some clothing can cause burns in MRI. Please consult with the MRI Technologist if you have any questions **BEFORE** you enter the MRI room.

PATIENT INFORMATION

Height: _____ **Weight:** _____ **When do you follow up with your Doctor?** _____

Do you have or have you ever had any of the following?

☐ Yes ☐ No Cardiac Pacemaker / Defibrillator
☐ Yes ☐ No Heart Surgery / Artificial Heart Valve
☐ Yes ☐ No Ventricular Assist Device (VAD)
☐ Yes ☐ No Internal Wires or Electrodes
☐ Yes ☐ No Brain Aneurysm Clips or Coils
☐ Yes ☐ No Electrical Nerve / Bone Stimulator
☐ Yes ☐ No Shunt
☐ Yes ☐ No Eye Implants / Spring / Wire / Retinal Tack
☐ Yes ☐ No Cochlear (ear) Implants / Stapes Prosthesis
☐ Yes ☐ No Implanted Insulin, Drug, or Infusion pump
☐ Yes ☐ No Stent, Filter, or Coil in a vessel
☐ Yes ☐ No Electrical, Mechanical, or Magnetic implant
☐ Yes ☐ No Ortho Pins / Screws / Rods / Joints / Prosthesis
☐ Yes ☐ No Tissue Expander (e.g. breast)

☐ Yes ☐ No Prostate seeds / Penile implant
☐ Yes ☐ No Gunshot wounds / Shrapnel / BB
☐ Yes ☐ No Implanted contraceptives (IUD)
☐ Yes ☐ No Medication patch / Silver dressing
☐ Yes ☐ No Tattoo / Permanent makeup / Body piercing
☐ Yes ☐ No Hearing aids / Dentures / Partials
☐ Yes ☐ No Hair extensions / Hair piece / Wig
☐ Yes ☐ No Injury to the eye involving metal fragments
☐ Yes ☐ No Other implant not listed _____

☐ Yes ☐ No Are you p regnant or breastfeeding?
☐ Yes ☐ No Are you claustrophobic?
☐ Yes ☐ No History of anxiety disorder?

Please explain all YES answers: _____

List any Drug/Contrast Allergies: _____

List any Previous Surgeries: _____

Please circle any personal history of: Diabetes / High Blood Pressure / Kidney Disease / Liver Disease Cancer / Tumors / Multiple Myeloma / Advanced Congestive Heart Failure (CHF) / Sickle Cell Anemia / Dialysis

Have you had Chemotherapy in the last 30 days? ❒ Yes ❒ No

Had an esophageal pH test (acid reflux Bravo chip) or capsule endoscopy (pill camera) in last 30 days? ❒ Yes ❒ No

Have you ever had MRI contrast? ❒ Yes ❒ No Allergic reaction? ❒ Yes ❒ No If yes, pre-medicated? ❒ Yes ❒ No

I attest that the above information is correct to the best of my knowledge.

Signature	Date / Time	Print Name of Patient/Parent/Representative	Relationship to Patient
_____	_____	_____	_____

FOR IP / ED RN USE ONLY

Form must be completed & faxed to MRI before patient will be transported to MRI
Patient must be able to cooperate for the exam

☐ Yes ☐ No Is patient stable, cooperative, able to lie flat and hold still for the MRI?
☐ Yes ☐ No Is patient claustrophobic, in pain, or have anxiety disorder? If YES, is premedication ordered? ❒ Yes ❒ No
☐ Yes ☐ No Is an interpreter needed? Language: _____
☐ Yes ☐ No Does patient have IV access? Size: _____ Location: _____ ❒ Port or PICC ❒ Power PICC
☐ Yes ☐ No Does patient have eGFR within last 24 hours? eGFR: _____ Date: _____
☐ Yes ☐ No Does patient have a Swan-Ganz Line or a Temperature-sensing Foley?
☐ Yes ☐ No Is patient on a ventilator?
☐ Yes ☐ No Have all foil-backed lead and EKG patches, medication patches and dressings (i.e. Acticoat) been removed?
☐ Yes ☐ No Is patient in hospital gown, all street clothes, bra, jewelry, watch, accessories removed? **(Required for MRI)**
☐ Yes ☐ No Has the Safety Screening Form been completed and signed by patient, appropriate family, or legal guardian?
☐ Yes ☐ No Is continued infusion required? If yes, RN must switch to MRI SAFE pump
☐ Yes ☐ No Does patient need to be monitored? If YES, RN is required for monitoring

RN Name: _____ Signature: _____ Date/Time: _____

MRI

❒ ID / Screening Form Verified ❒ Verbally / Visually Screened ❒ Safety Pause eGFR: _____ Date: _____

Notes: _____ Signature: _____ Date: _____

MRI Device & Implant Screening

Background

With the growing number of procedures that are being performed in medicine, the risk that a patient will receive an implant in their life is increasing. In order to identify if an implant or foreign body is a threat to the MR environment, it is important to understand origin/manufacturer of the implant, it's ASTM MR Labeling (Safe, Conditional, or Unsafe), where the implant is located, location of the implant relative to the anatomy being imaged, the type of MR transmit and/or receive coil, and if we can obtain manufacturer instructions. By understanding the areas of MRI that can result in patient harm, we can assess how much risk an MR procedure will have on the patient.

All implants should be scanned in Normal mode unless specified in manufacturer guidelines that scanning in First level SAR mode is acceptable. All patient related implants and non-removable devices should be documented on the MRI screening form with all available information. Any approval by supervising Radiologist should be documented on the Screening Form and in the Medical Record. Documentation should include:

1. Full name of Supervising/Approval Radiologist
2. Approved Field Strength (1.5T or 3T)
3. Date/Time of Approval

Considerations in Evaluating Implants

Questions to consider: What anatomic region is/are being scanned? What is the indication for the scan? What transmit and or receive coil will/can be used? Is there availability of local transmit receive coil for the anatomy of interest?

The **static magnetic field** poses a risk to patients who have implants or foreign bodies that are ferromagnetic and/or electrically conductive. The static magnetic may affect a translational as well as a rotational force on objects that enter the MR environment. This is due to the magnetic spatial gradient.

The **time varying radiofrequency** magnetic field is also a risk to our patient during an MRI procedure. The time varying radiofrequency system will deposit energy into the patient during the transmission of radiofrequencies. This can induce electrical fields on some implants or objects that can deposit heat risking subsequent heat damage (e.g., burns) to the patient.

The **time varying gradient fields** can induce electrical voltage which are described by Faraday's Law of Induction. Due to the changing magnetic fields found with the time-varying gradient magnetic field, electrical current induction in tissue can be produced in areas that experience the largest change in magnetic field. This may/most commonly manifest as stimulation of peripheral nerves.

Implant Classifications

There are 4 classifications of implants described in the following sections.

- **Active Implants** contain an electrical component or circuit that can interfere with the MRI unit, cause artifacts in the image, induce heating, or cause implants to malfunction.
- **Passive Implants** contain no electrical components but may still cause heating or artifacts. Examples of passive implants are screws, joint replacement, staples, stents, and sternal wires.
- **Foreign Bodies or Unknown Fragments** of metallic components intentionally or unintentionally placed inside of the patient. These can include shrapnel, bullets, BB, etc. These types of implants are a risk to the patient undergoing an MRI procedure. For that reason, it is important to understand the nature of the foreign body before we scan the patient. This can be accomplished by conducting a review of the patients records or performing screening X-Rays.
- **Body Expression** is a general term for anything knowingly done by the patient to enhance their body. This includes jewelry, tattoos, RFID chips, dermal anchors, piercings, etc.

Active Implants

Active implants include, but are not limited to, pacemakers, Implantable Cardioverter-Defibrillator (ICD), neurostimulators, and bone growth stimulators. Active implants require an *increased* sense of diligence in evaluating the risks associated with these implants**.** Manufacturer instructions should be followed.

Passive Implants

Passive implants are implants that contain no electrical components. Examples of passive implants include orthopedic implant, fusion hardware, dental work, breast implants, tissue expanders (some tissue expanders are magnetically active), ocular implants, wires/leads/sutures, IUDs, staples, stents and filters, foil backed medication patches, and screws. Scanning of passive implants should be at the direction of the MRMD.

Foreign Body / Unknown Implants

There are many ways a foreign body can enter a patient. Examples include work related incidents, injuries, or other factors. It is often difficult to identify the composition of a foreign body. Many times, a patient may not know they have a foreign body within them. This can pose a challenge to the MRI technologist. It should be assumed that the foreign body is ferrous and therefore may cause deflection (translation or torque) when placed within the static magnetic field. If these objects are not located next to vital areas (eyes, vessels, nerves, etc.), risks from the static magnetic field are minimal. In terms of induced heating, many times these objects are small in size (<2cm), meaning heating of less than 5° Celsius will be produced.

Undocumented Implant or Information Not Available

If full information is not available about an implant, partial and/or available information must be provided to the attending radiologist. This is to ensure an informed risk vs benefit decision can be made by the radiologist. This is a critical decision that could result in delay of care of the patient if all available

information is not presented to the attending radiologist. The Implant/Foreign Body Checklist will be used to relay information to the radiologist.

Body Expression

Individuals can express themselves in many different ways. This can be done through the use of jewelry, dermal anchors, or tattoos. Each of these can offer challenges for an MRI technologist in the field. It is important to understand the risks and obstacles associated with these implants so that we can perform an appropriate risk analysis for them.

- **Microblading** If MRI is performed less than 7 days after microblading, irritation may occur, and patient should be informed of risks. A heat sink (i.e., ice pack) may be used or the patient may be rescheduled outside of the 7 days.

- **Jewelry** Objects that are ferrous can translate or rotate in the presence of the magnetic spatial gradient. This may or may not present a risk to the patient, but it is good practice to have these objects removed. Dependent on the location of the patient's jewelry, artifacts are typically the largest impact to image quality. When running sequences that are very susceptible to field homogeneity, jewelry outside of the field of view can affect image quality as well.

  The radiofrequency fields can induce heating in some pieces of jewelry. This is dependent on the conductivity of the material, the size of the jewelry, and its location within the radiofrequency field. When feasible, place tape around unremovable jewelry to reduce the amount of contact with the skin. This should offer less of a chance for burns to take place.

  Due to the changing magnetic fields, Lorentz forces can occur causing vibrations within specific jewelry that are orientated in the presence of the time-varying gradient fields. Overall, it is good practice to remove jewelry when possible from patients and if this is not an option, minimize contact between the jewelry and a patient's bare skin should be achieved.

- **Dermal Anchors** The static magnetic field poses a minimal threat to these objects due to the fact that they are anchored within a patient's tissue. These implants however should still be investigated for ferromagnetic components. Most common dermal anchors/piercings utilize nonferrous materials. Artifacts can be present in the image which can degrade image quality. The RF field poses a minimal heating risk to our patient due to the size of the individual dermal anchor. These are typically small and will not produce enough electrical fields to produce a burn. The time-varying gradient fields can also produce vibrations in the external implants that can cause discomfort to the patient. The technologist should be in communication with the patient throughout the exam and if the fear of a burn is still present, a heat sink such as icepack can be used on top of the dermal implant to reduce the chance of a burn.

- **Tattoos** For patients with extensive or dark tattoos, including tattooed eyeliner containing iron oxide or other ferromagnetic metallic compounds, to decrease the potential for RF heating of the tattooed tissue, it is recommended that cold compresses or ice packs be placed on the tattooed areas and kept in place throughout the MRI process if these tattoos are within the

volume in which the transmit coil is being used for RF transmission (typically the whole body coil). Patients with tattoos that had been placed within 48 hours before the pending MR examination should be advised of the potential for smearing or smudging of the edges of the freshly placed tattoo.

- **RFID Chips** RFID Chips are typically very small and pose little risk to the patient. They are implanted under the skin and are not removable. Documentation should be provided by the patient before scanning. Data mainly from veterinarian literature and RFID wrist bands.

Implant/Foreign Body Checklist

Patient Name:_____ Date:_____
MRN:_____

Is the patient able to respond to verbal stimuli during exam? (circle one) **YES** **NO**

Implant type? (circle one): **Unknown/Foreign body** **Passive** **Active**

Unknown / Foreign Body or Patient Unable to Complete Screening Form

Are there any X-Rays, CT, or prior MRI Imaging? If prior MRI, please indicate field strength.

_____

*If unable to complete screening form, an XR or CT of Skull/Chest/Abd Pel are needed to clear pt. for MRI.

Approving Radiologist: _____

Are There Any Restrictions? _____

Passive Implants

Not Electrically Active (examples include Stents, Valves, Coils, Etc.)

Implant make and model: _____

Scan Considerations: _____

Active Implants

Any Implant with a Battery, Generator, or Control Device

Implant make and model: _____
Static Field restrictions: _____
SAR or B1+RMS Guidelines: _____
Scan time limitations: _____
Scan Exclusion Zones: _____
Can above Manufacturer guidelines be met at your facility? (circle one) **YES** **NO**
If Manufacturer guidelines cannot be met, please explain why:

_____

Technologist Completing Form: _____
Date:_____

Pt. Sticker

Notes:

Patient Communication

Background

Patients and other non-MR personnel should be accompanied by, or under the immediate supervision of and in visual or verbal contact with, one specifically identified level 2 MR person for the entirety of their duration within Zone III or IV restricted regions.

Patient Communication

During scanning, patient communication is primarily established through the MR scanner intercom system which allows for two-way communication between the patient and the MR Technologist. The patient should be instructed to notify the technologist if they experience any heating or other side effects that may lead to injury during the exam. The technologist may provide additional instructions via the intercom system during scanning.

Visual contact of the patient should always be maintained throughout the duration of the scan. Visual contact of the patient may be assisted through the use of a remote camera monitoring system when line of sight is not possible.

Before initiating the MR scan, the patient will be provided an emergency squeeze bulb that may be used to alert the technologist to an emergent situation. The patient will be provided with instructions for the use of the emergency squeeze bulb.

Non-Verbal Patients

Many patients undergoing MRI procedures may not be able to communicate with the MR Technologist. Examples may include patients under anesthesia, stroke patients, pediatric patients, and non-native English speakers. Patients who are incapable or unable of communicating with the MR Technologist must have visual contact with the patient during all times the patient is in Zone IV. The MR Technologist is encouraged to continue one-way verbal communication with the patient, as appropriate.

MRI Patient Notification (Squeeze Ball)

Background

Each MRI scanner is equipped with a squeeze bulb that allows the patient to set off an audible alarm to attract the operator's attention. The squeeze bulb should be made available to patients unless some alternative method of constant monitoring is in effect. Use of the squeeze bulb or some comparable form of continuous patient monitoring is mandatory. If the patient squeezes the squeeze bulb, a continuous audible alarm is emitted via the intercom and the alarm button has a red flashing light.

Responding to a Squeeze Bulb Alarm

1. If a scan is ongoing, click the "Stop Icon" button on the console using the mouse.
2. To stop the audible alarm: press the button.
3. Press the intercom talk button.
4. While holding down on the appropriate intercom talk button, speak to the patient to determine why the squeeze bulb was pressed. Make sure that the volume is turned up so that you can hear the patient's response.
5. If necessary, enter the room to further investigate and/or correct the problem.

Appropriate Response to a Squeeze Bulb Alarm

Reason for Alarm	Appropriate Response
Pain or discomfort for any reason	DO NOT PROCEED, investigate what is occurring. If the pain is the reason why they are here, attempt to make them as comfortable as possible. If the pain is new, contact the Radiologist.
Participant has an implant and feels any sensation in the area of implant or the surrounding tissues	Confirm MR scanner setting with published MR conditions for the device. Whenever feasible, re-check MR scanner setting with MRSO. Contact the radiologist.
Participant accidently squeezed the ball	After confirming that the patient is ok, proceed with scan.
Participant continuously squeezes ball due to an altered mental status	Contact Radiologist to see if the scan can be shortened in any way, find alternative method of monitoring.

Document in patient's chart all the reasons why the exam was stopped and the care the patient received.

Object Screening

Background

Objects brought into Zone IV can present a hazard if they contain ferrous materials. Ferrous objects can become projectile hazards and devices may no longer work as intended once exposed to a strong magnetic field.

MR Safety Terms

The MR task group of the American Society for Testing and Materials (ASTM) International has developed a set of MR safety terms. This terminology is NOT being applied retrospectively to implants and devices that previously received FDA approved labeling using the terms "MR safe" or "MR compatible". This applies to those objects tested prior to December 2005.

Particularly with regard to nonclinical and incidental equipment, current products marketed with ill-defined terminology such as ‘‘nonmagnetic’’, or the outdated classifications described above (‘‘MR compatible’’), should NOT be presumed to conform to a particular current ASTM classification.

To go along with the new terminology, the ASTM introduced corresponding icons consistent with international standards for colors and shapes of safety signs. They are intended for use on items that may be brought into or near the MRI environment as well as in product labeling.

MR Safe

Items that pose no known hazards in all MRI environments. Using the new terminology, "MR Safe" items include non-conducting, non-metallic, non-magnetic items such as a plastic Petri dish. The "MR Safe" icon consists of the letters "MR" in green in a white square with a green border or the letters "MR" in white in a green square.

MR Conditional

Items that have been demonstrated to pose no known hazards in a specified MR environment as long as specified conditions of use are met. The "MR Conditional" icon consists of the letter "MR" in black inside a yellow triangle with a black border. The item labeling must include the results of testing and the specific conditions of use sufficient to characterize the behavior of the item in the MRI environment.

MR Unsafe

Items that are known to pose hazards in all MRI environments. MR Unsafe items include magnetic items such as a pair of ferromagnetic scissors. The "MR Unsafe" icon consists of the letters "MR" in black in a white field inside a red circle with a diagonal red band.

Safety in MRI Not Evaluated

For devices that have historically not provided any information about MRI safety.

Object Screening

As a point of safety, all objects should be considered to be magnetic unless they can be positively determined to be non-magnetic (e.g., 100% plastic) or are specially designed to be MR-Safe. If in doubt, keep it out!

As part of the Zone III restriction and equipment testing and clearing responsibilities, all sites should have ready access to a strong handheld magnet (≥ 1000 Gauss) and a handheld ferromagnetic detection device. A handheld magnet and ferromagnetic detection device should be used to test each unknown object for ferrous materials before the object is allowed into Zone IV.

Objects designated as MR Conditional may only enter Zone IV if the conditions of the object and/or device are met. Any unlabeled object or object not evaluated entering Zone IV must be tested and labeled according to the procedure outlined in Designation of MR Safe & MR Unsafe procedure. Any MR unsafe object that is necessary and appropriate for the care of the patient (ex. arterial line, catheter bag with clip, body shaver) must be cleared by the radiologist before the object may enter Zone IV.

Designation of MR Safe & MR Unsafe

Devices and objects may come from a vendor or equipment manufacturer and be labeled as MR Safe, MR Conditional, or MR Unsafe. These objects should come labeled from the equipment manufacturer. Additionally, documentation of the manufacturer's results showing compliance with ASTM F2503 must be kept on site.

Designation of patient devices (i.e., implants, catheters, materials, etc.) that are unknown or have not been evaluated as MR Safe, MR Conditional, or MR Unsafe cannot be evaluated by the MR Technologist.

Level II MR Personnel may designate unknown external objects as MR Safe or MR Unsafe. Testing of unknown objects must be done with both a strong handheld magnet (≥ 1000 Gauss) and a ferromagnetic detection device. To designate an object as MR Safe it must not have any detectable attractive forces with the handheld magnet, be non-ferrous, and not require electricity to operate. MR Unsafe objects are those that demonstrate an attractive force with a strong handheld magnet, contain ferrous materials, or require electricity to operate. Designation of MR Safe or MR Unsafe is shown in the Table below.

	Results
MR Safe	Non-Ferrous AND Non-Electrical
MR Unsafe	Ferrous OR Electrical

Once an unknown object has been designated as MR Safe or MR Unsafe, the appropriate corresponding label should be affixed to the object. The results of the testing must be documented on the MR Safe & MR Unsafe Designation Form and include the results, date, time, individual performing the testing, and methodology. This record must be maintained on site.

MR Safe & MR Unsafe Designation Form

Date	Time	Object Description	Performing Individual	Methodology	Results
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
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				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe
				☐ Magnet ☐ Ferromagnetic Detector	☐ MR Safe ☐ MR Unsafe

Ferrous Object in MR Scan Room

Background

Every effort should be taken to ensure ferrous objects do not enter Zone IV. However, ferrous objects may inadvertently enter Zone IV from time to time. In the event of a ferrous object in the MR scan room, an evaluation of the situation must be done immediately.

The location of the ferrous object within the scan room as well as the object itself will determine the most appropriate actions.

Object Inside the Patient or In the Imaging Field

1. Stop the scan and speak with the patient. If the object is identified and can be removed safely (i.e., a bobby pin) do so with caution. Never remove any kind of weapon.
2. If the object is unidentified or unsafe for the MRI (i.e., undocumented aneurysm clip), the radiologist should be consulted to determine if the scan can be continued safely.
3. If the scan cannot be continued safely, **SLOWLY** move the patient of out of the magnet. The patient should not sit up and all movements should be slow until outside of the Zone IV.

Object is Pinning a Patient, Visitor, or Staff Member

1. If the person is unconscious, bleeding profusely, at risk of losing a limb or extremity, or in severe pain, you must manually quench the magnet to bring down the field in order to release the object and the person.
2. If the person is responsive and able to tell you they feel OK, you may be able to leave them in the position until service engineer can respond and ramp the magnet down slowly to avoid a full quench. If you choose the latter and the person then loses consciousness or their condition worsens, immediately quench the magnet manually.
3. Once the person is released, get them out of the room and obtain medical help. The MR Medical Director and site manager should be informed immediately.

Solitary Object; Not Life Threatening

1. If an object is pinned to the magnet and no one is pinned, do not attempt to remove the object. Contact Medical Imaging Engineering and the site manager. A service engineer can ramp the magnet down slowly to avoid a quench.

Acoustic Noise

Background

Movement of the gradient coils due to switching of the gradient magnetic field is the main source of considerable acoustic noise within the scanner room, registering up to 140 dB. Ear plugs and other hearing protection can reduce noise by 30 dB.

Hearing Protection

The noise generated by scanning may reach a level in the scan room and in the bore of the magnet that can result in temporary (and occasionally) permanent hearing loss. Properly inserted earplugs will limit the level of the noise that reaches the inner ear.

Any patient who undergoes an MRI, as well as anyone in Zone IV during a scan, **MUST** wear earplugs or other hearing protection that reduces acoustic noise by at least 30 dB. The earplugs or other hearing protection will be inserted or placed by the patient or MRI staff but must be verified for proper placement by the MRI Technologist before the initiating any MR sequences. The earplugs are Latex Free and have an acceptable NNR rating.

In pediatric patients, and patients with unusual shaped ear canals, the earplugs may not fit properly to limit the noise level. In these instances, MRI staff will use another form of hearing protection such as headphones or earmuffs that will hold the earplugs in place and further dampen the noise level.

If a patient has their own custom ear plugs, designed for their ear canals, it is acceptable to use after they have been evaluated for metal. MR staff need to check they are inserted.

Pregnant Patients & Staff

Staff

Pregnant health care practitioners are permitted to work in and around the MR environment throughout all stages of their pregnancy. Acceptable activities include, but are not limited to, positioning patients, scanning, archiving, injecting contrast, and entering the MR scan room in response to an emergency. They are not, however, to remain within the MR scanner bore or Zone IV during actual data acquisition or scanning.

Patients

If pregnancy is established, consideration should be given for assessing the potential risks versus benefits of the pending study in determining whether the requested MR examination could safely wait to the end of the pregnancy before being performed. MRI exams performed at 1.5T or 3T within normal operating mode and when total sequence time is less than 30 minutes should be considered safe in pregnant patients and do not require Radiologist approval.

When exams are not performed in normal operating mode or total sequence time is greater than 30 minutes, the attending Radiologist should be consulted so that a risk-benefit analysis can be performed. The radiologist should confer with the referring physician and document the following in the radiology report or the patient's medical record:

- The information requested from the MR study cannot be acquired by means of nonionizing means (e.g., ultrasonography).
- The data is needed to potentially affect the care of the patient or fetus during the pregnancy.
- The referring physician believes that it is not prudent to wait until the patient is no longer pregnant to obtain this data.

Contrast

MR contrast agents are NOT to be routinely administered to pregnant patients. The decision to administer gadolinium-based MR contrast agents to pregnant patients is done on a case-by-case basis by the attending radiologist and should be accompanied by a well-documented and thoughtful risk-benefit analysis. **Patient consent is required**. Any modification to standard dosing is made at the discretion of the supervising Radiologist.

Sedations

Background

Patient sedation may be required for patients undergoing MRI examinations. Reasons for sedation in an MRI environment include, but are not limited to, inability to remain motionless, claustrophobia, or other medical necessity.

Facility Policy

It is important to recognize that sedations in an MR environment do not differ from sedations performed outside of the MR environment. As such, Facility Policies for Adult, Pediatric, and Neonatal sedations should be used and adhered to.

Sedations in MRI

In addition to the above referenced policies, there are MRI specific concerns with regards to patient sedations. The principal concerns are related to the safety of the equipment used within the MR Suite. MR Safe or MR Conditional equipment should be available and used for all patient sedations if it may enter Zone IV. Examples include temperature monitoring equipment, neonatal isolation transport units and other warming devices. Other resuscitation equipment or crash carts that is MR Unsafe should be labeled appropriately and stored in a readily accessible area within either Zone II or Zone III.

Thermal Burns

Background

The Radiofrequency (RF) Field is the magnetic component of the oscillating electromagnetic field produced by the RF coils used to elicit an MRI signal form the patient's tissues. Power dissipation within the patient causes tissue heating and is a potential source of thermal injury. The patient will be instructed to notify the technologist if they begin to feel warm or hot during the course of their MRI exam.

Uneventful scanning at one field strength does not guarantee that a scan at a different field strength will not encounter thermal issues, since resonant frequencies vary with the field strength and wavelength. Implant safety at 3T does not guarantee safety at 1.5T.

Electrically Conductive Materials

All unnecessary or unused electrically conductive materials external to the patient shall be removed from the MR system before the onset of imaging. It is not sufficient to merely ''unplug'' or disconnect unused/unnecessary electrically conductive material and allow it to remain in contact with the patient within the MRI scanner.

When electrically conductive material (wires, leads, implants, etc.), are required to remain within the bore of the MR scanner with the patient during imaging, care should be taken to ensure that no large caliber electrically conducting loops remain within the MR scanner during imaging. 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 patient 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.

Care should be taken to place thermal insulation (including air, pads, towels, blankets, pillows, etc.) between the patient and the electrically conductive material, while simultaneously attempting to (as much as feasible) keep the electrical conductor from directly contacting the patient during imaging. Extreme care should be taken for unconscious, non-responsive, or otherwise incapacitated patients who may not be able to communicate and describe sensations of thermal heating.

Electrically conductive materials should not be covered or obscured from view by either thermal insulation, clothing, or the patient.

Position electrically conductive materials to exit the MR system bore as close to the center of the bore as possible (not along the side of the MR system or close to the body RF coil or other transmit RF coil).

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

Patient Positioning & Padding

Care shall be taken to ensure that the patient's arms or legs are not positioned in such a way as to form a large caliber skin loop within the bore of the MR system during the imaging process.

Patients must be instructed not to cross their arms or legs and to avoid arm-to-body or leg-to-leg contact in the MR scanner.

There have been reports of thermal injury associated with skin-to-skin contact such as in the region of the inner thighs, hand-to-thigh, heel-to-heel. This should be taken into consideration when imaging patients that may not be able to alert the technologist to heating sensations.

Pads between patient thighs and ankles, between arms and body, and between any other potentially apposed tissues (skin folds, etc.) may reduce the risk of burns. Pads between body and magnet bore may be particularly important at high field strengths.

Tattoos

For patients with extensive or dark tattoos, including tattooed eyeliner containing iron oxide or other ferromagnetic metallic compounds, to decrease the potential for RF heating of the tattooed tissue, it is recommended that cold compresses or ice packs be placed on the tattooed areas and kept in place throughout the MRI process if these tattoos are within the volume in which the transmit coil is being used for RF transmission (typically the whole body coil). Patients with tattoos that had been placed within 48 hours before the pending MR examination should be advised of the potential for smearing or smudging of the edges of the freshly placed tattoo.

Drug Delivery Patches

Some drug delivery patches contain metallic foil. Scanning the region of the metallic foil may result in thermal injury. Because of the potential of thermal injury, all transdermal drug delivery patches should be removed prior to scanning. Because removal or repositioning can result in altering of patient dose, consultation with the patient's prescribing physician would be indicated in assessing how to best manage the patient. If the patch delivery system is positioned on the patient so that it is in the volume of excitation of the transmitting RF coil, the case should be specifically reviewed with the radiologist or physician covering the case. Alternative options may include placing an ice pack directly on the patch. This solution may still substantially alter the rate of delivery or absorption of the medication to the patient (and be less comfortable to the patient, as well). This ramification should therefore not be treated lightly, and a decision to proceed in this manner should be made by a knowledgeable radiologist attending the patient and with the concurrence of the referring physician as well.

If the patch is removed, the MR technologist has the responsibility for ensuring that it is replaced or repositioned at the conclusion of the MR examination. If there are questions on how to replace the patch, the MR technologist should consult with the radiologist or prescribing physician.

Excessive SAR

Specific Absorption Rate (SAR) is the rate of power dissipation within the patient and is quantified as Watts per kg of bodyweight. MRI systems should be capable of displaying a SAR monitor on the scanner console. The SAR limits are outlined in the table below.

	Whole Body	Head
Normal Mode	2 W/kg	3.2 W/kg
1st Level Controlled Mode	4 W/kg	3.2 W/kg
2nd Level Controlled Mode	>4 W/kg	>3.2 W/kg

SAR may be reduced by a number of factors including the use of lower flip angles, longer or fewer RF pulses, increasing the TR, and reducing the number of image slices, echoes, or sat bands. Shorter RF pulses used in fast imaging increase SAR, and also necessitate the use of stronger gradient amplitudes, with an increased likelihood of electrical stimulation.

Those at higher risk of excessive SAR include neonates, pregnant patients, elderly, diabetics, patients with cardiovascular disease, obese patients, febrile patients, those on medications such as beta-blockers, calcium blockers, vasodilators, diuretics, those with retained wires, and those with large non-ferromagnetic implants.

Reporting & Follow Up

Any incident of thermal injury/potential thermal injury during an MRI scan shall be reported to the attending radiologist and MR Medical Director immediately. Outpatients reporting a potential burn must be examined by a physician before release from the facility. Inpatients reporting a potential burn must be examined by either a nurse or physician as soon as possible after their MR exam. It is the responsibility of the attending radiologist to notify the patient's physician so that appropriate treatment can be delivered.

MRI Gadolinium Administration

Background

No patient is to be administered prescription MR contrast agents without orders from a duly licensed physician. Intravenous (IV) injection–qualified MR Personnel may establish and attend to peripheral IV access lines if they have undergone the requisite site-specified training in peripheral IV access and have demonstrated and documented appropriate proficiency in this area. IV injection–qualified MR Personnel may administer FDA-approved MR GBCAs via peripheral IV routes as a bolus or slow or continuous injection as directed by the orders of a duly licensed site physician.

Practices relating to administration of these agents and recommendations regarding GBCA usage, adverse reactions, nephrogenic systemic fibrosis, and retained or residual gadolinium should follow the ACR Committee on Drugs and Contrast Media. The most recent version of the ACR Manual on Contrast Media should be followed.

MRI Safety Education & Training

Background

To establish a comprehensive safety training program necessary to ensure safety and compliance in the MRI environment. MRI Safety education is critical for the safety of all patients, individuals, and staff. The American College of Radiology (ACR) have established requirements and guidelines for establishing MRI Safety education in the healthcare environment. Initial and annual training in MRI Safety is mandated for all individuals who interact with the MRI environment.

Level I MR Training

Individuals who may occasionally interact with the MRI environment will receive Level I MR Training. These individuals will have received safety education targeted to ensure their own safety as they work within Zone III. These individuals must be granted access into Zones III and IV by Level II MR Personnel and are screened prior to entry to Zone III. Individuals who may be considered for Level I MR Training include hospital medical staff, OR staff, code teams, facilities staff, housekeeping staff, security, etc. Level I personnel must complete MRI Safety Awareness Training. This training provides general awareness of the specific MRI suites and illustrates why access is tightly controlled and monitored. Level I training will be completed initially upon hire and annually thereafter. Level I training will be approved by the MRMD. Training may be completed through online learning modules or directly with the MRMD.

Level II MR Training

Level II training in MRI Safety is mandated for all MR Technologists and any other staff who interact regularly with Zone IV in any of the MRI departments. Controlled access is limited to: Radiologists, MR Technologists, Biomedical Engineers, Physicists, and Radiology Nurses. These individuals must be extensively educated and trained in MR safety to include

- Employ comprehensive screening procedures to ensure safety and specifically address ferromagnetic and electrically conductive items, medical implants and devices, and risk for nephrogenic systemic fibrosis (NSF);
- Recognize MRI-related bio-effects and safety issues related to patient and equipment positioning activities to avoid thermal injuries;
- Identify equipment and supplies that have been determined to be acceptable for use in the MRI environment (MR safe or MR conditional);
- MRI safety response procedures for patients who require urgent or emergent medical care;
- MRI system emergency shutdown procedures, such as MRI system quench and cryogen safety procedures;
- Patient hearing protection;
- Apply proper patient management of patients with claustrophobia, anxiety, or emotional distress while in the MRI environment.

Level II training will be completed initially upon hire and annually thereafter. Level II training will be approved by the MRMD. Training may be completed through online learning modules or directly with the MRMD.

Scanner Operation Training

In an effort to orient new staff, all new MRI Technologists will complete MRI Skills Checklist and Level II training prior to performing patient studies.

Emergency Code Procedures

Background

In the event that a person within the MR suite should require emergency medical attention, it is imperative that those responding to a call for assistance are aware of, and comply with, MR safety protocols. This includes nurses, physicians, respiratory technicians, paramedics, security, and others.

MRI Hazards

Full resuscitation of patients within Zone IV is complicated by the inability to accurately interpret electrocardiographic data. Furthermore, this may place at risk of injury all within the Zone IV from ferromagnetic objects which may be on, within, or brought into Zone IV by emergency response personnel responding to a code if one is called in that area.

Specialized Training

Emergency Code Teams should receive specialized training for operating within the MR environment. This may consist of live or didactic training. Emergency Code Teams should also perform regular drills to rehearse and refine emergency response protocols to protect patients, MR staff, and responders.

In an emergency, it should be stressed that the magnetic field is **always ON**. It is the responsibility of appropriately trained and knowledgeable MRI staff to ensure the safety of all non-MRI personnel as well as that of patients and family.

Crash Cart

The location of the Crash Carts should be known by all MRI staff members. These will be checked daily by assigned MR staff for expired medications and functioning equipment.

Emergency Code Procedures

In the event of a Code in Zone IV, the following procedure should be followed

1. Initiate basic cardiopulmonary resuscitation (airway, breathing, chest compressions)
2. Remove the patient immediately out of Zone IV to a designated location where the code can be run.
3. Dial 911 or the operator and request a Code be called. Give your location.
4. Close and lock the scan room door. The door should be monitored by MRI personnel during the entirety of the code to prevent any accidental entry which could result in injury.
5. Obtain the Crash Cart and continue basic CPR until the Code Team arrives.
6. Other MRI personnel should offer assistance, such as directing Code Team to the right location.
7. The MRI physician should be notified that a code has been called.
8. When the Code Team arrives, they are responsible for the patient. MRI personnel will maintain the safety of all staff in the magnetic environment.
9. After the code, it is the responsibility of the MRI staff to call the pharmacy so that the Crash Cart can be restocked as soon as possible.

Infection Control & Medical Waste

Infection Control

Cleaning of Zone IV to include the table, pads, coils, and the inside of the magnet bore is performed by MRI staff to prevent the transmission of infections. Housekeeping staff are not allowed unescorted access to Zone IV because of the magnetic field hazards associated with the MRI environment. Housekeeping staff may have access to Zone IV; however, they must be screened by the MRI Technologist and complete the Non-MRI Personnel Log before each entry into Zone IV. Additionally, the MRI Technologist must maintain direct visual contact with housekeeping staff while in Zone IV.

Cleaning of the MRI table, pads, and coils is performed before and after each patient exam with an approved disinfectant. Gloves must always be worn when handling contaminated equipment and working with a cleaning disinfectant. All cleaning equipment must be MRI Safe.

Table pads should be inspected for fraying and tearing each week. Table pads should be replaced, as necessary. Patient contact inside the magnet bore of the MR unit can transmit infection. The inside of the magnet bore must be wiped down and disinfected at least weekly and after contact precaution patients, when it is visibly soiled, or as needed.

Medical Waste

Medical Waste must be handled and disposed of according the facility policies.

All medications, IV solutions, and their inner packaging used in the MRI Suite are disposed of using the Blue non-hazardous pharmaceutical waste bins located in the MRI Suite. External packaging can be disposed of as regular trash.

Magnet Quench & Cryogen Safety

Background

The coils of the superconducting magnet are immersed in liquid helium to prevent excessive heat buildup. Under normal operation, the helium slowly boils off and more liquid helium must be added only after several years' time. Risks associated with liquid helium include burns due to accidental direct contact with the cryogen or hypoxia as a result of a leak or quench.

A quench involves the rapid release of helium and results in loss or decrease of the magnetic field. A manual quench can be performed by trained personnel in the event of an emergency, such as a person being pinned to the magnet. In extraordinary circumstances, an uncontrolled quench can occur. If the helium gas enters the magnet room, the oxygen level in the magnet room may significantly decrease, causing a hypoxic environment. To reduce the risk of hypoxia due to the rapid release of helium, the MRI Suite that houses the magnet has a quench vent pipe which controls the release of helium safely into the environment outside of the building.

Quench

The MRI scanner is super-cooled with liquid helium. Quench is the rapid boiling off of this liquid either intentionally or unintentionally.

An intentional quench is performed in an extreme emergency only by qualified MR Personnel (Radiologists, MR Technologists only) to rapidly run the magnetic field to zero. A quench of the magnet should only be performed when:

- A person is pinned to the magnet and is unable to be removed from the scanner without harm.
- There is an uncontrolled fire in the MRI scanner, equipment, or console room.
- There is an uncontrolled fire in another area of the hospital and fire, smoke, or water damage is an immediate threat to the MRI Suite.

The MRI Suite is designed to exhaust gaseous helium directly outside the building through a vent pipe system. However, due to potential for displacement of oxygen and the creation of a hypoxic environment should there be a breach in the pipe; the MRI Suite should be evacuated anytime a quench is performed. Before allowing entry to the area after a Quench, properly trained MR Personnel should verify the static field is no longer present.

In order to perform a quench of the magnet:

1. Remove patient from Zone 4 MRI scan room prior to initiating quench if possible.
    - If the patient is pinned to the magnet or another event which requires quenching while patient is in the room, quench magnet then remove the patient as quickly and carefully as possible.
    - With a spontaneous quench, high pressure in the scan room 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 patient evacuated. In such a case the patient should be immediately evacuated and evaluated for asphyxia, hypothermia, and ruptured eardrums. Remember: Helium is not toxic; the hazard is that it will displace the oxygen in the area and create possibility of suffocation.

2. Activate emergency exhaust system.

3. Evacuate patient and personnel to a safe location.

4. Close all doors when leaving the area.

5. Notify the MRI manufacturer and Engineering.

6. Notify MRMD / Risk Management / Nursing Supervisor.

7. Complete a Root Cause Analysis.

Cryogen

Liquid helium and liquid nitrogen represent the most commonly used cryogens in MR environments. If exposed to room air, these cryogenic liquids will rapidly boil off and expand to a gaseous state. This produces several potential safety concerns, including:

- Asphyxiation potential as cryogenic gases replace oxygenated air.
- Frostbite considerations at the exceedingly low temperatures of these cryogenic liquids.
- Fire hazards can exist in the unlikely event of a quench, especially if some of the cryogenic gases escape into the magnet room.
- Pressure considerations within Zone IV can rarely exist in the unlikely event of a quench.

Periodic cryogen refills may be required as the cryogenic liquid slowly boils off. These refills should only be undertaken by appropriately trained personnel with appropriate precautions in place.

In order to help identify and correct potential weaknesses, stress/wear of pipe sections and couplings, loose fittings and supports, or signs of condensation that may lead to a blockage, an evaluation of the cryogen ventilation system will be conducted annually.

Reporting MR Safety Incidents

Background

In an effort to better understand the safety pitfalls in our MR environments, all adverse events, MR safety incidents, or "near accidents" must be reported. This will help to ensure a better understanding of opportunities for improvement as well as encourage transparency within all aspects of MR safety. Reporting safety incidents will also facilitate implementation of solutions to the most commonly experienced problems more effectively.

Internal Reporting

Reporting of MR Safety Incidents should occur as soon as possible after the incident and must occur within 24 hours of the incident. Reports should be directed to the MR Medical Director and Facility Safety. Notification of the MR Medical Director and Facility Safety should be followed by submittal of a Variance Report.

Examples of incidents that require reporting include, but are not limited to:

- Metallic, ferrous, or other MR Unsafe objects are brought into Zone IV.
- Patients with biomedical devices or implants that are not safe are allowed Zone IV and undergo an MRI examination.
- A patient receives an RF burn.
- A patient is injured during an MR examination.
- An emergency requiring a magnetic quench occurs.

A Root Cause Analysis will be performed by the MR Medical Director, Facility Safety, MRSO, and MR Technologists so that actions can be taken to prevent future reoccurrence.

External Reporting

At the discretion of the MR Medical Director, MR Safety Incidents may voluntarily be reported to the FDA Medwatch Program. The FDA Medwatch Program is a database that contains the majority of accidents that occur in the MRI environment with the purpose of identifying the areas in MRI Safety where increased focus is needed, and to review the scope of MRI accidents that exist.