MAGNETIC RESONANCE IMAGING (MRI) SAFETY TRAINING

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Two employees were pinned to machine for nearly four hours after a non-MR safe oxygen tank was brought into the room.
A six year old boy died after undergoing an MRI exam when an Oxygen tank was pulled across the room, crushing his head.

The routine imaging procedure was performed following surgery for a benign brain tumor the week before. The boy was under sedation at the time the accident occurred.
OTHER INCIDENTS

- Rochester, NY
  - An off-duty cop was told it was OK to walk into the MR Suite with his hand gun which immediately got pulled out of his hand, causing an accidental shot to go off. The bullet lodged in a wall and no one was injured.

- The Hairpin
  - After a woman forgot to remove a hairpin, it traveled up her nose and lodged in her pharynx. This required a procedure to extract the object.

- At least one record of a woman dying after receiving an MR procedure with an aneurysm clip.
DANGERS INVOLVED WITH MRI ARE IMMEDIATE AND POTENTIALLY DEADLY

The dangers of MRI are always present and can cause immediate and catastrophic damage:

- Projectile (Missile) hazards
- Medical device misplacement or disruption

The three previous slides clearly demonstrate these hazards.

It is the responsibility of the MR staff to understand their critical role in creating a safe MR environment for themselves, the patient, and/or any other MR personnel present.

Safety should always be a first priority.
TWO IMPORTANT REFERENCES PERTAINING TO MR SAFETY

Joint Commission Sentinel Event #38
- 10 explicit objectives for the institution
- 8 classifications of injuries that can and have occurred during the MR scanning process are described

- 14 Points
JOINT COMMISSION SENTINEL EVENT #38

10 Explicit Objectives

1. Restrict Access – Four Zones (Zone Posting)
2. Use trained personnel to screen all non-emergent patients twice
3. Ensure MR Tech has patient’s complete and accurate medical history and have literature readily accessible to reference the safety of any devices.
4. Have specially trained staff accompany any individuals inside the MR suite at all times who are familiar with the MR environment.
5. Education – Annually provide all medical and ancillary staff who may be expected to accompany patients into the MR Suite. Have materials available for patients and their families that explain the potential for accidents and adverse effects.

6. Precautions to prevent burns

7. Use only equipment approved for MR scans


9. Provide hearing protection

10. Never attempt to run a cardio-pulmonary arrest code or resuscitation within the MR Suite itself
8 Types of Injuries That Can and Have Occurred During the MR Scanning Process

1. Missile (Projectile) Effect
2. Dislodged ferromagnetic implants
3. Burns from objects that may heat (wires and leads are the most common)
4. Equipment or device malfunction due to the magnetic field (battery powered devices such as diffusion pumps and pacemakers)
5. Failure to attend patient support systems (sedation or anesthesia)
   - Oxygen or infusion pumps can run out if replacement is not readily available
6. Acoustic injury from machine noise
7. Adverse events from contrast agents
8. Adverse events to cryogen handling, storage, or inadvertent release in MR systems (quench)

2. Static Magnetic Field Issues: Site Access Restriction (Zone I-IV Postings)
3. MR Technologist
4. Pregnancy Related Issues – Patient and Worker
5. Pediatric MR Safety Concerns
6. Time Varying Gradient Magnetic Field Related Issues: Induced Voltages
7. Time Varying Gradient Magnetic Field Related Issues: Auditory Considerations
8. Time Varying Radiofrequency Magnetic Field Related Issues: Thermal
9. Drug Delivery Patches and Pads
10. Cryogen-Related Issues

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8. Time Varying Radiofrequency Magnetic Field Related Issues: Thermal

9. Drug Delivery Patches and Pads
10. Cryogen-Related Issues
11. Claustrophobia, Anxiety, Sedation, Analgesia, and Anesthesia
12. Contrast Agent Safety
13. Patients in Whom There Are or May Be Intracranial Aneurysm Clips
14. Patients in Whom There Are or May Be Cardiac Pacemakers or Implantable Cardioverter Defibrillators
MRI SAFETY ZONES

- Zones are conceptual
- Should be clearly posted
- Meaning of each zone should be understood by staff
ZONE I

- Includes all areas that are freely accessible to the general public
- Typically outside the MR environment itself
- Area through which patients, health care personnel, and other employees of the MR site access the MR environment
ZONE II

- Interface between the publicly accessible, uncontrolled Zone I, and the strictly controlled Zones III and IV
- Typically where patients are greeted and are not free to move about at will, but rather under the supervision of MR personnel
- Answers to MR screening questions, patient history, medical insurance questions, etc., are typically obtained
ZONE III

Area in which free access by unscreened non-MR personnel or ferromagnetic objects or equipment can result in serious injury or death.

Access should be strictly restricted, with access to regions within it (including Zone IV) controlled by, and entirely under the supervision of MR Personnel.

Should be physically restricted from general public access (i.e. key locks, passkey, or other reliable, physically restricting method that can differentiate between MR and non-MR personnel).
ZONE IV

Area is synonymous with the MR scanner magnet room itself
By definition will always be located within Zone III
Should be demarcated and clearly marked as being potentially hazardous due to the presence of very strong magnetic fields
Should be clearly marked with a red light and lighted sign stating, “The Magnet Is Always On”
Non-MR personnel should be accompanied by, or under the immediate supervision of and visual contact with, one specifically identified level 2 MR person for the entirety of their duration within Zone IV (and Zone III)
Level 1 & 2 MR personnel may move freely about all zones
MR PERSONNEL AND NON-MR PERSONNEL DEFINITIONS

All individuals working within at least Zone III of the MR environment should be documented as having successfully completed at least one of the MR Safety live lectures or prerecorded presentations approved by the MR medical director. Above should be repeated annually and documented.

Two levels of MR personnel: Level 1 and Level 2

- **Level 1**: Those who have passed minimal safety educational efforts to ensure their own safety as they work within Zone III.
- **Level 2**: Those who have been more extensively trained and educated in the broader aspects of MR safety issues and direct neuromuscular excitation from rapidly changing gradients.

MR medical director to identify necessary training and those who qualify as Level 2. Medical director shall have necessary education and experience to qualify as Level 2.
PATIENT AND NON-MR PERSONNEL SCREENING

Non-MR personnel wishing to enter Zone II must pass and MR safety screening

Only MR personnel are authorized to perform this

Screening process and forms for patients, non-MR personnel, and MR personnel should be essentially the same

Ferromagnetic detection devices can be a supplement to the screening process but not used in place of the screening process

Non-emergent patients should be screened on site by a minimum of two separate individuals

At least one of these should be performed by level 2 personnel and at least one should be performed interactively
PATIENT AND NON-MR PERSONNEL SCREENING

Remove all readily removable metallic personnel belongings and devices on or in them (i.e. watches, jewelry, pagers, cell phones, body piercings, contraceptive diaphragms, metallic drug delivery patches, cosmetics containing metallic particles (such as eye makeup), and clothing items)

It is recommended that patients wear a site-supplied gown with no metal fasteners when feasible

Anyone with a history of potential ferromagnetic foreign object penetration must undergo further investigation before being permitted entrance to Zone III

Once positive identification has been made, best effort assessments should be made to identify to MR compatibility or MR safety of the implant or object

Final determination of whether or not to scan any given patient with any given implant, foreign body, etc. is to be made by the level 2 designated attending MR Radiologist, the MR Medical Director, or specifically designate Level 2 MR Personnel
PATIENT AND NON-MR PERSONNEL SCREENING

All non-MR personnel with implanted electrically conductive devices upon which they are dependent should be precluded from Zone IV and physically restrained from the 5-Gauss line unless specifically cleared in writing by a level 2 designated attending Radiologist or Medical Director

Arrange to prospectively educate local fire marshals, fire-fighters, and police or security personnel about the potential hazards of responding to emergencies in the MR suite

   Even in the presence of a true fire (or other emergency) in Zone III or IV, magnetic fields may be present and fully operational

   Air tanks, axes, crowbars, other firefighting equipment, guns, etc might prove catastrophic or even lethal to those responding or others in the vicinity

As part of Zone III and IV restrictions, all MR suites must have clearly labeled and readily accessible MR Conditional or MR Safe fire extinguishing equipment physically stored within Zone III or IV
MR PERSONNEL SCREENING

Must undergo an MR screening process as part of their employment interview process to ensure their safety in the MR environment.

For your own protection and for the protection of the non-MR personnel under their supervision, all MR personnel must immediately report any trauma, procedure, or surgery they experience or undergo where a ferromagnetic object or device may have become introduced within or on them. This will permit appropriate screening to be performed on the employee to determine the safety of permitting that employee into Zone III.
DEVICE AND OBJECT SCREENING

Ferrous objects should be restricted from entering Zone III, whenever practical (including equipment brought by contractors).

Never assume MR compatibility or safety information about a device if it is not clearly documented in writing.

External devices or objects demonstrated to be ferromagnetic and MR Unsafe or incompatible may still, under specific circumstances, be brought into Zone III if they are under the direct supervision of specifically designated level 1 or 2 MR personnel and deemed by MR personnel to be necessary and appropriate for patient care. The designated level 1 or 2 MR personnel must be familiar with the device, its function, and the reason supporting its introduction to Zone III.
DEVICE AND OBJECT SCREENING

All portable metallic or partially metallic objects must be properly identified and labeled using the current FDA labeling criteria developed by ASTM International in standard ASTM F2503.

- MR Safe (Green square)
  - Wholly, nonmetallic
- Unsafe (Red circle)
  - Clearly ferromagnetic
- MR Conditional (Yellow triangle)
  - Objects with an MR conditional rating should be affixed with the yellow triangular label before being brought into the scan room/Zone IV.
MR TECHNOLOGIST – QUALIFICATIONS AND RESPONSIBILITIES

MR technologists should be in compliance with the technologist qualifications listed in the MR Accreditation Program Requirements.

Except for emergent coverage, there will be a minimum of 2 MR technologists or one MR technologist and one other individual with the designation of MR personnel in the immediate Zone II through Zone IV MR environment. For emergent coverage, the MR technologist can scan with no other individuals in their Zone II through Zone IV environment as long as there is in-house, ready emergent coverage by designated department of radiology MR personnel (e.g., radiology house staff or radiology attending).
Worker

Pregnant health care practitioners are permitted to work in and around the MR environment throughout all stages of their pregnancy.
PREGNANCY RELATED ISSUES

Patient

Present data have not conclusively documented any deleterious effects of MR imaging exposure on the developing fetus. Therefore no special consideration is recommended for the first, versus any other, trimester in pregnancy.

Pregnant patients can be accepted to undergo MR scans at any stage of pregnancy if, in the determination of a level 2 MR personnel-designated attending radiologist.

The risk–benefit ratio to the patient warrants that the study be performed.

MR contrast agents should not be routinely provided to pregnant patients. This decision too, is on that must be made on a case-by-case basis by the covering level 2 MR personnel-designated attending radiologist who will assess the risk–benefit ratio for that particular patient.

Studies have demonstrated that at least some of the gadolinium-based MR contrast agents readily pass through the placental barrier and enter the fetal circulation.

The risk to the fetus of gadolinium based MR contrast agent administration remains unknown and may be harmful.
Sedation and Monitoring Issues

- Children form the largest group requiring sedation for MRI, largely because of their inability to remain motionless during scans. Sedation protocols may vary from institution to institution according to procedures performed (diagnostic vs. interventional), the complexity of the patient population (healthy preschoolers vs. premature infants), the method of sedation (mild sedation vs. general anesthesia) and the qualifications of the sedation provider.
Pediatric Screening Issues

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.

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.
MR Safety of Accompanying Family or Patient

Although any age patient might request that others accompany them for their MR examination, this is far more common in the pediatric population. Those accompanying or remaining with the patient should be screened using the same criteria as anyone else entering Zone IV.

In general, it would be prudent to limit accompanying adults to a single individual.
SAR (Specific Absorption Rate):
Measures the power absorbed per unit mass of tissue (W/kg). Absorption of RF power increases tissue temp. In a way, this could be thought of as a measure of dose for RF fields.

FDA SAR limits are as follows:

- Whole body - <4 W/kg
- Head - <3.2 W/kg
- Extremities (or any 1 g of tissue) - <8 W/kg
The greatest risk of exposure to cryogens is when the magnet has an unintentional (emergency) shut down, this is known as a quench. During a quench, the cryogen evaporates rapidly causing a loss of superconductivity in the magnet. Emergency ventilating systems direct the cryogens through a quench pipe out of the building. If the expanding helium cannot be dissipated through an external vent it may be released into the scanning room which will cause the displacement of oxygen and present a risk of asphyxiation.

In the event of a quench:

- Evacuate all patients quickly & safely
- The entire MR suite should be evacuated and everyone should be moved outside the room
- The MR technologist must confirm the magnetic field has dissipated prior to the safe entry of response teams (i.e., Fire Department)
ADDITIONAL ITEMS:

Time Varying Gradient Magnetic Field Related Issues: Induced Voltages
Time Varying Gradient Magnetic Field Related Issues: Auditory Considerations
Drug Delivery Patches and Pads
Claustrophobia, Anxiety, Sedation, Analgesia and Anesthesia
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References:

   MRI Safety, R. Jason Stafford
   AAPM Report No. 20
   ACR Guidance on Safe Practices
   Interrelating Sentinel Event #23 with ACR Guidance
   Joint Commission Issue 38