MR Safety and the Role of the MR Safety Expert

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Chair, American Board of Magnetic Resonance Safety
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Disclaimer:
Implantable medical devices described within this presentation are for illustrative purposes only and do not constitute endorsement
Outline

1. Elements of an MR Safety Program
2. Accreditation Requirements
3. MR Safety Examples
Elements of an MR Safety Program


Expert Panel on MR Safety: Emanuel Kanal, MD,1* A. James Barkovich, MD,2 Charlotte Bell, MD,3 James P. Borgstede, MD,4 William G. Bradley Jr, MD, PhD,5 Jerry W. Froelich, MD,6 J. Rod Gimbel, MD,7 John W. Gosbee, MD,8 Ellisa Kuhni-Kaminski, RT,1 Paul A. Larson, MD,9 James W. Lester Jr, MD,10 John Nyenhuis, PhD,11 Daniel Joe Schaefer, PhD,12 Elizabeth A. Sebek, RN, BSN,11 Jeffrey Weinreb, MD,13 Bruce L. Wilkoff, MD,14 Terry O. Woods, PhD,15 Leonard Lucey, JD,16 and Dina Hernandez, BSRT16
Elements of an MR Safety Program

- Policies & Procedures
- Facility Design
- Personnel Training
- Patient/Personnel Screening
- Implant Devices
- Analgesia Anesthesia Sedation
- Contrast Agents

MR Safety
Recommended responsibilities for management of MR safety

Fernando Calamante, Bernd Ittermann, Emanuel Kanal,
The Inter-Society Working Group on MR Safety, David Norris

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draft was provided by the safety committee of ISMRM (Fernando Calamante (chair), Bernd Ittermann, Emanuel Kanal). An intersociety working group on MR safety was established with representation from each society as follows: Alberto Torresin (EFOMP); Renato Padovani (EFOMP); Sija Geers-van-Gemerden (EFRS); Csaba Vandulek (EFRS); Linda Knutsson (ESMRMB); David Norris (ESMRMB, ISMRM, chair); Stephen Keevil (ESR); Gabriel Krestin (ESR); Siegfried Trattnig (ISMRM); Titti Owman (ISMRM, SMRT).
MR Safety Expert

- Typically MR Physicist
- MR facility required to have ready access to services
- Not necessarily on site (not enough workforce)

- Likely has no medical education
  - Don’t expect advice on pharmaceuticals, anesthetics, etc
MR Safety Expert

- Provides high level advice on safe use of MR equipment (engineering, scientific, administrative)
- Advice on safety framework for MR environment
  - Help with local rules and procedures
- MR protocols – diagnostic effectiveness (artifacts, image contrast)
- Safety advice on risks associated with non-routine patients
- Safety audits
- Equipment selection
- Acceptance testing
- Maintain connections with local, national professional bodies
- Report back to MRMD
A Qualified Medical Physicist or a Qualified MR Scientist must be responsible for acceptance testing and monitoring of MRI equipment for the purposes of this practice parameter.

The Qualified Medical Physicist or MR scientist must maintain a thorough knowledge of the principles of MRI safety, physics, equipment, and relevant performance testing.

Resolution 10, adopted 5/23/2017
American Board of Magnetic Resonance Safety

Grassroots effort to establish “internationally accepted standards for MR safety competencies” – test beyond the registry/board exam

MR Safety Certified (MRSC™)

- Magnetic Resonance Medical Director (MRMD)
  Radiologist/Physician
- Magnetic Resonance Safety Officer (MRSO)
  Executes MR safety practices under direction of MRMD
  Could be MR technologist – someone at the site
- Magnetic Resonance Safety Expert (MRSE)
  Resource for MRMD and MRSO/Advisory
  Could be MR physicist

http://www.abmrs.org/
As a physicist, what am I thinking about?

- **B0** (Magnet)
- **B1 (RF)**
- **dB/dt (Gradients)**
Three main systems used for MR image formation

- **B0** – Static magnetic field
  - Aligns proton magnetic moments

- **B1 (RF)** – Tips magnetization into transverse plane
  - (Flip angle)

- **dB/dt (Gradients)** –
  - Encode spatial location
Projectile Effect – location of max force

Depends on $B_0$, $dB/dx$, and amount of ferrous material

**$B_0$**

Top view of the magnet

**Spatial Gradient of $B_0$**

(dB/dx)

At this location, the force on a magnetically saturated ferromagnetic object is greatest.
Projectile Effect – location of max force

Depends on $B_0$, $\frac{dB}{dx}$, and amount of ferrous material
Torque

**Strongest at uniform region within MRI bore**

Depends on

- $B_0$, geometry/magnetic moment of **ferrous** object
Aneurysm clips:
Many safe, some unsafe
Lenz’s forces

Depends on
- change in magnetic field, geometry of conductive object

Strongest near mouth of bore, force tends to oppose direction of motion
Static Magnetic Field Interactions

- Magnetic reed switches
  - Set to default programming
  - Pacemakers (magnet mode)

- Magnetic adjustments
  - Programmable shunts

- Mechanical failure
  - Pumps

- Projectiles
Radiofrequency (B1) Effects - MHz

Heating and potential for thermal injury

- Normal Mode operation – allows warming up to 0.5°C
- Proximity to RF transmit coil
- Patient skin-to-skin contact (Electric field loops within the body)
- Resonant circuitry (loops, antenna)

- Electrically conductive circuits/wires can get hot – thermal burns

- 10‐15 cm for 3T
- 20‐25 cm for 1.5T
Gradient Effects

KHz range – audiofrequencies – Hearing protection

Conductive objects:
- Eddy currents (case heating, Lenz’s forces)
- Pathway to enhance Peripheral Nerve Stimulation

Circuitry

- Current loops can have signals induced by changing magnetic field
- “Power on reset” when device gets confused and resets to base values

Gradient effects are typically pretty minor.
Use normal mode for active implants.
Cochlear implants (with magnets)

- **B0**
  - Magnets! Pull and torque

- **B1 (RF)**
  - Leads! Potential for heating

- **dB/dt (Gradients)**
  - Conductive, small surface area

- **Active Device**
  - Clicks and odd noises during scanning

*www.Cochlear.com*
Elements of an MR Safety Program

Where does the MR Medical Physicist fit?

Everywhere but contrast agents
Outline

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2015 ACR Quality Control Manual for MRI

Requirements went into effect
July 1, 2016
The resolution, linearity, contrast, and distortion criteria described above should be met.

For more details regarding evaluation of the SMPTE test pattern, see Medical Physicist/MRI Scientist's Appendix, Section V/L.E.

F. MR Safety Program Assessment

To minimize risks in the MR environment to patients, health care professionals, and any others that may encounter the fields of the MR scanner, each site must establish, implement, and maintain current safety policies and procedures. Information regarding establishment of a quality MR safety program can be found in the ACR Guidance Document for Safe MR Practices: 2013 [35]. The hazards in the MRI suite maybe divided into three categories: 1) facility design, 2) operational, and 3) clinical. Facility design refers to the facility layout in which zones are identified with appropriate signage and strategies for controlled access. Operational refers to procedures for screening both personnel and objects that may be introduced to the MR suite. Clinical refers to procedures that can be used to determine the MR safety and compatibility of implants and other medical devices.
MR Safety Program Assessment (pgs 111-113)

Divides safety concerns for MRI into three categories:

1. Facility Design
2. Operational
3. Clinical
ACR 2015 Requirements

- Additional form for Annual Report
- Sent to sites two weeks prior to Annual Testing
- Keep links to policies in the spreadsheet for easy review
Findings from initial MRI Safety Program Assessments

- RST – Policy regarding pregnant staff had vanished
  (not specifically requested for MRI in “Toolkit for Practice Sites”)

- Helpful for obtaining approvals for construction
  - Acquired hospital came Zone III-free
  - Sign off on
    “Facility has appropriate…methods controlled access”?

- Review with Mobile MRI Technologist:
  - Patients were changing in scan room (Zone IV) for privacy
  - Patient screening challenges
    lack of access to medical records
The Joint Commission – Diagnostic Imaging Requirements

- Effective July 1, 2015
- Both outpatient (ambulatory) and hospital programs
  - Managing MRI safety risks
  - Data collection on MRI incidents
  - Annual education requirement for MR Technologists
The Joint Commission –
Diagnostic Imaging Requirements

The organization collects data on:

- Patient thermal injuries that occur during MRI exams
- Incidents where ferromagnetic objects unintentionally entered the MRI scanner room
- Injuries resulting from the presence of ferromagnetic items in the MRI scanner room

Process improvement chapter
Outline

1. Elements of an MR Safety Program
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ICD - Artifacts

**FIESTA/SSFP techniques** – banding artifacts
- Use localized shim
- Switch to gradient echo sequences

**MDE** – artifact near lead tip
- Interferes with B1-field
- Flip angle not correct

“cannot exclude the possibility of artifact from nearby intracardiac CRT-D leads”
What can an MR Physicist do? Especially working with the Radiologist!

Myocarditis/? Subsequent fibrosis (ICD)

Interactive troubleshooting for these exams
- Can’t anticipate location of implant
- Can’t anticipate disease state or scan protocol
- Geometry within the scanner very important
- Can’t protocol ahead of time
What can an MR Physicist do? Especially working with the Radiologist!

**DBS 0.1 W/kg -> 3% of Normal Mode Operation**

My conversation with the radiologist:

- What is the most important sequence, given the patient’s indication?
- Standard 2D spin echo-based imaging techniques require about 1 minute per slice
- Can we limit scan coverage?
- Are you OK with 3D GRE T1’s with reformats? Post-gad too?
- DWI comes for “free” – no changes needed

**1 hour exam:**

MP-Rage, Cor T2 FLAIR, Ax T2 FSE,

DWI, T2* GRE
MRI Safety Training

Examples from your own institution make a powerful impact during training!

Oxygen tank

Screwdriver

Needle

Situation: An unsafe ladder was brought into an MR suite by Campus Operations personnel, and it was attracted to the back side of the magnet.

Recommendation: The cart that contained the MR unsafe ladder and light bulbs should stop outside of Zone 3. In addition, all employees should be thoroughly screened prior to entering Zone 4, regardless of experience within the MR area. The dept. will evaluate the staff not multitasking and ensure the Campus Operations staff waits until they have been fully cleared by the MR Staff. More to come after the RCA and debrief of the situation.

After RCA debrief:

✓ Light bulb cart will remain outside Zone 3
✓ Light bulbs will be stored near MR safe ladder in each of the scan areas
✓ Mini pause will be administered by MR tech prior to entry into Zone 4
✓ Use this example in upcoming Annual MR Safety Education
“Scary” Equation

Translational force equation for magnetic object

$$F_{trans} = \frac{V}{\mu_o D_a} \left[ B_0 \frac{\partial B_0}{\partial z} \right]$$

So, this is a scary equation, because the force is so hard to predict!

Depends on the object, its magnetic properties, its shape, and properties of the MRI scanner we can’t see with our eyes

Unrestrained force results in acceleration, and the acceleration might be faster than your reflexes!
Removed Spinal Cord Stimulator

2008

2017
MRI Safety Events

- **Projectiles**
  - Inpatient – tracheostomy stylet
  - Outpatient – eyeglasses case
  - Cleaning staff – mop
  - Inpatient – Flashlight
  - Anesthesia – needle
  - Equipment Services/Maintenance – Screwdriver
  - Potential – patient cart (2x)
  - **Potential – ferromagnetic oxygen tank**

- **Environment**
  - Accidental quench – inadequate button cover

- **Patient care**
  - Sedated patient event
  - Foil backed clonidine patch removal
  - Unread orbit screening exam

- **Devices**
  - Unrecognized cardiac pacemaker leads
  - Unrecognized vagal nerve stimulator
  - Unrecognized Pillcam
  - Unrecognized deep brain stimulator
Unsecured ferromagnetic oxygen tank in Zone III

Unsecured ferromagnetic O2 tank discovered Monday morning

- Anesthesia case over weekend
- “regular” personnel not present
Abandoned O2 tank responses

- Improved education for Anesthesia colleagues
- Empower “stop the line”
- Eliminate ferromagnetic O2 tanks
  - Carts must be adapted
  - Different diameters – 3/8 inch
  - Ergonomic benefits
Replacement of ferromagnetic oxygen tanks completed MCR

NEW ALUMINUM OXYGEN E CYLINDERS
THE RESPIRATORY THERAPY DEPARTMENT WILL BE STARTING TO CHANGE OUT ALL OF THE OLD, HEAVY OXYGEN E CYLINDERS TO NEW, LIGHTER ALUMINUM E CYLINDERS.

1 LBS. LIGHTER

NEW LOOK GREEN TOP ALUMINUM BODY

NO PRACTICE OR PROCEDURAL CHANGES NEEDED!

NEW CYLINDERS WILL BE DEPLOYED SOON.

New Aluminum Oxygen E Cylinders
In early March, the Respiratory Therapy (RT) Department will begin to exchange empty steel oxygen E cylinders in all patient care areas within the Rochester campus with a new oxygen E cylinder. The new oxygen E cylinder is made of aluminum and is four pounds lighter than the steel cylinders. The exchange process could take months as the RT Department is replacing the cylinders once they are empty.

There are no operational differences and no extra safety precautions with these new cylinders. This change will not affect any current policies or procedures.

Direct questions to William Clark, RRT.
Other parts on the Aluminum O2 Tanks

- Required to be in cart (prevent tip hazard, “the other missile effect”)
- Ferrous Free carts often get repaired with ferrous parts
- May be replaced with incorrect regulator
- Quarterly QC for any carts in the MRI areas, signature card and pink info tag
- Removal of ferrous O2 tanks significantly decreases attraction to magnet
  - More time to react even if in a ferrous cart
MRI Safety Events

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*Enterprise Event Sharing*
Enterprise Event Sharing

Pad QC Program
Technologist requests anytime

Biannual QC Program
Quick reference for how to avoid burns
Mentions several suggestions from

- Ensure that no items (such as leads) are formed into a loop, since magnetic induction can occur and cause burns.
- If the patient’s body touches the bore of the MRI scanner, use non-conductive foam padding to insulate the patient’s skin and tissues.
Conclusion

- MR Safety is collaboration across entire team

- Medical Physicist/MRI Scientist integral to safe facility design

- Alternate in-depth training and credentialing helps you know-what-they-know (MRMD/MRSO/MRSE)

- Patients benefit from solid knowledge of MR physics