

MR Safety Fundamentals

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Disclosures

- Member: ACR
- Member: Board of Directors, IAC MRI accreditation program (representing AAPM)
- Chair: AAPM MR Subcommittee

Why Are We Here?

2003: Wheelchair and Oxygen tank





2003: Floor Buffer machine



2007: IV Pole



2011: Laundry Hamper



2013: IV Pole





Michael Colombini (2001)



Ask yourself: Why WON'T this happen here?

In the Headlines:

- "Lynbrook police: Man injured, arrested after gun goes off in MRI machine" (*Long Island Herald*, June 20, 2018)
- "Man Gets Sucked Into MRI Machine At Mumbai Hospital, Killed, 2 Arrested" (*NDTV*, January 29, 2018)

Ask yourself: Why WON'T this happen here?

Framework of Safety

- Hazards exist in the MR environment
- Controlling the hazards requires knowing:
 - The environment
 - The interactions that cause the hazards
 - Who or what enters the MR environment
- Prevent all personnel and items from encountering hazardous conditions

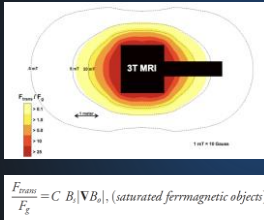
Physical Hazards

- Strong static magnetic field
- Strong, fast time-varying magnetic fields
- High-power radiofrequency magnetic fields
- Cryogenics

Physical Hazards

- Strong static field gradient:
 - **Missile effect**
 - **Ferromagnetic** objects
 - Displacement of patient implants/devices
 - Potentially damaging to devices
 - Lenz's Law forces on **moving nonferrous** metal objects

Projectile Hazards**



- Static field increases rapidly near scanner (“steep”)
- Active shielding
- Max force at “mouth” of bore
- Force on iron object:
~ 250 x F_g
- 1 lb. tool = 250 lb. attractive force

Panych & Madore, “The Physics of MRI Safety.” J. Magn. Reson. Imaging 2018;47:28–43

Acoustic Hazard



Physical Hazards

- Strong / fast time-varying magnetic field
 - Eddy currents → **nerve stimulation**
 - **Acoustic noise** (114-131 dBA)
 - 60 dBA: typical conversation
 - 85 dBA: permanent damage after 8 hour exposure
 - 100 dBA: permanent damage after 15 minutes' exposure
 - 120 dBA: immediate permanent damage

<http://dangerousdecibels.org/education/information-center/noise-induced-hearing-loss/>

How Loud?

- Early MRI systems = 84-93 dBA
- "Fast" scanning = 103 – 113 dBA
- Echo Planar 1.5T = 115 dBA
- Echo Planar 3T = 126 – 131 dBA
- Hearing protection is **REQUIRED** for all patients and anyone else in the room during scanning

<http://www.mrisafety.com/SafetyInfo.asp?SafetyInfoID=252>

Physical Hazards

- High power RF fields:
 - Higher power → improved SNR
 - SAR: Specific Absorption Rate (W/kg)
 - RF SAR $\propto f^2$ (or B_0^2)
 - Fast scanning increases *duty cycle*, increasing SAR
 - Heating of tissue → burns
 - **Metallic** objects, **loops**, **patient contact with bore/shroud during scan** increase hazard
 - **Tubing with conductive fluids/solutions**
 - **Implanted devices: injury** to patient, **damage** to device

Burns



<http://www.playformoah.com/moahs-mri-burn.html>

Physical Hazards

- Cryogenics
 - Liquefied helium; heating → rapid expansion
 - “Explosion”
 - Flash freezing
 - Displacement of oxygen → asphyxiation
 - Condensed/liquefied air (including oxygen) → fire / explosion

Cryogen-related hazards



© Paramus FD
March 6, 2015: “3 injured, 1 critically, when an MRI scanner exploded at a veterinary hospital in Paramus.”

MR SAFETY PROGRAM ELEMENTS

“Gold standard”: ACR White Paper



- Policies & Procedures
- Facility Layout
- Access Control
- Training
- Labeling
- Screening
- Contrast Media
- Implanted Devices

No regulations in most jurisdictions (at this time) 25

Access Control defines Zones

- **Zone IV:** THE MAGNET
 - No physical barrier between the magnet and the rest of the zone
- **Zone III:** Only 1 physical barrier between the magnet and the zone
- **Zone II:** Physical barrier controls access into Zone III.
- **Zone I:** “Outside world”, physically distinct from Zone II in some way.

Policies & Procedures define who & what may enter the Zones

- Must be in writing
- Under supervision of Medical Director of MRI
- Must be reviewed periodically, updated when appropriate

Access Control: Persons

- To enter Zone III or Zone IV:
 - Level 1 MR Personnel
 - Level 2 MR Personnel
 - *Screened* patients and visitors

Zone Access

Level 1

- May enter Zone III and Zone IV
- May accompany and supervise non-MR personnel in **Zone III only**

Level 2

- Full access to all Zones
- Only individuals who may accompany and supervise non-MR personnel in **Zone IV**

Labeling & Access Control: Objects



ACR Guidance Document on MR Safe Practices: 2013

- MR Safe: **Completely nonmetallic**
- MR Conditional: can be safe in MR environment under **certain known conditions**
- MR Unsafe: demonstrated **attractive forces** in magnetic field

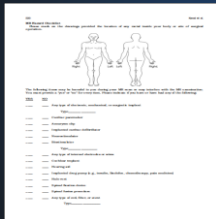
Object Access

- Ferrous / MRI Unsafe items kept out of **Zone III** when not absolutely necessary
- MRI Unsafe items must be under constant surveillance of **dedicated** MR personnel when brought into **Zone III** or **Zone IV**

There is NO SUCH THING as “**MRI Compatible**”!!!!!!

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Screening



- Same for all individuals entering **Zone IV**
- Done in **Zone II** – before entering **Zone III**
- Done by **2 separate individuals** who are MR personnel

Other important issues

- Medication and sedation
- Contrast media safety and reactions
- Medical emergencies inside the scanner

Gowning

- You would not believe what patients stash in their underwear...

Patient Preparation and Positioning



Hearing Protection

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Burn Prevention



- "Afterward, the patient said his legs had been pressed together before he entered the MRI machine."

Mandel et al. "A second-degree burn after MRI." Cleveland Clinic Journal Of Medicine 84(5); May 2017

Zone Signage



Zone Signage?



In Zone 3: Pay Attention!



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MRI Room Signage



MRI Room Signage



MR Unsafe items/equipment kept in Zone 3 and 4? (“Posting/Labeling”)

- Safety category labeled on items?
- Unsafe items controlled/supervised by trained personnel?
 - And/or tethered?



Training: MR Personnel

Level 1

- Individuals who have passed minimal safety educational efforts to ensure their own safety as they work within Zone III
- (e.g., MRI department office staff, patient aides.)

Level 2

- Individuals who have been more extensively trained and educated in the broader aspects of MR safety issues, including, issues related to the potential for thermal loading or burns and direct neuromuscular excitation from rapidly changing gradients
- (e.g., MRI technologists, radiologists, radiology department nursing staff.)

Training

- All personnel working in MRI have had safety training?
- When was their last refresher?
- Do they remember taking it?
- Records of training available?
- Training materials available?
- Medical Director approval, sign-off, and periodic review of training materials and requirements?

Non-MR Personnel

- Patients, visitors or facility staff **who do not meet the criteria** of level 1 or level 2 MR personnel will be referred to as **non-MR personnel**.
- Specifically, non-MR personnel will refer to **any individual or group who has not within the previous 12 months undergone the designated formal training in MR safety issues defined by the MR safety director** of that installation.

Clinical operational issues:

- Policies and procedures need to address – and staff must know – how to deal with:
 - Patient and staff pregnancy
 - Safety specific to pediatric patients
 - Medical emergencies in MRI patients
 - Quench, fire, and other environmental emergencies
 - Safety of emergency first responders
 - Patients with implants (stick around for this session!)
 - Hearing protection
 - Claustrophobia
 - (For full list see ACR Guidance Document)

Cryogen Safety

- Helium expands 1000X volume at quench
- Proper installation of quench vent pipes
- Regular *inspection* of quench vents
- Restrict access for planned quench:
 - Magnet room and surroundings
 - Quench pipe exit location

Quench Vent Inspections

Quench Line Check list of MR1000-10M

This checklist is to identify safety deficiencies with respect to the quench line installation. It is mandatory to complete this for inspection. After completion either installation, it must be handed over to the customer for their immediate information. For clarity, a copy of this checklist has to be submitted to the QV4000 tool.

Customer related information

Customer name: [redacted]
 City: [redacted]
 Country: USA

Quench-related information

Quench type: Single/dual
 Quench pipe size: [redacted]

Have installation details as described in order of the QV4000 tool been applied to the QV4000 tool? Done No

Provide the complete pressure drop calculation for steel applied to the QV4000 tool? Done No

Section 3: "Inspect the quench pipes"

Is the quench line under stress for loading?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Has customer been notified?	<input type="checkbox"/>
Are the quench pipes for this model frequency?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	Can pressure drop be done?	<input type="checkbox"/>

- Facilities department
- MRI vendor
- Ensure line open
- Safe venting area
- Installed & terminated correctly

Incident reporting and monitoring

Compliance:

- A policy and mechanism exists to collect and review data on adverse events in MRI
- JC: ferrous objects entering MR environment
- JC: patient burns
- "Near misses"

Value-Added:

- Ask if staff know when, how, and to whom to report
- Ask to see prior incident reports (do they exist?)
- Ask what was done as result of past reports/reviews.

Summary

- MRI risks include death and serious injury
- Proven administrative and engineering controls improve safety and reduce risk:
 - Physical access restriction
 - Training
 - Screening
 - Posting and Labeling
 - Incident Reporting and Analysis/Learning

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